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Fifteenth International Conference on Urban Regeneration and Sustainability

SUSTAINABLE CITY XV

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Preface

The present volume contains a selection among the papers presented at the 15th International Conference on Urban Regeneration and Sustainability (Sustainable City 2021), organised by the Wessex Institute of Technology. This conference was originally scheduled to take place in Bilbao, in Spain, but subsequently had to be held online due to SARS-Covid pandemic.

Sustainable City 2021 follows a series of very successful meetings that started in Rio (2000), followed by Segovia (2002), Siena (2004), Tallinn (2006), Skiathos (2008), A Coruña (2010), Ancona (2012), Kuala Lumpur (2013), Siena (2014), Medellin (2015), Alicante (2016), Seville (2017) and Valencia (2019). Last year's meeting was the first online edition, nevertheless, both 2020 and 2021 meetings attracted a large number of delegates as well as papers and presentations of high quality; this testified the worldwide interest in and success of the conference series.

Urban areas are met with a series of environmental challenges arising from the generation of waste and pollution as a consequence of excessive consumption of natural resources; this contributes to a rise in social and economic imbalances. As cities continue to grow all over the world, these problems tend to become more acute and the search of new solutions becomes necessary. Coastal areas and coastal cities are particularly important due to their specific features. Their strategic location facilitates transportation and the development of related activities, but this requires the existence of large ports, with the corresponding increase in maritime and road traffic and all its inherent negative effects. New challenges are triggered by the SARS-Covid2 pandemic, which will forever change the city as a whole, and that change must be carefully driven to avoid shocks and dead ends.

The contributors of this conference address a wide range of issues connected, among others, to:

- improving the capacity to manage human activities, pursuing welfare and prosperity in the urban environment;
- investigation on or planning of a city considering the relationships between the parts and their connections with the living world;
- consideration of the dynamics of its networks (flows of energy, matter, people, goods, information and other resources) which are fundamental for an understanding of the evolving nature of today's cities;
- development of well-planned and managed urban environments, not only for reasons of efficiency and economics but also to avoid inflicting environmental degradation that causes

the deterioration of natural resources, quality of life and human health;
- consideration of the function and maintenance of ordered structures directly or indirectly supplied and maintained by natural systems;
- the multidisciplinary components of urban planning, the challenges presented by the increasing size of the cities, the amount of resources required and the complexity of modern society.

Large cities represent a fertile ground for architects, engineers, city planners, social and political scientists, and other professionals able to conceive new ideas and time them according to technological advances and human requirements. The variety of topics and experiences is one of the main reasons behind the success of the series, which attracts a substantial number of contributions, in particular case studies investigated by contributors with distinct backgrounds belonging to different countries. The knowledge expressed, transmitted and discussed in all "Sustainable City" conferences will be crucial in shaping the post-pandemic cities of tomorrow.

For this reason, the papers contained in this book, as well as those from previous conferences since 2000, have been archived in the eLibrary of the Wessex Institute (http://www.witpress.com/elibrary) where they are permanently accessible to the international scientific community.

The editor wishes to acknowledge the support of the authors, the members of the International Scientific Advisory Committee (ISAC), the referees, Marta Graczyk, the conference co-ordinator, as well as the WIT Press staff and Isabelle Rham, in particular.

Finally, the editor and ISAC members wish to honour the memory of the late Professor Carlos Brebbia, founder of Wessex Institute, who established this series of meetings having foreseeing its impact and appeal.

The Editor, 2021

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SECTION 1
URBAN STRATEGIES

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CLIMATE-NEUTRAL AND SMART CITIES: A EUROPEAN POLICIES' OVERVIEW

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ABSTRACT
Cities are increasingly defined as one of the most important actors in the transition to a climate-neutral Europe. The reasons are multiple, and some of them are the increasing number of inhabitants and the demographic trends; the percentage of emissions produced by the urban areas; the innovation potential, thanks to the concentration of creativity and knowledge; the political dimension that helps in involving the citizens; the economical role and the fact that cities and towns are transport networks' hubs. Recognizing this crucial role, the European Union is updating its own policies on the matter, promoting challenging strategies as the Horizon Europe Mission on "Climate-neutral and Smart Cities". This article analyses the European policies and strategies aimed at tackling the climate change in the urban areas. They are making the cities the forefront where to speed up the transition and promote flagship actions able to pave the way for reaching the European Green Deal goals. Moving from the main policies, this article investigates the overall ratio behind them and presents the tools and the actions promoted by the European Commission to support the local authorities in recognizing and facing the challenge, which is at the very core of the New Generation EU programme and a key enabler in designing the post-Covid Europe. On the other hand, this article briefly presents the main activities that cities are expected to develop in the next decade in order to fully contribute to the European ambition to be the first carbon-neutral continent on the planet by 2050.
Keywords: cities, citizens engagement, climate change, tools for transition, policies.

1 INTRODUCTION

Since the beginning of 2020, we are experiencing a dramatic pandemic with millions of deaths and extreme negative social and economic consequences. Our daily life is unexpectedly radically changed, and all those elements have demonstrated to the humanity how fragile is the societal systems we assumed to be untouchable.

However, many scientists warn us about the fact that the consequences and changes caused by Covid-19 are minor in comparison to what we may see in the next decades due to the global warming and the climate change. Limiting our focus on direct health related risks, the Intergovernmental Panel on Climate Change (IPCC) underlines that "any increase in global warming is projected to affect human health, with primarily negative consequences and risks from some vector-borne diseases, such as malaria and dengue fever, are projected to increase with warming from 1.5°C to 2°C, including potential shifts in their geographic range" [1].

International efforts to limit the temperature increase are often judged by experts and environmental associations and activists as contradictory since declarations of commitment are not followed by concrete action plans. The Sustainable Developments Goals (SDGs) adopted by all United Nations Member States in 2015 sets the shared blueprint of the 2030 Agenda for Sustainable Development. This Agenda, together with the Paris Agreement, is today the most comprehensive international agreement on the issue. However, both these documents delegate member states in adopting adequate measures to contribute to the global effort, without setting a clear and common action plan.

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In the last years, the European Union proposed itself as the global leader of the climate transition, adopting ambitious policies and setting goals and milestones to reach the climate-neutrality within the 2050.

In this context, cities are assuming a main role. On one hand, urban areas are responsible of 70% of the global CO_2 emissions and two-thirds of the energy consumption. In the European Countries, “the building sector is the single largest energy consumer (40%), the largest raw materials user (50% of the extracted materials) and thus one of the largest greenhouse gas emitters (36% of energy-related direct and indirect emissions) [2]. As stated by the European Mission Board on Climate-neutral and smart cities, “cities cover about 3% of the land on Earth, yet they produce about 72% of all global greenhouse gas emissions” [3]. Considering that “the population residing in urban areas is projected to reach 83.7% in 2050” [4], it is clear how crucial it is to radically transform our cities.

On the other hand, there is an increasing number of cities adopting plans and strategies for facing climate change. European Eurobarometer has measured the growing concern of European citizens, underlining that “awareness of climate change and the need for action is increasingly widespread and one of the largest demonstrations of this in recent times is the youth movement for climate that has garnered strong support in countries around the word” [5].

Municipalities and local authorities are the first level of governance, with the stronger relation with citizens, and it partially explains local efforts. Furthermore, many cities are facing growing issues related to climate change, as floods, heat islands, pollution, extreme weather events, and this encourages them to act. But “cities are also the melting pot where decarbonization strategies for energy, transport, mobility and even industry and agriculture coexist and intersect” [6]. Considering all these elements together, we can assume the urban areas are one of the crucial actors in facing the climate emergency and putting in place ambitious policies and adequate solutions.

The European Commission recognizes this role through its policy documents. In the last Multiannual Financial Framework there are increased resources and activities devoted in supporting cities willing to promote and realize demonstrators, governance reforms and structural transition actions toward a net zero greenhouse gas emissions society within 2050.

2 FACING CLIMATE CHANGE IN URBAN AREAS: THE EUROPEAN GREEN DEAL AND THE MAIN RELATED POLICIES

The European commitment to climate change is growing every year more. A complex policies review is currently in place to align different legislations and regulations to the political objectives set by the European Commission and the Member States. New policies, strategies and regulations have been adopted as well, and the already existing legislations will be updated for guaranteeing a coherent scenario. The core of this approach set by the European Commission is the new European Green Deal.

92% of European citizens “agree that greenhouse gas emissions should be reduced to a minimum while offsetting the remaining emissions, in order to make the EU economy climate neutral by 2050” [7]. It seems that the communication of the European Commission establishing “a European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy” [8] benefits a widespread consensus among the European citizens.

The vision establishes a precise goal to be reached within the 2050: making Europe the first carbon-neutral continent on the planet. This ambitious target is rooted on the scientific evidence that underlines the need to face global warming containing the temperature increase within 1.5°C above pre-industrial levels. However, it is as well a development strategy, betting on climate neutrality as a fundamental pillar to guarantee Europe's prosperity.

According to this point of view, European Commission estimates that the EU economy will "more than double by 2050 compared to 1990 even as it fully decarbonized. A trajectory compatible with net-zero greenhouse gas emissions, together with a coherent enabling framework, is expected to have a moderate to positive impact on GDP with estimated benefits of up to 2% of GDP by 2050 compared to the baseline. Very important, these estimates do not include the benefit of avoided damage of climate change and related adaptation costs" [8].

The strategy "set[s] the direction of travel for the EU climate and energy policy, and frames what the EU considers as its long-term contribution to achieving the Paris Agreement temperature objectives in line with UN Sustainable Development Goals" [8]. The plan describes a holistic approach, and, for that reason, it does not promote new policies, but strives for influencing both the European and the national strategies, laws, and rules. The first legislations and regulations included in the European Green Deal are the Climate Law, the Climate Pact, the new European Strategies on Climate Adaptation, and the 2030 Climate Target Plan, which are presented in the following sections.

Figure 1: European green deal, regulations, and policies.

While active citizens engagement is at the base of the strategy, different sub-fields of intervention are energy efficiency, renewable energy, mobility, industry, infrastructures and agriculture.

In the framework of this long-term vision, citizens – who are requested to "embrace change, get engaged and experience it as beneficial for their lives and that of their children" [8], but also to play a key role as consumers – and cities have a crucial role. The European Commission recognizes that cities are already laboratories for transformative and sustainable solutions, underlining that many of the needed transformations can take place in the urban areas.

2.1 The climate law

The European Climate Law proposed by the Commission represents the legislative face of the European commitment in facing climate change. It defines roles and instruments for implementing the European Green Deal's principles, setting the path for both realizing the transition and monitoring it.

While we are writing this article, the Climate Law is still under negotiation between the European Commission, the Member States' Council, and the European Parliament. However, some agreements have already been reached and the main points which will characterize the law are already set down.

Thanks to the law, the objective of a net zero emission Europe within 2050 will be legally binding. Furthermore, intermediate targets will be established and the first refers to 2030 when Europe aims at reaching the target of reducing the greenhouse gas emissions by at least 55% compared to the 1990's levels. Moreover, the Commission will monitor if and how national measures will be in line with the European targets, and in case the targets are not met, the Member States will be obliged to take in due account the Commission's recommendations.

Moreover "the Commission proposes the adoption of a 2030–2050 EU-wide trajectory for greenhouse gas emission reductions, to measure progress and give predictability to public authorities, businesses and citizens" [9].

2.2 The climate pact

"We have not moved fast enough to prevent irreversible and catastrophic climate change" [10]: this is the main reason why, among the other policies, the Commission has decided to promote a European Climate Pact aiming at bringing together "regions, local communities, civil society, industry and schools [that] will design and commit to a set of pledges to bring about a change in behaviour, from the individual to the largest multinational" [11].

The Pact is not strictly a policy nor a strategy or a funding tool. On the contrary, it reflects the confidence about the essential role played by non-institutional actors in facing the climate change emergency. It is the reason which pushes the European Commission in looking into new inclusive and participative paths able to produce a huge impact on the European society.

Through the European Climate Pact, the Commission tries to actively involve different stakeholders – from citizens to bigger organizations – to:

- create a network of those already active in climate action and attract interest of those 'indifferent' or 'hard to reach', with the general objective of raising awareness.
- Engage with citizens and stakeholders, in order to spread potential solutions and best practices: the Climate Pact Ambassadors, who are volunteers endorsed by the European Commission, are at the core of this type of activity that foresee climate literacy and education programmes as well.
- Support citizens, local authorities, and other stakeholders in implementing actions, particularly thanks to digital tools aimed at helping citizen dialogues and spreading information through a Knowledge Hub.

Although the Climate Pact is designed to operate on all the different fields that influence climate change, four beginning topics have been identified: green areas, green mobility, green buildings, and green skills. These topics have been chosen for two main reasons: on the one hand, they are the most prioritized items from the European Union; on the other hand, policies, support mechanisms and European strategies on these topics are already in place and need to be boosted.

2.3 The new European strategy on adaptation to climate change

"Halting all greenhouse gas emissions would still not prevent the climate impacts that are already occurring" [12]. The European Strategy on Adaptation to Climate Change works on the other face of the coin: recognizing the fact that climate change is already ongoing – and the consequences are inevitable – the strategy emphasizes the crucial role of adaptation for reaching the European 2050's goals.

Knowledge and digitalization are at the core of this strategy. Sharing information and facilitate a climate assessment decision-making are two crucial points in the adaptation's path. By this means, the Climate Adapt Platform is at the same time a strategic European tool for disseminating knowledge and information and for promoting a European climate and health observatory. The platform collects information and data from different sources – as Copernicus – and contributors.

The local dimension is considered crucial for adaptation. For that reason, the strategy promotes two main pillars: on the one hand, it wants to foster a just and fair way for spreading adaptation measures; that means both supporting local authorities in implementing actions and reskilling workers through tailored educational programmes. On the other hand, the strategy aims at integrating climate resilience in national fiscal frameworks: this will push the development of tools for measuring the potential impact of climate-related risks on public finance and prevent the fiscal impact of climate-related events which may have a negative impact on economic growth.

Concerning the type of actions, nature-based solutions (NBS) on a larger scale are considered an important contributor for reaching multiple Green Deal objectives. They are not only useful for improving the resilience but are also considered as a solution for carbon removals. For that reason, the Commission aims at leveraging investment on this kind of blue and green infrastructure, which involve the urban areas as well. Regarding infrastructures, the strategy also underlines that "extreme weather and long-lasting climatic changes can damage buildings and their mitigation potential e.g., solar panels or thermal insulation […]. However, buildings can also contribute to large-scale adaptation" [12].

2.4 The 2030 climate target plan

In September 2020, the European Commission proposed new climate targets to be reached within the 2030, underling that "the climate crisis remains the defining challenge of our time" [13]. The Commission bases the proposal on the evidence that "in 2019 EU emissions, including removals, were down by an estimated 25% compared to 1990, while over the same period the economy has grown by 62%. This proves that we can tackle climate change and ensure sustained economic growth" [13]. On the other hand, measures foreseen by the existing legislative tools are non-enough in order to guarantee a secure, well-planned and sustainable path towards making Europe the first continent carbon-neutral within the 2050. For these reasons, a new and more ambitious target has been set up, and the Commission proposed to reduce the overall CO_2 emission by 55% within 2030, compared to 1990.

Reaching this goal means developing multi-sector actions, intervening also in areas in which to reduce emissions has been proved to be harder. From this point of view, particular challenges exist on transport, agriculture, and buildings.

The document set targets on different fields, like building and power generation, renewable energy, heating and cooling, buildings renovation, transport, industry.

3 TRANSFORMING THE CITIES: THE MAIN POLICIES

Specific policies have been established over the years to support local authorities in enhancing their actions on different fields. During the last years, the focus has been partially shifted on issues related to climate change, considering the actions fields from mitigation and adaptation to inclusiveness and awareness. How to govern the processes is a focal point as well. This section describes the main European policies aimed at enforcing the local governments' role in guiding the transition.

3.1 The new Leipzig charter

The Leipzig Chapter has been adopted by the European Ministers responsible on Urban Matters in 2007 and refocused in November 2020 with the aim of providing a policy framework to adequately respond the challenges underlined by the 2030 Agenda for Sustainable Developments, the Paris Agreement, and the European Commission's Green Deal. The document sets the strategic principles of a good urban governance.

It recognizes cities as enabler of cultural social, ecologic, and economic interaction, underling that culture is at the core of any sustainable urban development. According to this point of view, the chapter remembers that "most cities are unique, historically grown centers of outstanding cultural value shaping Europe's urban heritage and the identity of its citizens" [14]. For the same reasons, cities are places of pluralism, creativity and solidarity and laboratories for new forms of problem solving and test beds for social innovation.

The chapter identifies three spatial levels that need to be activated for pursuing the common good: the neighbourhood, where it is possible to set out actions aimed at community building and inclusiveness; the local authorities, which are the intermediate bodies linking the small-scale neighbourhoods with the wider functional areas; this last dimension is defined as the complex network of functional interdependencies and partnerships where a resilient development can take place. This implies a strong coordination and collaboration between town and cities and their surrounding suburban and rural areas.

Three different action areas characterize the urban transformation's concept, which has to integrate social, ecological and economic dimensions of the sustainable development: the just city, where no-one has left behind; the green city, where actions on green spaces, energy, building efficiency, biodiversity, green and blue infrastructures, natural-based solutions, mobility and services are designed and implemented in a coordinated and synergic manner; the productive city, promoting especially new small sustainable and local business, low-emission manufacturing and urban agriculture. Two are the main enablers: the digitalization and high-quality public spaces allowing people to interact, exchange and integrate into the society.

For reaching these goals, the chapter set a list of cities needs as well: clear and coordinated legal framework conditions; investment capacities; adequately skilled employees; steerability and shaping of infrastructures.

3.2 The New European Bauhaus initiative

"The New European Bauhaus (NEB) initiative is a think-do tank. A design lab, accelerator, and network at the same time. A creative and interdisciplinary movement, convening a space of encounter to recuperate and revisit sustainable practices forms, empower the most inspiring practices of today, and design future ways of living, at the crossroads between art, culture and science" [15]. This is the brief definition the European Commission gives about this new initiative strongly endorsed by Ursula Von Der Leyen at the beginning of 2021. In a video [16], the President of the European Commission said that the NEB is “a project of hope” that designs “how we want to live after the pandemic while respecting the planet and protecting our environment”. The initiative has been presented by her as “an inclusive and collective process” engaging “professional architects, citizens, CEOs of big companies and innovative start-ups” bringing their ideas together.

The keywords of the initiative are creativity, innovation, imagination design. The European Commission aims at fostering the transition requested by the European Green Deal connecting the actions required for facing the climate change with improvement of the citizens’ quality of life. Green and digital transitions are therefore mutually connected, and the expectations are to push transformations in the market and in the behaviours as well, focusing beyond buildings.

The New European Bauhaus has been structured in 3 different phases:

- The Design phase, with the aim to connect with existing initiatives and projects to see where and how the NEB can accelerate, concretize and materialize good ideas.
- The Delivery phase, that aims at learning and benefit from five NEB pilots selected through a call for proposals and open to all the design phase’s participants (“community of practice”).
- The Dissemination phase, with the aim to diffuse good ideas and concepts to a broader audience in Europe and beyond.

3.3 Involving the local authorities: Covenant of Mayors and Green City accord

The Covenant of Mayors is one of the longest running European initiatives related to sustainability and cities. Launched in 2018 by the European Commission as a tool for promoting energy efficiency and energy transition, it has been updated in 2015 as the Covenant of Mayors for Climate and Energy, after being merged with the twin initiative Mayors Adapt. Since 2016 the initiative joins forces with the Compact of Mayors, the global initiative launched by the United Nations in 2014.

It involves cities on a voluntary basis, committing the local authorities to a shared vision and common goals. With the latest updates, the initiative has aligned its goals with the European Green Deal, paving the way for reaching the 2050’s objectives.

“In order to translate their political commitment into practical measures and projects, Covenant signatories commit to submitting, within two years following the date of the local council decision, a Sustainable Energy and Climate Action Plan (SECAP) outlining the key actions they plan to undertake. The plan features a Baseline Emission Inventory to track mitigation actions and a Climate Risks and Vulnerability Assessment” [17]. After the approval the local plans are included in the initiative and the signatories commit themselves in monitoring the progresses.

Nowadays, more than 10,000 local administrations around Europe participate in the initiative, involving more than 334,832,000 European citizens. The Covenant of Mayors represents the most recognized European initiative that supports and coordinates the Municipalities in planning how to mitigate and adapt to climate change, but the participation is different within Member States.

The Green City Network [18] has been launched by the Commission in 2021, focuses on environmental management and involving cities on five main goals which the signatories want to achieve by 2030: improving the air quality; promoting water use efficiency; enhancing urban biodiversity; advancing circular economy and reducing noise pollution. The document does not set any baseline or target, which are both delegated to the signatory authorities which are expected to go beyond the minimum requirement set by EU legislation.

4 FINANCING THE TRANSITION: THE MAIN EUROPEAN TOOLS

Financial aspects are crucial for implementing policies and developing transformative actions that will radically change the urban landscape and lifestyles as well. In this section, we focus on the main financing tools provided by the European Commission, deepening those that are expected to provide the most disruptive innovations.

4.1 The financing programmes: Horizon Europe, Life and the new European Urban Initiative post 2020

We are currently at the beginning of the new Multiannual Financial Framework adopted by the European Parliament, EU Member States in the Council, and the European Commission on 10 November 2020. The agreement includes the Recovery Plan for facing the pandemic and its consequences, and the long-term budget for 2021–2027 consists of €1.074 trillion.

The Multiannual Financial Framework covers different funding programmes which focus on a multitude of topics and challenges. The main headings are:

- Single Market, Innovation and Digital
- Cohesion, Resilience and Values
- Natural Resources and Environment
- Migration and Border Management
- Security and Defence
- Neighbourhood and the Word
- European Public Administration

At least 30% of the overall budget will be spent on projects and activities contributing to facing the climate change. Certainly, the climate transition – which, on the European documents, need to be fair, inclusive, and just – will be one of the goals of every European Funding Programmes, and each of them will face the challenge from different points of view. However, two programmes will pave the path for the transition: Horizon Europe and Life Programme.

Horizon Europe is the framework programme for research and innovation, the one with the biggest budget in the European context. Climate change is a cross-cutting issue, characterizing all the three programme pillars. However, specific destinations and topics are included especially in pillar two. Concerning the cities' role, a specific section is included in the cluster 5, destination 2, where topics that aim at facing climate change in urban areas are proposed in the section "Communities and cities". Furthermore, following Professor Mazzuccato's proposal, Horizon Europe includes Missions defined as "commitments to solve some of the greatest challenges facing our world" [19]. One of these Missions is devoted to promoting climate-neutral and smart cities (see Section 4.2).

Life is the European funding programme historically devoted to preserve the environment, the nature, and the biodiversity. Since 2014, it has partially changed its own mission, including climate action as a sub-programme.

Towns and cities can find financial support also through the new European Urban Initiative post 2020, rooted on the experience of the programme Urban Innovative Actions, which have had five thematic calls in the period 2014–2020. The new initiative is structured on three main strands:

- capacity-building, with the aim of fostering a community of practice able to support cities around Europe in accelerating the transition.
- innovative actions, with which experimentation in the area of sustainable urban development focusing on innovation and governance can be carried out.
- knowledge dissemination, sharing data and information to support a better policy design.

This initiative is programmed under the European Regional Development Fund (ERDF).

4.2 The Mission "Climate-neutral and smart cities"

"The introduction of a Climate City Mission is a radical new way of achieving climate neutrality – and of doing so faster, by 2030. The Mission aims to promote system innovation across the value chain of city investment, targeting multiple sectors such as governance, transport, energy, construction, and recycling, with support from powerful digital technologies. As such, it requires a change in regulations, approaches and instruments combined with the willingness to go beyond existing schemes and habits. The Mission also demands a change of attitude towards practical aspects of implementation, but also as concerns people and organizations working together: citizens, local governments, central and regional governments, and European institutions. We expect citizens, city administrations and political leaders to show commitment, imagination and determination" [20].

The role the urban areas are gathering is well demonstrated by the Mission '100 climate-neutral cities by 2030 – by and for the citizens. If in the past cities were the location where deploying actions, this new approach defines them as one of the main actors of the transition. The focus changes and moves from technologies to governance. Even though innovation in different fields is still required, the process on how the transformation can be implemented is considered as the real potentially disruptive element for reaching the 2050 targets.

The most important innovation introduced by the Mission's approach is considering the governance as the key-enabler for any transformation. Focusing on how a zero-emission society can be reached, the Mission introduces two different but complementary levels: the first is the local level, where citizens need to be actively involved. That is not just a democracy issue: the inhabitants are at the same time citizens – having the right to participate in the transformation of the place where they live – and users, producers, consumers, and owners. It means that they are key actors without whom it is not possible to reach the goal. In other words, the concept of democracy is itself moving up from the delegation towards new decision-making forms in which "citizen engagement has to be inclusive, deliberative and influential" [21].

The second level is the one that includes different institutional actors. In the last decades, local authorities where more beneficiaries than actors of the European policies. They could receive funds for implementing actions, but the institutions involved in defining the priorities where mainly the regional and national governments. The Mission's approach, on the contrary, poses the cities at the very center# of the priorities' definition. It happens for two main reasons: on one side, differences between cities in societal, environmental, economic, and urban dimensions are recognized and solutions need to be designed taking into account these aspects. Starting from this evidence, the Mission asks the cities to self-assess their readiness and design specific and targeted solutions. On the other side, the Mission recognizes the interconnections between local, regional, national, and European policies, calling for an integrate and multi-level approach. By this way, local authorities become the nodal point of a network of institutional relations that involve all the different actors, connecting their actions with the regional and national strategies for carbon neutrality by

2050 and assuming that the measures taken should not be physically unconnected or stop working at the borders of the cities.

The main tool foreseen by the Mission as underpinning these characteristics is the Climate City Contract that should be the result of a co-creation's approach involving citizens, local communities, stakeholders, and relevant institutions. Ideally, the contract has to be signed by all institutions involved in the policies, both at the local, regional, national and European level.

The climate contract includes the goals and the targets, specifies the strategy and the action plan for transition, and identifies stakeholders and responsibilities.

5 POLICIES ANALYSIS AND SHORT CONCLUSIONS

The European Commission gives great emphasis on the potential role Europe can play in the global context for facing the climate change and the increasing importance of urban areas in developing actions in line with the ambitious goals which have been set.

Reading the Commissioners' statements and the principles set through regulations and strategies, we can find a comprehensive approach that covers many aspects related to the complexity of the challenge: air, soil, water, human activities, energy, buildings, mobility, and many other topics are part of documents as the European Green Deal. At the same time, we can find an increasing coordination between different strategies and policies, which refer to the same challenges covering different aspects. The funding instruments seem to be aligned with the strategic propositions; however, implementation will be crucial to understand the impacts of the actions.

Participation, civic engagement, and empowerment are often quoted in these documents. There is no doubt about the importance of involving citizens in changing our cities and our behaviours. However, it is still ambiguous which kind of participatory tools the European Union will set out in the following years. In the last months consultation appeared as the most used instrument by the Commission, and during the introduction of new policies like the European Green Deal and the New European Bauhaus, the European Commission asked citizens and stakeholders to share opinions and ideas. However, this may not be enough to ensure an increasing role to European citizens in defining policies, investments, and actions for facing climate change. Indeed, the decision process remains unchanged, and the tools introduced seems to be more like a kind of polls than new and innovative participatory paths.

Following this argumentation, the choice of the stakeholders to be at the core of the process will make a huge difference. In the last decades Europe has often been the space in which lobbies and multi-national powers strongly influenced the decision-making process whereas civic organizations and social movements had a very marginal voice. The kind of balance of power to be set out in the following years will define the strategy underpinning the climate transition, the selected technologies, and the social solutions. The Europe we will live in 2050 will be the results of this balance.

More in general, it is still unclear how successfully demonstrators and pilot actions promoted and funded by the policies presented in this article will be replicated in towns and cities. From this point of view, a clear European vision appears to be undeveloped, and the financing tools seem to be dedicated at promoting single best practices and flagship initiatives more than finding structural solutions that involve all the Member States. Moreover, how general objectives and challenging goals set out by the Commission for the European continent will be translated into national and local concrete actions and investments is an issue that the documents analysed in this article do not present in depth. Thinking about subsidiarity, this may seem as a good strategy; however, strong differences between Member States may negatively affect the final results, preventing Europe to reach the common goals.

How European strategies are transposed into national legislations is still problematic and represents a threat to the strategies' implementation.

Following this point, the European approach seems to still lack capacity building and technical support tools. Europe has dozens of big cities with efficient administrative structures, but we cannot forget the hundreds of thousands of small towns and villages, which are the core of the European urban landscape. These ones do not often have structured internal offices able to develop programmes and projects for implementing the European projects. From that point of view, new technical assistance instruments and dedicated financing initiatives seems to be crucial to spread best practices and involve all European citizens – and not only those living in the biggest and richest cities – in a just transition toward a net zero emissions Europe.

In conclusion, declarations and actions are still far from each other. The 2050 European vision is more a development plan than a social and ecological answer to the crisis; furthermore, following the Arnstein's Ladder [22] on the degrees of citizen participation, the citizens' empowerment seems more a tokenism than a real and effective citizens control on policies and choices. Member States still have the final world about how to implement the policies described in this article. Municipalities are often more engaged than national authorities in facing climate crisis, but without a strong coordination and multilevel synergies, the challenging goals the European Union wants to reach are not achievable. Cities are without any doubt key players in facing global warming and involving the inhabitants in huge changes: however, policies need not only a vision, but precise and mandatory goals, measurable impacts, and large investments. Involving European citizens in achieving a climate-neutral continent means shifting power from lobbies to communities, establishing common deliberative processes that municipalities can use in every European country in order to develop local mitigation strategies.

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PLANNING WITH NATURE: SUSTAINABLE URBAN PROTOTYPES FOR PORTUENSE DISTRICT IN ROME, ITALY

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ABSTRACT
The objective of this study is to regenerate the Portuense district of Rome, in the southwest quadrant of the city, referring to nature-based solutions (NBS) coupled with sustainable solutions in rainwater management. The role of water, both as a resource and as an essential element of urban landscape, was considered. Nature-based solutions include several concepts or technologies ranging from blue–green infrastructure to water saving measures to sustainable rainwater drainage, and their use can be an important tool to mitigate the negative effects of climate change. To this end, high levels of integration between experts from different disciplines are necessary, specifically urban planners, water engineers and ecologists, and the involvement of land and water managers, planners and policy makers on all spatial scales is required. The design solutions in this work were developed following the United Nations 2030 Agenda for the Sustainable Development Goals (SDGs) and fitting the following models of city [1]: the Oasis City where NBS solutions improve the thermal well-being of the inhabitants reducing the heat island effect (environmental function); the City of Sponges to increase soil permeability and control rainwater flow making more sustainable the urban drainage system (environmental function); the City for People to improve the liveability and sociability of the spaces (social function). Based on these principles, three design solutions, called prototypes, have been developed: Pocket Park (environmental function), Main Avenue (social functions), Tiber Park (environmental and social functions). The biotope area factor, BAF index, was used here as the main measure to evaluate the effectiveness of the design solutions. The solutions proposed in each prototype can be repeated for all the interventions conceived in the "network of spaces" of the Portuense district.
Keywords: sustainable urban planning, nature-based solutions, sustainable urban drainage, BAF *index, environmental comfort, urban outdoor spaces, City for People, Oasis City model, Sponge City model.*

1 INTRODUCTION

Urbanization and its adaptation to climate change are nowadays being discussed worldwide. It is important to address the resulting problems at all scales and certainly urban design has a key role: it can respond to the problems related to climate crisis mitigation and promote sustainable resource management [2], [3]. In regenerating the city and redesigning in the direction of an ecological transition, it is necessary to assume an integrated methodology of different disciplines operating on a nature-based principle. Public space is at the heart of the research proposals for the regeneration of cities. The liveability of spaces and their environmental quality can make a difference in the evolutionary process of cities towards sustainability [4]. Open spaces must be well designed, enjoyed by citizens, and meet environmental comfort requirements [5]. The comfort caused by good design is usually strongly linked to the use of natural elements. Only in the last 60 years it is understood that a balanced environment must contain all of the ingredients necessary for biological prosperity, social cooperation, and spiritual stimulation of humans [6]. These factors are addressed by ecology, one of the disciplines that led to the results of these studies. A project must be based on human perception and environmental needs, as well as their relationship. In this way, the quality of life of citizens is increased [7]–[9].

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Within this context, water has a fundamental role as a determining element of the new paradigm of sustainable eco-city. This paradigm is based on the assumption that “urban waters are the lifeline of cities and focus of the movement towards more sustainable cities” [10]. This paradigm extends from the microscale of the “green” buildings to the macroscale of the eco-city and urban water catchment [11]. Environmental engineers and urban planners are developing water/rainwater/wastewater management concepts based on reuse and recycling, and on the importance of water as an element characterizing the urban landscape, which affects the overall well-being of the inhabitants

In this sense, the research was developed according to 2030 Agenda for Sustainable Development Goals (SDGs), adopted by all United Nations Member States in 2015 (Goals 3, 6, 11, 13) [12]. In the project it was considered important to increase the quality of urban spaces at the same time as adopting useful strategies to mitigate the effects of climate change. Three types of cities have been taken as a reference, in line with the design laboratory REBUS (*REnovation of public Buildings and Urban Spaces*), conceived by the Emilia-Romagna Region in 2015 [13]: the Oasis City, for the well-being of the inhabitants; the Sponge City to increase permeable soils and control rainwater flow; the City for People, for the liveability and sociability of spaces [1].

2 STUDY AREA

The selected area is Pian due Torri, more commonly known as Magliana. It is a fraction of the Portuense district, in the southwest quadrant of the city of Rome, Municipality XI of the City of Rome. The Portuense district is bordered to the east by the Tiber River, to the west by the axis of the Via Portuense and to the south by the A91, the Rome–Fiumicino freeway. The whole area is located seven meters below the Tiber embankment. In the past it was infested with mosquitoes and unhealthy due to the frequent floods of the Tiber. Between the sixties and seventies of the last century the area was intensively built up.

3 METHODOLOGY AND MATERIALS

The research project developed as a result of some questions that stimulated our curiosity and showed us how necessary it was to look for new solutions to today’s problems in our cities. How can cities be rethought after the experience of the pandemic? Are cities a problem or can they be the solution? What role can the regeneration of public spaces play in view of the dual problem of the climate emergency and the health emergency? And finally, is it possible to rethink a transformation process that designs public spaces in such a way as to meet the needs of the contemporary city?

The methodology used to develop the project is articulated using the three city models proposed by REBUS Project [1] with the main objective of making the urban environment more resilient to the effects of the climate change, in particular to heat waves (City Oasis model) and the greater frequency of intense precipitation (Sponge City model), without forgetting to make the city more liveable for its inhabitants (City for People). The realization of these three city models is based on the use of nature-based solutions (NBS), sustainable drainage systems (SuDS), with the biotope area factor (BAF) index, as a measure of the effectiveness of the proposed design solution. The goodness of each solution was also evaluated by its ability to answer the inhabitants’ psychological, social, and cultural requirements. A schematic of the methodology is represented in Fig. 1, where each of the three city models corresponds to an objective to be reached and the set of tools to be used.

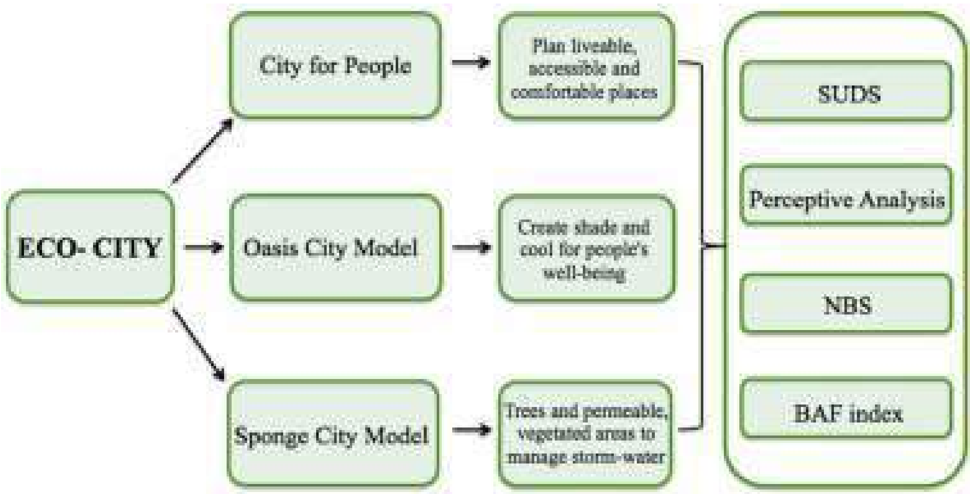

Figure 1: Outline of the methodology.

3.1 City for People model

The City for People model is about the liveability of public spaces. They are spaces in which inhabitants voluntarily decide to go and spend their time. It is essential that this kind of spaces are designed to be as accessible as possible and with wide space equipped for socializing. These aspects, integrated with others more related to environmental comfort, will allow the creation of public spaces with a high environmental quality. A more natural space, as stated by Gehl [14], is also more comfortable and attractive, and this greatly enhances its quality. In the project, to ensure a citizen-friendly city, the focus was supported by the methodology elaborated by Lynch [15]. The elements proposed by Lynch were selected to promote their enhancement and to make them the representative elements of the neighbourhood under research.

3.2 Oasis City model

In the Oasis City model the nature-based solutions allow the creation of thermal comfort zones to serve the inhabitants. In fact, cities can be places with higher temperatures than surrounding regions. This occurs because of the built environment that characterizes most urban lands. The goal is to mitigate the often dangerously high temperatures caused by climate change. The vegetated areas not only affect the climate of the area but also work simultaneously for the hydraulic safety, going to increase the area of permeable soil and the evapotranspiration and reducing rainwater velocity. The benefits can be evident when creating a real network capable of influencing the thermal and hydrological state of an area as large as the neighbourhood selected for the project. By reducing heat island effects, it will be possible to benefit from improved air and water quality, as well as increased comfort and human health.

3.2.1 Nature-based solutions (NBS)

Nature-based solutions can be considered as a term that encompasses different concepts or technologies ranging from blue–green infrastructures to natural water recovery measures, to ecosystem-based adaptation [16]–[18]. The NBS that have been considered for the neighbourhood concern a dense network of spaces and include interventions useful to the welfare, health, and safety of people. The tree species have been selected among those native and most capable of reducing pollutants and storing CO_2. Among the planned actions, the most influential is the creation of a totally self-sufficient linear park: Tiber Park. All the solutions foreseen have been integrated with sustainable drainage systems useful to reduce the run-off of rainwater and better detailed in the paragraph of the Sponge City.

3.3 Sponge City model

The model of the Sponge City is the second model considered. Following the experience of the French eco-neighbourhoods and permeable squares, now spread out all over Northern Europe, we try to respond to the hydraulic fragility of the Portuense area, introducing small but significant changes. Interventions for the water run-off control and water recycle are proposed, namely: infiltration trenches, grass swales, storage tanks and phytoremediation ponds to laminate and purify water. Also, permeable and vegetated pavements of the open spaces find their place in the project furnishing an important contribution to make drainage more sustainable and to mitigate heat island effects [19]. In fact, impervious, smooth and maybe sometime steep pavements, can cause an extremely rapid runoff during storm events: high peak flow can be reached in short time and a large amount of sediment and pollutants can reach the underground pipes and rivers, causing large damage [20]. On the contrary permeable and vegetated surfaces can play an excellent role in environmental control [21]. Furthermore, the use of vegetation to replace horizontal paved surfaces, but also vertical ones, can be an attractive decorative method.

3.3.1 Biotope area factor (BAF)

BAF is an index first applied to the city of Berlin in 1994 as part of the “Pro Landscape Program”. It measures the permeability of an area and evaluates urban planning solutions based on the ecosystem functionality of the built environment, as a function of ecological land use [22]–[24]. Soil sealing is one of the biggest problems found in cities today and is a reason for several natural disasters [25], [26]. Lately, our cities are much more frequently victims of floods or flooding and despite this, the urbanization process is continuing to expand and cover natural or semi-natural areas with asphalt and concrete [27]. Soil sealing is a very important fact and the well-being of both humans and ecosystem depend on it. Some examples among the benefits that soil gives us are carbon sequestration, microclimate regulation, biodiversity protection or food production [28], [29]. The index is often used, as in our case, to simulate an alternative mitigation scenario in a specific area of the city and enrich the debate on land consumption by giving support to sustainable urban planning [30]. The analysis using the BAF index was carried out, firstly, mapping the green areas of the Portuense neighbourhood, and then assuming to increase them in the next project phase. The BAF index ranges from 0, that means completely impermeable surfaces, to 1, complete permeable surfaces. It is calculated using the following equation:

$$BAF = \frac{\sum_i w_i A_i}{\sum_i A_i}, \tag{1}$$

where w_i is the weighting factor for the i-th sub-area and A_i the extension of each sub-area. The weighting factor was assigned a value according to the soil permeability feature (Table 1).

Table 1: Type of soil and weighting factor for BAF evaluation.

Surface type	**Weighting factor *w***
Sealed	0
Partially sealed	0.3
Vegetated but unconnected to the soil	0.7
Vegetated connected to the soil	1

For the limited extensions of the study areas BAF index was evaluated manually from the technical cartography of the municipality of Rome. BAF index is equivalent to other indices used to evaluate soil permeability and useful for verifying hydraulic invariance in urban transformations [31]. Specifically, it can be compared with the RIE Index, introduced in 2004 within the Building Regulations of the Municipality of Bolzano, Italy. BAF Index, beyond its original function, has an important role both within the context of urban drainage, heat mitigation and amenity of the places.

3.3.2 Sustainable drainage systems (SuDS).

This project makes use of sustainable drainage solutions in regenerating the Portuense district, which, due to its position and its average altitude, is subject to the risk of flooding whose frequency is increasing due to climate change. We can define "sustainable" a drainage system that manages rain water runoff taking into account the water quantity control just to reduce the risk of flooding, water quality to limit pollution, biodiversity to favor wildlife and plants and guarantee the amenity of the places. Guidelines for sustainable drainage were published as early as 1992 with the title "Scope for Control of Urban Runoff" [32]. These techniques initially found diffusion in the UK but today they are everywhere essential in the design and management of drainage systems [33], [34]. SuDs solutions are crucial in achieving the Sponge City model. They can be used both in green areas, to retain water and infiltrate it slowly into the ground and in built-up areas, also favoring the retention and infiltration of rainwater. Each site is unique, so the appropriate drainage technique must be chosen and applied.

In particular, in this this project, solutions that favor infiltration, slow down runoff, retain and purify rain water have been considered (Fig. 2). They can be summarized as follows:

- fully permeable drainage solutions, namely: dry vegetated channels or grass swales, filtering wedges, filtering strips, tree-boxes;
- partially permeable drainage solutions, i.e.: public space/parking surfaces, unconnected vegetated surfaces;
- phyto remediation ponds;
- retention tanks, used also for recycling water.

4 RESULTS

Three main interventions called "prototype" have been conceived, since the intention can be repeated for all the interventions foreseen in the "network of spaces" planned within Portuense district.

4.1 Prototype 1: Pocket Park

For the first prototype project a strategic location of the district has been chosen, the Villa Bonelli station of the FL1 railway line. It was decided to reduce the imperviousness of the

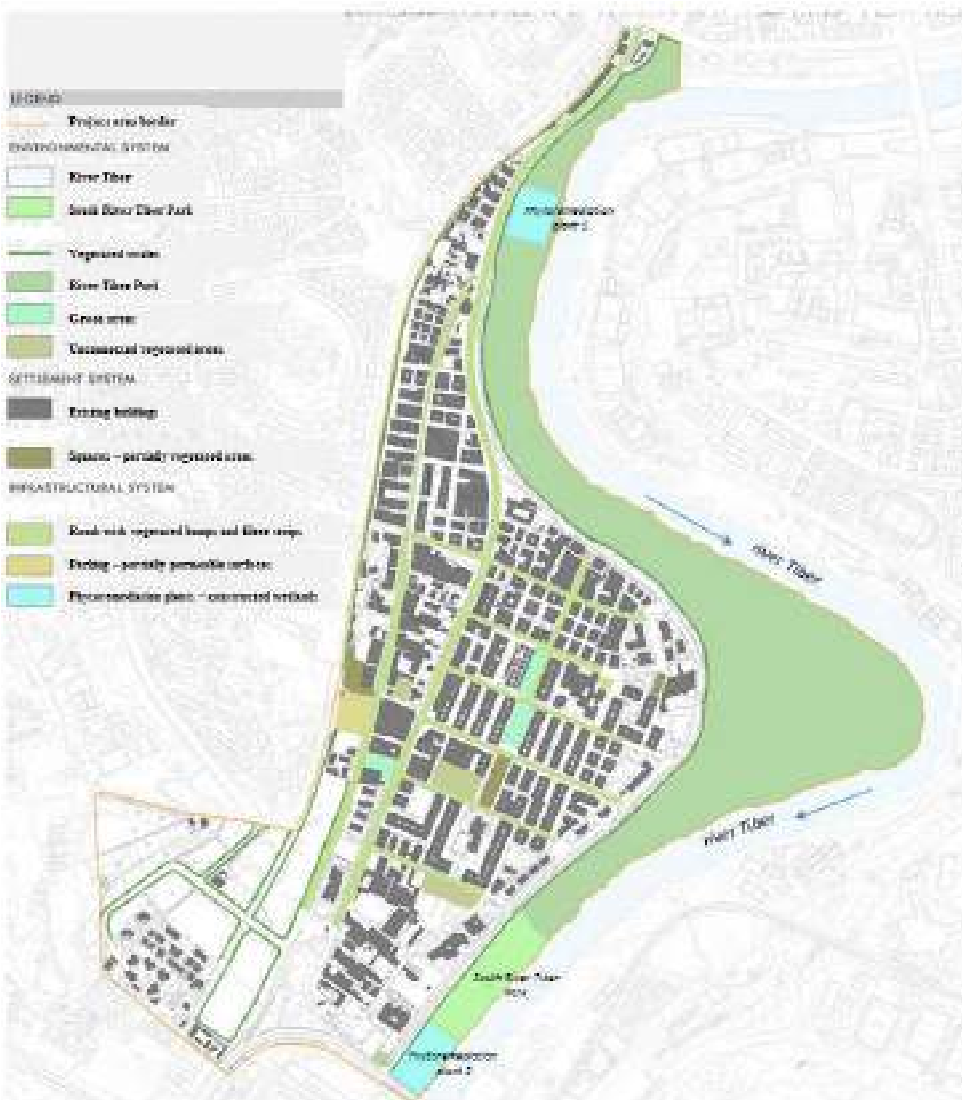

Figure 2: Map of the main design solutions.

train station and the adjacent parking area with a draining pavements. The whole area has been requalified with a wooden roof with seats for the terminus of bus line, the addition of a rest and refreshment area with equipped green areas and a short stop area for cars, with green areas of different use (Fig. 3).

For the area to regenerate, in front of the train station, a Pocket Park has been thought of. Its peculiarity is that it is located in a very busy place especially for the passage and it is above a public parking lot. The morphology has been designed to manage the flow of pedestrians coming from the Villa Bonelli station and from Via della Magliana: it has a

Figure 3: Prototype 1: localization, map and 3D view of Pocket Park.

central strip used for rapid passage that divides an area, more intimate and hidden, equipped with seats and used for rest and aggregation of citizens, and an area more exposed than the first, intended for both rest and transit. Because of its location on the public parking, the selection of vegetation has been rather constrained. Very small and high performance trees were chosen: *Acer palmatum*, to shade the seats and the paths; *Ligustum coriaceum* and *Pittosporum tobira*, which have high CO_2 storage and PM_{10} abatement capacities, and were used for the flowerbeds dividing the Pocket Park from the street and for the internal flowerbeds; *Lavandula* and *Glyceria maxima*, used for the internal flowerbeds and having high pollution and rainwater absorption capacities. The project was able to achieve the target BAF index of 0.3. The previously impervious areas of 9492.5 m^2 are now partially sealed or even totally permeable areas. With regard to the factors of absorption of pollutants related to the plantings chosen we have: the maples will absorb 0.213 grams/tree/day of NO_2 and 0.035 grams/tree/ day of PM_{10}, CO_2 sequestered will be equal to 0.0010 tons/tree/year.

4.2 Prototype 2: Main Avenue

The second prototype project was carried out in the central core of the neighborhood. The designed avenue includes the current Via Lari and Viale Vicopisano. The area has an important social role, being the main place of aggregation for the inhabitants. The idea is to realize an avenue marked by three different consecutive flowerbeds. Each flowerbed has a particular function according to the needs given by its position and is strongly characterized by a different color and type of vegetation. Mainly, there are two paths, a main one and a secondary one that resume the trend of a hypothetical river with a sinuous path, because of the proximity to the neighborhood of the Tiber River.

The reference of this project was the linear park Superkilen in Copenhagen, realized between 2011 and 2012. It is a large open-air installation divided into three basic parts, developed on a strip of land over 750 m long. The first two parts are made with the same material but characterized by different identification colors and uses, while the third has a more traditional lawn arrangement (Fig. 4). The project totally converted the area from impervious to partially sealed or permeable going to meet the target BAF index. The project gave special attention to the livability of these new spaces created for citizens. The aspect of perceptual evaluation was fundamental to create 11,000 new square meters available to citizens. These spaces will accommodate dozens of new functions including children’s playgrounds, sports equipment, performance areas, seating areas, etc.

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Figure 4: Prototype 2: Map of Main Avenue regeneration.

4.3 Prototype 3: The Tiber Park

The Tiber Park (Fig. 5) was designed in continuity with the park recently built in the southernmost part of the neighbourhood. The park as a whole can be flooded and will therefore protect the neighbourhood behind, from which a high embankment divides it. The park provides for the development within it of many functions, including a large central square as a space for aggregation of the inhabitants, a botanical garden for the increase and growth of biodiversity of the river, play areas for children and areas equipped for sports. The areas include spaces with both collective and individual functions, to allow the inhabitants to take care of their health in open spaces and enjoy alone or in company of the presence of natural elements.

Within the context of this prototype, to make the neighbourhood a part of a potential Sponge City, two phytoremediation plants were designed to purify rainwater drained by the collecting system. The water leaving these plants is collected in underground tanks from which it is taken by tank trucks and recycled for washing the streets and watering the green areas of the neighbourhood (Fig. 6). The plant species chosen for the phytoremediation plants are autochthonous species commonly used for constructed wetland in Italy: Schoenoplectus lacustris, Typha latifolia and Phragmites australis. In particular, each planting has a different threshold of root penetration and depending on the position in the tank, the most appropriate is planted (Fig. 7).

The park's output was accessibility, inclusion, and multi-functionality, in line with City for People goals. It is a rich, expanded public space that has been returned to citizens. Each function included in the park has been designed for a different age group of users, there are facilities for children from 2 years old and others for children from 6 years old, there are also sports facilities for all and walks on walkways and among the plants of the botanical garden that are also suitable for the older segment of the population. The filter area of 45,024 m^2 inside the park has about 110 specimens of white poplar of different sizes and plays a key role in the air quality of the neighborhood. The filter area contributes to the absorption of : 553.84 tons/year of CO_2, 27.14 grams/day of PM_{10} and 446.464 grams/day of NO_2.

Figure 5: Prototype 3: Map of Tiber Park.

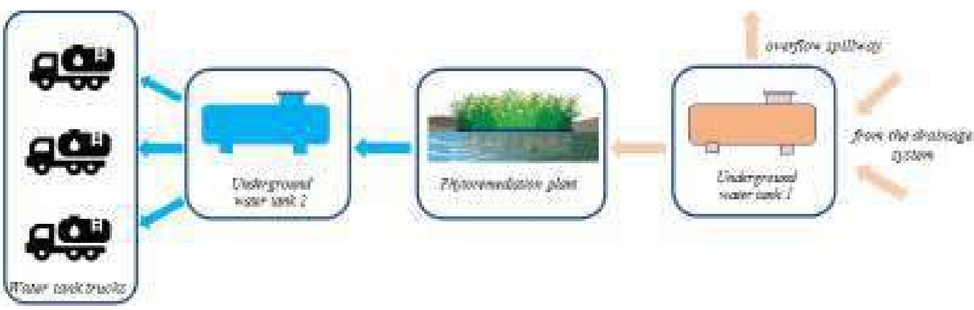

Figure 6: Prototype 3: Schematic of rainwater recycling system.

Figure 7: Prototype 3: Plant species selected for phyto depuration.

5 CONCLUSIONS

In this work, we wanted to affirm the need to unify the skills related to different disciplines for a perfectly aware urban design. The importance of a multidisciplinary approach involving knowledge related to urban climatology, hydraulics, botany, psychology, sociology, and ecology was highlighted. In this context, the goodness of the overall project will have to be evaluated starting from the results of each type of investigation, through "intelligent" cognitive maps capable of establishing connections between the disciplines. Specifically, key indices for each specific discipline must be linked together with connections that represent their reciprocal relationships. The result will be obtained through an optimization process on the overall effects of every single intervention. The "prototypes" proposed by this study and the related "green network" that they create, constitute a first step in the formulation of this design methodology which aims to regenerate our cities by increasing their environmental sustainability and improving the quality of life of the inhabitants.

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GROWING UP: AN URBAN DESIGN APPROACH BASED ON INCREASED DENSITY

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ABSTRACT
Throughout history cities have been the physical manifestation of human progress and a place of unique opportunities in terms of welfare, social mobility and economic prosperity. Under the pressure of continued global growth, cities have become complex multi-layered organisms and are facing an increasing number of challenges such as environmental quality, social balance, waste disposal, transportation systems, housing accessibility and urban space quality to name a few. In the context of economic and demographic pressure, one can wonder if large and dense urban centers can continue to grow while meeting complex functional needs and remaining attractive places to live. This paper proposes to discuss a strategy of urban development based on increasing the density of historical city centers by means of adding floors to existing buildings. In essence this concept is in keeping with the notion of urban growth as an incremental process where new building units and infrastructures are added and intertwined with existing ones. It also recognizes the value of old urban profiles. This urban design process has been developed and experimented in Hamburg, Germany for a number of years and presents an original and promising approach to urban growth. It has been relying on the use of lightweight construction, mainly wood based systems, due in part to their relative lightweight, ease of assembly and insulation value. This approach encompasses many fields of study as it deals with zoning laws, construction codes, structures, building systems, social identity and architectural expression. It constitutes an attempt to minimize gentrification, urban sprawl and create quality housing at attractive prices in desirable neighborhoods. A goal of this paper is to assess the impact of this urban design approach and to identify possible applications in other urban contexts.
Keywords: urban design, increased density, rooftop additions, sustainable urban growth, resilient cities.

1 INTRODUCTION

Today half of humanity's 7.6 billion people live in cities and it is projected that 5 billion people will live in urban areas by 2030 (United Nations Sustainable Development Report 2020). This trend of sustained urban growth is clearly driven by the many appeals of cities including opportunities of upward social and economic mobility [8]. According to the United Nations Sustainable Development Goals it is estimated that urban centers currently represent 70% of the world's gross domestic product. As cities continue to grow often into large or very large urban centers, they face increasingly complex challenges. In fact, the larger the city the more difficult it becomes to manage the flow of people, vehicles, water, waste and resources in general [9]. Even more so in a sustainable manner. Just as urban centers are undoubtedly places of great opportunities, they are also known to induce stress due to increased commute time, air quality and access to affordable healthcare and housing. Access to affordable housing within a reasonable distance of peoples' workplace is a particularly challenging issue. Typically, urban residents of large cities live in suburbs because the cost of housing downtown is disproportionately high compared to their income. As a result, they have substantial commute time to work generating both stress and a loss of productivity. The issue of affordable housing in urban centers is important in financial and practical terms but also in terms of access to services, culture, and social interactions. The idea of city centers being vibrant places composed of diverse ethnic and socio-economic groups represents a noble goal that is not always easily achievable. Mechanisms such as rent control and

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subsidized housing provide opportunities for low and middle-income individuals to live in urban settings and also close to their workplace. Unfortunately, these opportunities tend to be limited because of the limited housing supply as most of the production of new housing units occurs at the periphery of existing cities or in more distant suburbs, therefore posing the question of urban growth.

Metropolitan regions have been growing worldwide as rural areas continue to lose residents who are moving to cities. This trend has been well documented and mapped in Europe for many decades [1]. But the crucial question remains, how should cities grow? There are several different scenarios for urban growth. Cities can grow by expanding into surrounding areas, in which case they become very large. Most people associate urban growth with this geographical expansion but there are clear limits to this approach. As a city expands geographically its infrastructure and services must also grow with it. However existing infrastructures such as sewage systems and road networks can only expand so much until they have to be completely upgraded. This form of growth tends to generate incalculable costs for the public sector and therefore has spatial and economic limits.

Another strategy for growth can be described as a re-densification of the city. It assumes that the city would become more compact and people would live closer together. This idea of urban growth can be difficult for people to imagine and tend to be fraught with reservations or is not recognized as an effective relief for the housing market. Practically speaking, urban re-densification can follow several strategies. Land can be developed in a denser fashion such as in the case of backyard development, additions, demolition and new construction. Derelict industrial and commercial properties can be converted to housing units through adaptive reuse conversion and rezoning. Another possible option would consist in building new properties on top of existing ones. This last option, though surprising at first, offers a number of sustainable features. One of its most obvious benefit is the fact that it does not consume any existing vacant land and therefore does not “seal” the ground or add storm water issues associated with the increase of impervious surfaces.

2 OBJECTIVES OF THE STUDY AND METHODOLOGY

In the context of global population increase, the objective of this paper is to present an alternative strategy of urban growth for existing dense cities. As previously stated, there are clear limits to the physical expansion of urban centers; this invites us to consider a new approach to the overall issue. The idea of building residential rooftop additions on a large scale makes logical sense though it is fraught with a number of challenges in terms of technology, legal environment, sustainability and cost to name a few. Therefore, we propose to discuss both challenges and opportunities associated with this form or residential projects in order to develop a clear overview about the issue at stake. Our method of analysis will consist in evaluating positives and negatives as it relates to the socio-economic context, structure and technology, sustainability, legal issues and the overall economic feasibility. The data used in this paper was gathered in the context of a research project under the direction of Professor Bernd Dahlgruen in the city of Hamburg, Germany.

One of the benefits of building on top of existing structures is that it does not reduce the economic use of the existing urban fabric as is the case of adaptive reuse projects and preserves a mix of commercial and residential uses. In addition, it does not displace people living in the existing building due to demolition and new construction and does maintain the existing social fabric of a neighborhood. Other advantages lie in the fact that this strategy prolongs the economic and therefore the overall life of existing real estate by leaving it intact. This strategy also provides upgrades to existing structures especially in terms of energy efficiency. The only potential disadvantage is the disturbance to adjacent residents during the

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time of construction. However, this would appear to create only a minor impairment as these types of projects have a very short construction time.

However, as much as this form of housing development seems to be sustainable and socially acceptable, it is very important to identify and measure the impact and potential of these strategies in the broader context of long-term urban evolution in order to make a convincing case for it. In fact, local politicians and developers have expressed many concerns about these types of building additions as their feasibility was being evaluated [2]. Building professionals expressed well founded criticism regarding the design of these rooftop additions. It is in fact a construction challenge to add a new building component, which has to meet current requirements such as fire, sound and heat protection onto an existing building with completely different construction properties. What happens at the interface? How are the transitions constructed? What are the normative and legal requirements for the existing building, the new building and the transition? In consultation with construction experts, construction sample solutions were developed and made available to the public as part of the feasibility study for this type of project. There are obviously additional practical concerns regarding the construction site and its functionability. Often, there is simply not enough space for a construction site facility and it is not possible to set up a crane on a permanent basis. All these issues were taken into account in the development of a practical project planning. All project solutions included lightweight prefabricated components to be installed on the roof by means of a mobile crane in a couple of days at the most, preferably on a weekend. All other construction activities such as interior finishes and roofing would not require major site equipment.

Obviously, many of the concerns associated with this type of project are technical in nature and are associated with the ability of existing structures to carry additional loads. The compatibility between new requirements and old standards, especially with regards to fire and sound protection have also raised a number of questions. The tight physical constraints of constructing such projects can also appear to be challenging and generate excessive cost due to the unusual height of the construction site. In that case it may reduce the overall value of the existing building because of technical deficiencies. There are also legal concerns as existing buildings cannot be extended in accordance with current building legislation. Overall, city planners and politicians viewed rooftop building additions as having a very low impact on urban housing needs.

3 SOCIO-ECONOMIC CONTEXT

Over the past few decades, growing German cities such as Hamburg (see Fig. 1), Berlin or Munich have generated an increase in inner-city housing demand, due to the scarcity of land and few new housing projects. As a result, real estate prices have risen, and urban living has become more and more expensive for newcomers. As a consequence, the property prices for existing condominiums in the Hamburg metropolitan area in the 2011–2015 period have increased between 5% and 13% annually. Existing apartments in the Eimsbüttel area cost an average of €2,500 to €3,000 per square meter in 2011. In 2015 these apartments cost an average of €3,000 to €4,000 per square meter. In 2012 only 11% of the advertised rental apartments were for average income families and only 2% for low income families. The offering of affordable urban housing is far below the German average.

This sustained development in the real estate industry is leading to a gentrification process and threatens socially acceptable urban development. Therefore, we see urban densification by means of building additions as a form of development that can counteract this phenomenon because building additions can generate additional living space without using

Figure 1: Map of the city of Hamburg in the 1900s.

additional land. These housing units do not necessarily have to become rental properties but rather subsidized apartments for low or middle-income families.

In addition, these building additions promote sustainable and ecological urban development since they emphasize inner-city living and compact infrastructure as opposed to urban sprawl.

4 TECHNICAL AND STRUCTURAL CHALLENGES

In Europe, most historical urban housing is built of stone and in Northern Europe mostly of brick. These materials have high compressive and load-bearing capacity, which can be easily determined by calculation. By measuring the room depth, floor heights and wall thickness of load-bearing walls, one can obtain all relevant parameters for an initial structural assessment. The most important criteria here are the direction of the ceilings span, the wall thicknesses, floor heights and the window proportion of the load-bearing walls. As a part of our feasibility study for this type of project, we have provided a calculation tool for initial structural assessments, which can be used to determine whether existing buildings have sufficient load-bearing capacity for rooftop building extensions in less than 30 minutes [4].

When researching historical building methods, we noticed that it is rarely the wall structures that are statically problematic, but rather the undersized foundations. Their load-bearing capacity cannot be determined in advance without planning documents. For this purpose, an area of the foundations would have to be exposed in order to determine the construction and its load-bearing capacity. This can also be done with the calculation tool we referred to earlier and which is available on the HCU website. However, if the foundations are undersized for a building extension, it is still possible to increase the load-bearing capacity of the soil and foundations by injecting cement-water emulsions. This method is inexpensive and can be carried out without major construction work in the existing structure and can be performed on the foundations of the exterior and interior walls.

In summary, it can be said that the load-bearing capacity of the existing structure is easy to determine, foundations can be strengthened with simple means if necessary, though load-bearing walls unfortunately cannot. In this respect, the absence of existing load-bearing walls is an obstacle for these types of additions. However, a few hours of work and simple calculations can determine the feasibility of a project at the beginning of the process.

Though historical buildings in Hamburg are built with some type of masonry system and offer a good “base” for rooftop additions, the construction system most appropriate for such projects would have to be wood. When compared to concrete and masonry construction systems, timber construction systems have, in addition to the low dead loads further design advantages. Regardless of whether we consider a wooden frame, a panel, or box girder elements, these systems can be used with a high degree of precision. They can be prefabricated and assembled very quickly any time of the year as long as it is not raining (see Fig. 2). The prefabrication process implies quality control procedures and ensures a high manufacturing quality. The disadvantage of all wood systems lies in their vulnerability towards fire. For example wooden box girder elements are valuable when considered from a static point of view as they are light though cross-laminated timber panels have a much better dead-load to load-bearing capacity ratio.

(a) (b)

Figure 2: (a) Mobile crane; and (b) Prefabricated panel installation.

When designing lightweight structures, such as those used in rooftop additions, special attention must be paid to the issues of heat and moisture protection. Lightweight structures are often designed as frame structures and structural components are often located in the insulation cavity of a wall or roof system. Therefore, designers need to pay particular attention to issues such as thermal bridging, which constitutes a break in an insulated building envelope. Lightweight wood construction assemblies would then need to be designed as a multi-layered system in order to be air and vapor tight and provide adequate insulation. Lightweight construction has a low net weight and therefore little heat storage capacity, so the overall building envelope needs to be designed in such a way so that it provides adequate protection from the summer heat.

5 SUSTAINABILITY AND ENERGY EFFICIENCY

40% of the total energy consumption in the European Union is associated with new building construction and operation of existing building stocks. The construction and real estate industry continue to grow across Europe therefore contributing to increased energy consumption and CO_2 emissions. Given the ecological consequences associated with increased greenhouse gas emissions, the European Union adopted a mandatory directive on the overall energy efficiency of buildings. Member states of the European Union created national regulations aimed at reducing national energy consumption and CO_2 emissions from buildings in order to meet agreed upon measurements and calculation specifications. Starting on September 31, 2020, only low-energy buildings would be approved by the EU. Low-energy buildings are structures that have no or low energy requirements, mainly from renewable or locally generated sources. To achieve this 2020 target, member states of the EU are gradually introducing their national regulations on building energy consumption. The Federal Republic of Germany is also pursuing this strategy and implementing the EU directive currently with the Energy Saving Ordinance. Since building heating has the largest share of energy in the operation of residential buildings in Germany, efforts have been focused on the minimization of heat losses via the building envelope. These issues of insulation and heat gain are actually exacerbated by the fact that rooftop structures are especially exposed to the sun and cannot benefit from a night cooling cycle due to a lack of thermal inertia.

6 LEGAL ENVIRONMENT

Most building codes do not consider building additions and contain regulations that make this form of housing creation difficult or even impossible. For example, until 2015, Hamburg required elevators above a building height of 13 m and prohibited wood construction for fire safety reasons among other things. These regulations vary from country to country and should definitely be identified at the beginning of the project in order to be able to assess whether a building increase is feasible at all in the respective jurisdiction. As a part of the feasibility study for this project, we petitioned local politicians to adapt the jurisdiction for this type of re-densification. We only succeeded in this effort by making the following demonstration. The effectiveness of building extensions for creating living space was always considered too low due to the very small project sizes: “Rooftop additions are projects that typically create one or two residential units at a time!” Nevertheless, urban densification is a political goal of the state government in Hamburg and the exemptions granted by the authorities along with changes made to the building codes caught their interest and support.

With the help of our colleagues from the geoinformatics department, we determined the building-law potential for Hamburg on a building-by-building basis and arrived at a pure building-law housing potential of approximately 75,000 apartments [5], [6]. This number corresponds to the housing demand in Hamburg for 10 years. This determination does not take into account any construction and economic concerns, but only aspects of urban planning law, namely distance areas and maximum permissible building heights. We published this research online and shared it with a press release. The result was published in daily newspapers, discussed in the Bürgerschaft and finally exerted political pressure on the local government, which then partially overturned 140-year-old building regulations. Therefore, today in Hamburg we do not have any legal criteria in the building code that prevent rooftop additions. Demonstrating housing potential was and remains the most important step in getting interest and commitment at the political level for this form of urban re-densification.

7 ECONOMIC FEASIBILITY

However, the housing potential demonstrated above does not convince builders. They compare the construction prices with a traditional new building project, find out that the construction prices of building extensions are significantly higher and then state that building extensions are uneconomical. This approach is actually inaccurate because instead of focusing on construction costs only one needs to consider the overall project cost. In fact, in the case of rooftop additions, construction and planning costs are both more expensive. In addition, there are compensations for existing tenants and, if applicable, additional legal costs. Rooftop projects are also more expensive in terms of design and construction when compared to traditional projects. However, a key factor is that they do not consume additional land. Since the land costs actually exceed the additional costs, building extensions are very economical compared to traditional construction projects. Especially in the growing cities described above, the price of land relative to the overall project cost has exploded within the last ten years. In Hamburg, it has quadrupled within the last ten years and is as high as the construction costs. In the context of expensive cities rooftop additions can therefore turn into economically feasible projects.

8 SUMMARY OF ANALYSIS AND CONCLUSION

As was demonstrated throughout this paper, rooftop additions are now considered a viable form of urban development in Hamburg (such examples are shown in Fig. 3). They represent a significant potential in terms of number of housing units and can contribute to reducing the effects of gentrification downtown especially if rooftop projects are integrated with some form of subsidized housing program. This can help preserve a certain socio-economic diversity in downtown Hamburg and allow certain essential professions such as teachers, firefighters or police officers to reside in the city and near their workplace. The legal environment in the greater Hamburg area is now conducive to these kinds of projects as their economic feasibility is no longer in doubt. And though there are clear technical challenges to the execution of such projects, they are very manageable with proper planning and the recent advances made in the construction industry. The implementation of relatively new construction methods such as prefabricated structural wood systems offers speed of assembly, light weight and high building performance in line with European energy standards. With the use of appropriate materials and proper detailing, these prefabricated units can be very durable and make a long-term impact on housing demands within the city. Though potential heat gains need to be addressed, other unique advantages of these housing units include increased access to daylighting and views because of their unique location within the existing urban fabric.

The rooftop projects presented in this paper are within the specific context of a historical European city. It is clear that the specific nature of this context had an impact on the projects' visibility as it relates to the legal context, technology, resources and sustainable strategies. In a general context, such projects are challenging at a number of different levels and their occurrence has so far been limited to isolated cases. Though, as was demonstrated in the case of Hamburg, there is a real potential for this form of housing to contribute to a meaningful urban growth. Therefore, it is a model of development that could be applied in a variety of urban contexts around the world. A number of high-end residential rooftop projects have already been built in Europe and the US, but they are usually not part of a large scale concerted effort as is the case of Germany.

It is very conceivable for this type of housing project to be developed in other regions of the world including developing countries. With support from public institutions, a conducive legal environment can be developed as well as financial incentives. An important challenge remains though, which is the technical feasibility of such projects and the ability of existing buildings to receive an additional structure. Nevertheless, most urban buildings worldwide are either built with concrete, masonry, or steel therefore providing a potentially suitable base. Despite the lightweight nature of rooftop additions, important technical requirements will remain such as precisely aligning the bearing points of the new and existing buildings. The fact that these units are prefabricated and of high-quality would certainly contribute to improving housing standards especially in the case of affordable housing. The energy

Figure 3: Examples of completed rooftop additions.

efficiency of these additions would have a tangible impact environmentally as most of the urban growth in the next 30 years is projected to occur in the global south (United Nations Sustainable Development Report 2020). But ultimately these types of urban dwellings would present a tool for cities to slow down sprawl and increase density in a sustainable manner. It would also have a measurable effect on the environmental consequences of urban growth around the globe. Just as vehicle manufacturers are pivoting to all electric vehicles around the world, the design community and construction industry needs to propose innovative urban design strategies. The ability to create quality affordable housing within large urban centers remains a challenge worldwide but is crucial to the socio-economic diversity of our cities so they can continue to be engines of development as well as a desirable place to live.

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EXPLORING AN INTEGRATED PATHWAY FOR SUSTAINABLE URBAN DEVELOPMENT OF REFUGEE CAMP CITIES AND INFORMAL SETTLEMENTS

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ABSTRACT

More than half the world's population live in urban areas, and this number is expected to increase substantially by 2050. It, however, does not include temporary settlements stemming from forced displacement, now housing 82 million people worldwide. In many ways, refugee camps and cities face similar population dynamics, social issues, and environmental challenges such as the sustainability of resources, food security, sanitation and water management, sustainable energy, and waste disposal. But informal settlements, like Kutupalong Refugee Camp (KRC) in Bangladesh with almost a million displaced people, continue to slip through the cracks. Planners must acknowledge and plan for these urban settlements building their own organizational structures and economies. This paper reflects on whether the established principles of urbanism can form the basis of long-term developmental planning in spaces of refuge. It evaluates refugee camp cities through the lens of five urban dimensions and investigates innovative and integrated approaches to fill identified gaps. Two case studies undergo a meta-analysis from a "humanitarian urbanism" perspective to understand the process through which they are growing (KRC, Bangladesh) or have evolved (Amman, Jordan). Given the recurring nature of forced migration and burgeoning urbanization challenges of this century, the discussion hopes to spawn viable multiscale and multidimensional interventions in the future.
Keywords: refugee camp-city, informal settlements, humanitarian planning, urbanization, sustainable development.

1 INTRODUCTION

In 2018, more than half of the world's population lived in urban settlements. By 2050, urban areas are projected to house 68% of people globally [1]. This number, however, does not include those living in temporary settlements stemming from forced displacement, and it now stands at 82.4 million people [2]. Because the world's urban areas will absorb or interact with a big percentage of the displaced people eventually via assimilation, integration, or resettlement [3], the link between planned urban settlements such as cities and informal settlements associated with forced displacement is a strong one. For specificity related to this paper, it is also important to define and differentiate between voluntary and forced migration (and between migrants and refugees/asylum seekers). Informal settlements are often reviewed in the context of informal housing, but their categories are wide ranging. For this paper, "informal settlements" (IS) refer to migrant and refugee-majority settlements, and together with camp cities (CC) will be abbreviated as CCIS henceforth. Host Communities will utilize the acronym HC.

The UN 2030 Sustainable Development Goal 11 aims to "make cities and human settlements inclusive, safe, resilient and sustainable" [4], but most of these spaces fail to meet these criteria on multiple counts [5]. Most CCIS carry the additional burden of physical, social, and economic segregation, and have drawn special attention from world bodies. United Nations High Commission for Refugees (UNHCR) has published a manual called the UNHCR Handbook [6] with technical specifications for transient settlements such as refugee camps. However, the immense scale of the current migratory movements appears to render older manuals and urban plans inadequate [7]. Seemingly transient settlements are now the

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size of intermediate cities; a prime example is the Kutupalong Refugee Camp (KRC) in Bangladesh housing almost a million people between 27 scattered sub-camps. The phenomenon of protracted displacement and the evolution of temporary camps into permanent CCIS has led to an emerging consensus that these spaces are increasingly mimicking urban agglomerations in terms of urbanization challenges. Killian Kleinschmidt, one of the world's leading authorities on humanitarian aid, even calls them "the cities of tomorrow" [8]. The secondary challenges with CCIS are multidimensional: the "right to urbanism", official recognition, spatial limitations, lack of freedom of movement, spatial segregation with social exclusion, perennial dependence on outside actors, fragile ecosystems, and greater susceptibility to disasters. Because the biggest CCIS have sprouted this century [9], there are few investigative studies related to integrated planning approaches that go beyond addressing the physiological and safety needs at a rudimentary level.

This paper attempts to challenge the current narrative of refugee CCIS as state-planned geopolitical assemblies and explore holistic, interdisciplinary approaches combining the social sciences, humanities, and urban planning to encourage innovative and measurable solutions in sustainably developing them. With two frames of reference in Jordan and Bangladesh, this paper will broadly cover the complex and intertwined layers based on five established dimensions (and highlighted sub-dimensions) of urbanism within the CCIS setting: governance, infrastructure, society, environment, and economy (Fig. 1).

Figure 1: Dimensions of urbanism (*Source: UCL*) and CCIS juxtaposition (*Source: Author*).

1.1 Selection of case studies

Jordan has the second highest refugee to citizen ratio in the world [10] and has developed into a country defined strongly by its refugees over the last 70 years. The role of territorial players has never been more prominent: refugees (along with government institutions and NGOs) have been actors with economic, political, and social agency in playing an integral role in the Jordanian state's socio-spatial reconfiguration since its independence in 1946. By eliminating the dichotomy between city and camps, Amman makes the case for an integrated approach to urban development. As a city that has grown ten-fold over the last seven decades on the back of heavy refugee influx, Amman comes closest to the scaled-up response that a million-strong burgeoning CCIS in Bangladesh can utilize in its development.

The district of Cox's Bazar in Bangladesh hosts the world's largest refugee camp and, in terms of population, meets the requirement of a city. The settlement is in the infancy of what appears to be a complex development path following the abrupt establishment of scattered camps to accommodate the heavy influx of Rohingya refugees from Myanmar in 2017. As opposed to Amman which has documented a steady population growth trajectory due to spaced-out trigger events, Cox's Bazar was deluged by an overwhelming number of refugees seemingly overnight. Between 2017 and 2019, more than 700,000 refugees joined 200,000 Rohingya who had fled Myanmar years ago and lived among the 2.5 million strong host community [11]. Another important statistic is that more than 50% of the camps' residents are children, and humanitarian responses should include long-term development solutions catering to this demographic. Adding to the urgency, 75,000 children have been born in the camps over the last 3 years; with an implied population growth rate of 10%, the camps could see a two-fold increase over the next decade and a four-fold increase in less than 20 years.

The assessment of the locations against each dimension can offer a better understanding of the dynamics in play and the implementation of macro, meso, and micro strategies by relevant actors in the two countries. This can allow for an integrated and replicable plan to guide the urban transformation of CCIS and reflect New Urban Agenda principles and SDGs.

2 DIMENSION ONE: URBAN GOVERNANCE

The Refugee Convention of 1951, and the subsequent 1967 Protocol, broadly required that international laws legalize and institutionalize the existence of refugees, define the roles and responsibilities of receiving states, and ensure sufficient humanitarian, social and economic support for vulnerable forcibly displaced people [12]. Jordan and Bangladesh are both non-signatories to the Convention but their approaches to address the refugee crises strikingly differ. Over the last six decades, Jordan has encouraged its agencies to work with the UN and other IGOs to craft a MOU on addressing its refugee influx and integrating CCIS into its growing economy. Since the establishment of the Rohingya camps in 2017, Bangladesh has opted to isolate the CCIS politically and physically and has placed severe restrictions on the resettlement services IGOs and NGOs can offer.

Fig. 2 illustrates the sub-dimensions of Urban Governance and key SDGs associated with them.

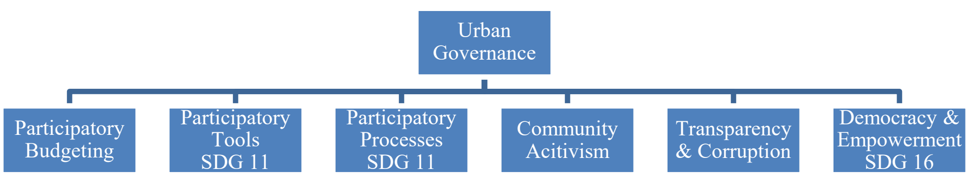

Figure 2: Organizational chart with Governance sub-dimensions and associated SDGs. *(Source: Author.)*

2.1 Challenges and strategies

Between 1951 and 1967, Jordan committed to taking in Palestinian refugees based on regional and national laws with support from the newly created UN. Between 1967 and 2004, the country continued to absorb waves of refugees from multiple Middle East trigger events with UNHCR support and on the principles of The Arab Charter of Human Rights. The government created the Ministry of Planning and International Cooperation (MOPIC) and the non-profit Jordan Hashemite Organization (JHCO) to coordinate with UNHCR on joint responses in specific sectors: "education, health, environment, justice, livelihood and food security, local governance and municipal services, shelters, social protection, transportation, wash and management" [13]. For its part, UNHCR coordinated its efforts with other UN branches such as World Food Programme (WFP), the UN Entity for Gender Equality and the Empowerment of Women, the UN Children's Fund, and the UN Office for Project Services [13]. The result was a Joint Response Plan which, despite some economic shortcomings, laid the foundation for refugee-related policy development. With international support, the 2016 Jordan Compact has been strengthening these protections and addressing the shortcomings with game-changing reforms and innovative mechanisms to expand economic opportunities for the CCIS and HC.

Figure 3: Jordanian Governance framework to manage refugee crisis. *(Source: MOPIC, 2015.)*

In contrast to Jordan's comprehensive response plan which has undergone several iterations, Bangladesh's organizational structure is relatively new. The key actors are the Government of Bangladesh (GoB), the Bangladeshi Army, the Majhi system, and IGOs such as UNHCR et al for CCIS management [14]. On the government's behalf, the Ministry of Disaster Management and Relief (MoDMR) is responsible for the overall governance of CCIS, and the Refugee Relief and Repatriation Commissioner (RRRC) represents the MoDMR in the Rohingya response. The Bangladeshi Army is/was the first responder to the crisis, and participates in evacuation, rescue, relief, and rehabilitation operations [14] in addition to overseeing road construction and infrastructure. For immediate assistance, the army also introduced the country's existing Majhi system to the response plan. Majhis, who act as local spokespersons for the Rohingya, were initially assigned to support the estimation of refugee populations, organization of distribution efforts, and channelling communication to the refugee community [14]. As the Rohingya population exploded, their roles were expanded to include dispute mediation, camp security, and assessment sources for humanitarian organizations. With informal but extensive power and responsibility over Camp Blocks and Camp-in-Charges, majhis have been the focal points of camp governance. The roles of IGOs like UNHCR have been limited to CCIS maintenance and organization, and the benefits of an organizational structure with participatory processes are yet to be felt.

In the absence of a true collaborative, the system has had to deal with lack of accountability and protection. Over the years, the majhi system (with a 90% male demographic) has been the subject of investigation of abuse of power and exploitation [15]. To ensure true representation at the micro level, the Joint Response Plan is experimenting with two community participation initiatives. The first created Para Development Committees (PDCs) to engage both refugees and host communities, and they included representatives from both parties. The PDCs identify common needs and work out solutions, act as dispute mediators, and liaise with the aids organizations and local authorities to coordinate on provision of services and resource distribution. The downside is that the PDC model is currently limited to the collective sites only and is not implemented in camps with 100% refugee populations. To address this, aid organizations have developed a second initiative utilizing a participatory townhouse-styled model which runs parallel to the majhi system. With all-round participation, the forums open channels of direct communication, assist with programming, and generally foster self-organization and self-determination among refugees.

In conclusion, micro governance has been improving since 2018, but meso and macro structures require changing the lens of a government that views long-term development as an obstacle to repatriation.

3 DIMENSION TWO: URBAN ECONOMY

With a GDP of $353 billion [16], and a need for $1 billion annually in humanitarian assistance for the camps, Bangladesh has been struggling to meet the demands of the refugee crisis. The dominant sectors are agriculture and industry which account for 32% of the country's GDP and employ 60% of the total workforce [17]. In comparison, Jordan's GDP has averaged just $12.2 billion from 1965 until 2020, reaching an all-time high of 43.74 USD billion in 2019 and a record low of 0.56 USD billion in 1968 [16] when its refugee population started exploding. The role of the informal economy in the development of CCIS requires a special mention. The informal economy is a global phenomenon and the backbone of third world economies. The International Labour Organization (ILO) estimates that 60% of the world's labour force participates in the informal sector, and that this number is more than 85% in Bangladesh. CCIS have always operated within shadow mechanisms in emerging economies; the system allows state actors and relief organizations to create and sustain multi-year relief operational plans by stretching limited budgets. Innovative mechanisms to trigger growth are the need of the hour.

Fig. 4 illustrates the sub-dimensions of Urban Economy and key SDGs associated with them.

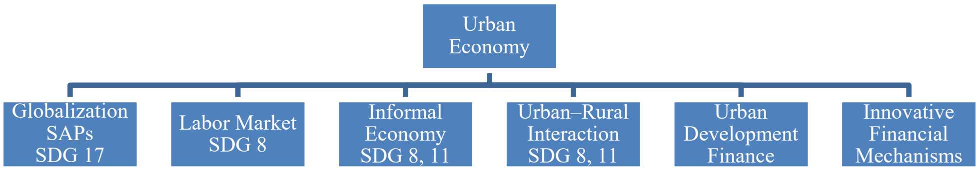

Figure 4: Organizational chart of economy sub-dimensions with associated SDGs. *(Source: Author.)*

3.1 Challenges and strategies

In Amman, the material and socio-cultural transformation of CCIS into city neighbourhoods was primarily funded by relief organizations such as UNRWA within their boundaries while Greater Amman Municipality (GAM) played a pivotal role in infrastructure development around their peripheries. The Jordan Compact of 2006 was a gamechanger in how host countries and IGOs responded to these challenges. Utilizing a combination of concessional financing, creation of special economic zones (SEZs), and beyond-aid incentives while simultaneously advancing legislative policies to benefit CCIS and HC, the Jordanian government has built a viable roadmap for inclusive and sustainable growth. The compact has had its share of failures as well: lack of refugees' perspectives at the outset, continued financial barriers and quality of services resulting in lower school enrolment, and non-access to critical sectors and self-employment for the refugees. The London Initiative of 2019 looks to address them with national policy tweaking, additional funding, and opening the labour market, but the results will not be visible for another decade.

GoB's decision to designate the majority of the Rohingya as Forcibly Displaced Myanmar Nationals (FDMNs) versus "refugees" has translated into developmental challenges across the entire urban spectrum. The meso and macro level impacts are forceful and, as with typical socioeconomic analyses, are associated with other related sectors such as governance, infrastructure, health, and education among others. In the absence of a compact in Bangladesh, all these sectors lack the framework for sustainable development. In conjunction with other sectoral changes, a dual-pronged approach using UN-Habitat's economic toolkit can set the tone. The first prong involves utilizing flexible instruments such as land-based finance with a socially inclusive approach to land tenure that provides equal rights to landowners and the land occupants, and the second encourages innovative financing arrangements and Public–Private-People-Partnerships (PPPPs) for CCIS. Fig. 5 illustrates the financing framework to guide the transformation.

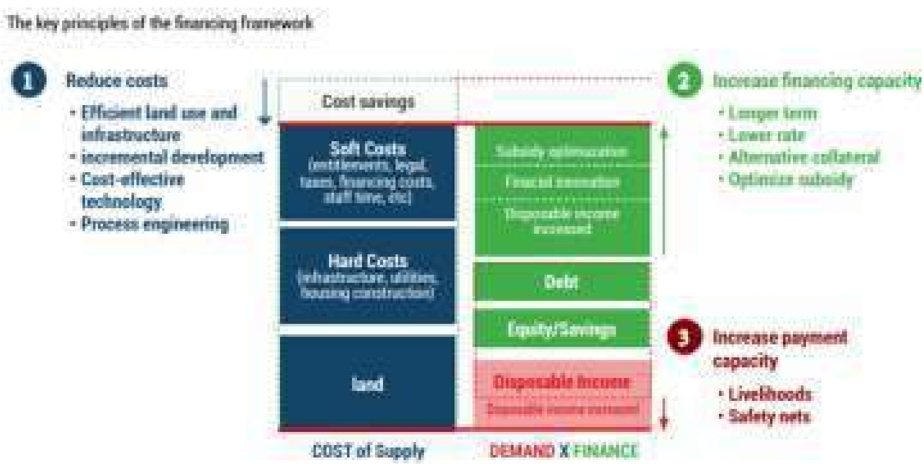

Figure 5: Sustainable financing framework. *(Source: UN-Habitat, 2020.)*

The Joint Response Plan of 2019 aims to boost public and private sector investment for economic opportunities and job growth. Recently, the Bangladesh Economic Zones

Authority (BEZA) has designated several zones across the country, including Cox's Bazar, to assist with these objectives. With agriculture and industry accounting for a third of the country's GDP, the focus should be on funding local value chains such as fishing, agriculture and agriwaste-processing, and clean energy, all of which can also help meet multiple SDG objectives. As an example, more than 5,000 acres of forest reserves in Cox's Bazar has been rendered unusable due to deforestation and hill cutting for shelter construction (resulting in landslides). Depletion of marine resources has also weakened the fishing industry, which employs nearly one in three persons [17]. Cash for work (CFW) programs for the refugee population, along with training and support in a new industry, can form the basis for a sustainable informal and circular economy until the legislative hurdles are cleared for employment outside the CCIS boundaries. New manufacturing facilities for sustainable building material from two sources (rice straw/husk particleboards from residue of rice production processes and prolific forest bamboo from the region) can provide additional opportunities. Both these products involve working with farmers, informal laborers, and the establishment of production facilities (mill, dryer, mat former, and hot press) to boost the local economy, and can lead a transition to a bio-based economy that benefits the CCIS and HC of Cox's Bazar as well as the entire region. With tourism also a big revenue generator in the coastal area, the government has an eye on the future with investment in a new railway line connecting Dhaka to Cox's Bazar and set to open in 2022.

In conclusion, the shift in the JRP from short-term humanitarian programming towards longer sustainable development is a welcome start. National policy changes related to refugee-resettlement, if implemented by a reluctant government, can open the doors for an effective "Bangladesh Compact" as the first big step towards socio-economic growth.

4 DIMENSION THREE: URBAN ENVIRONMENT

Prior to the start of the Syrian refugee crisis in 2011, Jordan was already struggling with water scarcity, rapid population growth and urbanization, lax agricultural industry standards, and deteriorating air quality. In Bangladesh, the situation is worse. The refugee influx into the Cox's Bazar district has led to a detrimental effect on the environment, the region's natural ecosystem, and the health and physical wellbeing of the CCIS and HC. In addition, its low-elevation location on the Bay of Bengal makes it susceptible to effects of climate change, with more than 500,000 lives lost from four cyclones in the last 50 years. Sea level rise, flooding, erosion, landslides, and salinization among others have already caused major displacements, and one in every seven people will be displaced by 2050 [18].

Fig. 6 illustrates the sub-dimensions of Urban Environment and key SDGs associated with them.

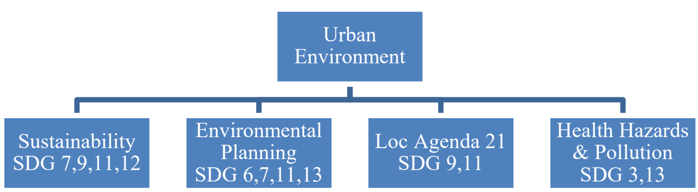

Figure 6: Organizational chart of Environment sub-dimensions with associated SDGs. *(Source: Author.)*

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4.1 Challenges and strategies

During the 1991 Gulf war, more than 1.3 million refugees (primarily herders) entered Jordan with 1.8 million animals who grazed down 7.1 million hectares of rangelands, resulting in serious habitat degradation [19]. The addition of more than 1.5 million Syrian refugees has added to the country's environment cost. In 2014, Jordan set up a national response platform to bring together government ministries, UN agencies, and NGOs to tackle its environmental problems. An assessment carried out by the joint venture called for "mainstreaming environmental factors into refugee projects is crucial to reduce long-term harm and minimize community grievances" [19]. A similar assessment of impact on refugee communities carried out in Bangladesh [20] identified multiple key risks/indicators for 13 environmental components.

Hill cutting for shelter construction and firewood for cooking has resulted in 5,000 acres of forest degradation and habitat destruction in the Cox's Bazar region. Soil erosion aided by climatic flooding has resulted in several landslides leading to loss of lives. Since tube wells are the primary source of water, the rate of water depletion is alarmingly high; deep wells are being researched but the shallow aquifer is expected to exhaust its resources soon. In addition, leakage and overflow from thousands of latrines close to water points has caused ground water contamination leading to increased public health risk. Loss of vegetation cover has reduced water retaining capacity and has decreased freshwater sourcing from the watershed. The hilly area and impermeable subsoil also restrict boring for ground water [20].

The wide-ranging concerns have prompted the GoB to team up with United Nations Development Program (UNDP) and adopt its Social and Environment Standards (SES) towards planning short and long-term protection for its fragile ecosystem. The Environment Management and Mitigation Plan identifies national and international partners and 18 impact areas and includes recommended actions to collectively address natural and manmade disasters in the region with a history of occurrences of landslides, flash floods, cyclones, earthquakes, and tidal surges. Short-term actions include distribution of cooking gas and alternative fuels to households (this has already decreased the deforestation rate by 50%), protection of water sources from excreta pollution, and improvement of sanitation, solid waste collection and disposition processes. Longer term actions require geophysical investigations to identify deep aquifers for piped water supply, scale up disinfecting treatment facilities for 2.5 million residents, preparation of contingency plans for natural emergencies, engineering and biological restatement of soils and terrain to minimize landslides, full vaccine coverage and reduction in population density to address communicable diseases, afforestation and reforestation through social forestry plantation and agroforestry, protection of national forest lands and parks including the Teknaf Wildlife Sanctuary and Himchari National Park, and habitat protection for wildlife [20]. Follow-up actions will require a detailed monitoring plan to verify the intended effects, detect environmental changes and trends, and allow for adaptive management.

In conclusion, the key to environmental planning of CCIS and HC is a plan that considers land and resource use patterns of both communities, the cumulative short- and long-term impacts of development on the ecosystem, and enhancement of other areas of the country to ensure no net loss in biodiversity. And if the plan is implemented under the umbrella of the UN Humanitarian Response Plan process, monitoring the CCIS using SDG indicators and benchmarks can demonstrate quantifiable progress.

5 DIMENSION FOUR: URBAN SOCIETY

A World Bank Report in 2018 studying "social cohesion" in the context of forced displacement noted that various factors such as the societal dynamics between CCIS and HC, spatial arrangements, duration of displacement, and perceptions of identity can affect the outcome of a proposed approach [21]. A successful long-term development strategy requires understanding of the five dimensions of social cohesion: belonging, inclusion, participation, recognition, and legitimacy.

Fig. 7 illustrates the sub-dimensions of Urban Society and key SDGs associated with them.

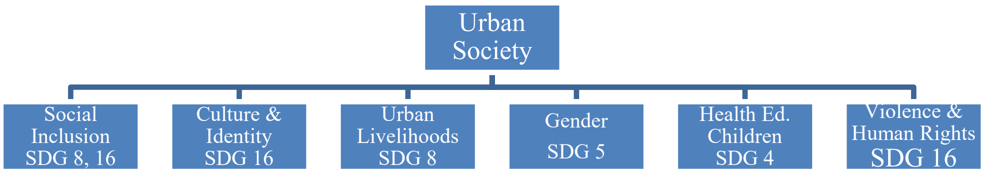

Figure 7: Organizational chart of Society sub-dimensions with associated SDGs. *(Source: Author.)*

5.1 Challenges and strategies

The characteristics of the nature of displacement in the two countries have led to varying approaches and outcomes. From the outset, Jordan's open and self-settled camps based on voluntary co-habitation with host communities differed sharply from Bangladesh's closed, restrictive CCIS with minimal or zero co-habitation opportunities. In response to the Syrian refugee crisis, the Jordan Emergency Services and Social Resilience Project (JERSSP) was established with a mission "to foster social cohesion through voice and participation" [22]. The project was context-specific and worked at the community level with established UNDP parameters like demographic profile, economic indicators, and social indicators to propose long terms solutions.

Bangladesh's challenge is bigger: being a closed camp with minimal interaction with host communities, the Rohingya have been physically isolated and socially segregated since 2017 due to national policy reasons. Fleeing from violence and human rights abuses, reports have found that even livelihood tasks such as collecting firewood for cooking exposes men, women, and children to significant risk, including sexual assault. Intimidation of Rohingya women appointed to outreach positions is another concern. [23]. With women and children accounting for 75% of the camps' population, their safety and education have been prioritized. In response to these challenges, IGOs and NGOs have proposed, and are executing community-level solutions such as designated safe spaces for women and children, and community kitchens which are treated as alternative safe spaces for women to voice concerns and exchange information [23]. The government has also contributed by providing LPG cooking cylinders in 2018 to reduce deforestation and enhance safety. Besides these protection concerns, issues related to culture and identity and education of children remain. As the Urban Infrastructure section indicates, preservation of the Rohingya heritage as a talking point has only begun earlier this year. The attention to education has also taken a new turn since April 2020 when, in response to global demand for a formal education for the camps' 400,000 children, a pilot program with a Myanmar curriculum was introduced for grades 6 through 9 [24].

Using a versatile tool such as the UNDP-developed Social Cohesion and Reconciliation (SCORE) Index to evaluate vulnerability factors and measure different components of social cohesion in the camps is the next logical step towards scaling up resilience capacity. The SCORE Content Framework focuses on five dimensions of societal functioning: human capability, human security, community cohesion and harmonious group relations, institutional and economic development, and meaningful civil participation and engagement [25]. As Bangladesh, Myanmar, and the rest of the world work towards a political solution to the crisis, engagement in advocacy of these societal challenges should continue unabated.

6 DIMENSION FIVE: URBAN INFRASTRUCTURE

Refugee camps and CCIS are almost always associated with rapid and uncontrolled urban development, inefficient land use, and single-year planning by political default as opposed to long-term approaches. Jordan and Bangladesh have utilized divergent planning approaches in dealing with their respective crises, each with micro, meso, and macro repercussions on urban development of CCIS and HC.

Fig. 8 illustrates the sub-dimensions of Urban Infrastructure and key SDGs associated with them.

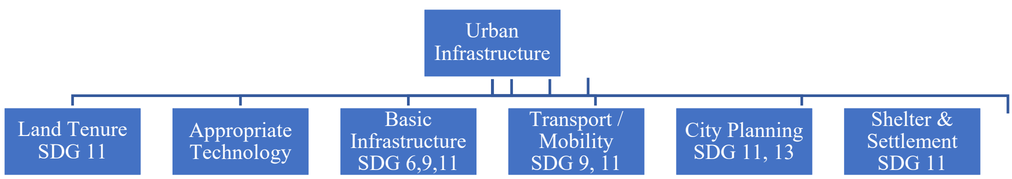

Figure 8: Organizational chart of Urban Infrastructure sub-dimensions with associated SDGs. *(Source: Author.)*

6.1 Challenges and strategies

The first connection between spatiality and its camps and marginalized informal settlements was documented in Amman's 1987 Master Plan (Fig. 9) which clearly demarcates its affluent western half from the poorer eastern half with low-income residents and refugees. Between the 1970s and the early 2000s, the built environment had materially and spatially transformed itself and begun exhibiting the complexity of a peri urban area. The shift in thinking is clearly visible in GAM's Amman Master Plan of 2008 (Fig. 9) which included specific housing zones for refugees/public housing and has spawned an unorthodox approach to metropolitan, urban, and community planning.

The planning occurred simultaneously on all three scales [26]. The objective was to not only compress the typical 5 year trickle down schedule from top-down metropolitan to community planning but also encourage active citizen participation for bottom-up interventions (critical for bringing vulnerable neighbourhoods into the planning fold). At the macro and meso levels, the "two Ammans" eventually fused into one and the city centre gravitated eastward from western Amman, completing a multi-decade spatial transformation.

Bangladesh's one-year planning strategy, weak building capacity, and rapid urbanization calls for swift, integrated spatial planning via a meso Urban Structure Plan that works towards

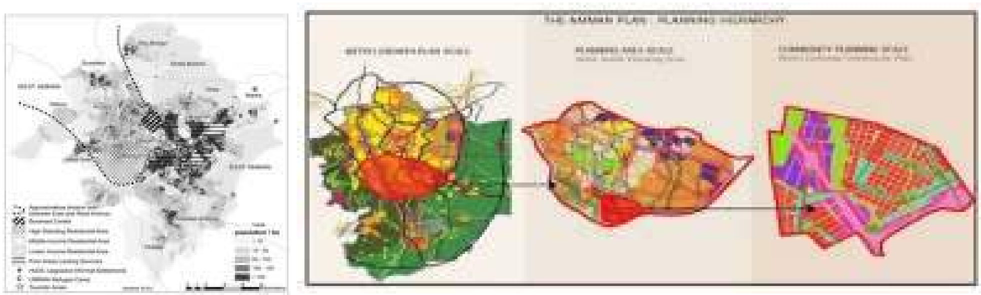

Figure 9: (Left) Divide between West and East Amman. *(Source: GAM Master Plan, 1987.)* (Right) The Amman Plan: Planning hierarchy diagram. *(Source: GAM, 2008.)*

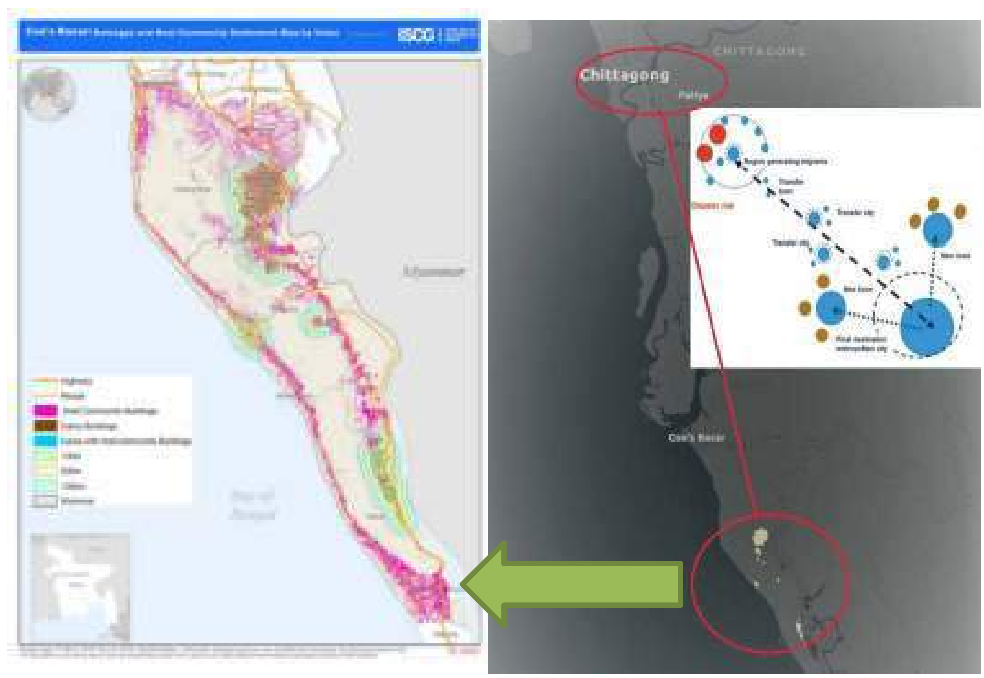

Figure 10: (Left) Cox's Bazar, Bangladesh, with camps and host communities. *(Source: ISCG, 2019.)* (Right) Strategy for migrant corridors. *(Source: UN/POP/EGM, Murillo, 2017, Author.)*

a common vision, ropes in all relevant state and non-state actors and a micro Urban Design Plan that uses extensive participatory tools and processes at the CCIS and HC level. A structure plan at the meso level can, as shown in Fig. 10, implement UN strategies for developing a regional migrant corridor [27] connecting 1 million refugees and 4 million residents (including 2 million from Cox's Bazar) to Chittagong.

Micro ethnographic interventions and spaces of cultural expression are critical components of socially inclusive urban design. In May 2021, the Rohingya Cultural Memory Centre (RCMC) opened its doors with support from the UN and other IGOs [28]. The space aims to express Rohingya culture, and the centre offers psychosocial support through art therapy and activities addressing the key factor affecting refugees' well-being: identity crisis. Another urban design intervention can incorporate existing information on infrastructure and amenities to produce inclusive and accessible public spaces to promote social healing based on common denominators. For example, superimposing existing worship facilities on a map with can locate a central place of worship (CPOW in Fig. 11) tied to the memory centre. The faith-based interventional methodology can be solidified further through architectural form (mosque-conjuring dome?) and material messaging impermanence and sustainability (soil, bamboo, rice strawboards?).

Figure 11: Partial map of Camps 7 and 8 in Cox's Bazar, Bangladesh, with legend and layers (*Source: ISCG, 2019*) with author's designation of CPOW intervention.

In conclusion, there are signs of progress at the urban design level as the creation of the RCMC has shown, but a longer term plan for regional regeneration is needed. Programs such as UN Habitat's SDG Project Assessment Tool and City-Scale Assessment Tool can assist with sustainability frameworks.

7 DISCUSSION

The analyses of these intertwining dimensions are as critical to the sustainable development of camp-cities as they are to traditional cities and urban agglomerations. Every dimension interacts with another to generate viable solutions. Governance must work with Economy to create innovative and accessible financing mechanisms. Infrastructure (Shelter Planning) must collaborate with Economy and Environment towards sustainability and livelihood. For example, establishing an industry which recycles rice straw with a cement mix to form a low-cost sustainable building material can boost the region's informal economy, provide opportunities for CCIS and HC, and reduce air pollution from the open burning of post-harvest straw. Infrastructure must also incorporate a governance model adopting participatory tools and processes to encourage refugee feedback and support bottom-up approaches. And finally, Infrastructure must incorporate principles of humanitarian urbanism and socio-social development to address trauma-driven societal challenges of forced migration.

An integrated, holistic approach then requires strategic interventions at the macro, meso, and micro levels. At the macro level, an international burden-sharing "Bangladesh Compact" that brings together relevant players and links humanitarian and development needs is required. Players must include the GoB, World Bank, the UN, and other donor governments with an interest in crisis mitigation. The model must achieve three primary objectives: legal recognition of the refugees with "right to the city", easing pressure on Bangladesh through burden and responsibility sharing, and increasing refugee self-reliance by enhancing the informal economy and quality of life. At the meso level, innovative urban regeneration strategies such as developing migrant corridors to sync with regional plans can achieve improved economic, social, and environmental outcomes. At the micro level, urban design approaches targeting CCIS's urban dynamics are key since they influence the production and character of social space. These should include (a) spaces for women and children founded on safety and security, (b) inclusive public spaces promoting identity, belonging, dignity, and cultural heritage preservation, (c) gender-empowering spaces for self-reliance, d) breaking-the-generational-cycle learning spaces for children's education, e) refugee health services for physical healing and mental health from migration-induced trauma. This integrated approach, utilizing SDGs and existing IGO tools, can eventually form the framework for a replicable global template in converting Camp-Cities and Informal Settlements (CCIS) into Integrated Sustainable Settlements (ISS). While the SDGs lay out a vision and a checklist of actions to meet UN goals, this discussion serves as a broader reminder to include the displaced 82.4 million and their informal settlements into the urbanization conversation. At the very least, it aims to increase awareness of the need for trans-disciplinary research. And in the best-case scenario, it can bridge new and existing concepts to spawn innovative strategies in addressing one of the biggest urbanization challenges of this century.

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HACKING THE NEXT MEXICAN TERRITORIES: HOW TO FACE THE "CRISIS" OF THE TERRITORIES AND THE GATED-COMMUNITIES' SYSTEM

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ABSTRACT
The uncontrolled development of private gated communities (PGCs) in Mexican Territories is one of the many issues that are putting at risk the weak alliance between Humankind and Environment in our contemporary times. To change this trend, can design find a new ally in technological development? A diffused lack of human spirit seems characterizing contemporary society and territories, where decisions are controlled more by the economy and the technological development, rather than by the humanistic decision. This crisis is given by a lack of decision-making authority, but also by a widespread sense of fear and anxiety towards a technology-based environment, which is at the same time more and more powerful and less and less handleable. In this background, PGCs find a favourable context where to bloom and, even if they don't bring positive benefits to the cities, nowadays they represent a very common phenomenon in all the American territories. Base on literature review and analysis of contemporary cases of digital interaction among citizens-IoT-environment, this research aims to (1) promote a reflection on the role that the technological and economic systems play in the development of contemporary territories, with particular reference to the phenomenon of PGCs, (2) analyze which analogies can be observed between urban-architectural design and technology to (3) define some strategies for designing new sustainable communities "hacking" technology-based environments. If territories are a combination between physical and digital dimensions, hacking them means working in the digital space, impacting the physical one. Thanks to technological devices, available to everyone in the daily life, procedures of re-designing territories and hacking the existing systems can be considered as a participative, fast and ubiquitous practice.
Keywords: private gated communities, sustainable territories, technological development.

1 INTRODUCTION

The relationship between the design and the technological dimension is a cornerstone of our society, arriving to increasingly characterize the cities and the territories where we live [1]–[5]. These contemporary characteristics that, day by day, people are experiencing doesn't refer just to the technological dimension as a new set of devices that influence our days. In fact, the technological dimension of our territories implies, firstly, a necessary reflection on the effects that this new system has on our culture and on the social relations that are generated in the sphere of the built environment. Among these reflections, one of the most relevant concerns the sense of confusion that characterizes the Individual of today. All those changes that have affected the Humanity, since the first industrial revolution, are the main reasons for the bewilderment which the contemporary society is living today. From the strategies to tackle climate change, to the challenges of AI, from the contacts between the biological and the digital spheres, to the plans for the colonization of other planets, Humanity is facing dilemmas that never before have been so preponderant and real in the social debate. Moreover, faced with these dilemmas, Humanity finds difficult to catch, not only the answers, but even a method of reasoning. In fact, one of the main problems is the incapacity to develop a way of thinking which is different from the technical one, which is the predominant one today. Umberto Galimberti repeatedly reminds us of the thought of Martin Heidegger who, almost a century ago, warned about the current danger: "It is not disturbing

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that the world becomes a huge technical apparatus, much more disturbing is that we are not ready at all for this radical transformation of the world, but what is even more disturbing, and we are at the third degree, is that we do not have an alternative thought to the thought as a calculation" [6], [7]. In a world where development is driven more by the needs of economic and technological systems than human will, humanity seems lost in understanding the directions toward the future. A general sense of loss and "crisis" dominates the relationship between Humankind and his Environment. Even when the subject of the speech is the natural or the social environment humanity is experiencing the same problems: it remains uncertain how we should actually behave in front of the contemporary challenges. It's difficult that politics could take decision on how to feat climate change, deforestation, plastic in the seas, on how to redefine the role of traditional institutions, globalization, economic inequality, migration or technological development. According to Harari, the recent pandemic crisis shows how the political system lost the Covid-19 challenges, while the technology and science came out as the winners [8], [9]. In fact, the most important solution to the pandemic came from scientists who developed the vaccines.

In the twenty years old book "In Search of Politics", Zygmunt Bauman reminds us that "Today few remember that the word "crisis" was coined to designate the moment to make decisions. Etymologically, the word is much closer to the term "criterion" – the principle we apply to make the right decision – that to the family of words associated with "disaster" or "catastrophe", in which today we tend to place it" [10]. Before crises were overcome by the belief that the acquisition of knowledge would mean the disappearance of the crisis, now we are not able to know how to overcome the incapacity to take decisions. Bauman continues, "What today we call "crisis" is not only the state in which forces of a contrasting nature collide [...] but, above all, a state in which no emerging form seems destined to consolidate and survive for a long time. In other words, the "state of crisis" is not the same as the state of indecision, but rather the state of the impossibility of the decision" [10]. Indeed, society seams becoming less and less able to take the decisions it really needs. More generally, the current inability to make decisions is seen in the inability to implement, with a political effort, a change of direction towards new models of growth that do not require consumption of resources and energy, as the contemporary ones are doing (what is called " decoupling", for example) [11].

How can we do, if we do not want to resign ourselves to this situation and live in the Max Weber's "iron cage" [12]? How can we, as designers, develop a new design strategy? Can we exploit, for example, the technological dimension of the city, in which we are always immersed, sometimes even unconsciously?

1.1 The modern territorial conception

In 1760 the Catasto Teresiano (Fig. 1) was completed: it was an innovative system which mapped the landed properties in the State of Milan, based (and here is the innovative aspect) not on descriptions but on exact plans associated with information. Data such as the owner, the destination of use and the valuation allow to calculate the tax due to the State [13]. Here, the modern conception of organizing and interpreting the territory, based on elementary units described by parameters, born. This concept evolves more and more, up to the contemporary regulations that order the territory. Thus, the organization and the design of cities and territories is controlled by constraints, technicalities and market logic. The mathematical thought that at the time of the Renaissance had generated the image of the ideal city (whose representation, based on perspective and calculation, does not show the most important

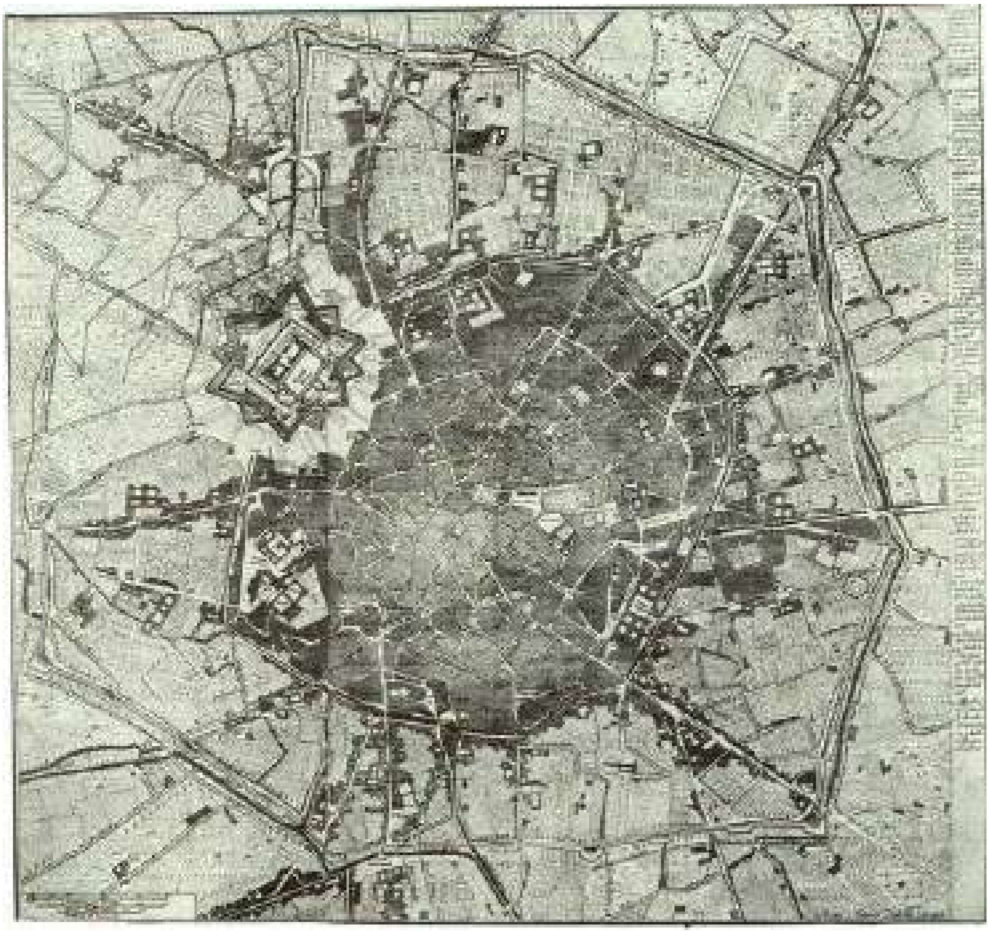

Figure 1: Marc'Antonio Dal Re (1697–1766), Map of Milan in 1734. Engraving. *(Source: Wikimedia Commons {{PD-Italy}}.)*

aspect of the cities: the inhabitants) – has now led to technical regulations that are more careful to rationalize the territory and the complex urban systems rather than listening to the variable needs of Humankind and supporting his extraordinary creativity.

The fact that technology, today, surrounds us is something not to be explained. Cities are now territories where the physical dimension, the one of architecture and space, is linked indivisibly with the digital dimension, created by data and information that our smartphones generate, transmit, receive, store and retransmit continuously 24 hours per day [14]. It makes no sense trying to understand the contemporary urban phenomena without considering the technological network that dominates them with the "internet of things" and the "ubiquitous computing".

This topic is the source of the concern presented in this contribution: if society is in a state of crisis due to the incapacity to take decisions – and this is mainly due to the predominant role of technology in our contemporary world – can we exploit the widespread presence of the technology itself to bring back the Individual being the central role of the urban life, as promoter of territorial regeneration? Can the spread ability to handle technology become an ally for urban and architectural design? Can diffused technology become a resource for a sincere and diffused participatory design or a source of inspiration for truly contemporary projects and drivers of change?

2 CRISIS AND COMMUNITIES

Individualism, created by those economic and technological forces that generate that sense of crisis that we just investigated, is at the same time the main cause for the crisis of our territories, where the basic concept of "community", the fundamental unit of the social sustainability of a territory, is often endangered [15]–[17]. Humankind has always taken into consideration living in community as a basic element of social organization: the community goes from an elementary nucleus that protects a few individuals, to a much larger group of individuals who share a belief or ideals [18]. Since the development of language and imagination, Humankind has been able to organize itself into small groups that allowed it to develop a protected environment around their own components. Since the first tribes and the first City-states, humanity has always adopted this "strategical communitarian support" to continue its journey of the social evolution. Being expelled by the community was one of the worst punishments for a citizen, and the hermit, who turned away from the community on his own, was a unusual personality [19]. Moreover, each culture has developed housing solutions that allow its concept of community to develop in the physical world. There are examples all over the world that indicate how community buildings played a key role in the development of society, helping in flourishing internal relations, while protecting it from the external dangers that threatened it. The Tulou in the Fujian region, the European farms or the Aztec Calpulli are just some examples [20]. With the modern illusion of being able to do anything thanks to the technical skills, Humankind has forgotten this natural dimension of the community [17]. Moreover, the pushed individualism that distinguishes contemporary society has made the situation worse, pointing out how much the economic profit and a cold urban planning are far more important than the community dimension of the territory.

For the relevance of the phenomenon in these regions, we take as reference the reality of Mexican territories, in which the concept of community is facing a significant crisis in urban and social terms. This is mainly due to the urban phenomenon of the "fraccionamientos", or private gated communities (PGCs), which are becoming the predominant element in the urban development of Mexican territories. Basically, these PGCs are residential areas, closed by walls and fences, where the management of the main services is provided by private gestors [21]. This urban phenomenon, which is spreading all around Mexico, involves not only new residential settlements, but also the existing ones. In fact, residents of different parts of the cities decide often to close the public roads crossing their settlement, to erect walls and to place private access controls to ensure a stronger perception of security and, even, better urban services provided by private companies.

In the last years, this phenomenon grown up a lot, mainly for issues related to the perception of urban security and for the benefits that the public administrations can obtain not have to provide basic services in these areas, where residents pay private services (in addition to the taxes) [22]. Within this scenario, there is a strong economical speculation of construction companies and several implications for the territories (accessibility, traffic, social and fiscal boundaries, unwalkable cities, etc…). In the north part of León (Guanajuato, Mexico) the 30% of the territory is closed by this kind of settlements (Fig. 2) [22]. While they are an increasingly common phenomenon in the American territories, these PGCs do not always have positive effects for the cities, nor can they be considered sustainable urban solutions [23], [24]. Although many times policy makers, construction sector and the wider society do not realize, there are many negative impacts that these structures have on cities, such as social segregation, sectorization of the territory or urban disconnection. At the base of this phenomenon, there is a structured economic system, capable to respond to the growing perception of insecurity and that motivates the diffusion of this residential proposal that will increasingly characterize the next Mexican territories. However, the biggest problem is that the negative effects of the PGCs are not yet popularly perceived. Researchers from the School of Architecture, Art and Design of Tecnológico de Monterrey conducted a survey among inhabitants of the already mentioned northern areas of León. Of the 180 respondents, the 62% believe that this enclosure has no impact on cities and of the remaining 38%, the majority believes that the impact is mainly positive than negative [25]. However, the reality is that, to allow the development of PGCs, several times, public streets are closed, complicating urban viability and increasing traffic, pollution and waste of time. Moreover, PGCs cut public spaces, which are the lymph of each city, and, even worse, increase the social disparity.

Figure 2: Northern region of Leon (Mexico) with the area closed by PGCs. *(Source: Cristian Charles-Arenas and Paola Gutiérrez-Guerrero, 2017.)*

For the importance of perception, it seems relevant to make here a very quick reference to the concept of "fear" in contemporary society. As Nan Ellin observes, the city has always been the place of safety, which, thanks to walls, ditches and gates, protected citizens from war and wilderness. But today, "from a place of relative security", the city has come to be associated, "more to the danger than to safety" [15]–[17]. The aforementioned Bauman highlights how this "demon" of the fear is spreading today in our cities, making it a phenomenon that grows stronger: "Once fallen in the world of men, fear feeds on its own, acquires its own logic of development, grows and spreads – in an unstoppable way – almost without need of care, of further contributions. [...] These are our reactions that transform the dark omens into everyday realities, making the word become flesh" [26].

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As already mentioned, the main problem of these residential settlements is mainly the one of physically and perceptually division of the territory, with causes that mainly concern social equity, traffic and pollution. Anyway, it's very important to understand that the problem are not the PGCs, which appear to be a solution to the understandable and reasonable demand for services and security, but the way in which these settlements are designed and, in particular, the lack of relations they produce with the social tissue. Here is the core of the problem: the strong economic and social reasons that motivate the design of PGCs, contribute to create a system, which is very difficult to modify or disturb with traditional design instruments. In fact, it would not be possible to change the contemporary urban system with traditional tools because: (1) individual and community are experiencing a crisis in decision making and (2) the existing system rewards economic – utilitarian aspects rather than aspects of human simplicity and daily life.

This is the reason why the urban-architectural design must think in a new strategy, able to change existing systems and, in the case of Mexican Territories, to propose settlements that guarantee services and security, while, allowing a sustainable urban development.

The concern expressed at the beginning of the contribution is applied here, to this consideration: since these contemporary urban systems are too difficult to change in traditional ways, can the urban design take advantage from the contemporary condition of a ubiquitous technology, making it the tool to modify and to disturb all these existing unsustainable urban systems? Can ubiquitous technology be a new ally for design? Can the ubiquitous technology be the tool for the humanistic development of the next territories?

3 HACKING

Since this study aims to refer to the digital layers existing in our territories, the authors started the analysis looking at the information technology (IT) world, where, if someone wants to change an existing system, improving it and going over its actual possibilities, he needs to *hack* the system. Inspired by this digital dimension, where this practice of revolutionizing systems is habitual, the research affirms how rethinking the design strategies can allow the redesign of the built environment and lead to innovative solutions in the design of contemporary territories characterized by PGCs. As pointed out by Ratti [27], if in the digital world you want to change a system, there are three steps to follow:

1. Understand exactly how the system works;
2. Understand how to change the system;
3. Take possession of the system.

While this procedure of "hacking" can have a positive meaning if used to improve a system and test its defence capabilities, the term is often associated to criminal actions and, therefore, for the public opinion, the term "hacking" has a mainly negative connotation. For example, in "The Global Risks Report 2019" of the World Economic Forum [28], "Critical information infrastructure breakdown", "Cyber-attacks" and "Data fraud or theft" are considered as some of the most dangerous risks for these years, showing a high index of impact and likelihood. Furthermore, a 2016 CNBC article reported that estimated the existence, by 2020, of over 29 billion IoT endpoint devices: all potential victims of cyberattacks [29]. To have an idea of the phenomenon, according to Pablo Tamez, Chief Information Security Officer at the Tecnológico de Monterrey, this institution receives on average 2 million cyber-attacks per month, which are stopped by the cybersecurity team [30]. By the way, the term was born at the MIT in the early sixties, precisely in order to indicate the ability of some computer experts to go beyond the "conventional" capabilities of a program and thus allowing to improve its performance. In the panorama of possible

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definitions attributable to the “hacking” phenomenon, the most significant concept is the one that associates the term with the efforts of IT experts to defend privacy and the right to free information. In fact, the principle that define hacker communities is “sharing”: the motto “Share your knowledge” means precisely this principle of behaviour according to which knowledge must be shared in order to achieve wellbeing and improve people’s lives. Exactly this aspect of “sharing” is another element that highlights how significant is referring to “hacking” for the design of next territories: we need to hack Mexican territories to improve people’s live, sharing communitarian belonging and social participation.

Hacking a territory means (1) taking possession of an existing physical system, like a public space that is the stage of urban phenomena, and (2) promoting new and different interactions between people and environment. Since the double essence of our territories, it can be done acting on the physical dimension or on the digital one. From the beheading of Louis XVI in Plaza de la Concorde, the square symbol of French Monarchy, to the revolts of the “Arab Spring”, which took possession of the main public spaces of the involved capitals, squares, streets and icons have been the urban elements that, more than any other, adapt to physically “hack” a territory. Without thinking to the extreme cases of revolutions, let’s try to reason on how technology can allow us to change urban spaces: how can technology allow us to reach more equitable territories, allowing each individual in a city to contribute in changing the social interactions spaces? Continuing to apply this thinking to the case of PGCs, so difficult to modify or disturb for the strong economic apparatus that impose and govern it, this opportunity to work digitally can allow to open a new front of work and to allow designing territories, where the PGCs would be not so much impacting in the physical and social environment. Considering the 3 steps, previously introduced, that define the hacking procedures [27], is possible to make a theoretical comparison with territorial dimensions. So, according to this principle:

(1) To understand how a territorial system works

Likewise hacking informatic systems brings principles of democratization and free access to information, in the cities, systems to map urban phenomena (traffic, contamination, temperature, people’s congestion, etc.) allow people to understand how complex modern urban systems really work and, based on the received information, to develop a more precise awareness and to take proper decisions.

This step allows immediate and well-founded responses to complex management situations. For citizens, this translates into the possibility of making better real-time decisions on how to behave in the territory (for example, choosing the shortest way to get home based on existing traffic). For policy-makers, this process allows to take decisions about urban management in a more appropriate way, for example, by changing the location of ambulances during an event based on the concentration of people. This level essentially refers to understand how a system works and to take decisions that affect behavior or organization.

Too many times, the interactions between citizens and these new digital-physical territories stops at this first step, where technology influences just people’s behaviours, without having the sufficient strength to bring the thinking to the deeper level to understand how to the urban system can be modified.

(2) Understand how to interact and to modify an urban system

The following step, forward to take just a decision that affects behaviour in the territory, is the possibility of developing an awareness of how to interact with the system, or how to modify some parts of it to allow better activities. This means defining which are the urban – architectural elements that influence the system and how they influence it: geo-referencing in a map an urban phenomenon allows to understand which elements contribute to generate the phenomenon itself and permits to redesign the elements to modify the system. This activity undoubtedly concerns individual citizens, but in particular policy-makers and designers, who can be aware of what physical elements influence the urban phenomena, and in this way they can act in the physical world, modifying the system in the best possible way. While the first step allows to understand the system and to change personal behaviours according to the system, this second step allows to modify the system according to the desired behaviours. At the second level, the need to develop a sense of awareness about the phenomena, which are being generated in the territories, arises. Going to this level implies that we need to develop a consciousness on how to acquire and interpret the data that the digital network provides us.

(3) Take possession of the urban system

The deepest level is precisely the appropriation of the system: the awareness acquired by people is not limited only to producing physical changes in the territory, but also creates new interactions between the elements of the territory. Applications allow the users to provide comments in a democratic way, informing and organizing digital communities, up to contributing to the change of the urban space. If we think about the development of the IoT it is easier and easier to see individuals that, with computer tools, can easily interact with the environment and modify it. This step represents the complete integration of the individuals in the digital dimension of the territories and makes people able to interact, through the IoT, with the architectural urban elements, modifying the physical world in real time. At this third level of depth, awareness does not stop at the interaction with the built environment, but spreads among the elements that make up the built environment (people, IoT elements, physical urban elements, etc.) allowing a democratic management of the system itself. The democratic management of the system implies the possibility of discussing, making decisions and implementing in the two digital and physical dimensions.

In this sense, according to the potentialities expressed in these steps, hacking territories is:

Participatory: everyone can (1) generate data that allows to better understand the territory, (2) propose solutions to modify the physical world and (3) participate, as aware individual, to the sustainable urban life;

Fast: generation, communication and processing of data occurs in real time, as well as the resulting decision-making and their effects in the physical-digital environments that can be quickly visible;

Ubiquitous: these processes can happen anywhere in the territory, and they encourage the uniform development of the territories, from the wealthy urban neighbourhoods to the vulnerable rural communities.

4 A HOPE

This contribution aims to open a discussion about the possibilities that the contemporary territories, which are more and more technological, offer to solve the controversial contemporary urban phenomena. These urban phenomena represent, unfortunately, the impotence and insignificance of Humankind in front of contemporary challenges, where technology seems to embody more a dangerous issue than a saviour resource.

In particular, Mexican territories, characterized by individualism and a sense of fear, are well representative of this contemporary condition. Here, an easy, but worsening, answer is given by the PGCs, which increase the strength of the economic – political – normative system that is at the base of this unsustainable development. Considering that individual initiatives (by citizens, designers or even political parties) are unable to face and to modify this system as it is, it is absolutely urgent and necessary to find a new way to change the system of our territories. An interesting strategy could be offered precisely by the technological dimension, borrowing its ability to modify and to improve existing systems.

As analyzed and discussed, this would means being able to give people the opportunity to directly modify the physical world, allowing them to experience cities and realities in a new way. Thus, hacking territories can shape the environments of the future by modifying or disrupting, in a democratic and sustainable way, all those contemporary urban systems that today, although we do not realize it, affect our lives.

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INTERACTION BETWEEN CREATIVE CLUSTERS AND THE BUILT ENVIRONMENT: DIGITAL TECHNOLOGIES VERSUS URBAN BUZZ

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ABSTRACT

Creative class supports the local urban development process with their social, cultural, and physical acts in the built environment while promoting the urban buzz. Because of the ongoing COVID-19 pandemic, the involvement of digital technologies in creative industries is inevitable. The study compares the conventional working model and online working process to clarify how digital turn affects the interaction between creative clusters and the built environment in consideration of social sustainability. Firstly, this paper looks at the social interactions in creative clusters, and investigates how creative class engages with the physical environment in the office environment. It also takes a step further and focuses on how digital turn takes place in this pattern by applying a case study through online surveys in İzmir, Turkey. It contains Architecture and Interior Design firms as a significant part of creative industries located in İzmir. The online survey was applied in order to get information about the space preferences of the creative clusters, and figure out the major differences between conventional working model and online working model in terms of social sustainability. The findings of this study provide insight about impacts of digitalization on creative clusters in the urban environments. It is seen that environmental behaviors of the creative class have direct effects on the process of the local urban development. Using digital technologies for communication has eliminated the surprise factor and damaged the use of urban-buzz areas where creative class meet their social and cultural needs. This study suggests that, during this adaptation period to the changing model, precautions should be taken in the earlier stages for the city development. Finding alternative ways to cooperate with creative class should be developed to keep the urban buzz alive in terms of social and cultural activities.

Keywords: creative class, creative clusters, social sustainability, local urban development, digital technologies, urban buzz, environmental behaviors.

1 INTRODUCTION

This paper provides research about social interactions in creative clusters and how the involvement of digital technologies in communication changes the dynamics of the relationship between the creative class and the built environment. Creative industries are an essential part of growing cities, especially considering principles of sustainability. Those industries can be defined as a growth sector that is embedded into the local urban environment with economic, social, and physical aspects. According to the Department for Digital, Culture, Media and Sport (DCMS) [1], creative industries rely on an individual's creativity, skill, and talent to create jobs and produce wealth through the generation of creative work. Florida [2] classifies those individuals as the creative class and defines them as “people in science and engineering, architecture and design, education, arts, music, and entertainment whose economic function is to create new ideas, new technology, and new creative content”. This article embraces Florida’s definitions for creative class concept. As a result of creative class’ space preferences, creative clusters are formed in the cities. Creative clusters are a type of urban quarter that has a high concentration of cultural activities and creative industry companies [3]. In this study, while creative class refers to the people who work in creative industries, creative clusters refer to the co-location of creative industry

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companies which are supported by social, cultural, and economic aspects within the built environment.

In this context, this paper starts with a literature review that introduces creative industries, creative class, and creative clusters in detail. Secondly, it discusses urban buzz and creative spill-overs as a representation of social interactions within the city landscape. Urban buzz can be defined as an entity that is produced by people's social interactions in the city environment, and it represents the liveness of the urban space. As an aspect of urban buzz, creative spill-overs refer to the positive impacts on the social and physical environment formed by creative industries.

Later, the study focuses on the involvement of digital technologies in creative industries. Creative industries can have the benefits of digital technologies in developing new ideas, research and development processes, and marketing strategies. Especially after the COVID-19 pandemic, working online and digitalization have become a new challenge for maintaining face-to-face social interactions, therefore its reflections on the environment to create urban buzz arises as a new research topic.

As the last part of the literature review, this paper forms a framework to analyze those changes in terms of social sustainability. Social sustainability is strongly related to people, well-being, community and healthy lives. According to Woodcraft et al. [4], social sustainability can be identified as a process for creating sustainable, successful places that promote wellbeing by understanding what people need from the places they live and work. Within this framework, this study examines Architecture/Interior Design firms in İzmir as a case study. An online survey is applied to compare people's earlier social experiences in the physical work environment as "conventional model", and their new experiences during the online working process as "changing model." After evaluating the survey results, this research compares two models and focuses on conclusions.

2 LITERATURE REVIEW

2.1 Creative clusters and the built environment

The creative class was first mentioned in 2002 by Richard Florida. Florida [2] defines creative class as people whose economic function is to create new ideas, new technology, and new creative content. He states that those creative people have the power to reshape the world as a result of their creative actions. On the other hand, creative industries are defined as industries whose main activities relate to individuals' creativity, skills, and talents. Those industries include both work and living, creating and consuming cultural and creative production. They have a potential for wealth and job creation through the generation and exploitation of intellectual property. DCMS groups creative industries as thirteen sub-sectors such as advertising, architecture, art and antique market, crafts, design, fashion, software, music, etc. [1]. As a result of the space preferences and locational decisions of creative class, creative industry companies can form creative clusters in specific urban environments. Creative clusters can be considered as a communication network for people who work in creative industries, share common goals, and contribute to the economy. UNESCO [5] states that those clusters are the geographic concentration that pools together resources into networks and partnerships to cross-stimulate activities, boost creativity, and realize economies of scale.

According to KEA [6], creativity comes from the combination of ability and environment; it is related to the people's capacity to think with imagination and challenge the existing. Creative industries have characteristics that prove to be conducive to innovation. Cities provide an ideal environment for the expression of creative abilities such as local cultural resources including cultural institutions and organizations, cultural heritage, festivals, and social events. Based on earlier studies, it is seen that creative industries tend to settle in particular places that create centers for culture, innovation and creativity; mostly in old industrial districts. They support local urban development by being a part of economic growth. According to Davis et al. [7], those industries are embedded into the local urban environment and political economy, because their production creates symbolic value that can facilitate place-making. Creative clusters emerge in specific urban frameworks and central areas [8]. Dronyuk et al. [9] point out that in creative clusters, an open and creative environment for communication and cooperation emerges, and as a result, new forms of interaction occur as an alternative to social capital. Such clusters help to carry out urban regeneration. Therefore, the importance of the built environment for creative clusters cannot be disregarded. Storper & Venables [10] explains that space gives rise to creative milieus by helping to form identity, credibility, lifestyle, and entertainment along with providing proximity that can foster face-to-face contacts and networking, and transfer tacit knowledge. They also point out the source of a local buzz economy is the communication and information exchange between different actors in the urban space.

2.2 Urban buzz and creative spill-overs

Besides the explicit relation with economic growth, creative clusters that generally emerge in specific urban frameworks offer strong possibilities to urban development by affecting the local environment and creating the urban buzz through space preferences. As a part of social sustainability, urban buzz comes with the advantages of the spatial concentration of people and activities. Those areas are powerhouses of innovation, creativity and unconventional lifestyles [11]–[13]. The concept of urban buzz is based on intensive social interactions in a compact urban space, predominantly through physical face-to-face contact. As a part of the city, those areas provide possible networking opportunities for people to share their knowledge and experiences. Arribas-Bel et al. [13] suggest that urban buzz districts are the combination of buzz producers such as restaurants, theatres, entertainment centers, recreation parks; and buzz consumers such as visitors and residents. Even the definitions of urban buzz and creative clusters show that the relationship between those two concepts is quite integrated. Creative clusters can be a source of urban buzz, as well as urban buzz districts can provide spaces for those clusters. In this dialectic, urban development comes as a result of this beneficial relationship. Social interactions of these clusters are highly important to keep the urban buzz alive, help to maintain social sustainability, and transform cities into creative and sustainable cities.

Cultural and creative spill-overs can be considered as another aspect of urban buzz. In the Cultural and Creative Spill-overs Europe Report [14], those spill-overs defined as “the process by which an activity in the arts, culture and creative industries has a subsequent broader impact on places, society, or the economy through the overflow of concepts, ideas, skills, knowledge and different types of capital”. Scott [15] points out that, firms can economize their spatial interlinkages to achieve the multiple advantages of labor markets, and utilize information flows and innovative potentials by clustering together. According to Creative Economy Report [16], the spill-over effect is the overflow of concepts, ideas, and knowledge from the creative industries. Those industries have a broader impact on the economy and society.

KEA [6] suggests that cities need to identify the culture and creative resources available and contribute to economic growth, social development, and innovation to support creative spill-overs. Local developers need to intervene in new relationships, initiate new connections between different fields and sectors. It is highlighted that, the local social fabric and the infrastructure provide a basis for new ideas, new interactions that lead to the invention of new forms of urban planning, new services, and new jobs. Innovation policies should support creative spill-overs as an integral part of the policy. Social aspects cannot be ignored, in the process of formulating policies to promote local creative economies and maximizing spill-overs.

2.3 The use of digital technologies in creative industries

A digital turn represents the arising use of digital technologies in daily life. Digital technologies are getting more involved with the sectors of the economy every day, and they have a significant impact on all aspects of people's lives. According to IDEA, KEA, and SMIT [17], it has been one of the most influential factors that affect creative value chains, especially in the last decade. Digital technologies lead to a constant emergence of new services, relying on innovative business models. The KEA report [18] states that the digital era represents both a challenge and an opportunity for innovation and growth in creative industries. Digitalization supports crossover innovations by challenging existing balances and sectoral relations by providing alternative models to create, produce, promote or distribute [17]. Especially after the COVID-19 pandemic, most of the stakeholders needed to change their working approaches, and they were forced to embrace digital technologies. Although there are several benefits of the use of digital technologies in creative industries, this turn in the working style has significant outcomes in social and urban life.

The evaluation of digital technology allowed users to easily access a variety of new digital technologies and tools. In this new digital economy, the ability to create social experiences and networking are now important factors of competitiveness. Social networks such as WhatsApp, Skype, Discord, Zoom, Microsoft Teams, and social media applications like Instagram, Twitter, Facebook allow people to communicate whenever and wherever they want. Those kinds of online platforms are important for several reasons such as exchanging experiences, achieving working opportunities, and finding new partners [18]. Those digital spaces are complementary to have creative innovations.

2.4 Social sustainability

Social sustainability has been neglected compared to environmental and economic sustainability until the 1990s. Woodcraft et al. [4] defines social sustainability as a process for creating sustainable, successful places that promote well-being, by understanding what people need from the places in which they live and work. According to the OISD definition, social sustainability stems from actions in key thematic areas, encompassing the social realms, encompassing the social realm of individuals and societies, which ranges from capacity building and skills development to environmental and spatial inequalities. It blends traditional social policy principles with emerging issues concerning social capital, economy, environment, notions of happiness, well-being and quality of life [19].

Later, Polèse and Stren [20] define social sustainability as a development that is able to occur by balancing the evolution of civic society. Social integration, cultural diversity, and equity play the most important roles in social sustainability. Polèse and Stren's [20] definition includes the importance of social aspects on the physical environment. On the other hand, Chiu [21] identifies three interpretations for social sustainability in terms of the built environment. The first interpretation is that social sustainability is affected by social norms and values. The second one suggests that ecological and environmental sustainability should be supported by social sustainability. And finally, as a more environmentally oriented approach, final interpretation refers to maintaining and improving the well-being of people for all. Therefore, social sustainability requires a combination of those interpretations based on the environment and people [21], [22].

Social sustainability outcomes cannot be measured in the same way that many environmental outcomes can. It is challenging because of the complexity of the issue and a lack of theorists in the field [23]. The measurement system for social sustainability is still a debatable subject. As one of the pioneers of creating a framework for measurement, Dempsey et al. [24] address this issue through a detailed exploration and define the concept of social sustainability within the urban context. They categorize contributory factors as non-physical factors and predominantly physical factors, depending on the literature review. Non-physical factors include education and training, social justice, participation, and local democracy; health, quality of life and well-being, social inclusion, social capital, community, safety, mixed tenure, fair distribution of income, social order, social cohesion, community cohesion, social networks, social interaction, the sense of community and belonging, employment, residential stability, active community organizations, and cultural traditions. On the other hand, physical factors include urbanity, attractive public realm, decent housing, local environmental quality and amenity, accessibility, sustainable urban design.

Berkeley Group and Social Life [25] takes a step further and creates a framework for the measurement of social sustainability in their report called "Creating Strong Communities" in 2012. In this study, Berkeley Group and Social Life's framework was used to measure social sustainability. This framework consists of three major dimensions: *amenities and social structure, social and cultural life, voice and influence* [4]. Those categories which include 13 different indicators, can be defined as:

1. Amenities and social structure: This category includes physical infrastructure (public transport, shops, etc.) and social infrastructure (community activities, etc.). It aims to capture previous attempts through design and services.
2. Social and cultural life: It refers to social capital and illustrates how people experience development. The main issues are; sense of belonging and local identity, relationships between neighbors and local social networks, feelings of safety, quality of life and well-being, etc.
3. Voice and influence: This category includes engaging residents in designing a new community in terms of empowering the community. It focuses on shaping the future by people's potential.

3 METHODOLOGY

This study is conducted as a case study in İzmir, Turkey. According to Seçilmiş, İzmir takes the 4th place in the settlements of creative industries in Turkey. Leading subsectors in Turkey are advertising, architecture, design, and movie industries [26]. In recent years, the number of employment initiatives and creative industries are in rapid increase in Turkey, compared with the traditional sectors. According to the İzmir Development Agency Report [27], approximately 6% of the creative clusters in Turkey have been working in İzmir. The three occupational groups with the highest share in the creative industries in İzmir are handcrafts (27.9%), advertising-marketing (27.7%) and design (11.5%) professions.

This study contains Architecture and Interior Design firms as a significant part of creative industries located in İzmir. Data were collected from 10 different companies that recently started working online. As a research method, an online survey consisting of open-ended and multiple-choice questions was conducted to the selected sample. The questions in the survey were classified into 3 categories according to the Berkeley Group/Social Life's social sustainability framework [25]: Amenities and Social Infrastructure, Social and Cultural Life, and Voice and Influence. Subcategories are revised by the researcher to analyze creative clusters in detail (see. Fig. 1). The conventional model and the changing model were compared in each category.

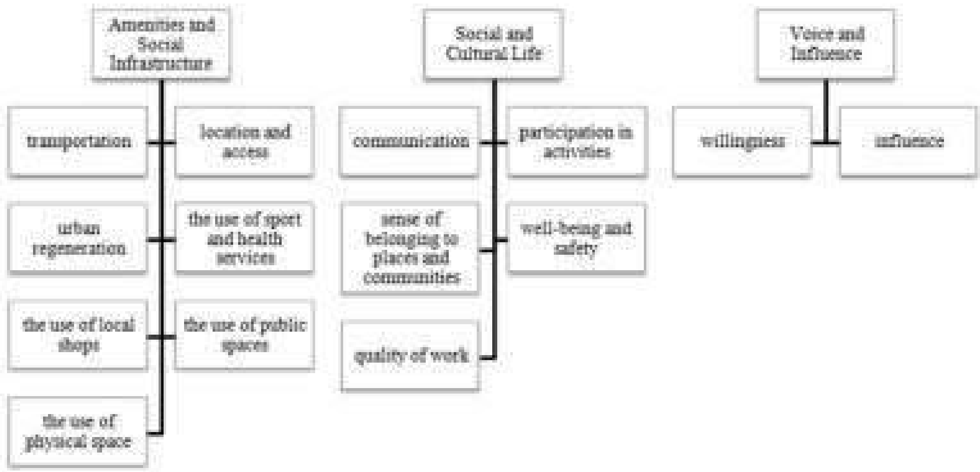

Figure 1: Framework for measuring social sustainability.

4 DATA ANALYSIS AND FINDINGS

In the evaluation of the survey results, office locations of the participant companies were divided into three main groups as central locations, semi-central locations, and rural locations, according to the distance from the city center and population density. The majority of the companies (five out of 10) were located in the central locations. Creative industries usually transform industrial and redundant areas and locate in cultural and economic quarters. In the İzmir Case, the Alsancak region is often preferred by creative clusters. This data supports previous literature on creative industry settlements, and shows that architecture and design companies often choose to be close to the buzz-areas.

The majority of the companies (eight out of 10) have been working online for 1 year, due to the COVID-19 pandemic. Although some of the companies closed their offices and embraced the home-office style, architects and designers are still attached to their offices during the process of online working. The most important part in the case of architecture and design firms is that construction site visits do not allow people to work fully online. There is an increase in construction site visits since some co-workers started to meet on those sites rather than the office to discuss ongoing projects.

In previous studies, the source of the urban buzz is associated with intensive social interactions in a compact urban space through face-to-face contacts. After the COVID-19 pandemic forced people to embrace digital technologies, the role of the office is now changed. The home-office working style has unattached creative class from their office buildings while creating independent co-workers that can work from different locations. Thus, the urban buzz is threatened in terms of maintaining the necessary interactions between creative clusters and buzz producers (restaurants, theatres, entertainment centers, recreation parks, etc.). The mobility and the physical interactions of creative clusters with urban areas that contribute to urban buzz might lose their dominance due to the decrease in the use of offices. This changing work style can cause damage to local urban development, in consideration of both economic and social aspects of sustainability.

4.1 Amenities and social infrastructure

In the first category, the participants were asked to rate the importance of amenities and social infrastructure elements from 1 (insignificant) to 5 (highly important) in order to understand space preferences of creative clusters, and their relationship with the physical environment in the conventional working model. Secondly, participants were asked to evaluate the importance of those categories in the changing model based on their online working experience (see Table 1). If the average score of the answers is 4 or more, those elements are evaluated as important elements for creative clusters' space preferences.

Table 1: Evaluation of amenities and social infrastructure by participants.

Category	Average score for conventional model (working from the office)	Average score for changing model (online working)
Transport infrastructure (public transportation and private transportation)	4.5	3.8
Access to public services (health services, education services, etc.)	3.4	4.2
Social security and safety	5	5
Access to public spaces and recreational areas	4.8	4.5
Access and proximity to cultural and leisure facilities (museums, galleries, cinemas, pubs, cafés, restaurants, shopping facilities, etc.)	4.5	3
Tolerance and open mindness (minorities, low income groups, gender, immigrants, etc.)	4.8	4.5
Social network opportunities	5	4.5

Based on the results on Table 1, it is seen that almost all categories have an impact on the space preferences in the conventional model. In urban buzz areas, location and access to buzz producers take an important place. Almost everyone stated that they evaluate their offices' proximity to public spaces, recreational areas, and cultural and leisure facilities as a factor that affects their space preferences. The creative class forms their network and boosts their creativity via cultural activities by sharing their knowledge and experiences. Especially in central locations, the benefit of the location promotes new possibilities for networks while keeping the urban buzz alive. Dynamism is seen as an advantage for creative clusters in the conventional model. Stores, restaurants, and entertainment centers are the most used places as buzz producers in almost every region. Also, almost all participants stated that they frequently use the public spaces around their offices. Five out of 10 people stated that they meet with new people who contribute to their network in local areas. Therefore, these results support the previous literature on creative clusters' interactions in buzz areas in the conventional work model. When the working styles are compared, it is seen that the major changes happened in two categories. While access to public services becomes more important, access to cultural and leisure facilities is evaluated as less important because of online working. Nevertheless, this survey is applied during the COVID-19 pandemic. These results might be reflecting temporary changes.

In the second part of the category, open-ended questions were asked to get more information about the changes during the online working process. According to the results, the mobility of creative class affects urban buzz closely and stimulates urban communications through inevitable contacts. The use of technologies reduced mobility of the creative class due to the lack of necessity to move in the changing model. The time spent on the road before is labeled as “extra time”. Participants stated that they are evaluating this “extra time” for doing personal activities such as doing sports, doing housework, being busy with hobbies, etc. However, a minority of the participants remarked working online can be more time-consuming in consideration of lacking quality communications.

4.2 Social and cultural life

In this category, the participants were asked to compare selected social and cultural life aspects in the conventional and changing models. Multiple choice questions were supported with open-ended questions in order to evaluate personal perspectives about the changes in the social and cultural life. Survey results show that there is a considerable amount of decrease in social interactions due to the lack of spatial engagements during the online working process (see Table 2).

Table 2: Evaluation of social and cultural life by participants.

Category	Average number for conventional model (working from the office)	Average number for changing model (online working)
Efficiency of communications	4	3.4
Interest in social activities in the region	3.4	1.9
Feeling of loneliness level	1.5	4
Feeling of safety level	4.3	4.4
Creativity level	4.2	3.9
Productivity level	4.2	3.7
Efficiency of team works	4.1	3.4

Based on the open-ended questions, it is seen that while face-to-face communications are decreasing, phone calls have increased along with the use of digital technologies. There is a certain decrease in the efficiency of the conversations among the creative class and their clients. These numbers show more serious differences in the quality of group actions and teamwork between co-workers. Working together in this changing model is not considered as productive as it used to be. Although it is easier to be able to communicate anytime and anywhere in the online working style, the changing model is not ready to replace face-to-face interactions in terms of efficiency. Participants labeled face-to-face discussions as more sincere and productive. However, as a negative feature, they highlighted that communication time decreased during the transition to the changing model. Social interactions between people in the online working process are more active and dynamic, and easier to access. But they still have a long way to catch up with the quality of face-to-face interactions. The major difference is that spontaneous meetings that provide unexpected networking opportunities and business deals have almost ended. Creative thinking, which is one of the key factors for the creative class, can be boosted through the surprise factor. Scheduled meetings eliminate the effect of surprise and create a more predictable lifestyle while causing negative effects on creative thinking.

Participants confirmed that social flow and shared knowledge in the physical environment have an impact on their level of creativity. This level declines for every participant after switching to the online working model. This shows that in the areas where the urban buzz is strong, creative clusters are affected by creative spill-overs, and they have a higher rate of success in consideration of creativity and productivity. A decrease in face-to-face social interactions reduced the overflow of ideas, knowledge, and skills. Some participants pointed out that knowledge spill-overs among creative clusters have come to the point of disappearing. Almost all of the participants stated that the disappearance of face-to-face meetings negatively affected the possibilities of exchanging ideas.

Even though the changing model does not have a direct negative impact on the quality and the amount of work done by the creative class, it affects employees indirectly in consideration of social aspects. In the conventional working model, knowledge spill-overs usually took place in a close physical environment around the offices by business dinners, cultural activities, entertainments, etc. In the absence of these activities, it is inevitable to see great changes in the daily flow of social and urban life. Nevertheless, those changes also have a negative impact on people’s well-being due to the fact that they become distant from socialization and psychological relaxation. Participation in the local activities, cultural events of the associations and chambers are also decreased at a significant level. Although these results cannot be evaluated without considering current pandemic conditions and limitations, people’s interest in participating in cultural activities is not like before due to the use of digital tools.

In addition, the most significant difference in social and cultural life was seen in people's level of loneliness. While people rarely felt lonely during office hours in the conventional model, the lack of face-to-face meetings in online work made people feel lonely. The survey results indicate that factors such as people’s well-being, the feeling of loneliness, and happiness need to be supported with physical interactions. Even though there is a constant communication network in the changing model, the quality of the interactions is more important than the quantity of the interactions.

4.3 Voice and influence

In this category, open-ended questions about willingness to participate at local organizations and community engagements were asked to the participants. In order to measure their commitment to the region where their creative clusters are located, their contributions to the regions, and differences after embracing the changing model were questioned. In the urban areas where people choose to be working instead of living, local development strongly depends on the actions of creative class. Those people’s influences on their cluster help to create a positive local identity and make those places desirable. Based on the results, the creative class’ sense of belongings were seriously damaged for their office areas while it was increasing for places where they live due to the online working. All participants stated that they started to lose their connection with their geographical clustering for working environment. If digital technologies will take over the face-to-face interactions’ place, urban developers need to adapt their strategies to fulfill the needs of creative clusters and attract them to the region while offering new possibilities to make them feel a part of the region. Local engagements are the core of creative clusters. Depending on the new situation of online working, losing connection and attachments might change the idea of creative clusters. It should be investigated in a longer period whether online working will change the whole concept of creative clusters and the need for office spaces. However, it is seen that people start to lose their loyalty to the region where they work. This causes a negative effect on the sustainability of the city.

5 DISCUSSION & CONCLUSION

This research shows there is a close relationship between creative clusters and the built environment of the city in consideration of social interactions. According to the case study conducted in İzmir which is a developing city within the scope of creative industries, it is seen that creative clusters often settle in central locations where urban-buzz is strong. This study contributes to the previous literature, and it proves that engagements of creative clusters can be considered as one of the key elements for achieving sustainable cities. This relationship has direct impacts on both individuals' well-being and local urban development.

This research underlines that amenities and social infrastructures are essential elements for the space preferences of creative clusters. Those elements form a direct relationship between creative clusters and the city environment. On the other hand, the use of digital technologies has an impact on the necessity of physical offices. Depending on creative clusters' transformation into a new online reality, adoption of online working styles reduces the importance of the elements that connect creative clusters to the environment. Survey results show that disengagement between creative clusters and the built environment did not happen yet, although amenities and social infrastructure started to become less important in the changing work model.

As a conclusion, creative class meet their social and cultural needs in urban-buzz areas while creating the urban-buzz in central locations by their interactions with each other and their close physical environment. Strengthening this dialectic should be in the consideration of local urban planners to achieve more sustainable and creative cities. In those locations, creative spill-overs are formed indirectly as a result of creative clusters' direct interactions with the physical environment.

Since the COVID-19 pandemic started, a digital turn is on the corner. The new changing model has its advantages and disadvantages. Digital technologies such as information and communication technologies (ICTs) became a part of daily life after the pandemic. Whether improvements in digital technologies will reduce the importance of physical space is highly discussed by many researchers. However, temporarily or not, the change is on the edge. Beyond the economical perspective, continuity of social interactions is adapting into a new, digital model.

As a result of the inclusion of digital technologies which dissociated the creative class from urban life, urban planners need to adapt their strategies to this new normal. In this research, it has been observed that some of the sub-sectors of creative industries such as architecture and interior design firms cannot fully adopt an online working style due to the active visits to the construction sites. Although, this digital turn still limits their social interactions. The use of digital technologies for communication has eliminated the surprise factor, causing people to communicate more regularly and frequently. But even if communication becomes easier and unnecessary time losses such as the time spent on the road decrease, quality and efficiency of the interactions are not the same as it was in the conventional working model. During this adaptation period to the changing model, precautions should be taken in the earlier stages for the city development and the well-being of the creative class. Urban developers need to find new ways to cooperate with creative class and provide spatial opportunities for social and cultural activities to keep the urban buzz alive. The chambers and associations of these creative industry sectors also need to take action as much as the urban planners.

Due to the continuous innovations in technology, the adoption of digital technologies will increase day by day. Although participating in social events is not as easy as it used to be because of the ongoing pandemic, attachment to urban buzz locations needs to be increased, especially for creative clusters. This research indicates that interactions between creative clusters and built environments cannot be disregarded to achieve sustainable cities. In further studies, the number of the participants can be increased in order to get more accurate results. Since the need for offices is changing by the use of digital technologies, long-term changes on the concept of creative clusters and how it affects city life can be investigated as a broader topic.

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URBAN PLANNING REVOLUTION FOR INCREASING PEDESTRIAN MOBILITY IN LISBON, PORTUGAL

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ABSTRACT

This paper focuses on the change in terms of spatial structure of the old cities with the urban renewal. The connection of places in the city through architecture and urbanism, encouraging walkability, will strengthen intergenerational and social interactions, will also reinforce cultural expressions, and provide social cohesion and security of the societies, as quoted in Habitat III – for better urban future. The permeability and connection between the different parts of the block, the street and the buildings will create links between space, shape and use will offer its users an increase in the quality of life, minimizing the use of motorized vehicles. The idea is to implement urban solutions that guarantee greater walkability by simulating an increase of passages in a neighborhood of Lisbon, Portugal. To test the feasibility of this idea, graph theory, space syntax, and data analysis methods and techniques were used to create several scenarios for increasing the pedestrian mobility in Lisbon. As results in all the three hypothetical scenarios created – increasing in number of passages and alternatives in a short-term (Simulation 1), medium-term (Simulation 2) and long-term (Simulation 3) intervention logic – there were somehow improvements in terms of walkability and accessibility. As the passages through the interior of the blocks increase, the network is also more easily accessible. The proposed research confirms that urban passages (e.g., the pasáž in Prague) are essential for changing the walkability paradigm in old cities rehabilitation planning.
Keywords: pedestrian mobility, accessibility, passages, walkability, normalized angular choice, normalized angular integration, to-movement, through-movement, urban planning, Bairro dos Actores.

1 INTRODUCTION

Focusing on the cities, which are expected to be occupied by two-thirds of the world's population by 2050 [1] and whose urban areas produce 70% of the emissions that are propelling the planet to an unknown climate [2] there is an urgent need to change the paradigm of the planet's population life by rethink and reimagining [2] the cities. At the same time, this becomes an obvious need and challenge. In this context, Otto [2] defines this need as a "planning revolution" accomplished by generating "compact cities strategically structured with neighborhoods and mixed-use buildings and with an emphasis on integrated urban systems."

The monofunctional and dispersed city, criticized by Alexander [3] led to the discovery of innovative ideas in processes of analysis and the urban design of forms in architecture; establishing a list of standards that provide guidelines for urbanism and architecture; where the graphs' theory was essential to find mathematical solutions for architecture and urban planning.

The exploratory research presented in this article seeks to incorporate this context. In old and consolidated cities, it is necessary to increase their permeability to encourage the walkability of their inhabitants. Inspired by the network communications, namely regarding the concepts of connection, communication, sharing, and exchange, it was then thought of creating passages that would open closed blocks, establishing connections between streets

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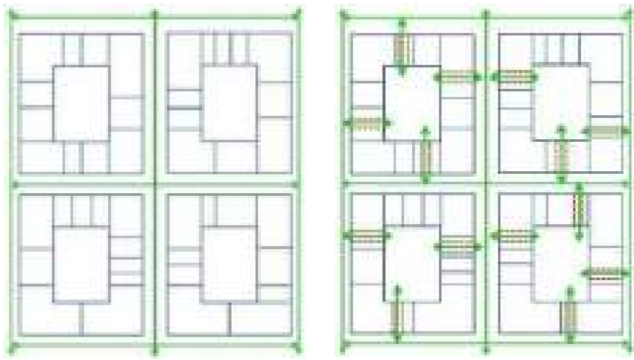


Figure 1: Schematic idea to open closed blocks using passages.

that enable pedestrian movements (Fig. 1). In other words, given a study area that includes a neighborhood with blocks with unused interior spaces, with buildings and shops that are degraded, abandoned or under renovations, different situations by opening of passages were created that would arise in these points of easy intervention.

In particular, the exploratory analysis aims to achieve improvements in terms of accessibility and spatial structure when the number of passages between existing streets is increased.

The hypothesis of this exploratory analysis is to assess whether the passages theoretically improve spatial structure and accessibility. Three hypothetical scenarios are created, and the respective simulations are performed in terms of measures under analysis. These scenarios are increasing in terms of number of passages and alternatives in a short-term (Simulation 1), medium-term (Simulation 2) and long-term (Simulation 3) intervention logic.

To test the feasibility of this idea, graph theory, space syntax, and data analysis methods and techniques and an historic neighborhood of Lisbon were used to simulate several scenarios for increasing the pedestrian mobility in Lisbon.

This approach will meet the Sustainable Development Goals of Good Health and Well-Being (SDG3) since people will walk more using those pedestrian paths in their dally-life bases; also, this involves a Climate Action (SDG13) as there would be a significant reduction of the use of cars, buses, and taxis; all these actions towards Sustainable Cities and Communities (SDG11).

This paper consists of six sections. After the Introduction, Section 2 presents a brief literature review about the context and the main tools. Section 3 presents the case study in Lisbon. The materials and methods used in simulations and the main results as its discussion are presented, respectively, in Sections 4 and 5. Section 6 presents the main conclusions.

2 LITERATURE REVIEW

The interdisciplinary knowledge about the cities is now, more than ever, a very important tool to increase the citizens' quality of life.

The relationship of systems and concepts resulting from architecture, economics, sociology, technology and urbanism, will allow the construction of cities without borders and with a predominance of open spaces, greater mobility, and biodiversity, where people will be able to walk in the city for periods of 15 minutes, called "hyperconnectivity" or “chrono-urbanism” as defined by the authors of [4] and [5]. The same idea, that the city should be experienced through pedestrian displacement [6], [7], considering the valorization of public space and the relationship that is established between buildings was also mentioned in [8]. The balance between urban architecture and man is notorious for harmonizing the experience of qualified public spaces, providing cities that are alive, safe, sustainable, and healthy for the citizens. The relationships between the built space (urban and architectural) and social behavior result from the establishment of guidelines achieved between architecture and urbanism; this means the relationship of the human scale achieved, and the sociological principles applied [9], [10]. The human scale can be represented in the city planning if considered by different scientific areas, starting from the particular to the general; working together on the small scale of the city, such as the street or the block, which in turn will influence the areas of closeness in a useful and consolidated way. The definition and establishment of city uses will create interconnections, depending on how the people felt the experience lived in these places, good or bad. The buildings’ design will be relevant [11] for gathering information about the urban space that will directly influence the way the pedestrian uses the public space [5], [12]. Ascher [13] studied the sociological point of view, the urban mobility and the dynamics of life-and-urbanization concerning to the modern cities and concluded that they are essential for cities to become alive and dynamic.

Considering the evolution of the functions of the city over time, from the modern city to post-modernity, the phenomenon of megalopolis was reached, as explored by Freitag [14]. The demographic growth and the territorial extension of the cities will cause the loss of cultural and architectural/urban references that are part of their societies, critically influencing the social, economic, and humanist actions that should be mitigated through sustainable, safe walkability and sociable, that can effectively connect people, places, goods, and services, providing a balanced and integrated development either architecturally or socially. Cities are expected to be safe, healthy, accessible, resilient, and sustainable places, providing, and fostering prosperity and quality of life for those who live or use these places. The connection of places in the city through architecture with urbanism, encouraging walkability, will strengthen intergenerational and social interactions, will also reinforce cultural expressions, and provide social cohesion and security of the societies, as quoted in Habitat III – for better urban future – Declaration of Quito [15]. The permeability and connection between the different parts of the block, the street and the buildings will create links between space, shape and use will offer its users an increase in the quality of life, minimizing the use of motorized vehicles and consequently an increase in the preservation of biodiversity within cities. So, it is essential to study the relationship between space and society in its different aspects.

Space syntax allows for analysis of space combining movement and land use factors with cognition and behavior [16]. It only considers how each space is related to all other spaces in terms of directional changes and angular deviation within a spatial system [17]. Space syntax measures to-movement (or closeness) and through-movement (or betweenness) potentials of every public street segment in relation to all other segments [18]. According to Hillier et al. [6] and Penn et al. [19], space syntax’s “theory of natural movement” is a useful tool for comparing “before” and “after” conditions of spatial changes that result from restructuring (or simulating new situations). The theory of the natural movement states that the flow of human movement in built environments depends on the degree of spatial integration (i.e., normalized distance from one point to all points [9]) of the street network. The higher spatial integration on various scale levels, the higher the flow of human movement [19].

For more than 30 years, the axial map has constituted the basis of the Space Syntax. However, from the beginning of the 21st century, angular segment analysis by metric distance becomes a more powerful tool [20]. According to Yamu et al. [16], the solution for successful computational angular analysis with various local radii were to break down the axial map into a segment map and incorporate segment length into the calculations [21]. This operation can be performed with the Depthmap software.

So, according to De Koning et al. [22], the measures within space syntax that best capture spatial configurations are [9] the potential to-movement which measures how likely a street is to be a destination of a route – the angular segment integration analyses (i.e., how close each segment is to all others in terms of the sum of angular changes that are made on each route); and the potential through-movement which measures how likely a street is used as part of a route–the angular choice analysis (i.e., counting the number of times each street segment falls on the shortest path – least angular deviation between all pairs of segments within a selected distance or radius). In Hillier et al. [18] a normalization of the measures of angular choice and angular integration is suggested for better properties of the measures. These measures will be referred to as normalized angular choice (NACH) and normalized angular integration (NAIN).

According to Orsini [23] the most important variables calculated by the angular segment analysis are choice and integration and while integration calculates the distance between all origin and destination spaces in a system (closeness), choice, known as betweenness centrality in graph theory, deals with the decision-making process and highlights which itinerary is preferred to move anywhere in the study area. Choice quantifies the flow passing through each space, by summing all nodes located on the shortest paths joining any destination from an origin space. That is why the measure must be normalized as the nodes located in segregated areas have total and average values higher than the nodes located in integrated areas. Choice values of each segment are divided by their total depth [18].

Considering the foreground and background network, according to Orsini [23], its robustness can be assessed with the angular normalization of both integration and choice variables. The two measures provide information on the spatial performance and morphological properties of the study area. NACH allows understanding the spatial structure of cities on foreground (maximum value) and on background (mean value) while NAIN indicates how both foreground (Max) and background (Mean) networks are easily accessible. The potential to and through-movement in the background network is represented by Mean values of NACH and NAIN and by Maximum NACH and NAIN indexes in the foreground network [24].

3 CASE STUDY

The need for expansion of the city of Lisbon, in the first decades of the 20th century, forced a rethink and introduced changes from an urban point of view, which led to its growth to the North, predominantly rural at the time. The General Plan for Urbanization and Expansion of Lisbon (PGUEL) of 1938–1948, would define new programmatic and architectural areas that aimed to represent a new way of living in Lisbon society.

Actores neighborhood (Bairro dos Actores) appears in the 1930s, as an integral part of PGUEL, and because of the lack of housing in the city and the desire to assert a nationalist political regime at the time [25], [26]. With an area of approximately 14 ha, it is limited to the west by Almirante Reis Avenue (Avenida Almirante Reis) and to the south by Dom Afonso Henriques Avenue (Alameda Dom Afonso Henriques) (Fig. 2).

Figure 2: Bairro dos Actores location in Lisbon.

The organization of facilities and the road hierarchy are the main innovations to be taken into account in this urban project for the city of Lisbon. The articulation between the different urban elements also contributed to the morphological and social homogeneity that defined the neighborhood units.

This part of the city is defined by four streets perpendicular to the structural road axis–Almirante Reis Avenue–which, in turn, intersect with other streets, creating an orthogonal standard metric between the blocks of the neighborhood.

The urban configuration of Bairro dos Actores allows for a direct relationship with its uses, allowing an intelligible walk throughout the neighborhood similar to the pedestrian route length.

There are some spaces belonging to these buildings, predominantly on the ground floor, vacant awaiting rehabilitation, and interventions in terms of uses and functions to adjust to the new needs of the neighborhood and greater urban mobility.

The relationship between urban form and its use, allows this place to become safe, inclusive, and resilient, and existing spatial configurations must be reconsidered, solving urban spatial conflicts, and creating attractiveness and well-being for those who live and travel through this neighborhood.

4 MATERIALS AND METHODS

For computing the space syntax analysis for the different simulations, basic maps were manually generated for the study area. The axial map was drawn on the city of Lisbon digital maps at a scale of 1:1,000 so that the location of the passages in the neighborhoods' blocks can be defined as accurately as possible. Considering the study scale and size of Bairro dos Actores neighborhood, to reduce the impact of edge effects the axial lines have been drown for a buffer area of 1,500 m, which corresponds to an average walking time of approximately 30 minutes (Fig. 3).

According to Yamu et al. [16] the solution for successful computational angular analysis with various local radii were to break down the axial map into a segment map (generated by breaking the original axial lines at their intersections) and incorporate segment length into the calculations [21]. And so, the axial map of Bairro dos Actores was transformed into a segment map (DepthmapX software, version 0.80 was used) to obtain more clearly the importance of the proposed passages to identify the increase/improvement of walkability within Bairro dos Actores.

The segment map allows for calculation and measures of different walkability possibilities in the existing and proposed street system for the neighborhood.

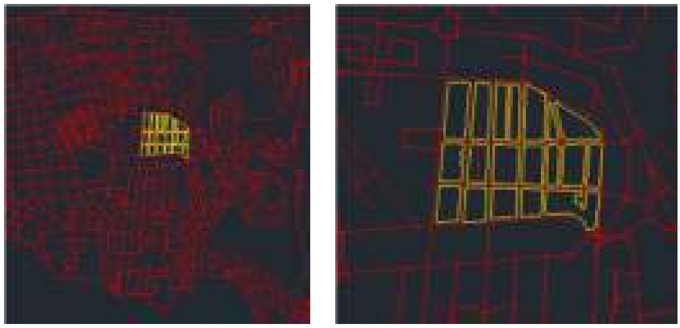


Figure 3: Axial map (red lines) and neighborhood structure (yellow lines).

According to De Koning [22], the measures within space syntax that best capture spatial configurations are [9] the potential to-movement which measures how likely a street is to be a destination of a route – the angular segment integration analyses (i.e., how close each segment is to all others in terms of the sum of angular changes that are made on each route); and the potential through-movement which measures how likely a street is used as part of a route–the angular choice analysis (i.e., counting the number of times each street segment falls on the shortest path – least angular deviation between all pairs of segments within a selected distance or radius). In Hillier et al. [18] a normalization of the measures angular choice and angular integration is suggested for better properties of the measures. These measures will be referred to as normalized angular choice (NACH) and normalized angular integration (NAIN).

This study focuses on the analysis of those two syntactic measures: NACH and NAIN. From the spatial analysis to the Bairro dos Actores, it was felt that the two syntactic measures, mentioned above, can better explain the potential to generate pedestrian movements, considering the possibilities of proposing new passages in the blocks in that urban area.

5 RESULTS

The use of Depthmap software allowed the angular computation of the NAIN and NACH segment map with three local radii: 250 m, 400 m, and 750 m. In addition to the 400 m and 750 m metric radii corresponding to 5 minute and 10 minute walk, respectively [16], it was also chosen to use the 250 m metric radii. In fact, given that the case study is part of a parish with a high aging rate (208.1 people aged 65 and over for every 100 people under 15 years old [27]), it is considered that the 250 m correspond to 5 minute walk for the elderly population.

Fig. 4 shows the NAIN results for the global area.

Globally and in any of the metric radii, there is an increase in NAIN as the number of passages increases, except in Simulation 3 (when the number of passages is the largest of those tested). Most likely, the study area acquires a too high leading role, becoming an attraction; this has the consequence of "drying up" the surrounding area and leads to the conclusion that the increase of connections is not enough only in a neighborhood, but it should be done in a wider area to increase global and not just local walkability.

Since NAIN measures the potential to-movement, i.e. how likely a street is to be a destination of a route, the increase of passages in Bairro dos Actores tends to attract the routes to that study area.

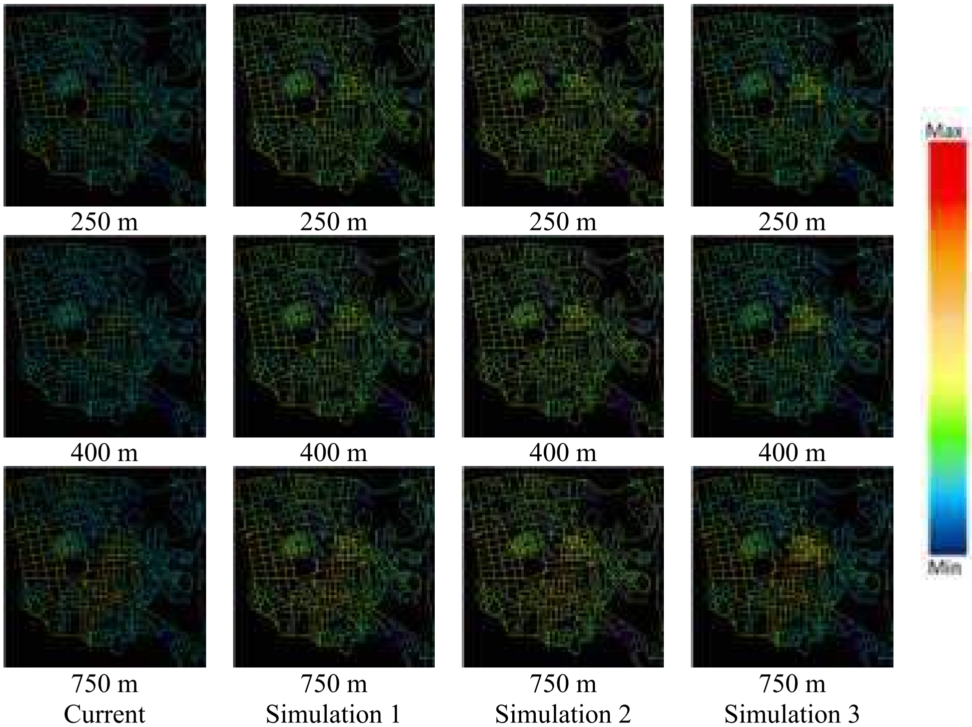


Figure 4: NAIN global map of current situation and three simulations.

In shorter metric radii (250 m – 5 minute walk for the elderly population and 400 m – 5 minute walk) there are no major differences in NAIN in any of the simulations considered, while in the larger metric radii (750 m – 10-minute walk) there is a considerable increase in the NAIN in areas with more regular urban grids.

Fig. 5 and Table 1 show the NAIN results for the study area.

Analyzing the maps of Fig. 5 there appears to be an increase of NAIN values across all metric radii. For a more accurate analysis, the NAIN values were quantitatively analyzed in terms of their variation (standard deviation), mean and maximum value.

Both in the current situation and in the three simulations, the standard deviation (SD) is reduced and identical in any of the radii, revealing results homogeneity. The to-movement potential [16] of the spatial structure on background (mean value) and on foreground (maximum value) [23] is always increasing. That is, as the passages through the interior of the blocks increase, the network is also more easily accessible [23], in all metric radii (Fig. 6). It also highlights that the smaller metric radii (250 and 400 m) present NAIN values higher than the corresponding values for the larger metric radii (750 m), revealing that the to-movement potential is greater in the smaller distances (Fig. 6).

Fig. 7 shows the NACH results for the global area.

Globally and in any of the metric radii, there is an increase in NACH as the number of passages in Bairro dos Actores increases, essentially in Simulations 2 and 3, with no evidence of the same effect detected in the case of NAIN.

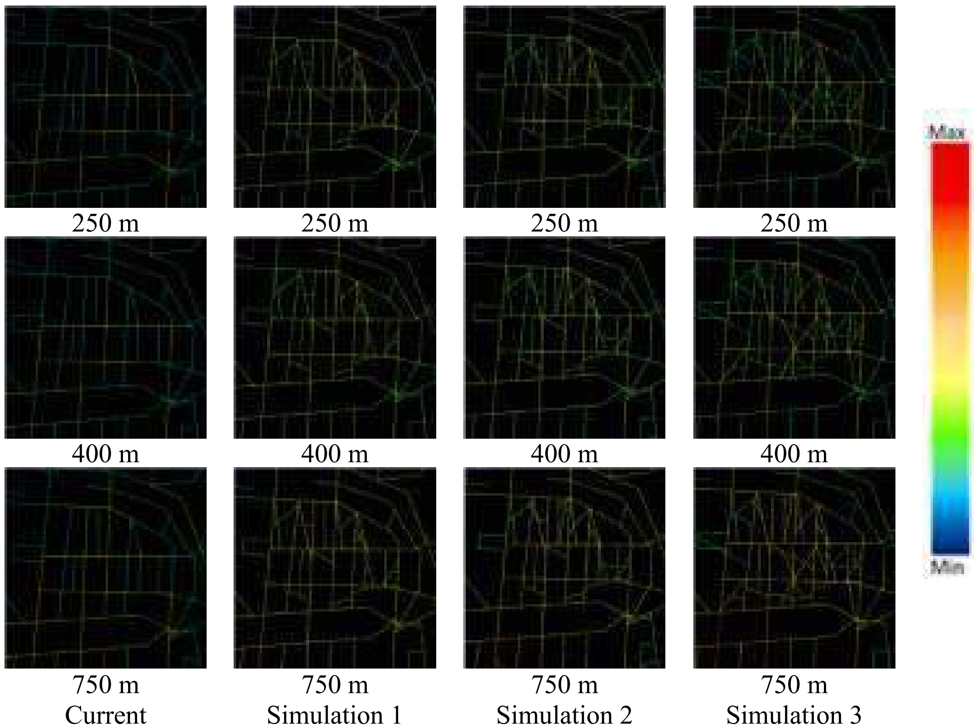


Figure 5: NAIN neighborhood map of current situation and three simulations.

Table 1: NAIN results of current situation and three simulations.

	Current			Simulation 1			Simulation 2			Simulation 3		
	Mean	Max	SD	Mean	Max	SD	Mean	Max	SD	Mean	Max	SD
NAIN250	1.624	2.128	0.241	1.646	2.244	0.285	1.636	2.244	0.289	1.702	2.341	0.284
NAIN400	1.525	1.965	0.220	1.603	2.191	0.270	1.613	2.259	0.283	1.717	2.420	0.283
NAIN750	1.224	1.562	0.129	1.298	1.647	0.154	1.329	1.672	0.166	1.440	1.810	0.176

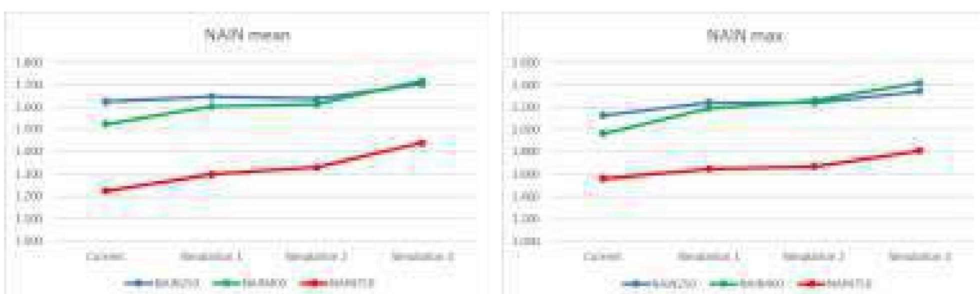


Figure 6: Evolution of NAIN (mean and max) in the different situations and metric radii.

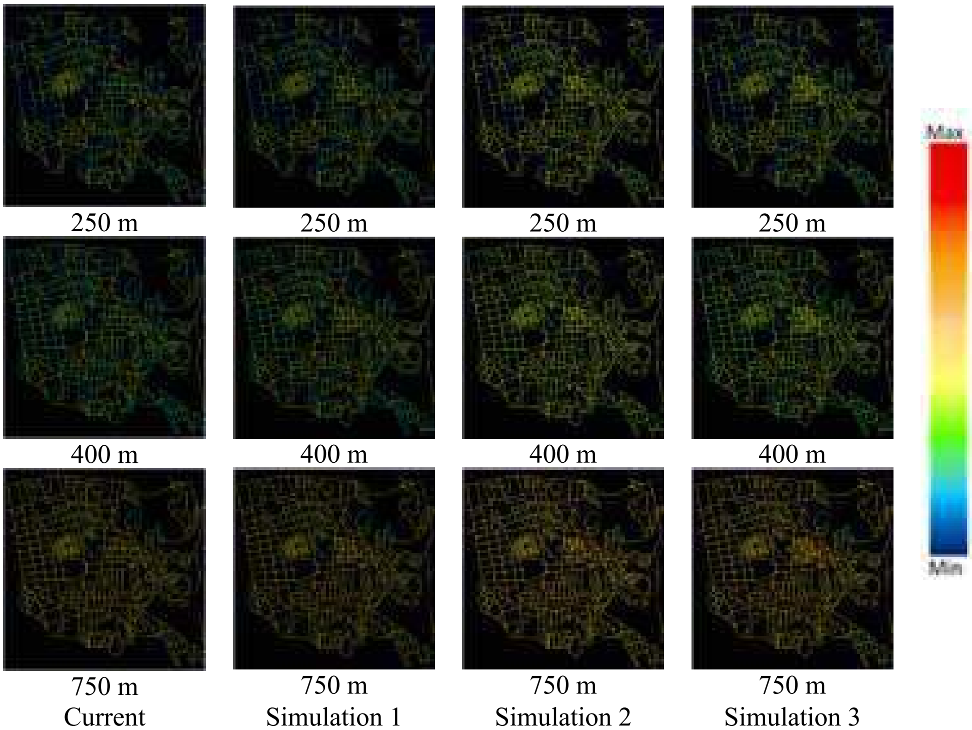


Figure 7: NACH global map of current situation and three simulations.

In shorter metric radii (250 m – 5 minute walk for the elderly population and 400 m – 5 minute walk) there are no major differences in NACH in any of the simulations considered, while in the larger metric radii (750 m – 10 minute walk) there is a considerable increase in the NACH.

Fig. 8 and Table 2 show the NACH results for the study area.

Analysing Fig. 8, it appears to be a greater increase of NACH values in the 750 m metric radii. Also, in this measure NACH values were quantitatively analysed in terms of its variation (standard deviation), mean and maximum value.

The homogeneity of the NACH results is also verified, expressed by the low and identical values of the standard deviation (SD) in the three simulations and in all metric radii. The through-movement potential [16] of the spatial structure on background (mean value) and on foreground (maximum value) [23] increases with the increase of passages through the interior of the blocks in almost all metric radii (Fig. 9). The only exception is a slight decrease of the NACH_400 max in Simulation 3 (Fig. 9(b)), i.e. the through-movement potential [16] of the spatial structure on foreground (maximum value) does not necessarily increase whenever there is a greater number of passages through the blocks.

By comparison, the study carried out in Orsini [23] shows how NAIN and NACH measures also allow analyzing walkability in an evolutionary way due to changes in urban morphology (the increasing number of passages in this paper).

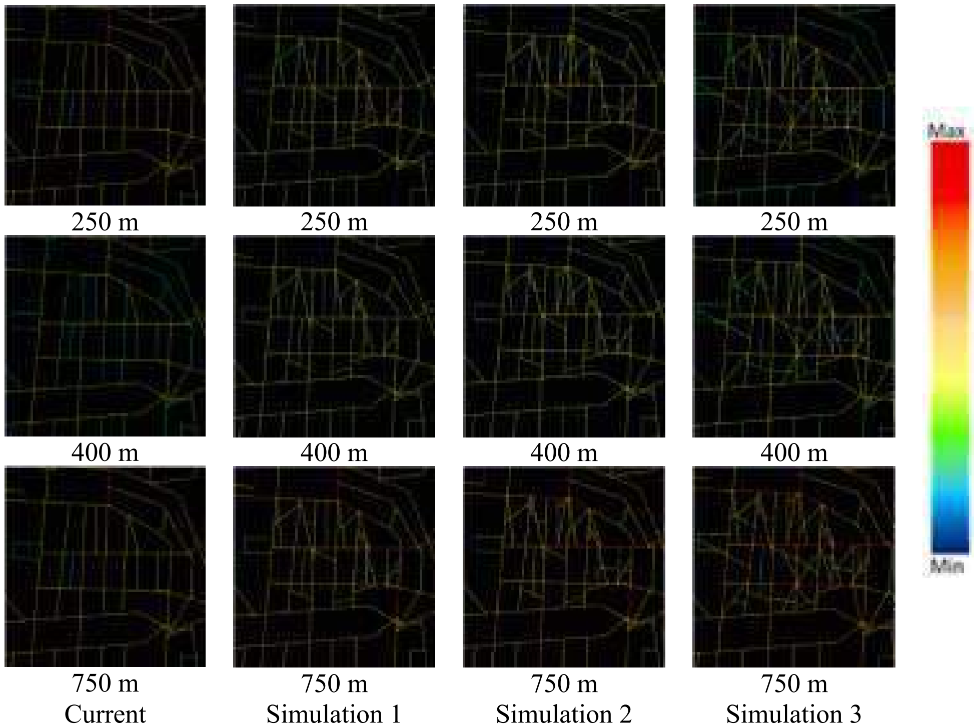
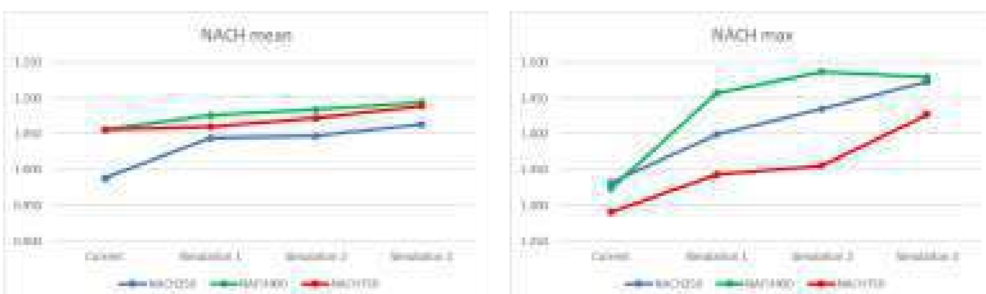


Figure 8: NACH neighborhood map of current situation and three simulations.

Table 2: NAIN results of current situation and three simulations.

	Current			Simulation 1			Simulation 2			Simulation 3		
	Mean	Max	SD	Mean	Max	SD	Mean	Max	SD	Mean	Max	SD
NACH250	0.988	1.332	0.238	1.044	1.399	0.253	1.047	1.435	0.237	1.063	1.473	0.237
NACH400	1.056	1.324	0.216	1.076	1.457	0.253	1.084	1.487	0.235	1.094	1.479	0.245
NACH750	1.056	1.291	0.210	1.060	1.343	0.248	1.072	1.356	0.235	1.089	1.427	0.242



(a) (b)

Figure 9: Evolution of NACH (mean and max) in the different situations and metric radii.

6 CONCLUSIONS

With this exploratory analysis we were able to accept the hypothesis that the increase in the number of passages improved spatial structure and accessibility of the study area. In all the three hypothetical scenarios created – increasing in number of passages and alternatives in a short-term (Simulation 1), medium-term (Simulation 2) and long-term (Simulation 3) intervention logic – there were somehow improvements in terms of walkability and accessibility.

The to-movement potential (which measures how likely a street is to be a destination of a route) of the spatial structure on background (mean value) and on foreground (maximum value) is always increasing. That is, as the passages through the interior of the blocks increase, the network is also more easily accessible, in all metric radii.

The through-movement potential (which measures how likely a street is used as part of a route) of the spatial structure on background (mean value) and on foreground (maximum value) increases with the increase of passages through the interior of the blocks in almost all metric radii, except in Simulation 3 (metric radii 400 m) where there was a slight decrease, so the through-movement potential of the spatial structure on foreground (maximum value) does not necessarily increase whenever there is a greater number of passages through the blocks.

In old and consolidated cities this idea of increasing their permeability to encourage the walkability of their inhabitants should be easy to implement if the opening of new passages were considered in the building rehabilitation plans. Simulations like the ones performed in this paper would be extremely relevant to access the feasibility of the new possible passages.

The proposed research confirms that Urban Passages play a crucial role in changing the walkability paradigm in old cities rehabilitation planning.

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SECTION 2
PLANNING, DEVELOPMENT AND MANAGEMENT

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MENTAL MAPS OF LISBON METROPOLIS (PORTUGAL) AS A TEACHING STRATEGY IN URBAN GEOGRAPHY

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ABSTRACT

Two weeks before the university lockdown, a group of twenty-three students from the Institute of Geography and Spatial Planning (IGOT) were invited to draw their image of the city of Lisbon and environs. The objective of the exercise was to compare their initial vision of the Metropolitan Area of Lisbon (AML) with the subsequent research conducted in situ, aimed at the investigation of urban planning and sustainability issues that needed intervention and change. As the university went online the 10th of March 2020, fieldwork became an impossibility. In alternative, the class was asked to identify the three main street grids, existent within the AML: (i) rectangular; (ii) irregular; and (iii) radio-concentric. To complement their assignment on the issue of urban morphology, the research further included the examination of three main square designs: (i) monumental; (ii) traffic squares; and (iii) gathering or reunion. Mental maps of cities were first used to evaluate the image of urban environments by their residents, in the work of Kevin Lynch, published in the 1960s. In this contribution, the mental maps of Lisbon drawn by the students were accompanied by an enquiry sheet with several personal data, as well as their plans for the future. In spite of the confinement, it was possible to overcome some movement limitations as, using Google Earth and Street View tools, the class examined in detail the urban morphology of the AML. In contrast, the impossibility to stroll along the streets, to interview city residents, service providers and traders, prevented the students from acquiring the necessary skills to propose urban renewal. Conclusion was that online work makes reproductive research plausible but innovation research is highly unlikely achieved. The usage of mental maps as a teaching strategy is, however, a good option, both in online and in-person Urban Geography classes.

Keywords: urban planning, urban morphology, mental maps, pandemic.

1 INTRODUCTION

Geographical enquiry about spatial information was first researched in 1913, by Charles Trowbridge that published the paper "On Fundamental methods of orientation and imaginary maps" in *Science* [1]. During the 1960s and 1970s, the issue was widely developed in English speaking countries, by such authors as Downs and Stea [2], Gould and White [3], Golledge and Stimson [4]. More recently, Spanish researchers have been using the images of places and the ranking of spatial preferences as learning tools in the education of geographers [5]–[7].

In fact, the representation of the relative location of places gives us the environmental perception of individuals, as the image they have of spatial information is dictated by their place of birth and their residence, actual or past, meaning, by their personal history in the place under scrutiny, as well as by their geographical education [8]. This is particularly evident in case of mental maps of cities and metropolitan areas, because spatial information is centered upon the location of our home. Navigation along streets in urban environments was developed in "The image of the city", by Lynch [9], giving way to the definition of five key elements present in the design of mental maps: (1) Neighborhoods; (2) Paths, like railways or streets; (3) Nodes, such as squares; (4) Edges or border limits; and (5) Landmarks, such as hills, towers, and public buildings.

In current study, we've used spatial information about the city of Lisbon and the Metropolitan Area of the capital city of Portugal (AML) as an educational strategy designed

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to encourage geographical learning, intended to fill the gaps in the student's locational ignorance, during the lectures and the fieldwork conducted in the Urban Geography classes, from the Institute of Geography and Spatial Planning (IGOT). As the university went online from the 10th of March 2020 onwards, fieldwork became an impossibility, because of the declaration of emergency dated 18th March 2020, valid for all Portuguese territory. In alternative, the Urban Geography class was asked to present several written essays, using Google Earth and Street View tools, and to post them or send the conclusions, together with accurate AML and Lisbon Municipality maps, to us.

Instead of fieldwork conducted in groups of five to six students in several municipalities, located in the axis Lisbon-Vila Franca de Xira, to the orient of the northern part of the metropolis (see Fig. 1), the Urban Geography students had to identify the three main street grids, existent within the AML: (i) rectangular; (ii) irregular; and (iii) radio-concentric. To complement their assignment on the issue of urban morphology, the research further included the examination of three main square designs: (i) monumental; (ii) traffic squares; and (iii) gathering or reunion.

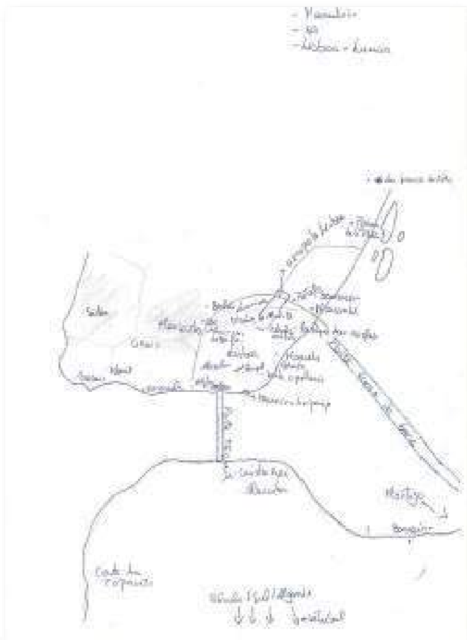

Figure 1: Mental map of the AML. *(Source: Class 2019/2020.)*

The initial objective of the project was to compare their vision of the Metropolitan Area of Lisbon (AML) drawn in their mental maps, with the subsequent research conducted *in situ*, and aimed at the investigation of urban planning issues that needed intervention and change. With the pandemic virus crisis, the learning process included no fieldwork but solely online work, as said. The structure of the paper, after this introduction, will explain the material and methods employed, then will include the presentation and the discussion of the results gathered during the second semester of the scholar year 2019/2020 (February–July 2020), illustrated with tables and figures of individual non-identified drawings and several Google Earth maps and Street Views presented by the students groups, towards a conclusion.

2 MATERIAL AND METHODS

Materials used were threefold: (1) A blank sheet of paper and a pen or a pencil, to be used in mental map design; (2) A questionnaire with the place of birth, places of residence, educational background and plans for the future, to be filled in by each student; and (3) Google Earth maps and Street Views of the geographical areas under scrutiny, presented in group assignments, during the online course of Urban Geography. The first two sheets of paper – the one containing each individual student mental map of the AML or Lisbon, at their choice – and the second – the enquiry sheet with the answers to the questionnaire– were given back to us, together. Table 1 presents the characterization of the students under study in this research project, by age and by sex.

Table 1: Personal data of the students.

Age	Student's sex		
	Males	Females	Total
18–19	14	7	21
20 or more	1	1	2
Total	15	8	23

Methodology followed previous work conducted in 2007 and 2008, in remote Southern Hemisphere islands–Mozambique and East Timor–among high school teenagers [8], together with recent research led in the IGOT, among university students [10]. Because this second line of investigation targeted specifically the urban realm and not Planet Earth, current project generally followed the methodology proposed by Lynch [9]. The first attempt to analyze the image that university students have of a Lisbon neighborhood was developed in 2019, and the results were published in a scientific journal, in Spain [11].

3 RESULTS AND DISCUSSION

Mental maps are sketches of our world, continent, country, city or neighborhood sensed from reality or memorized from cartography, coded, stored in our memory and organized according to our preferences and personal interests. They are usually distorted, incomplete and schematic drawings of the truth [4]. Mental maps are, however, good behavioural and perception tools that can be used to research individual preferences. They are also a good starting point in geographical learning, permitting to feed students curiosity about social, cultural and economic facts, intended to stimulate further study to fill in the blank spaces in their drawings, thus, allowing to design more accurate maps and data about the world around them. For two years we've been using mental maps as a teaching strategy in the Institute of Geography and Spatial Planning, acronym IGOT [10]. Fig. 1 reproduces a Lisbon student mental map, representing his view of the AML. On the top of the page, he mentioned his age (19 years), sex (Masculine) and place of residence (Lisbon, Lumiar neighborhood). Fig. 2 copies a Google Map of the same metropolis.

Table 2 presents the place of birth of the students that completed the Urban Geography classes with success. Only twenty-three of those students were present in the first classes and designed their mental maps, handed back to us together with an enquiry sheet. Some students were born in Madeira Island, in Alentejo or Algarve (South of the country), a

Figure 2: Google Lisbon Metropolis (AML) image.

Table 2: Places of birth of the students.

Municipality or location	Student's sex		
	Males	Females	Total
Lisbon municipality	8	–	8
Other AML municipalities	3	3	6
Other location in the country	4	5	9
Total	15	8	23

couple in Torres Vedras, located outside the AML. They lived in Lisbon, in student residences or with relatives and friends, but some of them returned to their official residence during confinement, so that they could be with their families. There was, however, one student from Algarve that we realized had stayed in Lisbon, during the pandemic virus lockdown, away from relatives.

Table 3 represents the residence of the students as stated in the enquiry sheet. During the pandemic virus lockdown we've handed out another questionnaire, by email, in order to inquire the students' actual location, as the classes went online. Only four of the twenty-three students gave back that second questionnaire, as for obvious privacy reasons they were not obliged to hand it back. As read in the table, fourteen students live in several other municipalities around Lisbon city, within the Lisbon Metropolis. Five students stayed outside the AML, as they lived not far away from IGOT, and could travel by train during the school year. The assumption is that they continued do live there, with their families, for the rest of the semester.

Table 3: Places of residence of the students.

Municipality or location	Student's sex		
	Males	Females	Total
Lisbon municipality	3	1	4
Other AML municipalities	8	6	14
Other locations in the country	4	1	5
Total	15	8	23

The drawings of the five students grown and resident outside the AML represented the metropolis in a quite schematic and incomplete way. They presented the following elements: (i) border lines for the coastal and River Tagus limits; (ii) dots representing cities and urban suburbs, not always correctly positioned, such as: (a) Cascais, Sintra, Oeiras, Ericeira, Algés, Loures, Vila Franca de Xira, in the northern part of the metropolis; (b)

Almada, Costa da Caparica, Moita, Pinhal Novo, Setúbal, in the southern part. Fig. 2 shows the structure of AML and its image in a Google View. The connection between the two Tagus River margins can be done by three main bridges, even though only two are visible in this section of the metropolis reproduced.

Similarly, in Fig. 1 the IGOT student clearly and correctly represented the same couple of bridges, tagging them: Ponte Vasco da Gama (the longest one) and Ponte 25 de Abril (the shortest). The author is a Lisbon resident, as said. However, we stress that the students that live outside the AML only represented 25th April Bridge. In fact, this group of outsiders gave us just three key elements in their mental maps, less than the drawings analyzed by Lynch [9]. Moreover, one of those so-called outsiders only represented the railway station where she took the train back home, as well as the metropolitan lines she took in her daily trips to the university, to attend classes.

The second group of students includes the majority that was born, grown and that lives inside the AML, totaling 18, 78% of those drawers who handed back a mental map of the metropolis. This group of Lisbon Metropolis residents can be subdivided in five: (1) Residents in the western neighborhoods of the AML (five students); (2) Residents to the orient of Lisbon municipality (three students); (3) Residents to the North of the capital city of Portugal (four students); (4) Residents to the south of Lisbon and Tagus River (two students); (5) Residents in Lisbon city (four students).

The first subgroup of students comes from the most favorable residential areas in the country, usually inhabited by high-income families. This is a locational evidence in several other Northern-Hemisphere urban centers, as they are placed by the Atlantic sea and have favorable wind circulation that minimizes pollution [12], [13]. These are the most informative mental maps targeting the city of Lisbon (see Fig. 3), but mostly the AML. The elements represented in AML mental maps are: (i) dots locating the neighborhoods, urban centers and cities located along the Atlantic coast, sometimes following the railway stations; (ii) the three Tagus River bridges, sometimes with the location they have when seen by car from the highway that connects Lisbon with Setúbal (South of AML); and (iii) they represent detached elements or landmarks, such as Jesus Christ Statue, in Almada. These mental maps present the 5 key elements described in the work of Lynch [9].

In Fig. 3, Lisbon squares are correctly represented but avenues and streets that connect them are incomplete. This is because the 18 year old student usually travels from Carnaxide to Lisbon, by train, using the Cascais-Lisbon western train connection, and then, he commutes the Metro lines. Therefore, the main squares of Marquês de Pombal, Saldanha, and Chile are represented in his drawing, because they are metropolitan line stations. In fact, his mental map started in Terreiro do Paço, the central monumental and historic square, so-called “the living room of Lisbon”, where, by the way, the assignment for the Urban Geography classes fieldwork was supposed to start. Then he represented other squares that he knew but failed to link them together. The avenues he knows – Avenida da República, Avenida Almirante Reis and Avenida Guerra Junqueiro–and the road–Rua Morais Soares–connect several metro stations, and follow the Metro lines. Besides that he also represents two gardens, both accessed by Metro stations – Alameda D. Afonso Henriques (Metro Alameda) and Parque Eduardo VII (Metro Marquês de Pombal). No surprise, he lives in the municipality of Oeiras, to the west of Lisbon municipality, and he is obviously not used to stroll along Lisbon streets.

The elements the IGOT student drew were: (1) Neighborhoods (Alameda and Almirante Reis); (2) Paths, like roads and avenues; (3) Nodes, such as squares; (4) Edges or border limits; (5) Landmarks, such as the monumental squares and the parks and gardens. It is

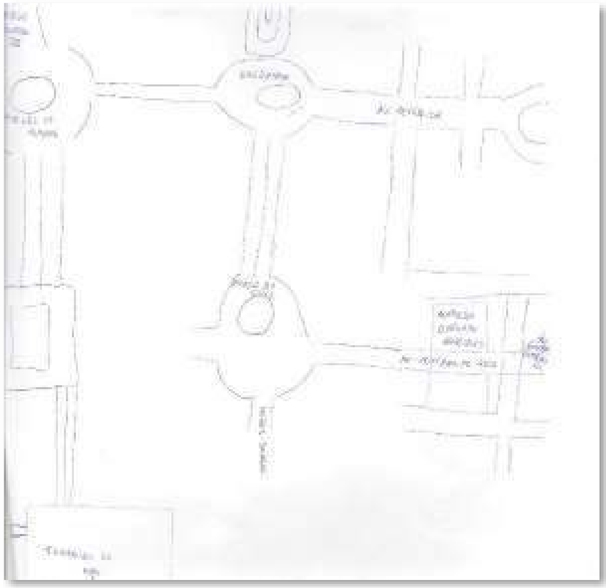

Figure 3: Mental map of Lisbon. *(Source: Class 2019/2020.)*

Figure 4: Street view of Terreiro do Paço Square in Lisbon (west is upwards).

interesting to emphasize that this mental map presents some similarities with the properties of a Mozambican Island 13 year old mental map [8], drawn with a similar cardinal orientation (N–S) and leftwards, as in a written discourse typical of western languages (from left to the right hand side), generating subsequent distortions in orientation, distance and shape of the city.

Because these sketches were so informative, Fig. 5 reproduces a female student mental map, where it is possible to understand that the knowledge she has of Lisbon metropolis is dictated by her daily travels to IGOT, by train and Metro. (1) In this drawing she signals the University campus where the Institute (IGOT) is situated, in itself a neighborhood; (2) Nodes are the train and railway stations, like Cascais, Monte Estoril, S. João do Estoril and S. Pedro is blurred (see Fig. 6). Then come the metropolitan stations, such as Campo Grande, part of the so-called Green line (verde, in Portuguese); (3) Paths but also border limits are the lines and the bridge, the 25th of April crossing towards the Southern margin of the metropolis; (4) The port of Lisbon marks another edge or border, correctly situated in her mental map; (5) The IGOT building, where face to face classes take place, is her landmark. We've presented the picture in rotation, in this Fig. 5. However, the student presented the image in its normal orientation, as the North was upwards. As is usual with female drawers, the IGOT student mental map is quite utilitarian.

Figure 5: Mental map of a Cascais municipality student. *(Source: Class 2019/2020.)*

Figure 6: S. Pedro do Estoril. *(Source: https://www.bluesoft.pt/blog/linha-de-cascais.)*

The subgroup of students that are residents to the orient of Lisbon municipality drew the following elements: (i) the railway line from Lisbon to Vila Franca de Xira, with the stations dotted; (ii) the border lines of the northern margin of Tagus River; (iii) two bridges over Tagus River – 25th April and Vasco da Gama; (iv) the metropolitan lines connecting the Orient station, an emblematic Calatrava building, to the University of Lisbon. Again, all five key elements studied by Lynch, were reproduced in the IGOT students' drawings [9].

The third subgroup of residents to the North of the AML drew very schematic mental maps: (i) border lines of the Northern part of the Metropolis (three students) or border lines for both Northern and Southern parts of AML (two students); (ii) the highway from Lisbon to Vila Franca de Xira, with several urban centers dotted; (iii) the metropolitan lines that connect Lisbon with suburban Northern neighborhoods and cities; (iv) only one Tagus bridge – 25th April – connecting the Northern and Southern margins of the Metropolis. We stress that they also drew the five key elements studied by Lynch [9].

One of the two residents to the south of Lisbon eligible for this project gave the first outline of the railway that connects the Southern part of the Metropolis with the North: (i) the bridge over Tagus River where the train circulates – 25th April (see Fig. 7); (ii) the railway stations dotted, from Entrecampos and Roma-Areeiro (N), close to the university campus located in Lisbon, towards Setúbal (S); (iii) detached buildings like the IGOT (Fig. 8) and Jesus Christ statue, in Almada: (iv) border lines of the Atlantic coast and the Tagus river margins. We emphasize that this female student also drew the five key elements studied by Lynch [9]. Again, she drew a utilitarian mental map.

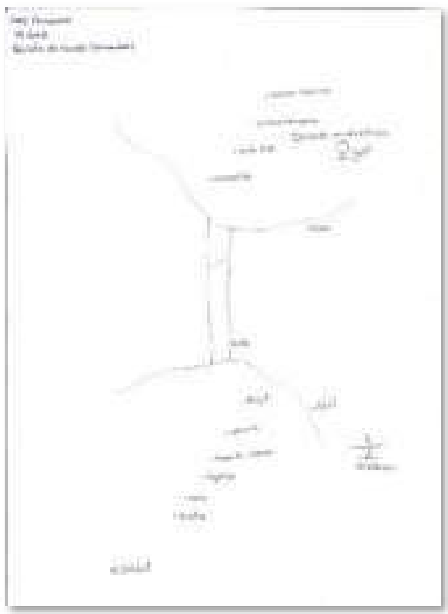

Figure 7: Mental map of a Quinta do Conde student. *(Source: Class 2019/2020.)*

Figure 8: IGOT building, Lisbon University campus. *(Source: IGOT website.)*

The last subgroup of students lived and grew in Lisbon municipality. Their mental maps represented the following elements: (i) border lines of the Atlantic coast and the Tagus river margins (see Fig. 1); (ii) the two main bridges over Tagus River – 25th April and Vasco da Gama; (iii) dots representing several Lisbon paradigmatic sites, such as Terreiro do Paço (Figs 1 and 4), the Orient Railway Station and Santa Apolónia Railway Station (Fig. 1); (iv) landmarks like Monsanto hill with park (Figs 1 and 2), Alvalade football stadium (Fig. 1), the Jesus Christ Statue in Almada (Fig. 1); (v) the metropolitan and railway lines with stations dotted, representing neighborhoods, like Belém, Alcântara, Benfica, Parque das Nações; (vi) monumental squares, such as Marquês de Pombal (Figs 1, 3 and 9). We stress that these four Lisbon city students also drew the five key elements studied by Lynch [9].

Figure 9: The monumental Marquês de Pombal Square.

Figure 10: Radio-concentric grid from Madre de Deus neighborhood.

3.1 Student's plans for the future

Table 4 presents the future plans' list for the universe of students under scrutiny. First and foremost they plan to finish their Honors degree, six of them aim the subsequent Master's degree, and only seven of them have more distant planning, regarding employment, namely as cartographers (two), schoolteachers (two), NGO workers (one), researchers (one) and municipality functionaries (one). Three students had no idea about their future, as they left a blank space in this question. The four students that filled in the subsequent questionnaire, during confinement, were more immediate in their wishes: (i) they wanted to be able to go the beach (three); (ii) to be with their family (two); (iii) with friends (three); (iv) to go back to IGOT (two); (v) to go to the movies (1); (vi) to exercise (one); (vii) to go to a restaurant and party (one).

3.2 Student's essays and the cartography presented

Urban Geography students have submitted three essays during the semester. Only one is admissible for analysis in the current paper. The class was asked to identify the three main street grids, existent within the AML: (i) rectangular; (ii) irregular; (iii) radio-concentric. Fig. 2 represents a Google map of the Metropolis, presenting the two main bridges over Tagus River and clearly a green spot corresponding to Monsanto hill and its public park.

Table 4: Students' plans for the future.

Type of planning	Student's sex		
	Males	Females	Total
Finish the Honors degree	5	2	7
Finish a subsequent Master's degree	4	2	6
To become a geography teacher	1	1	2
To become a cartographer (GIS)	1	1	2
To work in a municipality	–	1	1
To work in an NGO	–	1	1
To research physical geography	1	–	1
No plans	3	–	3
Total	15	8	23

Fig. 4 reproduces a Street View of the rectangular Baixa or Central Lisbon neighborhood, where the monumental Square called Terreiro do Paço can be spotted. Fig. 10 represents the radio-concentric grid of Madre de Deus neighborhood, located to the North-East of Baixa and of Monsanto, where the students have signaled the grid using the Windows tools. This way the groups of designers were able to illustrate their essay about the history and geography of the neighborhoods they selected.

To complement their assignment on the issue of urban morphology, the research proposed further included the examination of three main square designs: (i) monumental; (ii) traffic squares; (iii) gathering or reunion. Fig. 5 reproduces another Lisbon monumental square, Marquês de Pombal, located to the North of Baixa, as well as the high-income shopping Liberty Avenue and Edward the 7th Park, located northwards the tree shaded boulevard, either. This way students reproduced online cartography, copy-pasting the Street View images and Google Earth maps, as well as panoramic photographic views of squares and boulevards, yet they were not innovative in their assignments, as previous Urban Geography classes were, because they could not stroll along the streets, interview traders and residents, nor photograph streets and squares themselves.

4 CONCLUSIONS

In spite of the lockdown the University of Lisbon imposed, dated the 10th March 2020, due to confinement of both students and professors, a national governmental measure, it was possible to overcome some movement limitations as, using Google Earth and Street View tools, the Urban Geography class examined in detail the urban morphology of the AML, and was also capable to successfully explain the evolution of the street grids and squares selected for their group assignment. By contrast, the impossibility to stroll along the roads, to inquire city residents, service providers and traders, prevented the IGOT students from acquiring the necessary skills to propose urban renewal. Conclusion was that online work makes reproductive research plausible but innovation research is highly unlikely achieved. The usage of mental maps as a teaching strategy is, however, a good option, both in online and in-person Urban Geography classes.

Mental maps, also known as cognitive maps, are individual and very simplified versions of the City or the Metropolis, usually quite utilitarian, in the case of female drawers and more informative, in case of males. Lisbon city residents were more capable of designing the urban landscape situated close to their residence, but also more able to represent the whole metropolitan area. Residents outside Lisbon, who were more informative about the capital city, came from the western part of the metropolis. As stated by a French geographer, Suzanne Daveau, who lived in Lisbon for most of her life, the Metropolitan area has 2,569 km^2, but the most impressive element for tourists is the Tagus River estuary, a liquid mass of 261 km^2 [13]. The students' drawings also proved the Tagus River and bridges as key features in the image of the capital city of Portugal, for IGOT Geography learners.

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PLANNING SUSTAINABILITY IN HIGHER EDUCATION: THREE CASE STUDIES

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ABSTRACT

Sustainable development is a key principle of national and international policies, which has been strongly promoted by the European Union since 2015. Communication, education, the awareness of the importance of accelerating the transition from a linear economy to a circular one and of raising environmental awareness play a key role in the achievement of sustainable development goals (SDGs). To achieve the goals on a large scale, it is necessary to start from a local scale. In this sense, universities must experiment best practices and make them available to the society. In the last years, many universities have adopted environmental sustainability plans in order to implement green policies and develop a roadmap towards the achievement of the SDGs, while sharing best practices with university communities and society. This paper presents the case of two Italian universities and a Russian one. Specifically, the paper presents the contents of the current environmental sustainability plans of the Italian universities, discussing the reasons for the choice of the environmental sustainability goals and the expected results following the implementation of the related actions. A comparison between the approaches adopted in the sustainability plans of the two Italian universities will be presented in details. In addition, the paper analyses the potential implementation of a sustainability plan in the Russian university. The paper will discuss also potential criticalities in the achievement of the goals.

Keywords: environmental sustainability, sustainable development, planning, university networks, waste management, emissions, energy efficiency, mobility, health, communication.

1 INTRODUCTION

According to the Brundtland report, sustainable development can be defined as a modification process that aims at the harmonization of the exploitation of resources, of investments, of the direction of the technological development and of institutional reforms and advances with the needs of future generations, in addition to the current one [1]. After the commitments undertaken by the states that endorsed the Kyoto Protocol, which aims at reducing the greenhouse gas (GHG) emissions, increasing the energy efficiency and the production of energy from renewable sources, the interest of the public opinion towards environmental sustainability has considerably grown. In this framework, academic institutions play a fundamental role, acting as catalysts for innovation and disseminators of knowledge and good practices of environmental sustainability through their high-level educational programs [2], student engagement [3] and communication campaigns [4]. During the last decades, a growing number of universities have signed Sustainability in Higher Education declarations, to confirm their commitments towards environmental sustainability actions in education and research [5]. This phenomenon has gone hand in hand with the development of rankings for higher education institutions, with the purpose of measuring their environmental sustainability performance and stimulating the achievement of higher targets [6].

During the last decade, the number of universities pursuing targets of environmental sustainability has considerably increased, as demonstrated by more than 800 peer-reviewed publications on this topic. The increasing awareness of the role of universities in promoting

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environmental sustainability principles has led to the formation of university networks for the exchange of good practices, like the case of the Network of Universities for Sustainable Development (RUS), which was formed in Italy in 2015 [7]. RUS currently includes 78 universities of every size and location. The purpose of this network is to share solutions to increase the level of environmental sustainability and social responsibility among universities. RUS makes a clear reference to the 17 Sustainable Development Goals (SDGs), considered as the key targets to design the path towards higher sustainability levels in academic education. Several universities belonging to RUS have developed Environmental Sustainability Plans (ESPs) to plan and monitor activities that aim at increasing the level of sustainability within the academic communities and outside. Meanwhile, since the last decade, universities have had the opportunity to measure their progress and stimulate further achievements with the participation in university sustainability rankings. Among them, the UI Green Metric (UI GM) World University Rankings [8] and the Times Higher Education (THE) Impact Rankings [9] have involved a high number of universities sharing their levels of sustainability in recent years.

The present paper aims at presenting the cases of two Italian universities (the University of Trento and the Insubria University) and their respective ESPs. Differences and similarities will be highlighted between the two universities. In addition, the present paper will investigate the potential implementation of an ESP in a Russian university (the Ural Federal University) that has demonstrated growing sensitivity to the topic of environmental sustainability in the last decade. The paper will contribute to enriching the series of publications on sustainability in higher education with a focus on two different countries with similar motivations in the promotion of good practices of sustainability in university environments.

2 CASE STUDIES

2.1 University of Trento

The first case study refers to the University of Trento (UniTrento), located in the Trentino region (Italy). Trentino is an Alpine region with a high touristic vocation, a long tradition of respect for the environment and a strong bond with landscape and nature [10]–[12]. In 2018, UniTrento was composed of 16,305 students, 889 doctoral students and post-doc fellows, 673 professors and researchers, and 693 staff employees. UniTrento consists of ten departments, one faculty and three inter-departmental centres, displaced in five geographic areas: downtown Trento, Eastern hills of Trento, the town of Rovereto, the hamlet of Mattarello and the village of San Michele all'Adige (Fig. 1).

Considered that the populations of Trento and Rovereto (the main municipalities that host the Unitrento campuses and research centres) account for 118,288 and 39,972 inhabitants, respectively [13], the university community represents 11.7% of the whole population living in those two towns. Such numbers cause a high degree of environmental pressure to the municipalities involved, in terms of mobility, consumption of natural resources and waste generation [14], [15].

In 2016, for the first time, UniTrento issued a document entirely dedicated to environmental sustainability, with a road map for the achievement of 14 different targets grouped in four areas: "Emissions, energy and natural resources", "Buildings and procedures", "Culture and education" and "Health and well-being" [16]. Being this a first attempt to reach several ambitious targets in a unified manner, the pathway revealed as

Figure 1: Location of the UniTrento and Uninsubria campuses in northern Italy. *(Source: Adapted from Google [17].)*

arduous, partly because of the high number of targets. However, that 2-year period allowed highlighting issues whose entity was new at that time: problems regarding waste management, issues concerning the second area ("Buildings and procedures"), difficult collection, circulation and management of data within the different universities departments. In 2019, a new ESP (version 2020/2021) was drafted to increase the level of sustainability of the university and continue the path started in 2016.

2.2 Insubria University

The Insubria University (Uninsubria) is composed of about 12,000 students and hosts about 15,400 people in total, including lecturers, researchers, administrative and technical staff. Uninsubria was founded in 1998 and consists in three main campuses located in the towns of Varese, Como and Busto Arsizio (Fig. 1). The three campuses are composed of about 40 buildings in total. Uninsubria hosts seven departments. Three of them are located in Como and the remaining four departments are located in Varese. One of the departments of Varese has also a branch in Busto Arsizio.

Uninsubria formally started its path towards sustainability initiatives in 2016, when the university joined the RUS and drafted its Strategic Plan for Sustainable Development. The latter was concretely realized with the approval of the Environmental Sustainability Plan 2019/2020, containing proposals for initiatives and a roadmap to implement actions for reducing the environmental pressure of the campuses, improving the quality of life of the users and promoting the culture of sustainability. Concerning this last aspect, Uninsubria believes that becoming an example of virtuous community would be beneficial to other sectors of the public administration, of education and to the territory in general.

2.3 Ural Federal University

The Ural Federal University (UrFU), named after the first President of Russia B.N. Yeltsin (UrFU), is located in Ekaterinburg (Russia). UrFU is composed of about 56,000 students and is divided into 14 buildings. This makes UrFU the largest Russian federal university. Moreover, UrFU has six subsidiaries in Sverdlovsk region as reported in Fig. 2 [18], [19].

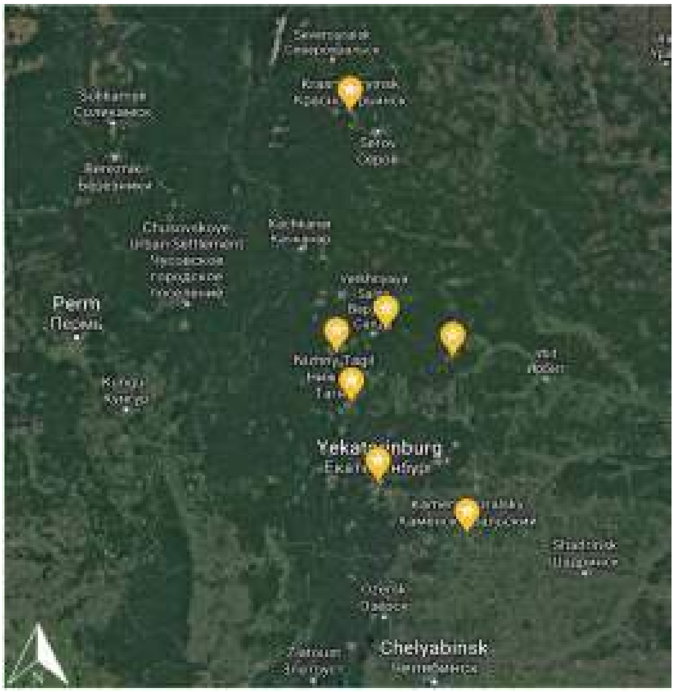

Figure 2: Location of the UrFU campuses. *(Source: Adapted from Google [17].)*

UrFU has a Development Program for 2010–2020 that includes five main sectors [20]: Educational activities; Research activities; Human Resource Development; University infrastructure development and Organizational development.

Global development trends were considered, as well as the situation in the Russian economy and the Ural Federal district. Since 2019, Ural Federal University has been implementing a digital transformation program that develops existing information services and creates new ones.

3 ENVIRONMENTAL SUSTAINABILITY PLANNING

3.1 University of Trento

The Environmental Sustainability Plan 2020/2021 aims at pursuing higher sustainability levels through two modalities: a participation process and a proposal for technical actions resulting from the previous two-year period. The participation process will allow the community making proposals, discussing ideas and strategies complementing the technical actions. One of the tools available to the community will be the UniTrento Environmental Sustainability Days, which will take place annually. During such events, the community will be able to discuss ideas, highlight criticalities and propose strategies, together with experts of the university in environmental sustainability.

Concerning the technical part of the Plan, the sustainability targets are organised in four sectors, including 11 subsectors (Table 1). Each sector includes the United Nations Sustainable Development Goals (SDGs) targeted [21].

Table 1: Organization of the technical targets of the ESP 2020/2021 of UniTrento.

	Sectors			
	Emissions, energy and natural resources	Buildings and procedures	Communication and culture of sustainability	Health and well-being
Subsectors	University carbon footprint Renewable energy Waste management Drinkable water management Sustainable mobility	Consumption monitoring system Green procurement	Sustainability communication Curriculum of studies	Indoor air quality Working life
SDGs targeted	n. 7: Affordable and clean energy n. 11: Sustainable cities and communities n. 12: Responsible consumption and production n. 13: Climate action	n. 12: Responsible consumption and production n. 13: Climate action		n. 3: Good health and well-being

Regarding sector n. 1 ("Emissions, energy and natural resources"), the Plan has declared a set of targets to achieve an efficient use of resources and minimize waste production. Specifically, regarding subsector n. 1.1 ("University carbon footprint"), the Plan aims at providing a yearly estimate of the GHG emissions from electric energy use, thermal energy use and mobility of staff, professors, researchers and students. The inclusion of subsector n. 1.2 ("Renewable energy") in the Plan is motivated by the following reason: in the Italian public sector, every year the companies that supply electric energy are selected through a tender noticed by the Ministry of Economy and Finance. Since the evaluation is not based on environmental criteria, but only on the lowest price, the suppliers are often unable of granting a large share of renewable sources in the energy mix. UniTrento currently compensates for this drawback by producing electric energy from photovoltaic panels installed on the roof of the Central University Library. However, the Plan indicates that renewable energy production should be increased by equipping future university buildings with systems for the production of electric and/or thermal energy by renewable sources. Waste management (subsector n. 1.3) is a particularly critical sector. External contributions of waste by strangers have been noticed in the past years in the areas outside the university buildings that host the dumpsters, which are periodically emptied by the municipal utility in charge. Since the taxes for waste management are calculated on the basis of the number of times each dumpster is emptied by the local utility, external contributions imply additional costs. Furthermore, if dumpsters are not properly locked after the disposal of waste by the personnel, the local utility may proceed to empty dumpsters that might be only partially filled. This translates into additional (and avoidable) costs for a public university. UniTrento intends to propose guidelines for the surveillance of the external areas, installing water dispensers in proximity of the vending machines to discourage the purchase of water in PET bottles, replacing paper towels with electrical hand-dryers [12], supporting specific projects proposed by the community, banning single-use plastics from bars, canteens and catering services. Subsector n. 1.4 ("Drinkable water management") prescribes a census of the status of public toilets in UniTrento, as a preparatory step towards the introduction of water-saving devices on the restrooms' taps. The last subsector (n. 1.5, "Sustainable mobility") aims at improving the conditions of public and shared transport and favor forms of mobility with lower environmental impacts. The criticalities of the town of Trento in terms of mobility were described in a recent publication [15].

Sector n. 2 ("Buildings and procedures") includes two subsectors. Subsector 2.1 ("Consumption monitoring system") aims at gradually automating the monitoring of water and electric/thermal energy in the buildings of UniTrento. Subsector 2.2 ("Green procurement") aims at implementing a homogeneous green procurement policy at every level in UniTrento.

Sector n. 3 ("Communication and culture of sustainability") plays a fundamental role in raising the community's awareness of the present challenges and of the opportunities deriving from increasing the level of environmental sustainability of UniTrento. Subsector 3.1 ("Sustainability communication") is designed to specifically meet these targets and to increase the visibility of UniTrento (both internally and externally) on sustainable development. In addition, this subsector includes the organization of the Environmental Sustainability Days and the production of scientific contributions on sustainability. Given the key role of students, UniTrento aims at improving its teaching programs on sustainability. Subsector 3.2 ("Curriculum of studies") is designed to achieve these targets.

Sector n. 4 ("Health and well-being") includes a set of actions aimed at improving the quality of life of the university community. The first subsector (4.1 "Indoor air quality") was created as a response to the relatively high concentrations of carbon dioxide (CO_2) in indoor air. Although in classrooms/offices CO_2 concentrations are not critical for human health, symptoms similar to the so-called "sick-building syndrome" may occur [22], [23]. To reduce the CO_2 concentrations within acceptable levels, the Plan aims at mapping structural and installation issues that may negatively affect indoor air quality, monitoring indoor air quality to highlight possible criticalities, and developing guidelines to manage indoor air. Meanwhile, initiatives concerning the work/home balance are also considered (subsector 4.2 "Working life"). In addition to the ongoing initiatives supporting parenthood, the Plan intends to achieve additional targets: 1) create spaces dedicated to the personal well-being and the health of people, where people can spend some time for health reasons; 2) create "silence spaces", dedicated to whom needs quite moments for meditation or praying during the working day; 3) renovate sport facilities; 4) improve the indoor visual comfort; 5) improve the communication to the community concerning the routes to reach classrooms, offices and other key destinations of the university, with specific regards to handicapped people.

3.2 Insubria University

In 2019, Uninsubria generated the second version of its Environmental Sustainability Plan, whose duration, similarly to UniTrento, is 2 years. The Environmental Sustainability Plan considers four sectors and nine targets (Table 2). Regarding the first sector (Emissions, energy and natural resources), the Uninsubria aims at estimating the carbon footprint of the university on the basis of the methodology recently developed by RUS [24]. The workgroup on climate change will strongly cooperate with the mobility workgroup in case mobility reveals as the primary sector contributing to carbon emissions. Specifically, Uninsubria will evaluate strategies to raise the awareness of the users to the use of public transport and car sharing/pooling services, and will implement actions to improve the offer of public transport in the area. GHG emissions are also strongly related to the consumption of fossil fuels for heating. Thus, Uninsubria aims at reducing the energy consumption in buildings, but also evaluating initiatives to become producer of electric energy from renewable sources. Uninsubria intends to reduce the consumption of drinkable water too. However, the first essential step is a census of the sanitary appliances of the university, which may be the primary cause of excessive water consumption. In analogy with UniTrento, Uninsubria is facing the problem of residual waste [18], caused primarily by the presence of a few undefined waste bins located in the university buildings and by the uncontrolled external areas that host waste dumpsters. The Plan proposes actions for the removal of undefined waste bins, protocols for the surveillance of external areas and initiatives to raise the users' awareness on responsible consumption and proper waste disposal through dedicated communication campaigns.

Table 2: Organization of the technical targets of the ESP 2019/2020 of Uninsubria.

	Sectors			
	Emissions, energy and natural resources	Mobility	Culture and education	Health
Subsectors	CO_2 emission inventory University and carbon footprint Energy efficiency, renewable energy and buildings Reduction of drinkable water consumption Waste management	Sustainable mobility	Networking of sustainability Sustainability office Curriculum of studies	Health and well-being in workplaces

Sector n. 2 ("Mobility") deals with the proposal for initiatives in the field of sustainable mobility. Uninsubria has already obtained important results in this sector. More specifically, the university signed an agreement with a well-known private company offering bus transportation services, which allows students and personnel to purchase travel tickets at a discount price. An agreement with the local public transportation company allowed improving the frequency of the existing bus routes to and from the university campuses, especially during rush hours. New routes were also added to the existing ones and a working group on the railway transport was created with the aim of improving the connection with university campuses. A questionnaire on the needs in terms of mobility was distributed to the users of the campus of Como and a worktable on the local mobility was set up in cooperation with the local administration.

Regarding sector n. 3 (“Culture and education”), Uninsubria aims at organizing an event every year involving RUS members and taking part in events on sustainability, both at a national and international level. Uninsubria considers the option of participating in international university rankings on sustainability, but only if the criteria are scientifically validated. This theme was the object of a debate in a paper concerning the UI GM university ranking, which highlighted potential limits in the formulation of the evaluation criteria [25]. Another target of sector n. 3 is the creation of an office entirely dedicated to environmental sustainability, to the management and monitoring of the initiatives listed in the Plan and to the development of new ones. Finally, Uninsubria aims at promoting the culture of sustainability by increasing the number of courses on this topic and promoting both internships in companies working on themes related to environmental sustainability and theses on this topic.

Sector n. 4 (“Health”) primarily aims at protecting the health of all users (students, lecturers, researchers, administrative and technical staff) from the exposure to air pollutants that originate from cigarette smoking. Uninsubria has carried out research on this field by monitoring campaigns on the concentration of particulate matter at the entrance of buildings [26]. In addition, analogously to UniTrento, Uninsubria has planned monitoring campaigns on the concentration of CO_2 in the indoor air of university buildings. Another common target with UniTrento is the proposal and implementation of initiatives to improve the quality of life at work.

3.3 Potential implementation of an ESP at the Ural Federal University

The theme of sustainable development is becoming a topical subject in the Russian higher education system. One of the first initiatives in the field of sustainable development of universities was the “Campus” program developed by Tetra Pak in 2013 with the support of the World Wildlife Fund (WWF). The purpose of the “Campus” program was to spread ecological awareness among students and young people [27]. The program also consisted in several eco-projects and initiatives for universities. A few years later, the program “Green universities of Russia” has evolved and got the government support. The main goal of the program is greening of Russian universities by introducing a separate waste collection system, energy saving technologies, and conducting educational activities in the field of ecology and environmental protection for students and University employees [18], [28]. UrFU is currently the participant of this program.

Moreover, a few Russian universities are included annually in the GreenMetric World University Rankings [8], [28]. This rating evaluates the commitment of world universities to the ideas of sustainable development and the designing of eco-friendly university infrastructure.

In order to determine the effectiveness of UrFU in the field of sustainable development and its perspectives, a comparative analysis of Russian universities (Ural Federal University, Moscow Institute of physics and technology, Higher school of Economics, peoples ‘friendship University of Russia) in the framework of implementing sustainable development activities in 3 main areas was developed (Table 3).

According to the results, Russian universities demonstrate the high interest in the topic of sustainable development. Most of the reviewed universities are currently introducing separate waste collection system, developing programs for improving working conditions, landscaping or working on sustainable development plan, etc.

Table 3: Comparative analysis of Russian universities in terms of sustainable development initiatives, with indication of the relative advances (+) and delays (–) in their application.

Sectors	Name of university	Sectors	Name of university	Sectors	Name of university
	UrFU Ekaterinburg		UrFU Ekaterinburg		UrFU Ekaterinburg
Green campus development:	No plan on environmental policy	Green campus development:	No plan on environmental policy	Green campus development:	No plan on environmental policy
Waste management	–	Waste management	–	Waste management	–
Energy efficiency, renewable energy and buildings	–	–	–	+	–
Work on the improvement and gardening areas	–	+	+	+	+
Sustainable mobility	–	–	–	+	–
Reduction of drinkable water consumption	–	+	–	+	–
Health and well-being:	No official plan	No official plan	No official plan	No official plan	No official plan
University medical facility	+	+	+	+	+
Health and well-being activities supported by university	–	–	–	+	+
Culture and education:	No official plan	No official plan	No official plan	No official plan	No official plan
Curriculum of studies	–	+	+	+	+
Sustainability office	–	+	–	+	–

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UrFU is at a very early stage of sustainable development planning: the university has implemented the separate waste collection system in several areas, participates in associations of sustainable development and develops various environmental initiatives; a special role is given also to the improving of the University infrastructure.

Digital technologies (for instance, the online portal of sustainable development) might become the basis for developing a transparent system of sustainable development at UrFU. The suggested sectors of the on-line portal are reported in Table 4. The goals are listed below:

- to ensure transparency and accessibility of data on the University's sustainable development;
- to digitize processes for evaluating the achievement of sustainable development plans;
- to create a competitive spirit between structural divisions in the field of energy saving quality;
- to develop a culture of responsible attitude towards nature in an intercultural educational environment.

Table 4: Suggested sectors of online portal about University Sustainable Development.

Sector of online portal	Proposed contents
Separate waste collection	Map of separate waste collection systems (academic buildings and dormitories); Statistical data on waste collection and waste treatment; Short segregation instruction for students and employees.
Health and well-being	Indoor air quality information; Guide to healthy eating; Sport activities at UrFU.
Clean air	Statistical data on air pollution in Ekaterinburg; Statistical data on the carbon footprint produced; Guide “How to reduce air pollution? ”
Energy conservation	The information on the applicable energy saving technologies; Statistical data on energy consumption in university building and dormitories
Greening of campus	Map of campus greening; Information about landscaping projects

UrFU has all the prerequisites for ESP developing and implementation:

- MSW selective collection system was introduced in five places at the main university building and is extending to all the UrFU.
- Heat and electricity come to the university building from the boiler-turbine of the experimental production complex of UrFU. Its eco-modernization will reduce emissions of harmful substances into the atmosphere and ensure rational resource consumption through the introduction of energy-saving technologies;
- Working together on joint “green” projects with regional enterprises, a positive impact on the indicators of environmental activity will be achieved.

4 CONCLUSIONS

The present paper showed how universities are preparing for the mission of pursuing higher level of environmental sustainability and promoting good practices both within universities

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and to society. Every university usually works in autonomy, but the involvement in university networks is strongly important to share principles and results.

The cases of UniTrento and Uninsubria showed that both universities have a similar scheme of actions, very likely influenced by the involvement in RUS. Both universities have to face issues, especially regarding waste management and mobility, but specific initiatives are planned in their respective ESPs.

The topic of sustainable development in the system of higher education is quite new for Russian universities, therefore it is significant for the government to provide financial support for the universities and determine the need of ESP. It is important also to develop a unified system for assessing sustainability adapted to the national legal framework in Russia.

The three universities might also commit to participate in the UI GM and THE rankings, as many of the goals presented in this paper reflect the evaluation criteria of these rankings (e.g., energy and climate change, waste, water, transportation and education in the UI GM and the contributions to the achievement of the 17 SDGs in the THE rankings). However, especially with regards to the first ranking, the selection and evaluation of the assessment criteria should overcome the limitations that affect the scientificity and rigour of the methodology [26].

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ITACA PROTOCOL: A POSSIBLE PATH TO SUSTAINABILITY IN THE GOVERNANCE OF THE BUILDING PROCESS

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ABSTRACT
Pursuing and disseminating the principles of sustainable construction requires, at the highest levels, an overview of the issues affecting the area and a detailed analysis of the potential that some regulatory instruments offer. For these reasons, the governance of the territory must start from an accurate assessment of the objectives to be pursued and the careful choice of the means to do so. In Italy, Institute for Innovation and Transparency of Procurement and Environmental Compatibility (ITACA) has been promoting the principles underlying the sustainable development of the territory for over 20 years. The areas of action of the Institute are various and varied: drafting of tools and documents necessary for the evaluation of the sustainability of interventions, training of technicians and personnel who take part in the certification process, involvement of stakeholders and third parties and collaborations with national and international bodies. After the first approval of the ITACA protocol, which took place in 2004, the assessment tool has undergone numerous changes and evolutions until it was approved as UNI Practice in 2015. Now the UNI Reference Practice 13:2019 – Environmental sustainability in buildings – Operational tools for the assessment of sustainability is a nationally recognized rating system and its use and dissemination throughout the territory is being promoted through specific training courses for experts and inspectors. These courses will also allow to obtain the certification of skills according to the ISO/IEC 17024 standard. The ITACA protocol, over the years after its first approval, has been applied by various Italian regions within their own regional legislative autonomy and therefore constitutes a real shared institutional and "public" protocol. The Institute is also focusing on the development of the "urban scale protocol", urban areas are in fact experiencing an unprecedented rate of population growth facing very complex environmental challenges.
Keywords: construction sustainability, rating tools, sustainability assessment.

1 INTRODUCTION

The term sustainability is very widespread today, but only recently it received the right connotation and is being used appropriately. The current urban and territorial planning tools follow guidelines that place sustainability as a postulate and as a fundamental criterion for guiding choices in the use of available resources. Although, as early as 1972, in the European Soil Charter, the Council of Europe stated that "soil is one of humanity's precious assets and is a limited resource that is easily destroyed" and that "Governments and administrative authorities they must rationally plan and manage the resources represented by the soil", only in the last twenty years has been developed an awareness of the fragility of the environment. The territorial governance system should consider the different meanings of the term "environment" (anthropic, ecological, landscape and naturalistic) and the environmental values of the territorial systems in order to implement a sectoral division of competences at various levels of scale. It is to respond to the need for specific tools for the design and assessment of environmental sustainability that today various ranking systems have spread nationally and internationally. In Italy, the most widespread are ITACA protocol, LEED,

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CasaClima, based on the analysis of requirements and the attribution of scores that take into account the performance of buildings in energy and environmental terms. Precisely by virtue of the adaptability and replicability of these methods, many regions in Italy have adopted and regulated these assessment tools within specific processes, to promote and disseminate the principles of environmental sustainability and provide technicians with guidelines for quality design. Several universities are actively engaged in improving calculation methodologies and continuously updating the results obtained.

2 ITACA: INSTITUTE FOR INNOVATION AND TRANSPARENCY OF PROCUREMENT AND ENVIRONMENTAL COMPATIBILITY

In 1996, in Italian regions founded the non-profit association called ITACA "Institute for transparency, updating and certification of contracts", with the aim of carrying out actions shared by the regional system and undertake, at national level, a common and shared path and to promote and guarantee an effective technical coordination between the regions and the autonomous provinces in order to ensure a better connection between the state, the local authorities and the national associations representing operators economic sector.

Since 2005, ITACA has adopted the new name of "Institute for innovation and transparency of procurement and environmental compatibility", underlining its commitment also in terms of issues relating to environmental sustainability.

The Institute operates on specific objectives of stimulation, coordination and harmonization in key sectors of the activity of the public administration, trying to enhance its autonomy and responsibility, and carries out its activity through technical tables constituted not only by regional experts, but also by representative state and local administrations and representative bodies of the sector categories. This work has allowed a broad and concrete discussion on issues identified from time to time as well as the exchange of knowledge and sharing of projects that can constitute hypotheses of socio-economic and environmental development for the country. The issues that the Institute deals with are: public procurement; job security; specifications and prices; contracts regional observers; regional aggregators; environmental training and sustainability.

Among the statutory purposes of ITACA, the issue of the quality of public procurement emerges substantially, both in reference to the planning, design and awarding phases, and to the execution, transparency and control phases of contracts. "Working groups" and technical tables have been set up for each area made up of managers, officials of the regions and autonomous provinces and experts in the sector, who carry out study, research and in-depth study of the subject, drafting of documents and guidelines to support the activities. Training is among the most important activities and is provided by the Institute on the basis of the most comprehensive programs and initiatives for stakeholders. The training offer, created by favoring the use of interactive and remote methodologies, is also modulated on the basis of the results of the study, research and experimentation activities developed by ITACA.

2.1 The promoting committee of the ITACA protocol and environmental sustainability

The promotion and dissemination of good practices for the environmental sustainability of buildings is one of the activities that have characterized the work of the Institute since its inception, assuming a significant role on the issues of environmental sustainability of buildings and on an urban scale. Topical issues increasingly at the center of European and international policies, related to the reduction of pollution, global warming, water consumption, energy efficiency, land protection and human health.

In particular, ITACA supports national and regional policies through the development and management of environmental protocols that propose and evaluate project choices in line with and in compliance with new sustainability models. In the Interregional Working Group for Sustainable Construction, discussions on specialized issues are promoted with the representatives of state and local administrations and specific sector categories stakeholders. The aim is to exchange knowledge and share objectives. Within this working group has been developed the first version of ITACA protocol in 2004.

The protocol is an aid tool for the activity of designers, companies, public administration in control procedures, and customers. It is the reference tool of the national construction inspection system, accredited by ACCREDIA Technical Regulation 33-2013, which established the ITACA National Protocol Register (RNPI). The register verifies the conformity of projects and/or the construction of buildings according to the protocol. The managing body of the National Register is the promoting committee of the ITACA protocol set up by the ITACA board of directors in 2013 for the promotion and dissemination of the environmental sustainability of buildings.

The committee carries out its activities nationally and internationally by promoting the environmental sustainability of buildings, pursuing innovation processes through the implementation of the certification processes of environmental sustainability of buildings according to the UNI PdR13:19 standard; supporting research, training and development of good practices, looking for collaborations with research centers, universities and other subjects interested in sustainability, organizing conferences, seminars and any other training initiative, including the dissemination of educational and information materials. The general goal is to promote the culture of environmental sustainability. As part of its institutional activities, the promoting committee has established the national lists of experts and inspectors of the UNI PDR 13/19 and it has approved the regulations for training courses for technicians aiming to become expert and/or inspectors. The Polytechnic University of Marche, as part of a collaboration with the promoting committee, is developing a software for calculating the global sustainability score through the UNI 13/19 reference practice.

2.2 The ITACA protocol and the UNI reference practices

The ITACA protocol is, at national level, one of the most widespread tools for assessing the level of energy and environmental sustainability of buildings; as other rating systems allows to verify the environmental performance of a building from different points: human health, expenditure of energy, water and other resources; it also promotes the construction of increasingly innovative buildings and the use of sustainable materials produced with low energy consumption and able to guarantee high levels of comfort. The protocol gives an objective and comparable evaluation using indicators and verification methods compliant with the technical standards and national laws. The protocol must be understood as a versatile document having different purposes in relation to its different use: it is a tool to support planning for professionals, control and guidance for the public administration, to support the choice for the consumer, to enhance an investment for financial operators.

ITACA implemented the protocol as part of the Interregional Working Group for Sustainable Building established in 2001. The goal was to provide regions with tools to support territorial policies and to promote environmental sustainability in the construction sector which to date continues to be the sector with the highest energy consumption (about 40% of the total) which affects and determines the most unsustainability of our countries. Since the approval of the first version of the protocol, in 2004, this instrument has been adopted by many regions and municipal administrations in various initiatives aimed at promoting and encouraging sustainable construction through the approval of regional laws, building regulations, tenders, urban plans, etc. Its wide diffusion is due to the intrinsic versatility of the document; the protocol derives from the SBTool international evaluation model, developed as part of the Green Building Challenge research process. The contextualization of the international method to the Italian territory took into account national characteristics. The starting point for the definition of the evaluation system are:

- the determination of the areas of assessment and of greater environmental impact;
- the identification of criteria that make it possible to measure the environmental performance of the building in question;
- the definition of reference performance (benchmark) considered the national and international legislation in force with which to compare those of the building for the purpose of assigning a score
- the attribution of weight to the criteria that determine its importance;
- the final aggregation of scores to determine the final synthetic score that defines the degree of improvement of the overall performance compared to the standard level.

This articulation determines the hierarchical structure of the protocol divided into areas, categories and evaluation criteria. The evaluation areas, which are the macro themes that determine the sustainability characteristics of the intervention, are: site quality, resource consumption, environmental loads, indoor environmental quality and service quality. With reference to the context and location of the building, the tool adapts by allowing the exclusion from the global system of criteria whose indicators cannot be evaluated due to the intrinsic characteristics of the building or the place of intervention. The evaluation criteria for calculating the performance score are organized in "criterion cards" and are grouped by reference category. The output of the activity conducted for the calculation of the performance score is an "evaluation report", carried out on a single building and its external area of relevance, containing the results of the evaluation with respect to the set of criteria taken into consideration. Since 2004, versions of the protocol for the evaluation of residential, commercial, office, industrial and school buildings subject to new construction or renovation have been approved.

In 2014, the 2011 residential ITACA protocol was replaced with the new UNI/PdR 13: 2015 reference practice "Environmental sustainability in buildings – Operational tools for assessing sustainability", created within a specific ITACA-UNI technical table. The document was then updated and published in July 2019 as UNI/PDR 13/19. The practice, which maintains the same calculation methodology through its hierarchical structure, allows the evaluation of new and renovated buildings and it is divided into three sections: Section 0 is about general framework and methodological principles; Section 1 and Section 2 which specify the criteria for the assessment of environmental sustainability and the calculation of the performance score of buildings for residential and non-residential use (for offices, commercial, school, industrial and hospitality). The update of the document in 2019 took into account the approval of the Ministerial Decree (DM) 11 October 2017 which contains the "Minimum Environmental Criteria (CAM) for the award of design services and works for the new construction, renovation and maintenance of public buildings" trying to standardize the criteria indicators to the reference benchmarks of the decree.

2.3 The urban scale ITACA protocol

Urban regeneration is commonly defined as a set of actions aimed at the recovery and redevelopment of an urban space, a process based on the environmental sustainability of the recovery interventions at the level of infrastructures and services, limiting land consumption and aiming at improving quality. of life in the social, economic and environmental spheres. Since 2013, the ITACA board of directors has welcomed these stimuli and expanded the assessment scale of the building's environmental sustainability to the urban scale, establishing an interregional working group dedicated to "environmental sustainability on an urban scale". A first version of the ITACA protocol at urban scale was approved in December 2016. It is configured as an evaluation tool capable of measuring the level of sustainability of interventions in the urban environment: from the block to the city, aimed at both public, and to operators involved in the development or transformation of urban areas. A very open and flexible tool, potentially usable on areas of application at various scales (isolated, sector, neighborhood), for the evaluation of projects (masterplan) or urban plans to be applied both in the design and monitoring phase.

3 REGIONAL CERTIFICATION SYSTEMS

Many Italian regions have adopted ITACA protocol as environmental sustainability assessment tool. Fig. 1 shows the overall situation of the regions using, having used or about to use ITACA protocol. At present they are 13 out of 20.

Figure 1: Regions using, having used or about to use ITACA protocol.

Three different levels of use of the regional protocols can be identified: a zero level for regions not having implemented any legal act in order to create a complex of procedures and uses of the protocol. A first level is characterised by regions having implemented some legal act and some procedures but with a small number of buildings going through the process of evaluation. A second level is identified by regions able to promote the evaluation process and with a considerable number of buildings being assessed. These considerations on different levels of use are related to the present situation but things can evolve and some regions could change their status. For example, the Tuscany region is in the process of getting legal approval of the regional law implementing the evaluation process and for these reasons is included in the level 1; it is likely for Tuscany to skip quickly to a higher level once this step will be completed. Table 1 summarises the various levels of use of regional protocols; Sections 3.1–3.6 show the main regional legal acts and uses of regional protocols.

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Table 1: Summary of the various levels of use of regional protocols.

Regions	Level
Piedmont, Umbria, Marche, Apulia, Calabria	Level 2: Ability to promote the evaluation process and with a considerable number of assessed buildings
Aosta Valley, Liguria, Veneto, Friuli, Lazio, Tuscany, Campania, Basilicata	Level 1: Implementation of some legal act and some procedures but with a small number of assessed buildings
Lombardy, Trentino South Tyrol, Emilia Romagna, Abruzzo, Molise, Sicily, Sardinia	Level 0: Not legal act and procedures approved

3.1 Apulia region

Since 2008 with the Regional Law n.13 Apulia region has adopted ITACA protocol a regional version (Apulia ITACA protocol). The regional version has the same areas of evaluation of the national version but a lower number of criteria. The Regional Law n.13, with the aim of encouraging the construction of sustainable buildings and good construction practices, has introduced some incentives (volume increases and tax relief) linked to the achievement of good Apulia ITACA protocol overall scores. Sustainable building interventions covered by the regional law must involve the entire building and belong to one of the following types:

- implementation plans;
- new building interventions including extensions of existing buildings (in this case the assessment is extended to the entire building);
- building renovation;
- demolition and reconstruction.

During 2017 Apulia region has updated the regional version with two different sub-versions (one for residential buildings and the other one for not residential buildings). Apart from the regional protocol Apulia region has put great emphasis on training and qualification of technicians implementing a considerable number of courses: final result has been the creation of a list of technicians named “Apulia ITACA protocol experts” who are in title of preparing the documentation for the evaluation. This effort has given remarkable results and, as average, about one hundred buildings is being assessed every year.

3.2 Calabria region

The Calabria region, starting from 2015, has embarked on a virtuous path that has resulted in a program aimed at creating an organic system of procedures aimed at sustainable development of the territory. The implementation of the provisions contained in Regional Law no. 41/2011 “Standards for sustainable living”, which aspires to promote and encourage environmental sustainability and energy saving both in territorial and urban transformations, and in the construction of public and private building works, had now become an obligatory step to start the sustainability path required by the European Community and by the 2030 Agenda.

In 2016 the D.G.R. n. 521, approved the regulations and the technical regulations for the implementation of the L.R. nf. 41/2011 which implemented the ITACA protocol for residential and school buildings of the Calabria region and defines the fundamental aspects of the certification process. In November 2017, the ITACA protocol for public buildings was also implemented. The regional ITACA protocol for residential buildings was developed as part of a university project taking into account the climatic–environmental characteristics and criticalities of the Calabrian territory and there are new indicators and criteria. The regional protocols derive from UNI/PdR 13: 2015 and have a variable number of criteria between 33 and 36.

The technical regulation requires obtaining an environmental sustainability certificate, with a minimum score of 1, for all interventions carried out with public contributions and which intend to make use of concessions and incentives. The Calabria region, since November 2016, requires as a requirement for participation in the notices for the granting of funding and contributions, the preparation of an assessment report of the level of environmental sustainability of the intervention that is proposed for selection. The value declared in the application phase must then be confirmed in the subsequent phases with the final obtaining of the environmental sustainability certificate. In the Regional Law n. 21 of 2010 and subsequent amendments, the so-called house plan, a volumetric premium is provided according to the level of sustainability achieved by the intervention.

The region has also defined the figures who, in various capacities, play fundamental roles in the certification process. The accreditation system of the Calabria region provides that the environmental sustainability assessment of the intervention can only be carried out by the evaluators, or by technicians enrolled in a special regional list: "List of ITACA Protocol Experts" which can be accessed by attending specific courses. Currently in Calabria several hundred technicians are registered on the list. Since February 2020, the region has adopted the UNI/PdR 13:2019 Training Regulations for Experts approved by the promoting committee and the national list established.

In May 2019, the Calabria region hosted, in the splendid landscape of Scilla, one of the international conferences of the SBE (sustainable built environment) cycle. The focus of the SBE19 Scilla conference was focused on policies, programs and action plans aimed at improving the sustainability of the built environment and representatives of the United Nations Agency for the Mediterranean Sustainable Development Program (UNEP Mediterranean Action Plan Coordinating Unit), of the Government of Catalonia, of the European Energy Cities network, of the European Sustainable Cities network, with the awarding of the best experiences, of the European Commission, Directorate General for the Environment.

3.3 Piedmont region

Piedmont region has been the first to use the protocol as tool for assessing buildings and has started since the early 2000s applying it to some urban regeneration programs called Neighborhood Contracts 2. Since these first experiences Piedmont region has signed an agreement (three times resigned so far) with ITACA to get direct support. The Piedmont region has developed and implemented regional version with respect to the various building types and territorial peculiarities. The protocol has been experimented in different areas of intervention such as public social housing, private housing, commercial building, school and public bodies buildings. At present the current regional version in force is the third one and it has been implemented in 2018. The Piedmont region, as partner, is involved in several European projects with the aim of promoting the level of sustainability of the built environment both on a neighborhood and territorial scale; in all these projects the regional version is used. During the years Piedmont region has used ITACA protocol in many regional invitations to tender, it is worthy to remind some of them:

- Urban redevelopment programs for sustainable rental housing;
- Housing Program: 10,000 housing units by 2012;
- Invitations to tender for school buildings;
- Calls POR FESR 2014/2020;
- Invitations to tender for commercial buildings.

As happened in other regions also Piedmont region has a regional version with the same areas of evaluation of the national version but with a lower number of criteria. Similarly to other regions also Piedmont region has put great effort on training and qualification of technicians implementing a remarkable number of courses leading to a regional list of experts.

3.4 Lazio region

In Lazio the first edition of the ITACA protocol is from 2008 with the first regional version for residential buildings. Two years later the non-residential buildings version completed the possibility of using the protocol; both of them have been updated in 2015. Although several regions have developed some kind of tool to facilitate calculations when operating with the protocol Lazio region in 2015 was the first to launch a software. Such a software, free and downloading from the Lazio region internet site, allowed technicians to design buildings taking into account the protocol and, at same time, it helped the public administration in the control procedures. After this first experience in Lazio region the idea of developing some software able to make many of the calculations required by the criteria of the protocol, as a consequence of their connection to a considerable number of technical standards, has become a goal for ITACA at a national level and something is going to happen in a near future. As in other regions the local version has a lower number of criteria and it has been used in some invitations to tender as an instrument to assess projects.

3.5 Umbria region

The current versions of the technical regulations for the evaluation of the environmental sustainability characteristics of buildings are the instruments used by Umbria region to revise the certification criteria, making them more applicable. The regulatory framework governing the assessment has been introduced by Regional Law 17/2008 and it has already been completed with the publication of the first version of the criteria for residential buildings (DGR. n. 581/09), followed by the second (DGR. n. 1322/09) and the third one (DGR. n. 130/13). Currently, the regulatory framework is represented by the fourth version for residential buildings (DGR n. 743/18), the second version for office buildings (DGR 503/19 replacing DGR n. 1079/13), the first version for school buildings (DGR n. 844/19) and the rules for mixed-use buildings (DGR 480/19 replacing DGR n. 953/13). In the meantime Regional Law 1/15 has repealed. R.L. 17/08 and 13/09, maintaining the approach given by the previous rules, including possible bonuses deriving from Sustainability Certification of buildings. The regional version of the protocol includes a lower number of criteria and also in this case has been used in some invitations to tender as an instrument to assess projects. Umbria region is one of the smallest Italian region but it has achieved remarkable numbers in terms of assessed buildings: as average every year around 150 projects are being evaluated.

3.6 Marche region

Since 2003, Marche region approved the simplified system of evaluation of eco-sustainable building projects, according to a performance method related to the international system “Green building challenge”, based on the identification of requirements to meet grouped by evaluation areas (28 requirement sheets).

In 2005, a summarized section of the protocol (15 sheet requirement protocol) was updated to comply with current legislation. Regional Law no. 14/2008 was issued to make the “Protocol” operational and develop a set of regulatory and technical tools.

The law defines the certification of sustainability of buildings based on the principles of the ITACA protocol, the instrument to promote and incentive actions for the sustainability of buildings, to be implemented through a series of economic aid and incentives.

The main section of the law concerns the system of certification of the sustainability of buildings and the technical modalities of awareness and control of the level of performance reached. Later, the region set out the procedures and controls, the accreditation of professionals qualified for certification, and the acquisition of the certificate and defined the general principles of the technical procedures for assessing the sustainability of buildings, in accordance with the principles of the GB Tool, based on the methodology adopted by the ITACA protocol. These tools define the structure of the technical specification, the technical tool at the basis of the building certification. Alongside these are the guidelines, a sort of explanatory manual and guidance also containing practical examples that illustrate in detail how to achieve the chosen levels of performance and a computerized system that makes it easier for users (designers and certifiers) to fill in the forms contained in the technical specifications. The region, in addition to the checking and updating of the system, together with the municipalities, carries out sample checks and controls on buildings and projects to be certified.

The law is based on a hypothesis of voluntary integration of the mandatory certification of energy performance resulting from Article 6 of Legislative Decree 192/2005, which applies to broader environmental performance, aiming to create a sort of “virtuous competition” between owners, builders, designers.

In 2011 the system and procedures for energy and environmental certification of buildings, the criteria and procedures for the training and accreditation of qualified bodies for the issue of certification and the criteria and procedures for the allocation of subsidies and the adoption of incentives were approved. A regional register of certifiers of the environmental energy sustainability of buildings has also been established. The register is updated every 6 months and currently has 621 members.

In 2016, the Guidelines for the environmental energy assessment of residential buildings were replaced with the reference practice UNI/PdR 13:2015, which already contained the aforementioned new calculation methodologies.

Marche region adopted the UNI PdR 13:2019 Reference Practice in 2021, in addition, the accreditation system was updated and the regulations for training courses for Experts/Inspectors were approved.

4 PILOT PROJECTS: EXPERIENCE OF THE MARCHE REGION

The incentives set out by LR n.14/2008, (reduction of secondary urbanization charges, construction costs and volumetric increases), are applied on new buildings according to the score obtained by the application of Protocol ITACA Marche. In 2009, the Marche region financed certified sustainable building projects by launching a call for tenders for €100,000.00 for companies, real estate companies, cooperatives, construction companies and private citizens for residential building projects of high environmental quality, to be certified according to the ITACA protocol – Marche. Interventions could concern both new constructions and recoveries, as well as already realized works if documented. Interventions should obtain an overall score lower than 1 of the ITACA protocol.

The general objective is to improve the energy and environmental quality of residential buildings starting from a substantial reduction in energy consumption, expanding the theme to water saving, quality of materials, indoor comfort. The specific objective is to encourage and monitor, also in order to make any corrective improvements, the sustainability certification system of buildings, especially in its initial application.

In 2021, a framework agreement between the Marche region, UNIVPM (Marche Polytechnic University) and ITACA to promote, develop and consolidate opportunities and initiatives for collaboration in the field of environmental sustainability of buildings was approved. It promotes research activities, joint participation in regional, national, European and international calls and research programs, with particular attention to the Framework Programmes of the European Commission, technical and scientific consulting activities, promotion of dissemination activities of scientific and technological culture on the territory. Moreover the council approved an implementing agreement for the application and dissemination of the UNI/PdR 13:2019 on the regional territory, which provides for the launch of training, communication and dissemination activities on issues of environmental sustainability of buildings, the development and updating of an IT tool to support professionals for the application of the ITACA protocol and the assignment of a performance score, the launch of experimentation activities of the ITACA protocol on an urban scale with real cases, the collaboration in the activities of training courses for experts and inspectors ITACA protocol, recognized by the promoter committee, the start of implementation and updating activities of the UNI/PdR 13:2019.

The national legislation on the Piano Casa (house plan) foresees interventions of enlargement, demolition and reconstruction on residential buildings or buildings of different destination, to be carried out as a derogation to urban planning instruments and building regulations in force.

Regional Law 22/2009 aims to the improvement of the quality of buildings in terms of seismic safety and energy efficiency. Marche region is currently participating as a partner in the Interreg Europe LC District project whose main aim is to create low carbon districts. An action plan is foreseen within the implementation of the project activities. One of the actions includes the design of low-carbon districts in the Marche region using a methodology that combines the design to environmental energy certification through the application of the ITACA protocol both at building and urban scale. This approach will ensure projects with high environmental energy performance resulting in a low impact at the level of CO_2 production. This process has involved both the interregional partnership and local stakeholders with particular reference to the municipalities involved. Through the collaboration with the Polytechnic University of Marche foreseen by the framework agreement, curricular and extracurricular internships will be activated at the Marche region premises for experimental applications of the two protocols at urban and building scale in different contexts of the regional territory.

5 CONCLUSIONS

In recent years, the dissemination and promotion of the principles of environmental sustainability carried out by ITACA has led to the achievement of significant results:

- disseminating the principles of sustainable construction among stakeholders;

- developing the UNI PDR 13/2019, the ITACA protocol at urban scale and the operational tool;
- legal acts from various regions implementing assessment procedures;
- thousands of buildings certified or in the process of certification;
- training of technicians and personnel who take part in the certification process.

On the basis of what has been described in the previous paragraphs, it is easy to glimpse future developments and possibilities:

- nationally and internationally dissemination of principles and tools for the design and assessment of the environmental sustainability of buildings;
- further developments and updates of UNI PDR 13/09, urban-scale protocol and operational tools;
- participation in national and international projects and initiatives on environmental sustainability
- partnership with entities interested in building sustainability;
- capillary training involving universities and other stakeholders.

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TEACHING AND RESEARCHING SUSTAINABLE URBAN DEVELOPMENT PROCESSES THROUGH SIMULATION

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ABSTRACT
Apart from innovative design and technology, sustainable urban development is about processes through which the actual people involved interact and cooperate to realise that development. Many, often conflicting, interests are at stake and it requires talents and skills to bring the right people together to find common ground and understanding and, hence, to start working towards a common goal. In higher education, students should learn and, preferably, experience how such processes can be initiated and led. The purpose of our research was, therefore, threefold: first, we wanted students to learn how to study this type of collaborative governance processes, using the model by Ansell and Gash as an analytical framework. Second, using the model, two distinct groups of students analysed three cases of transit oriented development. The results of the analysis, in terms of actors involved, their interests, and interventions to start and maintain an alliance, were translated into two serious games. Third, different groups of students played the games in slightly different settings, after which the learning effect was assessed. Results show that playing both games enhances students' knowledge of, and insights in the interests that are at stake and the trade-offs to be made. In addition, players report that they felt involved in the process as well as in the alliance itself. Conclusions are that both creating a simulation game, based on a guided analysis of real-life cases, and playing such a game are powerful methods to learn about processes that are not readily learnt from a textbook. Furthermore, the simulations can be used to research the effect of certain interventions that can – or must – be undertaken by the process facilitator for the alliance to be successful.
Keywords: urban development process, collaborative governance, alliance formation, role playing game, higher education.

1 INTRODUCTION

Sustainable urban development is not just a matter of innovative design and technology. Ultimately, it is the actual people involved that interact and cooperate to realise that development. In any urban development, a large number of stakeholders is usually involved, such as real estate owners, small and medium enterprises (SME's), housing corporations, different departments of local and regional governments, residents, transport services, et cetera. All of these actors have their own objectives and, often conflicting, interests. Yet, these people need to be brought together in some way to get started. It requires talents and skills to do so: find and invite the right people, make them find common ground and understanding and get them to start working towards a common goal. Students in urban development must learn and, preferably, experience how such processes can be initiated and led. A role playing game could bring this about.

Even a cursory glance at the literature reveals that a plethora of role playing games or serious games exist in the realm of (sustainable) urban planning and development. Most of these have been designed to highlight a specific issue, such as energy (e.g. [1]), climate adaptation (e.g. [2], [3]), tourism (e.g. [4]), or mobility (e.g. [5]). Some have a more general character, such as AudaCity [6] and Metropolis [7]. This type of games is known to foster cognitive, normative and relational learning [8].

One of the key characteristics of games is that they have rules about the actors participating, their objectives, their possible actions, and the way in which one gets to actually

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win the game. In reality, though, it is not at all obvious beforehand that all the right stakeholders meet, nor are there explicit rules for their conduct and actions. Students' learning experiences must include choosing which actors to invite – and how to entice them, if necessary – as well as the interventions through which actors are stimulated to form an alliance. In an alliance, participants collaborate to reach a common objective, formulated as a response to a jointly defined set of urgent issues in the area. Developing and playing a role playing game could precisely provide that type of learning experience.

Our aim was threefold. First, we aimed at familiarising students with a model to analyse the process of alliance formation. Second, we had two distinct groups of students study three cases of transit oriented development using this model as an analytical framework, in order to find the most common types of actors involved, their interests, as well as the interventions that were undertaken to start and maintain an alliance. Results were presented in the form of two serious games, designed by the students themselves. Third, different groups of students played both games in slightly different settings, and took a test in order to assess the learning effect.

2 ANALYTICAL FRAMEWORK

Urban development is an extremely complex process: multiple stakeholders negotiate in multiple arenas within multiple policy networks, constituting a seemingly chaotic sequence of interrelated decisions. Each of these may be small and seemingly of little significance, but together they cause a spatial plan to be materialised [9]. The outcome of this process is affected by the way in which authority is shared among different, state and non-state, actors and institutions. Such a multi-level governance system is adequately described by the model of Ansell and Gash [10]. The core of the model is a collaborative process, modelled as a cyclical sequence of face-to-face dialogue, trust building among the actors involved, their commitment to the process, shared understanding among them, and intermediate outcomes they arrive at. This sequence is greatly influenced by three types of boundary conditions. First, the starting conditions, such as asymmetries in power, resources or knowledge and the history of cooperation or conflict among actors; these determine the possible incentives for and constraints on their participation in an alliance. Second, the institutional design, consisting of who can participate, whether there are other arenas where actors can pursue their goals, the rules that apply to the process and its transparency. The third boundary condition is the quality of the alliance's facilitative leadership.

The core purpose of the cycle in this model is for the actors involved to find common ground. Important facilitating factors of common ground were found to be trust, actors' orientation towards reaching consensus, and boundary spanning activity [11]. The latter activity is displayed by so-called 'boundary-spanners', persons who facilitate the communication between the alliance and the organisation to which they themselves belong [12].

In order to also analyse the actual interventions staged by the facilitating leadership, insights from co-creation research were used. Successful co-creation processes, in this case within an alliance, depend on the willingness of the participants, the social capital within the alliance group and a smoothly running organisation. Willingness is found to be based on whether participants were approached because of their competences and skills [13]. In addition to the boundary conditions formulated by Ansell and Gash [10], Rădulescu et al. [14] found a sense of urgency to be conditional for successful co-creation in development projects. Furthermore, their work reveals that the number and diversity of actors either enables or hinders the process. From network management theory, we know that facilitators adapt their strategies to these variables: in larger networks, managers tend to invest in finding common ground ('exploring') and new organisational arrangements ('arranging'); in networks with more hierarchy, they relied more on a connecting strategy, through e.g. mediation, incentives or activating resources [15].

3 METHODS

Three distinct methods were used: case studies to find the factors that determine success or failure of alliances, the actual construction of the role playing game and the assessment of the learning effect of playing the games.

3.1 Case studies

The first part of this research was a case study [16]. We selected three cases of transit oriented development in Dutch cities, all facilitated by the same advisor; in this way, we would expect to find comparable sets of stakeholders and the same menu of possible interventions to guide the actors towards an alliance.

Students were familiarised with the model of collaborative governance by Ansell and Gash [10]. They were issued documents describing the alliance formation process, readily available on the internet. In addition, they interviewed some of the key actors within each of the cases, including the main facilitator, asking specific questions about the success factors of each case and about the interventions made during the process.

3.2 Game construction

Students were given only limited instruction as to how they had to use the data they had collected and transform these into a role playing game. The group of master students were shown the model of collaborative governance and its applicability to the type of cases at hand. The group of bachelor students were instructed to first conceive an analytical framework, based on the model of collaborative governance and then write a report on each case, containing:

- the spatial situation at the onset of the project studied;
- the actors involved and their main interests and objectives;
- the intervention(s) through which actors were brought together and through which they were to arrive at the issue(s) they commonly felt need their attention;
- the way(s) in which actors were enticed to tackle the issue(s) identified and what the result was of these actions;
- whether the alliance led to continued cooperation between partners and in what way.

Both groups were instructed that their end product should meet the following conditions: it should be a (real or fictitious, but realistic) case, containing at least a description and an image of the area to be developed, the actors involved, their interests, the opportunities each actor sees for developing the area, and possible interventions to stimulate actors to collaborate on concrete issues.

3.3 Assessment of learning effect

After both role playing games were produced, they were tested within the group that conceived the game. In both groups, this led to some elaborations and changes. The finished games were played by a completely new group of 26 students, all third year bachelor students Built Environment. These students were only given the instructions included in the games.

Groups of 4 or 5 students played both games online, as a consequence of corona restrictions, during two consecutive morning sessions that lasted 1½ h each. At the end of each session, we had a classical, online, debriefing of about 15 minutes, during which students could share their (learning) experiences and the lecturer discussed the alliance formation process. Before and after playing the two games, students took a quiz of 2 multiple-choice and 6 open short-answer questions, in order to assess their knowledge about alliance formation in urban development before and after playing the game. The pre- and post-game tests had the same questions, except for the last one, that in the pre-test tested students' knowledge about the objectives of the process facilitator and in the post-test prompted students to illustrate three of the variables in the model of collaborative governance, that was discussed in class as part of the debriefing after the game. All students participated in the pre-test; 50% also participated in the post-test.

4 RESULTS

This section first presents the results of the case studies, in particular the elements that were found to be vital for alliance formation. An impression is also given of the role playing games developed by the students, followed by the most relevant results from the learning effect assessment.

4.1 Case analyses and role playing game elements

From the documents they analysed and the interviews they conducted, both groups of students presented the circumstances and actions that determined the alliance formation process. These could easily be brought in a format that lists the main variables contained in the model of collaborative governance [10]. The result is presented in Fig. 1. Discussing these intermediary results with the students, we jointly identified several vital elements for the role playing game they were going to develop.

Firstly, the right actors should be invited to participate/In all three cases, an analysis was performed of each actor’s urgency, ambitions and abilities – or competence – to contribute to the development, further termed ‘UAC-analysis’.

Secondly, an alliance may contain local actors as well as actors that are active regionally or nationally. Obviously, in TOD, national and regional public transport companies are important stakeholders. In the Haarlem case, development of the station was important to the Amsterdam metropolitan region (MRA), because it could absorb some of the pressure on the capital itself.

Thirdly, the Haarlem case made clear that a conflict of interest is not necessarily detrimental for an alliance to form, provided guarantees can be given to protect these interests in some way. In this case, the objections by industrial companies in the area against the proposed development as a residential area were circumvented by granting that industrial activity could be continued after the development had taken place for at least 10 years.

Fourthly, in all cases a common goal was readily identified, namely the improvement of public space quality. Each participant in the alliance was in the position to contribute to this goal through relatively small actions like refurbishing the plinth of their building or contributing to an investment in nicer street furniture. These placemaking activities then formed the basis for larger investments, often made possible through external subsidies.

Fifthly, the process facilitator’s primary concern in all cases was to entice alliance members to focus on a common problem linked in some way to each individual member’s goals and interests. The common problem then puts in motion the cyclical process of dialogue, trust building, commitment, shared understanding and intermediate outcomes.

Variable	Case 1: Bunnik	Case 2: Haarlem	Case 3: Rotterdam
Starting conditions			
Power-resource-knowledge asymmetries	No apparent asymmetries.	Industry stakeholders were able to hamper or block land use change.	No apparent asymmetries.
Incentives for and constraints on participation	Shared discontent about station area quality, but no urgency for large scale development	Stakeholders recognised necessity to improve spatial quality. TOD is important to MRA.	Stakeholders recognised necessity to improve spatial quality and safety.
Prehistory of cooperation or conflict (initial trust level)	None	Industry was cautious about residential area in their vicinity.	Several actors had cooperated in upgrading the station building.
Institutional design			
Participatory inclusiveness	Actors with interest through money, property or competency were invited.	Actors with interest through money, property or competency were invited.	Actors with interest through money, property or competency were invited.
Forum exclusiveness	Neighbouring stations considered for large scale development.	The alliance was 'the only game in town'.	The alliance was 'the only game in town'.
Clear ground rules	Not explicitly researched.	Continuation of industrial activity was guaranteed.	Property owners and tenants were given guarantees in advance.
Process transparency	All participants were well informed after each session.	All participants were well informed after each session.	No predesigned plan; actors' ideas were transparently assessed.
Facilitative leadership			
Facilitative leadership	Independent facilitator, ensuring consensus-building.	Independent facilitator, ensuring consensus-building.	Independent facilitator, ensuring consensus-building.
Collaborative process	Cyclical: Two joint sessions with several work sessions in between.	Cyclical: Two joint sessions with two workshops in between.	Cyclical: Two joint sessions with four work sessions in between.
Face-to-face dialogue	Open, pleasant discussion.	Open, factual and pleasant discussion.	Open, factual and constructive discussion.
Trust building			
Trust building	Actors engaged in small, no-regret solutions.	Actors engaged in designing transformation plan (yet to be financed).	Existing quality improvement plans were tuned. Municipality invested first, other real estate owners followed.
Commitment to process			
Mutual recognition of interdependence	Not explicitly researched.	Extensive exploration of actors' ideas and means; partly conflicting interests.	Extensive exploration of actors' ideas and means; partly conflicting interests. Actors' roles and responsibilities were explicitly recognised.
Shared ownership of process	Establishment of comakers' group.	Establishment of alliance group.	Establishment of alliance group.
Openness to explore mutual gains	Formulation of shared ambition, laid down in short, middle and long term scenarios.	Formulation of shared ambition, laid down in short, middle and long term scenarios and concrete measures.	Formulation of shared ambition, laid down in short and middle term concrete measures.
Shared understanding			
Clear mission	Shared ambition formulated in 3 scenarios.	Shared ambition formulated in 14 concrete measures.	Shared ambition formulated in 10 concrete agreements.
Common problem definition	Common view from the start about urgent issues on short term.	Common view of urgent issues and necessity of political commitment.	Over time, a common view emerged of urgent issues on short term.
Identification of common values	Shared ambition laid down in pact document.	Ambitions laid down in pact document calling for political commitment.	Shared ambition laid down in pact document.
Intermediate outcomes			
Small wins	Small quality improvements in station area.	Placemaking initiatives.	Local investment fund for marketing / branding of the area.
Strategic plans	Development scenarios.	Development scenarios and concrete measures.	Short and middle term actions only.
Joint fact finding	During first meeting.	During first meeting.	Not explicit.

Figure 1: Analysis of three cases of transit oriented development (TOD), following the variables contained in the model of collaborative governance. Colours indicate the degree to which a variable is deemed conducive to alliance formation (green), hampering it (red) or neither (orange). MRA = Amsterdam metropolitan region.

Sixthly, from the interviews it became clear that it is important for all alliance members to firmly stick to their individual role. Therefore, the process facilitator would sometimes ask the question: “what if we abandon the project now altogether; then, what would be the damage to every partner to the alliance?”

4.2 Games constructed

One group developed a role playing game that started with the UAC-analysis by the player that had the role of process facilitator. Urgency, ambitions and competence were included in the role descriptions issued to each of the other players. In the second round of the game, players, as members of the alliance formed in the first round, were to negotiate about the realisation of a bike park facility that would make an end to the chaotic situation caused by randomly parked bikes on the station square. Negotiations must be started about the capacity and type of bike park – underground or at street level – and the way in which it will be financed. The game contained descriptions of both the role of the process facilitator – including tips to start and maintain the dialogue – and the game supervisor, i.e. the lecturer using the game during class.

The other group constructed a combination of a board game and a role playing game, emphasising the actual development of the area by the alliance rather than the formation of the alliance itself. The outcome of the UAC-analysis for each alliance member was given beforehand as part of the role description and at the onset of the game, all players are put in the position of the process facilitator, selecting which actors would be at the table, solely on the basis of each actor’s playing card, showing a diagram that depicted the levels of urgency, ambition and competence of that actor. Then, each player can choose one of the selected actors, turn over the actor’s card and read its role description. No explicit role was written for the process facilitator, other than de description of the course of the game. During the first round of the game, players can make smaller investments, like adding street furniture or trees, paid for from their initial budgets. In the second round, major investments were possible, involving changes of the assets on the board, but also negotiations among players, since neither of the individual budgets is large enough to allow one individual alliance partner to realise such an investment. Fig. 2 gives an impression of the game, played during an MS Teams session.

4.3 Learning effect

When asked to mention four possible types of actors in transit oriented development, students came up with several plausible answers – which is obvious since these were third year bachelor students with basic knowledge of urban development. Yet, the answers to the post-test were less diverse and the number of times specific actors – developers, SME’s and the metropolitan authority – were mentioned increased significantly.

Students were also asked to mention three interests of the station owner in cases of TOD. In the post-test, the quality of the station area was mentioned in 69% of the answers, versus 38% in the pre-test. Also the number of travellers was mentioned more often after playing the games (54%) than before (12%). More general interests, like sustainability and safety, were mentioned in the pre-test, but no longer in the post-test. Other interests, like comfort and accessibility of the station area, were equally mentioned in both tests.

Before playing the games, students mainly indicated residents and travellers as the actors interested in the quality of public space (54% and 58%, respectively); only 35% mentioned

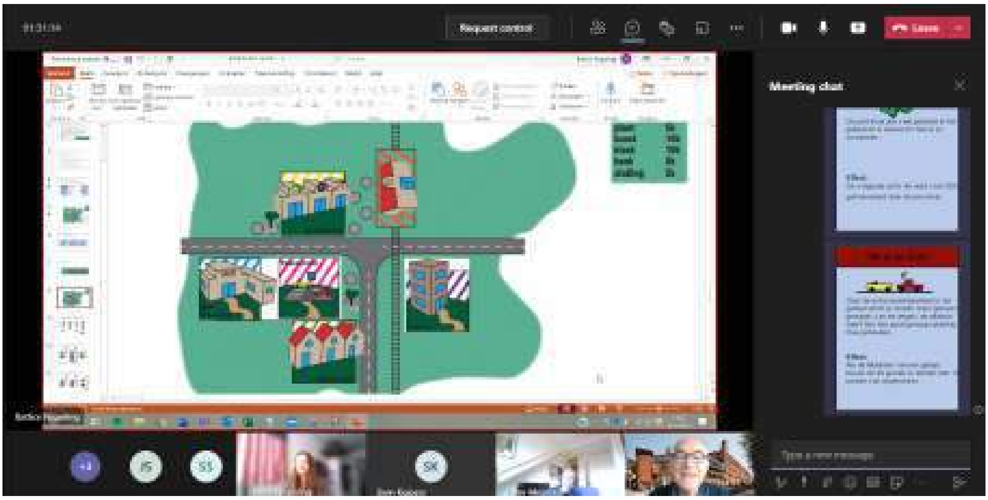

Figure 2: Screen shot of the board game in PowerPoint version for online play.

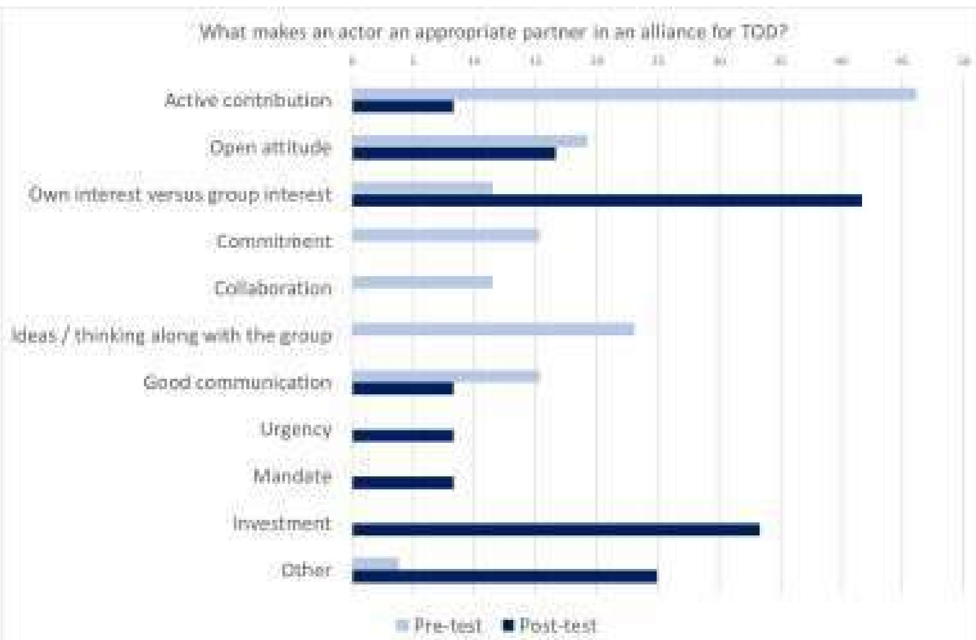

Figure 3: Learning effect with respect to what makes a good alliance partner.

the municipality. After they had played the games, 85% indicated the municipality as well as residents (69%) and travellers (31%). SME's were mentioned more often (54% versus 8% in the pre-test) and 23% indicated the developer as having an interest in public space quality (versus 0% in the pre-test).

In a multiple-choice question about selecting alliance partners by the process facilitator, before playing the games 65% selected an actor analysis as the most appropriate instrument and 11% the UAC-analysis. After playing the games, these numbers were almost reversed, 15% and 69%, respectively. Also, the correct answer to the multiple-choice question about what is meant by 'placemaking' was selected more often in the post-test (77%) than in the pre-test (50%).

Students gave widely varying answers to the question "what makes an actor an appropriate partner in an alliance for transit oriented development?" Answers were clustered and the relative number of times an answer was given was put in a graph, shown in Fig. 3.

After playing the games, students were able to pinpoint the properties of an appropriate alliance partner in terms of balancing their own interests with those of the alliance as a whole, ability to invest, urgency and mandate, rather than more general terms more often used in the answers to the pre-test, like active contribution, commitment, collaboration and the contribution of ideas.

When asked for possible causes for an alliance to fail, students came up with a broad range of – rather obvious – causes, both before and after playing the games. One of those, namely "conflicting interests", stood out, because in the post-test it was mentioned by 58% of the respondents in the post-test and only 19% in the pre-test.

The final question in the pre-test was about the objectives of the process facilitator and the way in which such a person would try to achieve it. Almost all 26 answers contained elements about facilitating cooperation among actors and/or eliciting ideas and ambitions from the alliance members.

In the post-test, the final question was to list at least three occurrences during the games that illustrate one or more of the variables in the model of collaborative governance that was discussed in class after playing the games. Of ten answers given, seven were adequate or more, one was incomplete and two did not answer the question.

During the in class debriefing, students remarked that they had enjoyed playing the games. Some preferred the board game, because they felt it had a defined objective and could be 'won'. Others stated that they had learned most from the negotiations about financing the underground bike park. As to the two groups of students who developed the games, the evidence for learning is self-reported in the reflection documents that were made as part of the assignment. All three master students stated in one way or another that the conceptual model of collaborative governance and its variables helped them formulate a useful analytical framework, which provided insight into the factors that crucially influence a successful alliance. The group of bachelor students, in their written group evaluation, also indicated that they had learned from the group work, but did not specify what exactly the learning effect was.

5 DISCUSSION AND CONCLUSION

Using the model of collaborative governance by Ansell and Gash [10], students were quite able to indicate in each of the cases the vital steps in the process that the alliance went through. Cases were sufficiently documented for students to unearth which actors participated, what their concerns, interests and ambitions were and what the outcome of each alliance process was. Interviews with key actors, particularly with the process facilitator of the three alliances, brought to light relevant do's and don'ts when inviting actors to the alliance, start the alliance formation and keeping actors working towards a common goal. In particular the master level students, who also had some years of experience in the field of urban development, appeared interested in and sensitive to factors that determine an actor's competence, e.g. the mandate a person has to act in the alliance meetings on behalf of their organisation or the amount of money they could invest.

The games that resulted from these case analyses were found to be useful – after some major alterations that proved necessary upon internal testing – as a tool in our bachelor course on urban development to teach students the important features of alliance formation and, more generally, collaborative governance. As both games were developed starting from different perspectives – one focusing on the initial UAC-analysis, the other a bit more on the actual intermediary outcomes of the alliance process – we had our bachelor students play both games consecutively. These students reported diverse learning effects and, more importantly, the tests that students took before and after playing the games show that their understanding of actors and their interests as well as their insight into the purpose and course of the alliance process had increased.

The assessment of the learning effect with the students that played the games is more objective than the self-reported estimation of learning discussed during the debriefing in class. Results shows that answers to open questions contain more elements that were probably derived from the games. On the other hand, these were third-year students who had already some knowledge of urban development. In addition, taking the pre-test – and maybe even discussing it with fellow students – might also induce some learning.

Although not investigated objectively, there is also a certain self-reported learning effect in the students that performed the case studies and developed the games. This is supported by the fact that the games indeed showed many of the features present in the literature about network management and collaborative governance.

There is ample evidence that playing serious games, including board games and role playing games of the type used in this research, is conducive to learning about social interaction among actors in urban development [8]. Most of these games, though, are often used in a professional situation with specialists from different disciplines or with members of the general public. When used in an educational setting for teaching students, the games have often been designed by the university staff or a professional game developer. To our knowledge, no educational settings have been reported in which the game was developed – rather than just played – by students and the learning effect was assessed. Yet, the observations made in the research presented here are in line with earlier findings during a similar student project [17]. We therefore conclude that creating a simulation game, based on a guided analysis of real-life cases, and playing such a game are both powerful methods to learn about processes that are not readily learnt from a textbook.

In real life, a process of alliance formation in urban development is a one-off. There is never an opportunity to start over the whole process under the same conditions and try a different intervention to initiate or maintain the dialogue. However, in a role playing game, it is possible to experiment through making small changes and find the interventions that best support the building of trust, the finding of common ground, the formulation of common objectives and the collaborative action to reach (intermediary) results.

Several recommendations can be given at this stage. One is to repeat the case study and game development process and objectively determine the learning effect of these activities by letting students take a test before and after. Secondly, the two games should be integrated in order to merge the learning experiences about starting and maintaining the cyclic process off collaborative governance and actually solving any of the commonly defined problems by (negotiating about) necessary investments in the area. Thirdly, the actual learning effect of playing the revised game should be determined in much the same way as was done before, but with larger groups of students. Lastly, we recommend playing the game repeatedly in the same setting – as much as possible – and experiment with different interventions to find out whether in this way interventions can be found that work best and are truly evidence-based.

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DELIVERING NATIONAL ECONOMIC INFRASTRUCTURE IN SOUTH AFRICA: A REVIEW OF STRATEGIC INTEGRATED PROJECT #3

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ABSTRACT

The South African (SA) government has for many years pursued much needed social and economic transformation. This journey is far from a path void of obstacles and complicated challenges. However, the significance of providing economic and social infrastructure is one of the strategies prioritised by government to enable entrepreneurship, employment opportunities, access to essential services by the poor, and empower people through education and skills development. In this regard, to address critical socio-economic challenges in SA, in 2012, the Government adopted a National Infrastructure Plan (NIP) supportive of the SA National Development Plan (NDP) imperatives. The vision of the NIP is to transform the economic landscape through the implementation of strategically integrated infrastructure projects. The NIP strategy foresaw economic sustainability for the future and an improved standard of living for many impoverished communities in SA. In this light, and in support of the NIP vision, the Presidential Infrastructure Coordinating Commission (PICC) was established to integrate and coordinate the original eighteen Strategic Integrated Projects (SIPs). SIP projects were selected based on their catalytic nature and grouped into several infrastructure programs (SIP-1 to SIP-18). In January of 2013, the Minister of Water and Environmental Affairs formally directed the Trans-Caledon Tunnel Authority (TCTA) to take-up the program coordination role for SIP-3. This study is to better understand the SIP-3 Coordination function and performance through a review of the SIP-3 program. The paper highlights a path through SIP-3 Coordination experiences from its inception in 2012 to present (2021). The review is in line with, but not limited to, the SIP-3 program business plan, the coordination function of SIPs, the intended and realised impact of the program. Lessons are drawn from the review outcomes and recommendations are made for improving national infrastructure development and coordination that is supportive of economic and social advancement in South Africa.

Keywords: South Africa, infrastructure, planning, strategies, social, economic, sustainable.

1 INTRODUCTION

As detailed in the National Development Plan (NDP), South Africa needs a strong network of economic infrastructure designed to support the country's medium and long-term economic and social objectives [1]. In response to critical economic challenges in South Africa, in February 2012 during the State of the Nation Address, the President announced the adoption of the National Infrastructure Plan (NIP) [2], that comprises of strategic projects which support the National Development Plan (NDP) imperatives. It is noteworthy to mention that the United Nations 2030 Agenda [3] for sustainable development reflects on South Africa's vision through its NDP 2030. The goal of the NIP is to transform the economic landscape and to create significant employment opportunities through structured planning and implementation of strategic projects across the country. By leveraging job creation, skills development and localisation through a long-term infrastructure pipeline is one of the ways intended for South Africans to collectively build an equitable society.

The NIP recognised that weak capacity, poor coordination, and weak integration limit the development impact of infrastructure. Accordingly, in response to these challenges, Cabinet resolved to establish the Presidential Infrastructure Coordinating Commission

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(PICC) to: coordinate, integrate and accelerate infrastructure implementation; monitor the NIP from a central standpoint; identify and assign responsibility and accountability of infrastructure implementation; develop a 20-year planning framework beyond one government administration to avoid an uninterrupted infrastructure roll-out.

As such, Government, through the PICC, established SIPs, and in April 2012, SIPs Programs (SIP-1 to SIP-18) had been launched across the country [4]. These projects were identified, developed, and approved with the intention of promoting and catalysing economic development, as well as addressing service delivery in SA's impoverished provinces.

The objective of this paper is to highlight South African national infrastructure development through its SIPs programs, with a focus on SIP-3. The paper seeks to inform and define the path traversed by SIP-3 in its coordination role and function within its governance framework and seeks to accentuate the SIP-3 program and coordination developments and challenges. The purpose of the paper is to: describe the SIP-3 program background and experiences; review the SIP-3 program, function, and impact reflective of its objectives; draw review lessons; make recommendations in improving the SIP-3 program function, and effectiveness. The resultant outcome of this paper is intended to guide an informed approach in the evolution of strategic integrated infrastructure development within South Africa.

2 METHODOLOGY

The research was conducted through the collection of data from the combination of a desktop qualitative review of literature on SIPs, a workshop, a seminar, and interviews which shadowed a thematic analysis approach. The literature review focused on the analysis of key sourced information which included industry and government publications on infrastructure development, as well as peer reviewed journal articles, technical reports, other publications on SIPs, and the SIP-3 Business Plan. The paper development benefited from a one-day workshop and a knowledge sharing seminar relating to the review of SIP-3 which focused on the accomplishments and challenges faced by the program. Each session was well attended by SIPs stakeholders comprising of built environment specialists, infrastructure finance specialists, engineers, and project managers. Participants in the workshop and seminar deliberated broadly on the SIPs programs, the associated challenges principally affecting SIP-3 and SIPs in general, as well as opportunities which exist in improving the effectiveness of the SIPs business.

The author's job responsibilities and knowledge of the NIP and SIPs progression also contributed to the research construct. Contextual information was extracted from several policies, including the following: The New Growth Path (NGP); the NDP; the NIP and the Infrastructure Development Act (IDA). Ultimately, the data collection included interviews with the SIP-3 program staff and stakeholders. Most insights into the SIP-3 Coordination function were gained from provincial social and economic development partners, previous SIPs coordinators, Project Owners, PICC SIPs leads and managers. The information was supplemented with SIP coordination memos, letters, meeting records and progress reports.

3 UNPACKING THE SIP-3 PROGRAM (SOUTH-EASTERN NODE AND CORRIDOR DEVELOPMENT)

At the onset of SIPs, the SIP-3 program comprised of 12 projects. These projects, for ease of coordination, were clustered into nine (see Table 1) theme-linked projects.

Table 1: Original SIP-3 projects. *(Source: SIP-3 Business Plan 2012.)*

Project	Project name	Project owner
P1	Manganese Sinter Plant	Kalagadi Manganese and Industrial Development Corporation (IDC)
P2	Manganese Rail Upgrade	Transnet
P3	Manganese Smelter	IDC, Kalagadi Manganese
P4	Transhipment Hub	Transnet
P5	Mthombo Refinery	PetroSA
P6	N2 Wild Coast Highway	SANRAL
P7	Clustered projects – Mthatha Airport, N2-Mthata Bridge and the Nelson Mandela Legacy Bridge	Eastern Cape Provincial Government
P8	Power Transmission and Distribution	Eskom
P9	Mzimvubu Water Project	DWS

SIP-3 was among the first SIPs launched, with the TCTA being appointed in April 2012 to coordinate its implementation. In January 2013, the Minister of Water and Environmental Affairs formally directed the TCTA to take-up the program coordination role for the SIP-3 program. The program, referred to as the South-Eastern Node and Corridor Development, mainly focuses on the catalytic development of the Eastern Cape province of South Africa, and to a smaller degree the Northern Cape and Kwa-Zulu Natal provinces.

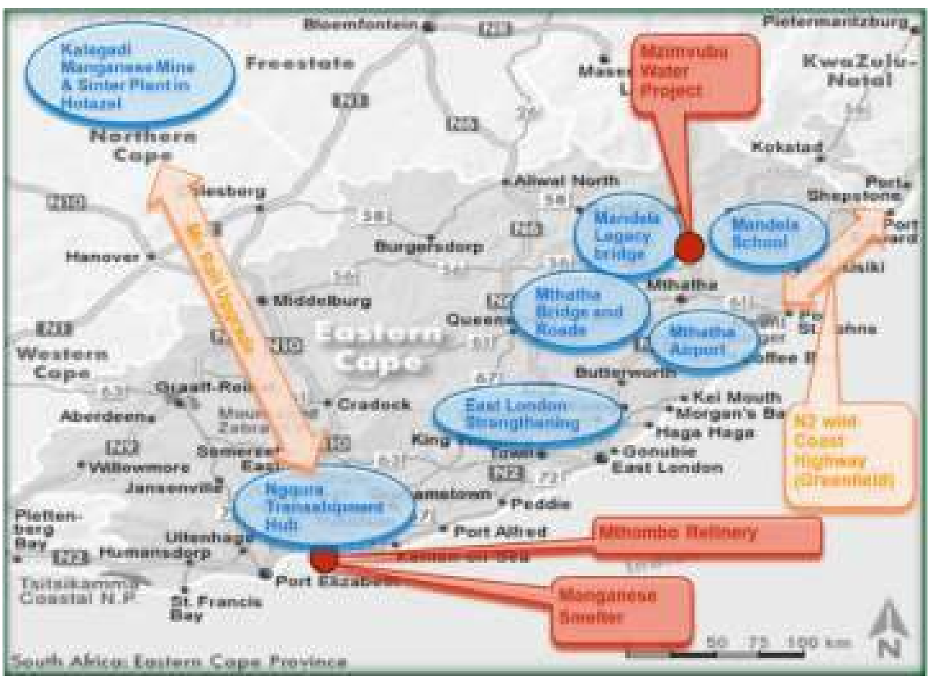

Figure 1: Map of the Eastern Cape province, depicting the location of key SIP-3 project sites. *(Source: SIP-3 Progress Report.)*

Fig. 1 illustrates the location of SIP-3 projects within the Eastern Cape, Northern Cape, and the Kwa-Zulu Natal provinces. Tabs highlighted in blue are projects that have been completed. Tabs highlighted in orange represent projects that are in the construction phase but have experienced delays. Tabs highlight in red represent projects that are on hold or have not started due to challenges experienced, resulting in implementation delays.

Investments in infrastructure such as energy, water, transportation, and communication technologies promote economic growth and help to alleviate poverty and improve living conditions in developing countries [5]. Within this frame of understanding, the primary aim of SIP-3 is to unlock economic development in the Eastern Cape by supporting industrialisation, agriculture development, tourism, mining, and the automotive sector. More specifically, SIP-3 aims to achieve the following:

- Strengthen the economic development of the Port Elizabeth area through an upgraded manganese railway line from the Northern Cape, beneficiation of manganese by means of a new sinter plant at Hotazel and a new smelter plant, as well as a new manganese terminal, located at Coega;
- Unlock the industrial and export potential of the Eastern Cape region through the development of a multiple purpose transhipment hub at Ngqura, and the establishment of the proposed Mthombo oil refinery, also located in Coega;
- Promote rural development in the Eastern Cape through a new dam, irrigation and hydro-electric scheme on the Mzimvubu River, and enhance integration of the region with national supply chains through the N2-Wild Coast Highway and a number of smaller, transport-related projects;
- Enhance electrical transmission within the eastern part of the province, through the Greater East London Strengthening project.

The institutional arrangement for coordinating the SIP-3 program is reflected in Fig. 2. With respect to coordination and monitoring activities, the TCTA, as the SIP-3 Coordinator reports to the PICC, while actively inter-facing with the Inter-Governmental Forum (IGF) or as defined in the IDA, Act 23 of 2014, Forum of Executive Authorities (FEA) for regular guidance. All SIP-3 stakeholders and specialists formally convene on a quarterly basis constituting a Program Technical Committee (PTC), where technical inputs are disseminated and deliberated upon with the aim of achieving program objectives.

In many parts of the world, the negative repercussions following the lack of planning and coordination of infrastructure development is well noted [6]. Acknowledging this, the SIPs coordination institutional arrangement promoted an enhanced infrastructure coordination process, in contrast to earlier approaches which often resulted in unstructured and disintegrated approaches to project monitoring, oversight, evaluation, and implementation.

The TCTA SIP coordination function embodied the concepts of information gathering and sharing information on national infrastructure build programs at various platforms and meetings i.e., SIP Program Technical Committee (PTC) meetings, SIP Coordinators Forums (SCF), SIPs workshops, one-on-one sessions with the PICC, and other project and program partners. These engagements provided security of uniform, non-conflicting exchange of information, and assisted in reducing reporting duplication and inaccuracies during project and program progress reporting amongst stakeholders.

As a SIP-3 Coordinator, in performing its coordination and monitoring functions, the TCTA is guided by the Ministerial Directive, provisions of its Notice of Establishment of 2000, and the Public Finance Management Act (PFMA). Overall, TCTA was mandated to

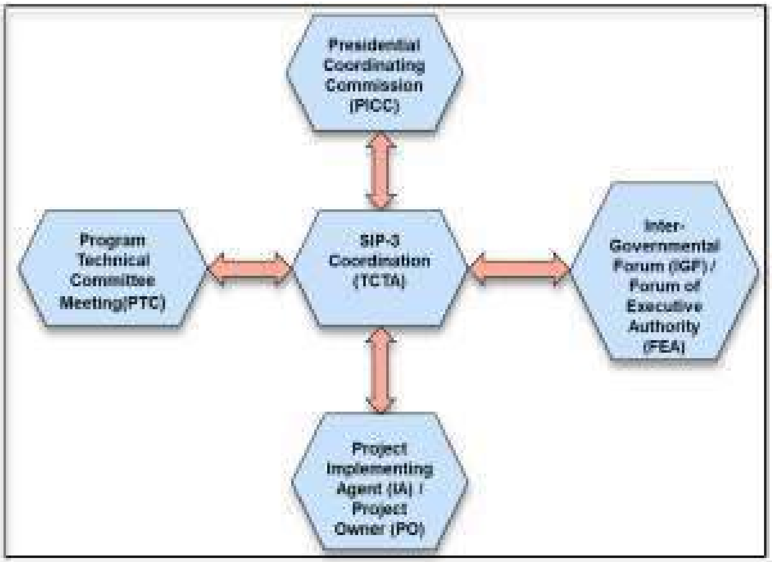

Figure 2: SIP-3 coordination institutional arrangements. *(Source: SIP-3 Business Plan.)*

establish and resource a Project Management Office (PMO). This PMO for most parts was authorised to: Coordinate deliverables and development plans; report on the construction jobs figures and localisation performance; assist the infrastructure implementation process in achieving the broader goals – including skills development, industrialisation, and localisation.

4 SUSTAINING SOCIO-ECONOMIC GROWTH THROUGH INFRASTRUCTURE

The "New Growth Path" framework identified structural problems in the economy and pointed to opportunities in specific sectors and markets or "jobs drivers" to reach its goal of five million new jobs by 2020. The first jobs driver is infrastructure – laying the basis for higher growth, inclusivity, and job creation [7].

Infrastructure investment could be an extraordinarily useful tool for macroeconomic stabilisation [8]. With this in mind, providing infrastructure for communities and the economy is one of the leading ways South Africa can realise inclusive and jobs-rich growth. Quality, affordable infrastructure raises economic productivity, permits economic expansion, and allows marginalised households and communities to take advantage of new opportunities.

By convention, infrastructure is broadly divided into two categories: economic and social. Economic infrastructure conventionally covers traditional services like water, sanitation, roads, and electricity. Educational facilities, for example, are widely denned as social infrastructure, but play an important role in generating human capital, which is certainly also an economic function and carries important growth implications [9].

Addressing the Skills Gap – the gap between the skills of the current workforce and the skills businesses need to achieve their growth plans, is widening [10]. As far back as the former government, it was understood that there existed a massive shortage in the skilled workforce more especially amongst the youth in our society.

The PICC highlighted the skills scarcity in SA as a significant challenge which needed urgent attention. As such, the SIPs programs was an opportunity to assume a key role in bringing about skills development within various sectors and disciplines.

For this to happen, a skills plan was required for SIPs. This task was best positioned to be headed by the Department of Higher Education and Training (DHET) and in collaboration with the Industrial Development Corporation (IDC).

SIP Coordinators would also play an integral part in the process of skills identification. The project owners of SIPs projects residing at State Owned Enterprises (SOEs), institutions and relevant authorities would also participate in identifying and proposing strategies to address the skills and training gaps and shortages that exist.

Promoting localisation – economic localisation refers to providing directed support for as many aspects of local production and consumption as possible [11].

Localisation is a key strategy known to drive local economic development linked to the progressing of local businesses and entrepreneurship. In addition to cultivating local businesses, localisation encourages condensed supply chains, thereby strengthening the local economy and simultaneously creating better community and business relationships.

The IDC, with its extensive experience and knowledge was tasked with progressing the SIPs localisation initiative through a Localisation Unit formed to assist entrepreneurs. SIP Coordinators were requested to provide support to the IDC in driving the localisation programme and integrating this idea with the delivery of SIPs infrastructure development to the benefit of local communities and businesses. It was envisaged that localisation would assume a key performance indicator to which the SIPs would be monitored against.

SIP-3 projects in terms of its program composition transcends sectoral boundaries, localisation would therefore benefit many business sectors. TCTA had given assurances in support of the localisation initiative in relation to the execution of the SIP-3 program.

5 PROGRESS AND IMPACT OF THE SIP-3 PROGRAM

Fig. 3 illustrates the SIP-3 project pipeline indicative of estimated capital costs. The total estimated value of the SIP-3 Program is in the region of R219 billion. Currently, R9.9 billion worth of projects are under construction.

As a way of highlighting key SIP-3 achievements, Fig. 3 outlines an overview of the program’s progress from its inception to date by illustrating the measure of projects that were successfully completed – the red tabs indicate projects that have not progressed as anticipated and therefore reside within the initiation and planning phases of the project lifecycle. The blue tabs specify projects that have past the construction phase and are now complete and have been handed over to the respective clients for operations and maintenance.

Over the last 8 years during which time SIP-3 has been operational, admirable progress has been achieved through the completion of several projects (valued at about R18.9 billion), comprising: The Greater East London Strengthening, completed in 2015 – consists of an electricity transmission system for the Eastern Cape; the Nelson Mandela Legacy Bridge, completed in 2016 – creating better access to services and strengthening economic activity into Mvezo area and villages; the Kalagadi Manganese Sinter Plant and Mine located in Hotazel Northern Cape was commissioned in 2013 and 2016 respectively and are operational; the Mthatha Airport upgrade was completed in 2017 – improving access to the Eastern Cape business fraternity; the Ngqura Transhipment Hub completed in 2019 – improving the export corridor via Ngqura in the Eastern Cape.

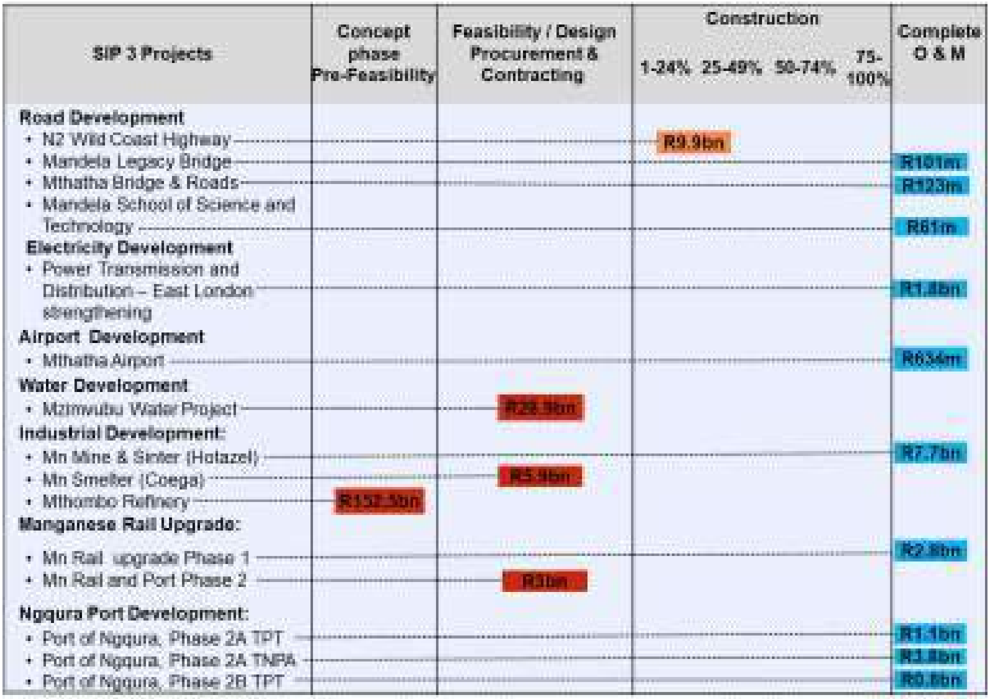

Figure 3: Status of SIP-3 projects, with estimated capital cost amounts. *(Source: SIP-3 Progress Report.)*

While noting the outstanding work above, there are some aspects of the program which have not progressed as planned. Therefore, it is important to highlight the challenges that confront SIP-3. These include the decrease in the number of active projects in the implementation phase. The following four of SIP-3's remaining five projects are among the large capital projects in the country: The Mthombo Refinery (estimated at R152.5 billion), the Mzimvubu Water Project (estimated at R28.9 billion), the Kalagadi Manganese Smelter (estimated at R5.9 billion) and the N2 Wild Coast Highway (estimated at R9.9 billion). These mega projects are considered catalytic for the economy of the corridor leading into the Eastern Cape province. However, they all face considerable challenges that hamper implementation. Part of the responsibilities of SIP-3 Coordination, is to unblock challenges that hinder project progress, SIP-3 had for years put in efforts to unlock these blockages, but regrettably have not yielded the desired outcome.

Given the complexity of the challenges, very few of the above-mentioned projects are likely to go into implementation soon. Having said that, the only exception is the N2 Wild Coast Highway project, which commendably has advanced into the construction phase, but continue to endure difficult challenges. Many of these challenges do fall outside the control of the implementing agent and cannot be easily unlocked, even at the level of political leadership.

Implementing the Kalagadi Manganese Smelter project has over the past several years been delayed because of volatile commodity prices. Due to challenges, three of the five remaining SIP-3 projects are stagnant, albeit the N2 Wild Coast Highway project is now progressing, SIP-3, in its current form, will depend mainly on the development of one project, being the Transnet Manganese Rail Upgrade, which thus far has experienced many lengthy delays. At present, execution of the Transnet project is temporarily halted due to an anticipated shift in strategy. This inevitably will delay the completion of the project even further having negative economic implications for the rail corridor and the Eastern Cape.

It is clear from the program status that an intervention is necessary to address stagnant projects and or to expand the project portfolio of SIP-3 with new catalytic projects.

6 SIP-3 PROGRAM COORDINATION ACCOMPLISHMENTS

The SIP-3 Coordination team has worked devotedly to identify and assist in resolving challenges or bottlenecks affecting project progress. The team have executed its responsibility in improving tracking, monitoring, and reporting of projects. SIP-3 Coordination encourage collaboration among key project partners through the creation of platforms for strategic engagement. These engagements stimulated information sharing amongst stakeholders and debating of issues that plague infrastructure development in South Africa. The coordination team has consistently prepared and submitted quarterly construction update and progress reports to the PICC, this included investigating and reporting of key project challenges. During its course of coordination efforts, SIP-3 had planned, convened, and facilitated two IGFs (also known as FEA as per the Act) where CEOs of state entities and political principles provided inputs into the program.

Further to the responsibilities and activities defined above, the SIP-3 Coordination team has been part of other critical interventions within the context of achieving the SIPs objectives. The following describe some of these interventions where SIP-3 Coordination was involved.

6.1 Program Technical Committee (PTC)

The SIP-3 PTC forum was established as a platform for program coordination on a technical level, where stakeholders can engage freely with the aim of resolving infrastructure implementation challenges and bottlenecks. But more specifically, the forum endeavoured to achieve the following objectives: Engage on SIP-3 construction update reports presented by project owners; provide an opportunity for project owners to gain insight into project related timeframes, inter-dependencies, potential risks that they may be faced with; enable provincial partners to engage in identifying opportunities for local economic development initiatives; create an opportunity for the SIP-3 Coordinator to identify challenges and solutions through engagement with key stakeholders.

6.2 Integrating with other SIPs programs in resolving infrastructure and service delivery

As part of SIPs initiative, government seeks to improve the quality of lives for its people, which includes people inhabiting the 23 least resourced districts as identified by the PICC. To achieve this goal, the PICC established SIP-6 which is dedicated to supporting coordination and integration of infrastructure delivery in these 23 districts.

The PICC had observed some inconsistencies between the reports provided by the various SIPs involved in these districts. This was due to limited coordination integration, and to improve coordination efficiency, it was resolved that a working group dedicated to supporting the 23 districts be established. Also, noting that most of the 23 affected districts were in the Eastern Cape region made sense for SIP-3's involvement, providing strategic support to this initiative. SIP-3 Coordination has also supported by tracking progress and unblocking bottlenecks affecting delivery of infrastructure and the following important services to communities: Water and sanitation; electrification; roads; health care facilities; schools; digital migration; broadband and human settlements.

6.3 Supporting SIPs skills development

The Eastern Cape province is where most of the SIP-3 projects reside, is largely rural and is home to a substantial portion of South Africa's unemployed population which contribute to its growing levels of poverty. The SIPs Skills strategy envisioned the creation of job opportunities beneficial in improving the livelihoods and quality of life of the communities within this province. SIP-3 Coordination committed to working closely with and support those championing the SIPs skills initiative (IDC and DHET). SIP-3 engaged often with the DHET and assisted by providing support in the development of the SIP Skills Plan.

6.4 Supporting localisation

As part of the assistance provided to the IDC's Localisation Unit, the SIP-3 Coordination team identified localisation opportunities that exist within the program. In this regard, SIP-3 earmarked key opportunities relative to SIP-3 projects, and highlighted enablers that would elevate localisation and the economy in communities and the region. Through these opportunities, SIP-3 embraced the localisation vision for businesses to support the SIP infrastructure build program through spin-offs in establishment of local small to medium businesses and concurrently establish job opportunities. Further to this, SIP-3 also highlighted opportunities for promoting localisation within the labour sector where most of the semi-skilled and unskilled labour recruited for SIPs projects could be sourced from local communities. This labour localisation approach was brought to the fore to significantly address the skills shortage.

7 SIP-3 PROGRAM AND SIP COORDINATION CHALLENGES

Over the years of SIPs implementation there have been many challenges confronted by Coordinators that impact SIPs programs. Most of these coordinating and program challenges are shared across most SIPs. The following are some key challenges that is specific to SIP-3, but are not uncommon to other SIPs programs:

Diminishing Number of Active SIP-3 projects – significant projects in SIP-3, in terms of value, have not advanced as anticipated. The current portfolio of active projects has diminished and in need of augmentation to maintain the momentum in catalysing the economic development of the Eastern Cape region. SIP-3 Coordination started an initiative, in collaboration with the PICC, to enhance the program by incorporating new strategic and catalytic projects. SIP-3 had engaged with the Eastern Cape Socio-Economic Consultative Council (ECSECC) and the Eastern Cape Department of Economic Development, Environmental Affairs and Tourism (DEDEA) including other key Stakeholders during the Eastern Cape Economic Cluster meeting held in October 2016, to request guidance with the process of selecting new projects to augment SIP-3. Further to the above, SIP-3 Coordination and the PICC have also engaged with the Eastern Cape Office of the Premier in September 2017 to gain an improved perspective toward progressing the SIP-3 enhancement initiative within the province. The meeting was a productive one, but due to certain political challenges, resulted in the enhancement initiative not progressing as hoped. In fact, it came to a standstill in the latter part of 2017.

Several projects within SIP-3 have failed to gain traction due to funding challenges. Broadly speaking, funding constraints on SIPs were observed to be systemic and cutting across all the strategic programmes. Using SIP-3 to illustrate the challenge, a greater portion (87% of estimated R219 billion) of the program value has failed to progress into the construction phase. As a result, the planned economic catalysis and social development benefits planned for the Eastern Cape are being held back.

With a weakened economy and dwindling fiscus which precedes the resultant effects of regulations associated to COVID-19 lockdowns, South Africa is in a difficult position with respect to its sovereign credit rating and its ability to raise appropriate funding for infrastructure. Yet, there remains a huge degree of optimism by Government through an introduced economic recovery plan announced in October 2020 which prioritises infrastructure spending via an Infrastructure Fund (IF) managed by the Development Bank of South Africa (DBSA) [12]. The IF is seen as a key element of the economic recovery plan and aims to diversify government funding sources available for infrastructure by combining capital from the public and private sectors, development finance institutions and multilateral development banks [13]. Government funding plans are admirable but considering the urgency of infrastructure demands faced by SA, a detailed funding strategy is essential to demonstrate the availability of funding and allocations to prioritised strategic infrastructure projects [14].

Funding for SIP Coordinators – when state entities were directed by various Ministries to be SIP Coordinators, funding did not accompany these directives, making it difficult to appropriately execute responsibilities of the coordination function. Due to the lack of dedicated funding, the TCTA SIP team have experienced challenges in validating the cost associated with the coordination of SIP-3, by the same token, SIP-18 being the other SIP program which the TCTA has been directed to coordinate, also share the same funding issues. Considering SA's protracted poor economic climate, some state entities responsible for SIP Coordination, including the TCTA, have had to carry out SIP coordination work with very limited resources.

Localisation and Job Creation – as with SIP-3, most SIP Coordinators functioned with limited resources while aiding the IDC Localisation Unit in driving the localisation, industrialisation, and Job creation initiatives. These initiatives deserve concerted effort and is not a quick process, necessitating continued research in identifying opportunities and new suppliers and allowing further time for entrepreneurial development and growth. In 2012 a Business Plan for SIP-3 that TCTA submitted to the PICC contained localisation opportunities and associated benefits within the various sectors of the SIP-3 program. The SIP-3 Business Plan was approved by the PICC Secretariat. Since then, there have been many engagements with the Localisation Unit, though there hasn't been significant progress.

South Africa still grapples with increasing levels of unemployment [15]. Overall, the will and required framework to ensure localisation is in place, yet a key challenge extends to government and SOEs that still lack implementation capacity. Just one example of this lies in the limited capacity of procurement officers to select local suppliers, which is critical to ensure effective implementation [16].

8 STAKEHOLDER INSIGHTS ON SIPS AND SIP-3

Insights from SIP-3 stakeholders are highlighted below, reflecting on their experiences, perceptions and views of the successes and challenges encountered during coordination of the SIP-3 program. These insights and views also develop a deeper understanding of the program's performance. The stakeholders who engaged with the SIP-3 Coordination team in discussions included: Managers and SIPs leads from the PICC; SIP-3 Project Owners

(Transnet, Eskom, TCTA and SANRAL) and Eastern Cape Provincial Partners (ECSECC and DEDEAT).

A common view expressed by Project Owners (POs) were of infrastructure having not realised the economic benefits and jobs creation post construction. The SIP-3 Mthatha Airport upgrade was used as an example of completed infrastructure having great economic potential had it been appropriately and timeously planned for. As emphasised by POs, prioritised projects should be an ideal candidate for appropriate financing and should be implementation ready to secure economic benefit soonest. POs stated that projects under SIPs should not form part of a "wish list" – SIP projects should be weighed upon its ability to drive catalytic economic growth. As part of the SIP-3 review process, POs debated that the economic impact of SIPs be measured. However, this argument concluded by the understanding that it would be difficult to measure at this stage and would need a more comprehensive study into the business and operational plans of every project and all catalytic benefits that were derived therefrom. POs impressed upon the idea of SIP Coordinators involvement in the project selection process. It was of the view that the constitution of the current SIPs programs (SIPs 1 to 18) were not appropriately selected due to a rushed selection process. Requests were made for a better synchronised process in infrastructure roll-out and for SIP Coordinators to play a more active role in future SIPs selection.

The PICC in general had commended SIP-3 Coordination in progressing the SIP-3 projects, The PICC pointed out that there were many positives resulting from SIP-3's coordination efforts. Nonetheless, the PICC had also indicated that there is still room for improvement. The key issue in the SIP-3 program is funding – within the context of a weakened economy, the funding challenge persists and is one that is not easily resolved, even by political principals, as such, this challenge does necessitate concerted effort to overcome.

The following matters were also highlighted by the PICC as areas were improvement in SIP-3, including other SIPs can be fostered, by all SIP stakeholders:

- Project selection should have sound planning and full feasibility studies;
- Efficacy of the SIP process in achieving its objective of social and economic development;
- An empowered review process is needed to appraise projects against SIP objectives prior to being uploaded as a SIP;
- Enforce "obligations" on POs having projects in SIPs programs – there are certain POs that do not regularly and effectively report on project progress and challenges;
- Regularly review and update projects in the SIPs programs – prioritised pipeline of projects must be implementation ready and should not remain stagnant over years;
- Improve SIP-3's efforts in enabling localisation, skills development and job creation – these initiatives are key to economic prosperity.

Provincial partners related the need for job creation and skills development which were not realised as envisioned. Hence, provincial partners questioned if SIPs were in fact strategic and adequately integrated within infrastructure development plans for the province. A concern over the political fraternity was highlighted with respect to projects that were announced as being ready for construction, but regrettably were not delivered as promised – these unfulfilled declarations severely impact on beneficiaries needs. The following proposals were also highlighted by SIP-3 provincial partners to improve SIPs operations:

- Entrench better integration at project and program level across SIPs;
- SIP Coordinators and supporting structures must be given more authority, being better empowered in driving the SIPs agenda;

- Secrecy and "silos" from SIPs program coordination and reporting should be detached – project information sharing should be further encouraged, even at the political level;
- SIP-3 Coordination should be more involved in project implementation decision making – i.e., project launch announcements by politicians, funding, strategy review and stakeholder engagement.

9 CONCLUSION AND RECOMMENDATIONS

SIP-3 stakeholders had provided valuable insights into why the SIP-3 program can be considered effective or alternatively not as effective as it was initially imagined. Although many stakeholders had spoken proudly of the benefits experienced with SIP-3, generally the principal view by most was that the SIPs Coordinators and the PICC be further empowered.

While embracing all views from stakeholders, the benefits associated with a project being part of SIP-3 should be emphasised. Broadly speaking, SIPs programs does promote integrated project planning, design, and execution, including a focus on completed projects, are well operated, managed and maintained, particularly as SA battles with a vast backlog of infrastructure that is in disrepair and at risk of collapse [17].

In addition, projects selected for SIPs programs are not selected in isolation but are reviewed on their relationship with broader regional or national development programs. The SIPs approach promotes systems and integrated thinking and planning. SIP-3 collaboratively functions with other Coordinators and stakeholders to promote strategic unblocking of key challenges that projects generally encounter.

While SIPs status does not automatically qualify a project for funding, it does give it a higher level of preference should funding be available. However, supporting SIP-3 and other SIPs with access to available funding is fundamental in successfully implementing an infrastructure-led economic growth. Globally, especially in countries where infrastructure development programs are meeting its economic development goals have been incorporating widely researched and detailed funding strategies – Public–Private Partnerships (PPP) funding approach is moreover proving successful in public infrastructure development. Given governments' funding constraints, the PPP – has emerged as a new way to deliver and govern infrastructure assets [18]. Noting this perspective, SA does require more effort in developing and promoting PPPs that support infrastructure development.

PICC need to assist SIP-3 and other Coordinators in ensuring that the FEA assemble regularly, including establishment of SIPs Steering Committees to provide strategic guidance and support as stipulated in the Infrastructure Development Act. These critical structures have not been effectively instituted and if properly functioning would help accelerate decision-making, unblocking of challenges and fast-tracking program progress in achieving SIPs socio-economic objects.

As acknowledged by SIP-3, the value of coordinating national infrastructure also lies in undoing "silos" that exist not only at a project or institutional level but also at a departmental and ministerial level. SIPs encourages collaborations and new ways of shared thinking across multifaceted issues that affect society and its relationship with infrastructure, and it improves access to quality infrastructure and efficient services by communities.

Furthermore, it must be said, that with any initiative or intervention, especially one which is a pillar of inordinate significance to a nation's economic reconstruction and recovery [19], must be strengthened by refined policies, regulations, and will. Policies must be wholeheartedly supported, and aimed at a sustained, robust, and impactful infrastructure coordination structure.

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ENVIRONMENTAL ASSESSMENT AND TOURIST CARRYING CAPACITY FOR THE DEVELOPMENT OF GEOSITES IN THE FRAMEWORK OF GEOTOURISM, GUAYAQUIL, ECUADOR

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ABSTRACT

The current world situation marked by the COVID-19 pandemic, plus the various specific situations in each locality, require an adequate response to promote development. One of the most recommended is the development of tourism, and precisely that it is linked to the environmental environments of nature. For this reason, geotourism offers guarantees of biosecurity, open spaces, and better conditions in the current situation. Guayaquil, a cosmopolitan city on the Ecuadorian coast, has unique characteristics for the development of geotourism. This work aims to carry out an environmental analysis, using the cause–consequence method and tourist carrying capacity in geosites for sustainable geotourism development. The methodology includes: (i) strategic geosites selection; (ii) environmental assessment of geosites and analysis of their carrying capacity for tourism; and (iii) interpretation of results and strategy development. The results reflect that Guayaquil has very significant potential given its natural geological and biological conditions. The union of geodiversity and biodiversity give the Guayaquil metropolis a special uniqueness, auguring an excellent future for geotourism development. It is vital the develop geosites with an environmental consideration that allows projecting towards sustainable development.

Keywords: geotourism, geosite, tourist carrying capacity, environmental assessment, Guayaquil.

1 INTRODUCTION

Megadiversity is characterized by many plants or animal species that inhabit the same geological site, providing biological richness [1]. The geodiversity and biodiversity present in the most megadiverse countries make these geographical areas highly recognized and visited by many tourists [2].

Geodiversity is recognized as the basis for ecological biodiversity [3], improving the use of natural resources and the tolerance of ecosystems to climate change [4], allowing its development as a natural [5], geological [6], mining [7] and cultural [8] heritage.

The geodiversity and biodiversity of a place are essential characteristics for the confirmation of the natural heritage [9], in which the development of human beings, their cultural traditions and the history of the sector stands out [10]. These sectors consist of a universal value that encompasses the scientific and educational perspective [11], promoting the conservation and maintenance of the natural beauty that magnifies its importance and reason for visitation [12].

The natural heritage is related to the geological heritage since it focuses on the places where the geological and landscape processes of the place are manifested, being unique characteristics that promote cultural, scientific and educational interest in the called geosites

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[13]. At the same time, there is a relationship with mining heritage, which focuses on anthropogenic activities performed on the surface of the earth or below it, called mining, which implements for tourism and educational purposes [14].

Geosites are essential as the abiotic matrix of ecotopes and an existing relationship between geomorphological and geological interest [15]. In addition, these sites drive the development of geotourism, offering scientists the opportunity to conduct research to enrich knowledge, promote conservation, and achieve sustainable development [16].

Geotourism is a new form of geographic tourism that focuses on visiting fantastic scenic and scenic places [17], [18]. This term was born as a strategy of geoconservation of the biophysical and cultural characteristics of the geosite, being an option to promote sustainable development in rural areas [5].

Geoconservation is a term used to refer to the set of actions and strategies aimed at the conservation and preservation of geological heritage [19]. This motivates the development of strategies to conserve the site's natural resources, habitats, and flora and fauna [20], [21]. These characteristics are essential for the creation of the so-called geoparks [22].

UNESCO Global Geoparks are a network of unique geographic areas of international geological importance [23], which makes use of geological heritage to improve the awareness and understanding of society through geotourism [24], [25]. In addition, these places have an ethnographic, ecological and cultural variety, having their first appearance in European countries and later joining South America, such as Ecuador [26].

Ecuador recognizes as a megadiverse country located in the southern hemisphere of the American continent [27]. It has scenic and tourist attractions that frame its geological evolution. These places stand out in the various geographical regions of continental and insular Ecuador. Its unique features include valleys, volcanoes, basins, and other geographical features that frame the geo-biodiversity it possesses. [28]. Therefore, there is an extensive natural, geological and cultural heritage within the territory that has changed over time due to geological and geomorphological processes [29]. The first geopark in Ecuador, recognized by UNESCO in 2019, is the Imbabura Global Geopark, located in the northern Andean part of Ecuador [30].

Guayaquil, also known as the pearl of the Pacific, and Ecuador's main port, is a city of international interest since it has very significant potential given its natural geological and biological conditions [31]. Moreover, the combination of the geodiversity and biodiversity of the metropolis of Guayaquil gives it a special uniqueness [32], auguring an excellent future for social, economic, cultural and geotourism development [16]. The city has heritage values that emphasize elements of geodiversity [33], [34], recognizing it as a symbol of the Ecuadorian coast.

2 OBJECTIVES

The problem that occurs in Guayaquil is defining by the following question: How would we recognize the environmental status and physical carrying capacity of four geosites of the city of Guayaquil for taking measures in the context of sustainable development? Therefore, the research aims to evaluate four geosite of Guayaquil city, considering environmental aspects using a cause–effect matrix. The tourism topic is also considering, calculating the carrying capacity of each of the geosites in the study area. Environmental valuation and carrying capacity are crucial to establishing strategies that lead to sustainable development.

3 MATERIALS AND METHODS

The present work focuses on the application of three different phases (Fig. 1), focused on: (i) strategic geosites selection; (ii) environmental assessment of geosites and analysis of their carrying capacity for tourism; and (iii) interpretation of results and strategy development.

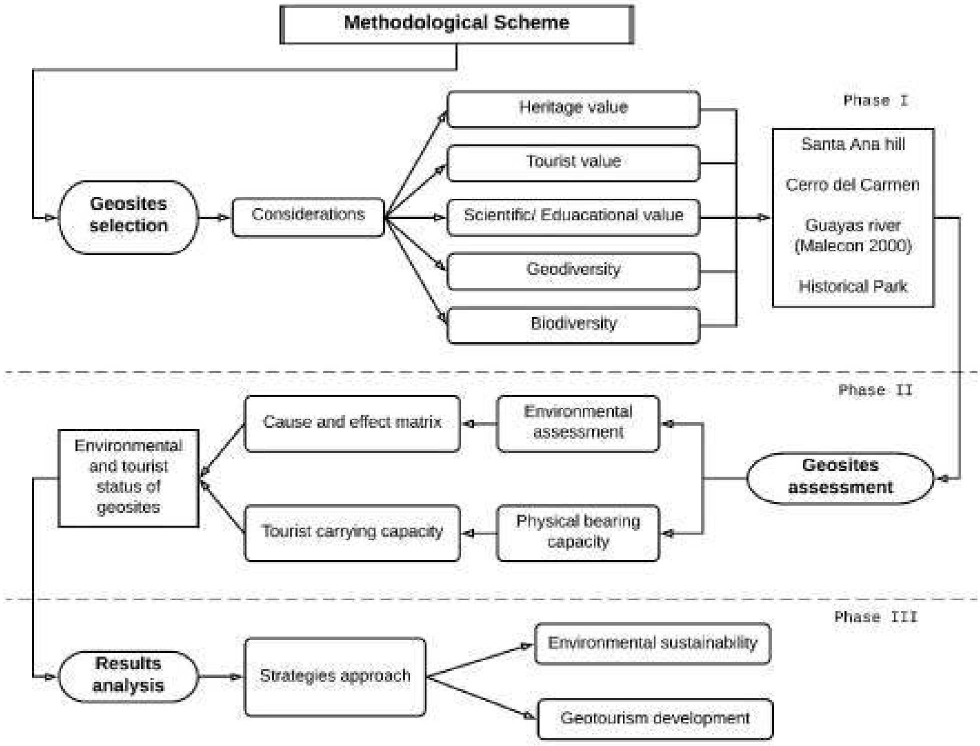

Figure 1: Diagram of the methodology and phases implemented in the development of the research work.

3.1 Phase I: Strategic geosites selection

From a group of geosites already valued for their geological relevance in the scientific contribution of Carrión-Mero et al. [16], four geosites representatives of the city of Guayaquil are selecting. Among which are: Cerro del Carmen, Santa Ana hill, Guayas River (Malecón 2000) and the Historical Park (Fig. 2). It should note that these places have an already established tourist preponderance in the city, and in this work, their geological value is adding for a critical, synergistic and developmental analysis.

These sites are recognizing for their high tourist, educational and recreational activity. However, these sites need an assessment of their current environmental status and the maximum capacity of tourists they can accommodate, given the reality of the COVID-19 pandemic.

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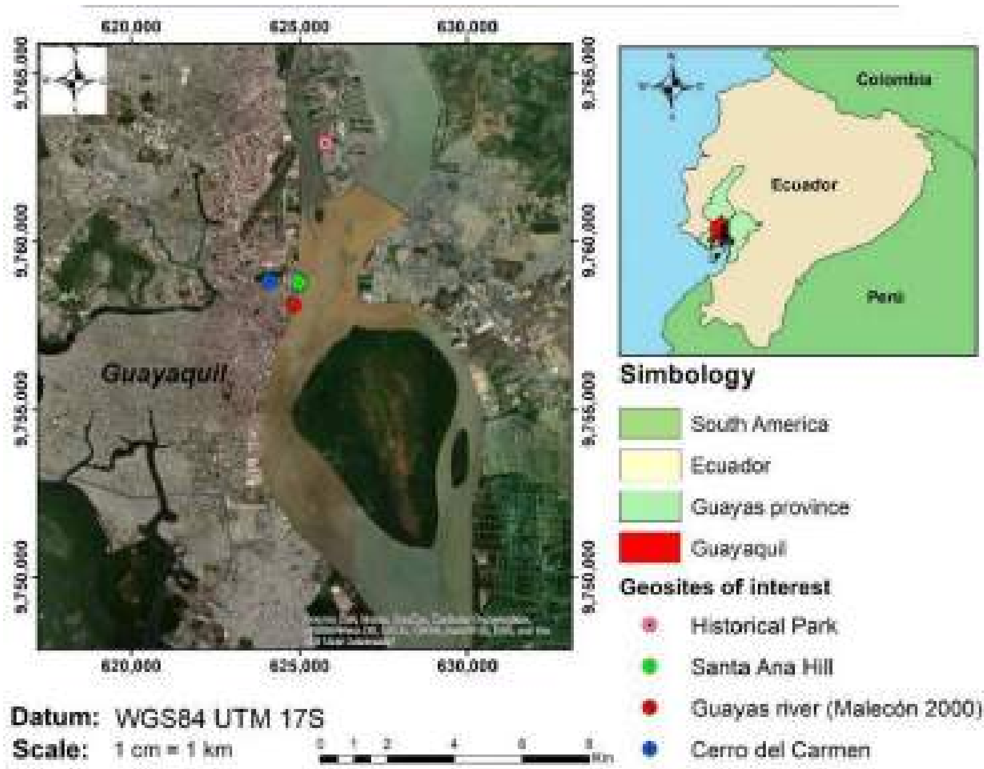

Figure 2: The geographical location of the geosites in Guayaquil, Ecuador. *(Source: Modification of [35].)*

3.2 Phase 2: Environmental assessment of geosites and analysis of their carrying capacity for tourism

The cause–effect method is an interactive matrix implemented for environmental impact studies to represent the interactions between two components, natural and anthropogenic. This matrix is a double-entry table, where the rows are the environmental factors to be assessed, while the columns contain the value corresponding to each factor (Table 2). For this purpose, the results are analyzing with the valuation ranges in Table 1.

The calculation of the tourist carrying capacity consists of the application of three different sections, which refer to the physical carrying capacity (PCC), real carrying capacity (RCC) and effective carrying capacity (ECC) (Fig. 3). The PCC is the limit of visits that can be made to the site per day, while the RCC is a series of correction factors to the PCC that affect the site directly or indirectly, and finally, the ECC is defining as the maximum of visits that can be allowed given its management capacity [36], [37].

Table 1: Significance ranges.

Range	Features	Significance
81–100	E(+)	(+) Highly significant
61–80	D(+)	(+) Significant
41–60	C(+)	(+) Moderately significant
21–40	B(+)	(+) Insignificant
0–20	A(+)	(+) Not significant
(–)1–20	A(–)	(–) Not significant
(–)21–40	B(–)	(–) Insignificant
(–)41–60	C(–)	(–) Moderately significant
(–)61–80	D(–)	(–) Significant
(–)81–100	E(–)	(–) Highly significant

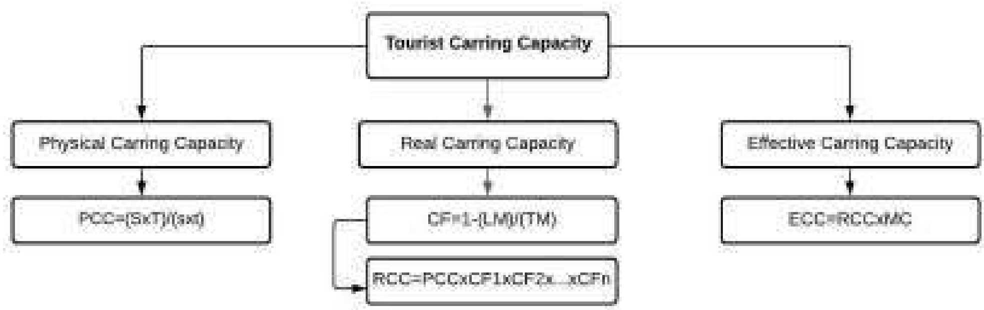

Figure 3: Main parameters analyzed for the calculation of tourist carrying capacity. S = Surface or total area of the geosite destined for tourists; s = surface per person; T = Time for visitors; t = time a person needs to visit the geosite; Lm = Limiting magnitude; Tm = Total magnitude; PCC = Physical carrying capacity; RCC = Real carrying capacity; ECC = Effective carrying capacity; CF1...n = Correction factor of the variable (1, 2, 3, …, n, depending on the case); MC = management capacity.

3.3 Phase 3: Interpretation of results and strategy development.

The results allow us to analyze the status of each geosite, considering the environmental impact of tourist and human activity, and the maximum capacity to which they are limited to accommodate under COVID-19 conditions. This phase focuses on the generation of a focus group to discuss the values obtained after the evaluation of each site (Delphi method). It is an essential tool for exploring the results and determining practical actions for strategy and decision making [38].

4 RESULTS

The results reflect the environmental value of each geosite, determining the most relevant environmental aspects and their impact on the geosite (see Table 2).

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Table 2: Environmental assessment of four geosites of Guayaquil.

	Historical Park		Cerro del Carmen		Santa Ana Hill		Guayas River (Malecón 2000)	
Environmental aspect	Impact value		Impact value		Impact value		Impact value	
Gas emissions perception	–12.5	A(–)	–32	B(–)	–32	B(–)	–24	B(–)
Soil quality perception	27	B(+)	27	B(+)	27	B(+)	15	A(+)
Electricity consumption	–24	B(–)	–24	B(–)	–48	C(–)	–50	C(–)
Bad odors perception	–12	A(–)	–21	B(–)	–21	B(–)	–17.5	A(–)
Noise and vibration perception	–20	B(–)	–54	C(–)	–54	C(–)	–40	B(–)
Generation or presence of wastewater	–30	B(–)	–100	E(–)	–100	E(–)	–48	C(–)
Fauna	56	C(+)	12	A(+)	12	A(+)	21	B(+)
Flora	54	C(+)	28	B(+)	12	A(+)	24	B(+)
Ecosystem impacts	27	B(+)	–54	C(–)	–54	C(–)	–24	B(–)
Construction for geosite adjustments	8	A(+)	–7	A(–)	–7	A(–)	–8	A(–)
Reforestation	24	B(+)	–27	B(–)	–27	B(–)	–18	A(–)
Organic waste generation	–36	B(–)	–48	C(–)	–54	C(–)	–24	B(–)
Inorganic waste generation	–16	A(–)	–54	C(–)	–54	C(–)	–32	B(–)
Hazardous waste generation	–8	A(–)	–48	C(–)	–48	C(–)	–48	C(–)
Loss of vegetation cover	–7.5	A(–)	–18	A(–)	–24	B(–)	–24	B(–)
Industrial activity	–15	A(–)	–45	C(–)	–54	C(–)	–72	D(–)
Commercial activities	48	C(+)	21	B(+)	48	C(+)	54	C(+)
Employment generation	42	C(+)	27	B(+)	48	C(+)	48	C(+)
Service generation	54	C(+)	36	B(+)	54	C(+)	54	C(+)
Excessive visual or landscape load	27	B(+)	56	C(+)	72	D(+)	56	C(+)
Social recreation	48	C(+)	6	A(+)	42	C(+)	56	C(+)
Physical carrying capacity	40	B(+)	40	B(+)	56	C(+)	72	D(+)
Tourist safety	54	C(+)	21	B(+)	24	B(+)	20	A(+)
Symbol or figure cultural	54	C(+)	70	D(+)	90	E(+)	80	D(+)
Presence of vehicles (transport or machinery)	35	B(+)	–63	D(–)	–42	C(–)	–48	C(–)

The historic park has a negligible negative impact. The perception of gas emissions is deficient given that the park is located in an area with little intervention by vehicles, although smoke particles can founding retained in part of the vegetation, which contributes to mitigating noise pollution and transforming it into pleasant sounds. Organic waste generation and electricity consumption have a negligible impact due to the biological needs of the animals and the fact that not all the park is illuminated at night (recreational areas, restaurants, and event hall). On the other hand, the unique characteristics that make this park a vital geosite are highlighted, such as the animal shelter (where they can interact and be cared for) and the diversity of vegetation (which is cared for and reforested), positively benefiting this ecosystem.

Given the proximity between El Cerro del Carmen and Santa Ana Hill, similar negative impacts are not very significant, such as the perception of gases from vehicles travelling in the surrounding area. Electricity consumption and the perception of noise and vibrations are other impacts caused by the presence of houses, lights, vehicles of the residents and commercial activity in the sector, in addition to nighttime activities such as bars and nightclubs. Wastewater generation is another significant factor, mainly influenced by housing and services provided by hotels and restaurants, which are also involved in solid waste and are considered a moderately significant factor. Despite the adverse effects, both geosites have significant characteristics that highlight their importance, such as the generation of jobs and services, geoforms that frame their geological activity, cultural and historical figures, and other peculiarities that make these geosites the unique cultural places in the Guayaquil city.

In the Guayas river (Malecón 2000), there are negative impacts on electricity consumption due to the installation of lights for monuments and roads, the perception of gases, noise and vibrations due to the presence of extreme games, ships/land vehicles passing around and live shows on weekends and holidays. The generation of wastewater has a moderately significant impact, given the presence of commercial establishments and other tourist activities that encourage the use of the facilities. Therefore, industrial activity is more prevalent and affects the ecosystem. However, this geosite also highlights characteristics of the city's identity, such as the generation of employment, social recreation, great tourist carrying capacity, as well as the presence of symbols, and cultural and historical figures of the Guayaquil city, which makes it one of the most visited sites by tourists and citizens.

The tourist carrying capacity of these geosites highlights the maximum number of people at each geosite, which can see in Table 3.

Table 3: Tourist carrying capacity.

Results (visits per day)			
Geosites	CCF	CCR	CCE
Historical Park	31,250	2,021	1,887
Cerro del Carmen	113,333	27,036	21,629
Santa Ana Hill	56,000	25,701	23,559
Guayas river (Malecón 2000)	255,000	118,109	110,236

Considering the surface in square meters for visitors and the area of each geosite, in the PCC, it is possible to determine the maximum number of tourists that can access in a single day. However, in the RCC, there are correction factors for the previously calculated data, which significantly influences the stay and number of people on the site. Finally, the ECC presents multiple variables that refer to the capacity of each geosite to be managing most appropriately. Therefore, the geosites have a significant number of people represented by the ECC, such as the Historical Park with a maximum of 1,887 tourists, Cerro del Carmen with a permissible limit of 21,629 people, similar to Santa Ana Hill with 23,559, but the one with the most significant capacity to accommodate visitors is the Guayas River (Malecón 2000), with a capacity of up to 110,236 tourists.

5 DISCUSSION

From an environmental and tourism perspective, Guayaquil city has problems regarding the lack of environmental culture among its citizens and their activities that affect the environment [39]. Furthermore, contamination by the solid waste in the Guayas River

(Malecón 2000) is another environmental problem present in this site, due to improper disposal [40], as well as the high energy consumption caused by the site's facilities, and the contamination of its banks by wastewater discharged into the river from industrial activities [41]. However, it has a tremendous socioeconomic, cultural, and recreational importance, being a geosite with great tourist/historical interest and a large tourist carrying capacity.

Despite being a tourist site that maintains its structures in better condition than the others, the Historic Park also has negative impacts from the surrounding area and slightly from within, so tour guides must receive training to inform tourists adequately [42]. On the other hand, its geographic location allows for local flora and fauna development, making it a geosite of great value for the interaction between humans and nature.

Cerro Santa Ana and Cerro del Carmen are very characteristic places of the city since they are sites with predominantly cultural and historical heritage, besides being the neighborhoods where the city of Guayaquil began [43], However, they are deteriorating due to carelessness of urban infrastructure and lack of an inhabitants culture, which has led to an increase in the crime rate [44].

Knowing the tourist carrying capacity of the four geosites is necessary to improve the sustainable use of the site. The number of people in a given geosite depends not only on the space available for their tour but also on the circumstances and factors (climatic, anthropogenic, among others), which can affect visitors' availability and interest during their visit. In addition, the physical state they present emotionally influences the tourist to see the level of management or conservation of infrastructure, equipment, and public services available to people [45].

The environmental assessment of a geosite represents an action of great importance to establish conservation strategies and an optimal environmental, social, cultural and tourism development for the site, as is the case of the National Protected Areas System of Uruguay, where three geosites are environmentally analyzing for the sustainable development of tourism [46]. With this objective and through the calculation of the carrying capacity, it intends to improve the environmental and tourism status of the geosites, allowing to know the maximum capacity of people and emerging problems in these sites receiving tourism [47]. For this, consider the site's internal characteristics, such as infrastructure, anthropogenic activities, and the natural and geological resources of the area. Therefore, keeping the status of these resources up to date is essential for the continuity of geotourism activities, thus reducing the possibility of socio-cultural deterioration and the deterioration of the sector's experience [48].

6 CONCLUSIONS

Four relevant geosites in Guayaquil (Historical Park, Cerro del Carmen, Santa Ana Hill, and Guayas River (Malecón 2000)) have been studied, considering environmental aspects using a cause–effect method, and the tourist carrying capacity conditioned by the effects of the COVID-19 pandemic restrictions. These calculations make for a valuation of the preservation of these geosites and visitors capacity according to health security. The strategic importance of these sites and the preponderance of geotourism as a driving force for the socio-economic aspects of Guayaquil city are demonstrating.

The cause–effect matrix allowed determining the most relevant environmental factors in the geosites within Guayaquil city. The consumption of electricity has been seen as a significant negative aspect in most geosites, being a common characteristic given the availability of these places for night events, allowing them to be part of a tourist attraction that benefits the sector socially and economically.

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The four geosites assessed are affected by the daily activities of the city (vehicular traffic, gas generation and urban noise), which are perceiving by these places and, in a few cases (Historical Park), are buffered or absorbed by the existing vegetation, which favors this type of places that are considered the lungs of the city and promote a respite for the inhabitants of their daily lives. Industrial activity is present as a negative aspect. However, in some geosites, it is the reason for jobs and services provided to the city's citizens. In addition, the inhabitants near the sites of interest benefit from the socioeconomic and tourist increase they have. Even so, they are the reason for the increase of solid waste and wastewater through housing, restaurants, hotels and other sectors that house or meet the needs of tourists.

Currently, the global COVID-19 pandemic has negatively affected tourism activity and the sectors that depended on it (restaurants, hotels and commerce in general). However, and under certain restrictions on people's capacity, geosites become an optimal socioeconomic source for the resurgence of tourism activity. This pandemic has generated significant economic loss within the tourism industry since it influences all environmental aspects, such as social distancing. However, the spread of the virus can avoid, and tourism can become a recreational activity, safe and in conditions to promote sustainable development.

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QUALITY AFFORDABLE HOUSING CONCEPT: CASE STUDIES IN MEHR, IRAN, DHARAVI, INDIA, AL-SHARQ, JORDAN AND BASHAYER AL-KHAIR, EGYPT

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ABSTRACT
The provision of adequate, good or quality housing for the population has always been a major challenge and aim for many nations in the world particularly the developing countries. However, most of these countries suffer from the same problem, the gap in the low-income housing sector is increasing day after day. Moreover, the main problem is that the population is increasing, and their needs are changing constantly. Governments all over the world are trying to reach most of affordability ratio in the housing sector for low-income. Yet there are many concepts that should be considered such as Quality Affordable Housing Concept. The paper has a main aim which is to evaluate affordable housing projects based on quality affordable housing criteria. Therefore, qualitative, quantitative, analytical and comparative methodology are chosen to reach the paper's aim. Four housing projects selected to be case studies for this paper: Mehr in Iran, Dharavai in India, Al-Sharq in Jordan and Bashayer Al-Khair in Egypt.
Keywords: affordable housing, low-income housing, quality affordable housing, housing market, low-income, affordability.

1 INTRODUCTION

Housing is an essential aspect in life. In 1977 Lazenby suggested that three ways that architects, planners and social scientists can work together in developing a framework for the provision for good quality affordable housing:

a) The architect or planner must gather information which will be integrated to produce good quality affordable housing according to the needs of residents.
b) Architects and social scientists have to collaborate in the evaluation of a residential environment from the point view of the users.
c) Architects, planners and social scientists should gather their talents in efforts to set those dimensions of housing and residential areas which contribute to the overall quality of life.

Therefore, low-income housing is one of the essential structures of any housing development strategy. However, affordability on the housing sector turned into an obstacle of the housing development process in especially in Egypt and India [1].

This study aims to analyze four different affordable housing projects based on the criteria of quality affordable housing. The researcher had to choose qualitative and quantitative methodologies to outcome the criteria of quality affordable housing. Also, analytical, field and comparative methodologies used to clarify case studies of this paper. The case studies selected according to several aspects: similar scale of the projects, number of households, number of housing units, aim of the projects, and type of affordability.

2 CRITERIA FOR QUALITY AFFORDABLE HOUSING

The provision of adequate, good or quality housing for the population has always been a major challenge and task for most nations in the world particularly the developing counties,

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Egypt, India, Iran and Brazil. As such various measures have been undertaken towards this end [2].

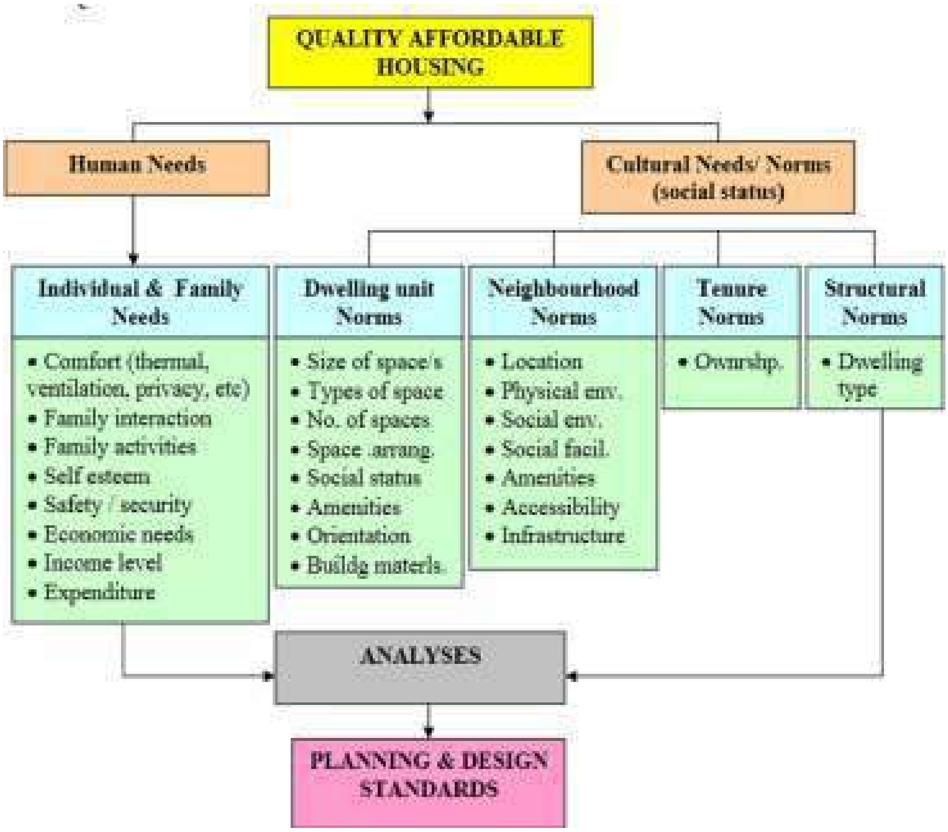

Figure 1: Criteria of quality affordable housing [2].

3 CASE STUDIES

3.1 Case of Mehr Housing Project, Iran

Mehr projects are a housing for low-income, constructed in 2007. These projects constructed in three locations: new cities, lands around cities and old areas to facilitate modernization and improvement. Mehr is still going project aimed to reach one million and five thousand of housing units. These number of units will cover six million population of the country, which is approximately 12% of urban population. Ministry of housing, Housing Foundation, Ministry of Cooperatives, Central Bank, Municipalities and Central insurance collaborated altogether to construct Mehr Housing Projects [3].

This project main aims are to bring equality in between supply and demand of housing by omitting the land price, housing for low-income people and poor people, control and prevent the skyrocketing the prices of lands and housing, housing boost production and increase production volumes of housing and reducing the cost of housing (Rent, mortgage and buy). Also, it is aimed to give solution for the future housing needs, justice in access to quality affordable housing [3].

Therefore, the researcher had to choose Mehr to evaluate the project using quality affordable housing criteria. First criteria: Location and accessibility: In Mehr housing projects the ones that locating inside of the cities have much more benefit than the ones that are located outside of the cities. They have better access to public transportation but the houses that located outside the cities suffer from the lack in transportation. However, most of the households in suburbs houses are workers in other cities and the big cities next to these suburbs' projects, the government is ignoring the shortage of transportation system.

Second criteria: Location features: Mehr Projects that are located in the cities have access to different facilities such as educational, entertainment, bazars, sport and health facilities. They also have access to gas, electricity, water, telephone and sewage system. However, the projects which are located outside the cities suffers from lack of access to entertainment, health, educational, bazars and sport facilities. Also, some of them have lack in gas, water, electricity and telephone.

Third criteria: Safety and security: One of the most important factors that should be considered in housing design in Iran is earthquake. Unfortunately, most of the housing units are not constructed regarding the natural factors. Imagining, if there are any natural disasters happened in Mehr projects, there will be no facility can help and support the households of these projects. Mehr housing projects located in Tabriz, Hadishahr and Marand were not designed by considering the environment factors. Due to Neyshaboor earthquake in 2017, most of Mehr housing units were destroyed, Iran government created an insurance program for all Mehr projects.

Fourth criteria: Public open spaces and recreational activities: The projects that are located in the cities have access to park and green areas. However, in projects in suburb areas, they have lack in public areas, gardens and playground for children.

Fifth criteria: Plan layout and functions: There are different plan types in Mehr housing projects as shown in Fig. 2. These apartments are categorized as high rise and medium rise buildings. The plans of Mehr housing projects should be suitable for the population density and also culture of the city. They are designed by considering the climatic factors of different cities and sun orientation plan of two types of housing unit, one of them 75 square meter and the other 62 square meter.

Sixth criteria: Physical features: the designer of the housing units had to consider any natural disaster such as earthquakes. On the other hand, the project typed as quality affordable housing for low-income people. However, most of contractors who participated in the project chose to use low quality construction materials for the own money saving, households' satisfaction ratio is low. Generally, In Mehr housing projects there is a semi open balcony for each unit. In parallel to the religion of this country, generally families have more privacy and they are not using these semi open spaces as a socializing area [3].

3.2 Case of Dharavi Housing Project, India

This example will focus on Navrang in Dharavi, India to be fitting with this thesis's study scale. Navrang has about 300 households. The Indian government chose to upgrade this area, which mostly contains shanty houses.

Indian government aimed to upgrade quality of life of the regional household through providing the basic human needs in the community and eradicating shanty houses in the area. Also, one of the most essential aims of this project is to decrease unsafe areas in

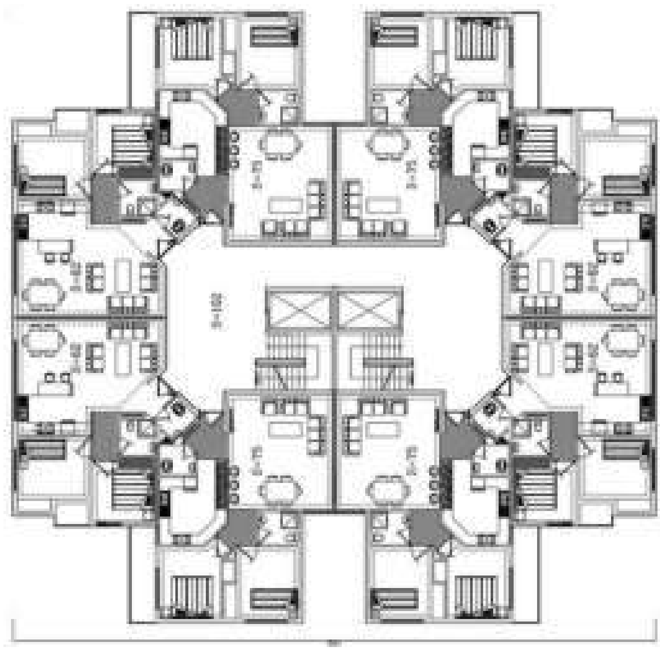

Figure 2: Typical floor plan of Mehr housing [8].

Dharavi. Thus, Indian government aimed to increase livability in Dharavi through providing more services for the community, such as educational, transportation, recreational areas, shopping malls, kids gardens, and health care centers [4].

Therefore, the researcher had to choose Dharavi to evaluate the project using quality affordable housing criteria. First criteria: Location and accessibility: Dharavi housing project located in central location in the city, for higher accessibility and integrated urban form. Also, the project has a good access to transportation facilities and walkable distance between housing units and services. The distance between the housing project and workplaces is a walkable distance.

Second criteria: Location features: Because of the project location, it is high accessibility to community services such as educational, transportation, recreational areas, shopping malls, kids' gardens, and health care centers as shown in Fig. 3. However, Indian government supplied most of community services facilities, these facilities considered as a low-quality service and need to improve.

Third criteria: Safety and security: Livable urban structure aims to reduce crime percentage in the project and establish the sense of belonging. Also, Government aimed to remove unsafe areas in Dharavi to provide sense of safety and community eye. However, Social rejection for Dharavi households is affecting directly on crime percentages.

Fourth criteria: Public open spaces and recreational activities: The housing blocks that are located in the cities have access to park and green areas. However, no maintenance for public spaces, recreational areas and gardens is the main aim for decrease quality of these services.

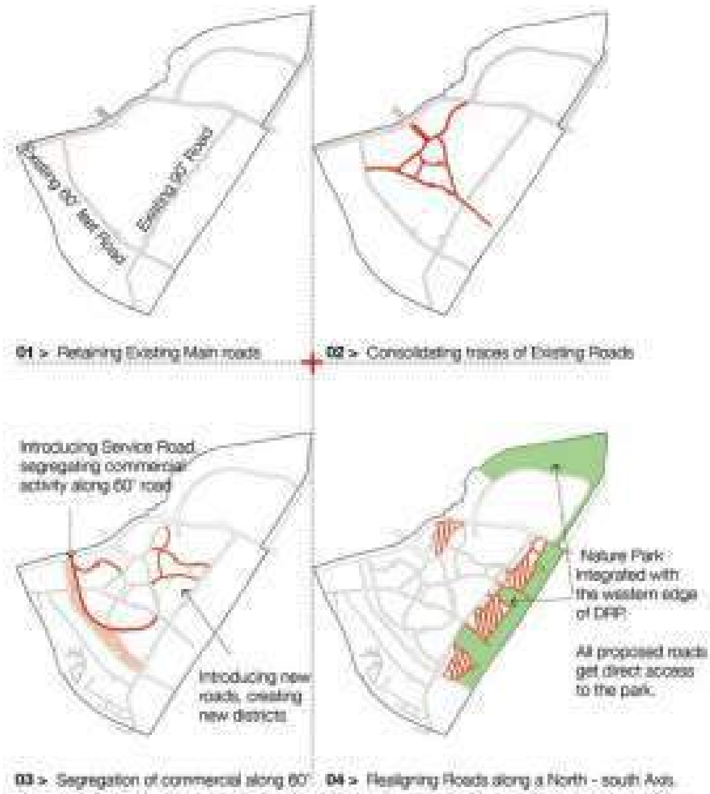

Figure 3: Dharavi project master plan analysis [7].

Fifth criteria: Plan layout and functions: Skeleton reinforced structure system is the used construction method in Dharavi housing project. It provided two different housing units with the ability to be extended which shows its flexibility approach: 49 m^2 housing type and 24.5 m^2 housing type.

Sixth criteria: Physical features: As shown in Fig. 4, a very flexible design and ability to extend are the most important factors in the housing units. There is an Increase quality of life through providing a new infrastructure for the community, however, it is affecting on the public health by indirect ways. And socio-spatial segregation is highly shown in Dharavi [4].

3.3 Case of Bashayer Al-Khair, Egypt

This project, which is a developed area of “Ghait Al-Enab”, is recently one of the leading distinguished national cases, represented in the Egyptian Armed forces and Alexandria Town Council. They cooperated with the society to implement the strategy not only to develop Ghait Al-Enab to Bashyer Al-Khair, but also to replace it with efficient affordable housing for low/middle-income categories [5].

The strategy had to be set to encounter those challenges and problems to include a detailed study of all urban dimensions without ignoring the social and development dimensions. This strategy is summarized in several points, including [5]:

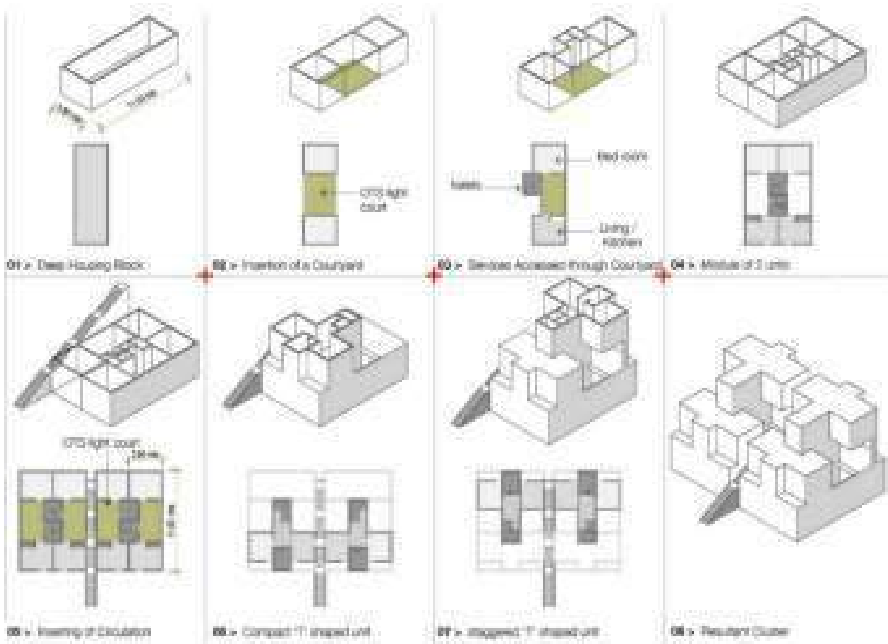

Figure 4: Analysis of Dharavi project and housing units [7].

1. The development and upgrade of urban standard and the improvement of the quality of life as well as environment that surround these families.
2. The achievement of a comprehensive development of families in all fields and qualifying them for living in newly developed societies.
3. Enabling the community members in those areas to achieve self-reliance to find solutions for their problems by self-efforts and by cooperation with the states represented in the armed forces.
4. Training youth and women to gain skills and experiences that would help them achieve a material return to ensure them the means of a decent life.
5. The invitation was made for social participation and participation of businessmen along with volunteers as an inevitable necessity to encounter the problem of low potentials and resources that are encountered.

Therefore, the researcher had to choose Bashyer Al-Khair to evaluate the project using quality affordable housing criteria. First criteria: Location and accessibility: The project is located in one of the districts of East Karmouz in Alexandria, which is popular area with several tourist attraction sites, including the Mast Column. In addition, there are monumental tombs of Kom Al-Shoqafa. Karmouz shares a border in the South with Mariot Lake and in the east with Moharram Bek District which is adjacent to it. It is bordered in the north by Labban and Attar districts.

Second criteria: Location features: While Ghayt Al-Enab was transferred to deteriorating area because of poor planning, in addition to cracking of the old units that were situated one hundred years ago, the area was one of the political leadership’s priorities to transfer it to new residential units that provide all services to enable average citizens to live their safety and security.

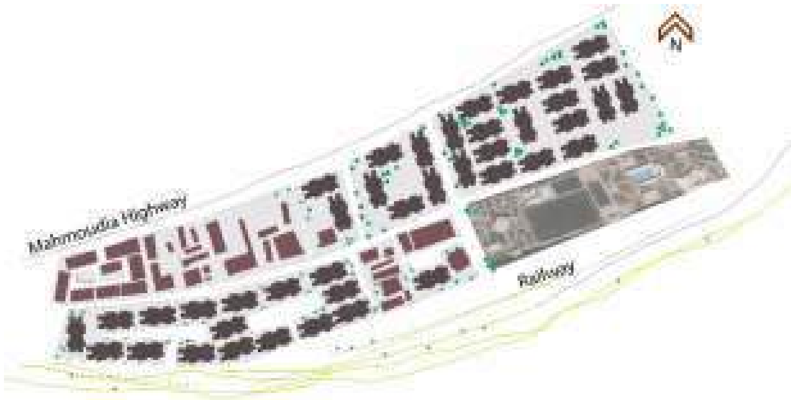

Figure 5: Site plan of Bashayer Al-Khair [5].

Third criteria: Safety and security: Ghayt Al-Enab reached a state of deterioration and severe urban underdevelopment. The intensity of the deterioration increased by occupation of general spaces that surround the case study by many families. This resulted in a relatively high increase rate in such areas where the ownership of lands and spaces in that area is commonly without the control of the government of Egypt.

With the critical social call for development of such deteriorating residential areas as a direct result of many social, security, political and other direct reasons. The aspect that raised the concern of the potential contribution of Egypt represented in the armed forces and businessmen in the removal of the dust of the surrounding environment. The government of Egypt has set the borders of the development area, which is 12.3 feddan.

The Government of Egypt created a price list for the local residents of Ghayt Al-Enab and another one for the new residents of Bashyer Al-Khair:

a) The local residents of Ghayt Al-Enab:

1. The payment of a monthly fee to own the housing unit.
2. Paying 50EGP per month for maintenance of electricity, elevators, water pumps and other items.

b) The new residents of Bashyer Al-Khair:

1. The unit's price is between 250,000 LE and 300,000 LE. This price could increase according to the unit's location.

Fourth criteria: Public open spaces and recreational activities: The project includes a charity hospital (Gamal Hammad Central Charity Hospital) which is equipped with 150 beds and outpatient clinics community, dialysis unit and an emergency unit. Besides the center, there is a training center and a workshop. In front of them to the left, there is a big branch of the National bank of Egypt and beside it is the consumer complex and retail market that contains 58 stores, malls, and workshops [5].

Fifth criteria: Plan layout and functions: Bashyer Al-Khair contains 34 residential buildings with a total of 1,632 residential units and an area of 90 m^2 per unit as shown in Fig. 6. This includes the infrastructure, finishes and preparation so that the building consists of ground floor + 11 floors with electric elevators [5].

Sixth criteria: Physical features: Reinforced concrete skeleton system is the construction method of the project; therefore, each housing unit consists of [5]:

1. A living room which is the space where all possible living activities can take place such as sitting, television, food and sometimes sleeping. Rooms of multiple living use, including bedrooms, a kitchen and a bathroom are distributed in it.
2. Bedrooms: each residential unit contains three bedrooms (girl's bedroom, boy's bedroom, parents' bedroom) that open to the living room.

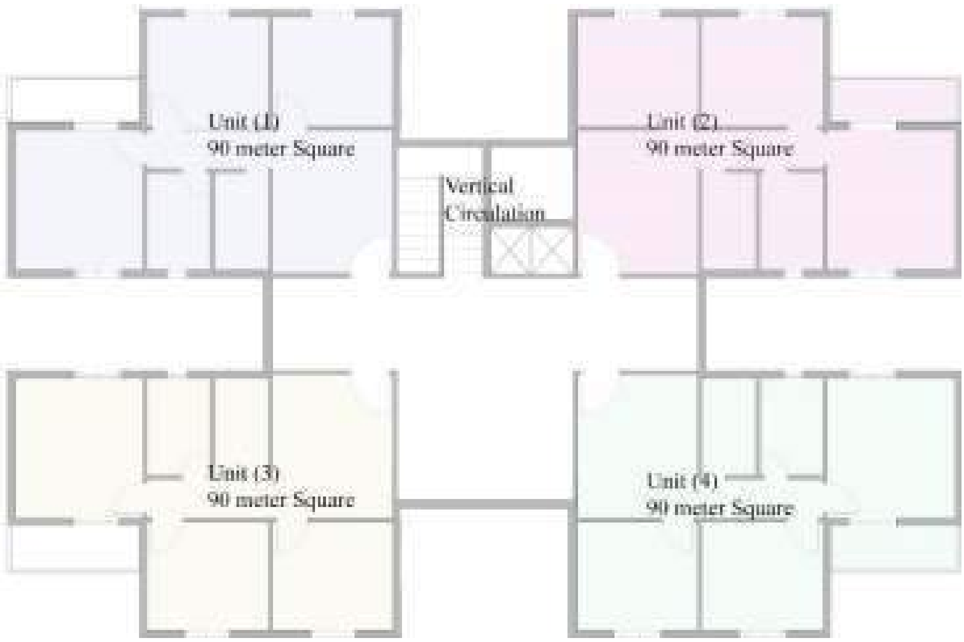

Figure 6: Typical plan of Bashayer Al-Khair [5].

3.4 Case of Al-Sharq project, Jordan

Al-Sharq housing project is a massive scale affordable housing project in Jordan that gives a solution to solve the population growth. The government transformed site of the military camps in Zarqa to quality housing project. It was chosen to measure the degree of housing quality that Al Sharq housing project obtains in terms of residential satisfaction with the social, environmental and physical conditions of this housing project [6].

This project aims to create a modern, integrated city, that forms a major urban landmark and a natural extension of the city of Zarqa. Al-Sharq housing project development site mounts 2,500 hectares and is divided into six construction phases. The constructed phase of the project covering 250 hectares is located along the Amman–Zarqa highway. It includes a set of districts [6]:

1. Five residential districts – 135 hectares;
2. A peripheral commercial district – 40 hectares; and
3. A central commercial distract – 75 hectares.

4. As for the main components of the project plots are, namely, 925 residential plots, 235 commercial plots, seven mosques, seven public parks, seven schools, seven kindergartens, one health center, one hotel and one youth center.
5. The types of implemented housing in this project are, namely, housing complex, row housing and detached houses/villas.

Therefore, the researcher had to choose Al-Sharq to evaluate the project using quality affordable housing criteria. First criteria: Location and accessibility: Walkable neighborhood: pedestrian friendly exclusivity and privacy green spaces Has a transport system, that is, environmentally friendly. Accommodates multi-modal transportation (i.e., pedestrians, bicyclists and drivers) [6].

Table 1: Detailed analysis of Al-Sharq project land use [6].

Land use	Area (hectare)	(%)
Housing	91.22	36.30
Commercial	47.85	19.4
Public services	17.04	6.78
Roads	74.48	29.64
Gardens and open spaces	20.70	8.24
Total	251.29	100

Second criteria: Location features: the row housing as an alternative configuration that guarantees privacy, freehold ownership and also provides individual gardens for each dwelling. At present, there are 170 row houses built around an open communal garden. However, Detached homes contain an open area, a specific area with limited roof and villa where people live. These homes are highly valued across the world more than any other kind and are considered the dream residence. These types of houses enjoy significant advantages such as:

1. The family level of privacy and freedom is maintained, as single-unit (detached) properties are segregated from each other and each land parcel is given to a particular family; tranquility is prevalent; and little or no noise pollution from neighboring homes.
2. Nowadays, due to the increased population, such properties are rarer in areas where new residences comprise mainly of apartment buildings.

Third criteria: Safety and security: Over 40% of the residents were dissatisfied, with the lack of safety, security and privacy being the most significant failing. However, 30% of our sampled residents were satisfied with some of the social factors including the sense of place, of community and belonging and good social relations between the residents themselves.

Fourth criteria: Public open spaces and recreational activities: the first three characteristics that are considered priority for the physical dimension, and which could be included in the Al-Sharq city master plan. These characteristics are, namely, abundance of parking lots, pedestrian-friendly neighborhood and multi-modal transportation. Moreover, this survey shows that the most suitable physical facilities are: health services; educational services (primary schools); and nearby commercial services [6].

Fifth criteria: Plan layout and functions: Apartments building height five floors where family members live as neighbors within the defined area. It also contains public services and recreational places that are commonly used by the residents. Nowadays, the vast amount of urban society lives in these apartments due to high population density and the cost of land. Second type of residential units, attached housing as an alternative configuration that guarantees privacy, freehold ownership and also provides individual gardens for each dwelling. At present, there are 170 attached houses built around an open communal garden.

However, detached housing contains an open area, a specific area with limited roof and villa where people live. These homes are highly valued across the world more than any other kind and are considered the dream residence. These types of houses enjoy significant advantages such as: the family level of privacy and freedom is maintained, as single-unit (detached) properties are segregated from each other and each land parcel is given to particular family; tranquility is prevalent; and little or no noise pollution from neighboring homes.

Sixth criteria: Physical features: Reinforced concrete skeleton system is the construction. The project has several partitional, the researcher described them into the following

a) Provide large green areas, gardens, playgrounds, hiking and sitting Contemporary urban lifestyle.
b) Provide an efficient and organized public infrastructure and services.
c) Participation in collective groups and networks in the community.
d) Has design and architectural features that are visually interesting.
e) Contemporary urban lifestyle.

4 COMPARISONS BETWEEN THE CASE STUDIES

Housing concept should perform a double function: (1) the interior, one of providing a place where a household of different age, sex, education, occupation, intellectual modes and values can meet in harmony; and (2) the exterior, one of providing meeting grounds for groups of households and for the healthy and enjoyment enrichment of their lives and the life of the community.

However, a group of World Health Organization experts defined housing as:

"The residential environment, neighborhood, micro-district or the physical structure that mankind uses for shelter and the environments of that structure, including all the necessary services, facilities, equipment's and devices needed for the physical and mental health and social well-being of the family and the individuals".

In economic term, housing is categorized as a commodity which has a market value and can be bought and sold. Through housing is reflected the type of household, high/middle/ low household, and affordability to reach a certain level of quality of life.

Governments all over the world is trying to reach most of affordability ratio in the housing sector. However, quantity of housing units is directly affecting on the affordability ratio, the concept of quality affordable housing should be considered. The paper aims to evaluate affordable housing projects based on quality affordable housing criteria.

5 CONCLUSION

Housing is a complex and multi-dimensional phenomenon. Therefore, in developing a model which can be used as a guideline for design and provision of quality affordable housing would require analysis of the various parameters or perspectives particularly with respect to the individual and family needs, the physical, physiological, economic, affordability, social, cultural, dwelling unit or space requirement, environmental,

Table 2: Comparison between affordable housing projects based on quality affordable housing criteria.

		Criteria	Affordable housing projects			
			Mehr, Iran	Dharavi, India	Bashyer Al-Khair, Egypt	Al-Sharq, Jordan
Quality affordable housing	Human needs	Comfort	◑	○	◑	◑
		Family interaction	◑	◑	●	●
		Family activities	◑	◑	●	●
		Self esteem	●	◑	●	◑
		Safety and security	●	○	●	◑
		Economic needs	●	○	○	●
		Income level	●	●	○	●
		Expenditure	◑	◑	○	◑
	Dwelling unit	Size of spaces	●	◑	●	●
		Type of space	◑	●	●	●
		Number of spaces	●	◑	◑	◑
		Space arrangement	○	◑	◑	●
		Social status	○	◑	○	●
		Amenities	○	◑	●	◑
		Orientation	◑	◑	◑	◑
		Building materials	◑	●	◑	◑
	Neighborhood	Location	◑	◑	●	●
		Physical environment	○	○	●	●
		Social environment	○	◑	◑	◑
		Social facilities	◑	◑	◑	●
		Services	◑	●	◑	◑
		Accessibility	○	●	●	●
		Infrastructure	◑	◑	○	◑
	Ownership norm		●	◑	○	●
	Structural (dwelling type)		●	◑	○	◑

○ Poor; ◑ Moderate ● Good

neighborhood, location, tenure, structural norms and also psychology of the occupants, which constitute the pertinent parameters for the formulation of standards or criteria for the planning and design affordable housing.

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ASPECTS OF THE PUBLIC DOMAIN IN REGENERATING WATERFRONTS: A CASE STUDY OF BELGRADE'S WATERFRONT, SERBIA

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ABSTRACT
The paper is a presentation of the evolution of the treatment of urban public land in the urban planning and design of the regenerated waterfront area, in different social conditions. The authors assess the certainty of achieving high quality urban space, by comparing the circumstances and aspects of the public domain. For several decades, urban plans have declared change of land use for the attractive Sava river basin (and the Danube) in Belgrade, with the purpose of relocating industrial warehouses and traffic facilities such as the train and bus stations. In order to initiate the process of regenerating a new area of the city, between the historical core and the newest and most modern part of the city, at the end of the 20th century local and international urban planners and architects were invited to propose uses and forms for the future waterfront skyline in the so-called "Project for the 3rd Millennium". The purpose of the project was to produce a multifunctional connection with the river between two parts of the city, both different in their development concepts. The accent was on the public domain: culture, education, entertainment, and tourism, which included planning new buildings for museums, venues for opera and ballet, and concert halls, as well as scientific centres, hotels, etc., with pedestrian promenades and greenery. Unfortunately, mainly because of the political situation and economic crisis, but also because of unrealistic ideas and foundations of the concept, the implementation failed. The future development depended on political will and demanded enormous investment, and it also had to wait for the next three decades. Belgrade's Waterfront project that started several years ago is based on this general idea to change the area's appearance, but with significant exceptions. It is officially a result of foreign investment, and the concept was not a result of open urban competition, but rather based on a 3D model developed abroad, in addition to which, a percentage of public land was given over for residential and commercial structures, and the height of some buildings changed the skyline of Belgrade's hill completely. All of these issues have been bitterly criticized by the professional and wider public.
Keywords: waterfront, regeneration, public land, urban competition, urban plan.

1 INTRODUCTION

Cities that are positioned next to water surfaces (such as a sea, lake or river) have an advantage, and they have been treated differently at different periods of their development. Industrial use, as a port, or for shipbuilding, storage or production, was dominant during the period of industrialization. In modern times, when "dirty" processing has been displaced from cities, empty locations near the central core, with attractive banks and views, have become subject to the regeneration process. New functions, for example as public buildings, or residential, office or commercial space, have taken the place of industrial zones. Planning such a transformation is an excellent opportunity for inserting missing city facilities, reconsidering principles and goals, and designing the desired image and appearance.

1.1 Methodological framework

This research presents a case study observing the phenomenon of urban regeneration, and the public domain within the context of the study area, which is limited to the part of the Sava's right bank enclosed by the mega project of the Belgrade Waterfront development. The

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academic relevance of the paper is that it contributes to an understanding of the anomalies in the urban planning process which have occurred in this special and significant city location. This research analyses different requirements in the usual integrated urban planning process, including the protection of public goods and the preservation and presentation of cultural heritage, as well as a number of deviations and opportunities.

1.2 The study area

This part of the right bank of Belgrade's coastline and the area surrounding it, known as Savamala, just next to the city centre, started to develop and change rapidly in the 19th century, with the enthusiasm of rich merchants interested in building residential buildings, hotels and shops in the drained location of the former swamp. In the 20th century, after WWII, the area was repeatedly considered by means of master urban plans, various projects, studies and competitions, such as the "Centre of Culture – Project for the 3rd Millennium" in 1985 and "Europolis" in 1995 [1], [2]. The common goals of all previous plans and projects included the transformation of the extremely valuable but devastated ambient into something more functional and rational, modelled on experience from other cities, which had also liberated their own coastal areas from industry, transport, ports and warehouses, and turned them into new spaces, primarily for public use, but also for entertainment, trade, business and housing. Urban regeneration, namely the change of land use and interaction between the city core and its rivers, as an essential need for this area, has never been in dispute. But there was no opportunity for any form of implementation, since decades of having a bad economic and political situation precluded any initiative to change the situation, especially having in mind that urban regeneration would demand serious and wide interventions, including location of the rail tracks and main railway station [3]. This neglected city district, at the beginning of the 21st century, started to transform spontaneously, by itself, becoming an alternative and popular scene, occupied by young people, with clubs and start-up hubs in restored warehouses [4].

The Spatial Plan for the Special Purpose Area (SPASP) of the Sava coast for Belgrade's Waterfront project was prepared in accordance with the Decision on the Development of the Spatial Plan (Official Gazette of the Republic of Serbia, No. 34/10) [5], in addition to the previously adopted conclusion of the Government of the Republic of Serbia that the particular project has significant importance for the state and the City of Belgrade. The specificity of the plan, covering a total area of 177 ha, is certainly its theme, namely, the development of part of the prominent coastal urban area of the central zone of Belgrade, which comes out of common topics of interest for this kind of plan: protected areas with natural, cultural and historical or ambient values, the exploitation of minerals and mining, the development of mountain tourist locations, or the possibility of using of hydro potential. However, it refers to the last two possible options that the law provides as the basis for carrying out projects that the government determines as relevant to the Republic of Serbia and for constructing buildings for which permits are issued by autonomous provinces. At least one of them can be considered undefined to the end, free in interpretation and arbitrary in evaluation, used as an option as needed.

1.3 Theoretical framework

Numerous academic papers concerning Belgrade's Waterfront development have been published since the urban reconstruction was announced. They all have in common a deep criticism of the project, beginning with the procedure and the absence of professional influence in the creation of the area's identity and its relationship with the hinterland [6]–[8]. It has been stressed several times that urban and architectural competitions are a crucial, but missing, factor for this kind of location, program and volume of intervention [9], [10]. Creating and displaying an anonymous model of the future project, even before a plan had been developed was particularly annoying and offensive for the majority of authors. Another issue is public transparency in the decision-making process and the lack of awareness among citizens that extremely valuable urban land will be privatized for exclusive residential, office and commercial buildings, instead of providing space for public uses that are currently lacking, like museums and galleries, an opera house, a concert hall and similar, with plenty of open public spaces [11]–[16]. The visual aspect of the project, with extremely high skyscrapers, raises the question of the skyline and the disrespect of the views and scenery relating to the old part of the city, first and foremost, the interruption of Belgrade's Fortress as a symbol of the city. The announcement that the mega project is a foreign investment from the United Arab Emirates, but hiding all of the contract details, including the obligations of the city government with regard to preparing the location for building, together with the proposed appearance of the architecture, has provoked an association with Dubai's development, in a negative context [17], [18]. Other papers have reviewed issues related to transport logistics and climate change in the context of the new development [19]–[21]. There are also several studies about the organization and management of the large-scale project [22], [23], and participation in it [24], [25], and above all, about civil sector rebellion and protest [26], [27].

2 THE REGENERATION IMPULSION

There are many examples of the reconstruction of coastal city zones on the global level. In the industrial era these areas were used for ports and docks, industrial zones, shipyards, storage space and similar, but with technological change they have become valuable space for public use, culture and leisure time. Some cities, like Montreal and Vancouver in Canada, Cape Town in South Africa Republic, London and Glasgow in the UK, and Barcelona and Bilbao in Spain, have applied new master plans for regeneration, with mixed-use development, and the most prominent structures in them were designed by well-known architects and their teams [28]. That was the basic idea, and desire, for Belgrade's river shore, too, at least in the minds of urban planners. The final realization of the aspiration to connect city with the rivers in a qualitative way suddenly accelerated, but some crucial steps were neglected.

What became contentious and difficult to accept in the case of Belgrade's project, first and foremost by the profession, but also by citizens, is the way it was being implemented, because of the enactment of the Law on the Determination of the Public Interest, and special procedures of expropriation and issuance of building permits. Therefore, this legal act was called in the media *lex specialis*, meaning that is stronger, special and more detailed, with higher priority than regular urban planning acts. What the profession had persistently sought for decades, for example an international competition for the urban and architectural shaping of this valuable and unrepeatable part of the city, was avoided in 2012. Then there have been questionable deals with foreign investors, especially with regard to the level and dynamics of foreign investments, conditions of implementation, and the high level of city investment for clearing the present uses and infrastructure equipment from the site. Particularly contentious is the final shape and appearance of the structures, because it became clear that the new buildings would change the silhouette of the city and jeopardise some of the most beautiful views of the old part of the city, especially of Belgrade Fortress.

Through a persistent campaign, the public has been assured that Belgrade will get exactly what it needs, that there is no other or better solution, and that this megalomanic project has no alternative. The 3D model (Fig. 1) of the project was presented even before the plan was finalized, and that was moment when it became obvious that some decisions had already been made, especially those about land use, spatial organization, height of the structures and architectural design. There was no place or time for urban competition, gathering, evaluating or choosing the best ideas and solutions. The future will show the advantages and disadvantages of the whole enterprise, but the fact is that experiments in urbanism have a high price, that guarantees of success are often lacking, and that mistakes are very difficult to fix or cannot be fixed at all. The second, devastating fact is the lack of continuity in decision making, and changes in the selection of the capital's strategic goals, which is not just a feature of contemporary society, but a cancer of this society in general. Initiated urbanisation constantly suffers changes, deviations, and the influence of external and internal uncertainty factors. The public's role in the planning process should not be circumstantial, but rather decisive and direct [29]. Citizen movements have organized protests, performances against the project and debates, but there has been no interaction with decision makers. With regard to the plan, everything else has been done professionally and very correctly, by an experienced team, who have made every effort to maintain a high level of expertise and professionalism. In this sense, it is called a spatial plan for a special purpose area, but in terms of its form and content, and level of detail, it is completely comparable to an urban plan of detailed regulation. The team has had the thankless and unenviable position between two opposite sides, with pressure to conclude assigned job and to justify their knowledge and professional attitude.

Figure 1: D model. *(Source: http://rs.n1info.com.)*

3 GOALS AND FALLACY

The declarative goal of the plan for the 177 ha was to define the planning basis for the use, regulation and protection of the area of part of the Sava coast in the city of Belgrade, in accordance with sustainability principles. In addition, the needs and obligations for determining the development of strategic preferences, planning solutions, conditions and guidelines were established by other documents: The Spatial Plan of the Republic of Serbia, Regional Spatial Plan of the Administrative Area of the City of Belgrade, General Plan of Belgrade 2021 and Development Strategy of the City of Belgrade. One of the main prerequisites was the displacement of the main railway station and the continuation of the railway node at a different location, in order to release this area for the construction and formation of a new complex of business and commercial zones and buildings for public purposes. The goal was to produce planning documents that can be applied directly and easily, primarily in the organization and landscaping of the space, as well as in the construction of facilities, in order to attract and implement investments.

The special principles for the future development of this part of the River Sava's coast in the area of the City of Belgrade are based on strengthening competitiveness as a potentially strong regional and European metropolis, by activating unused, inadequately used or devastated spatial potential, as well as enabling the diffusion of development, and the equal and rational use of resources. The plan mentions several principles, such as:

- Cohesion – the integrity of the coastal zone within the whole of Belgrade, based on accessibility, infrastructure equipment and connectivity. The great advantage of the city's position on European corridor VII has not been adequately used. The key task is strengthening cohesion by increasing accessibility and developing the coastal area as a complete and diverse entity.
- Polycentrics – one of the most important policies, which aims to use territorial capital and untapped potential in the best way possible. The polycentric and balanced development of individual content in the coastal zone, as a whole environment within Belgrade's urban space, and the strengthening of relations between central and fringe areas, will reduce disproportionate development in certain parts.
- Accessibility – to important points in the area and aquatoria, which provides citizens with ease of communication and availability for tourists. It is necessary to ensure that all points are connected to traffic and technical infrastructure, while strengthening and improving the links with an emphasis on activating all forms of river traffic.
- Identity – is an important basis in support of the development of the economy, especially tourism, expressed through the sense of citizens' belonging to the city in which they live.

Respecting the above general and special principles should lead to liberation from inadequate content and the formation of multi-significant space and the preservation of identity, values and potential of space. The zone, in the projection of future development, is the potential generator for developing new activities, thanks to the existing and planned traffic connections with the city centre. In accordance with the analysis of the existing state, the overall goal of the plan was to transform and completely reconstruct the dilapidated area into a new, modern city centre – socially acceptable, economically viable and spatially integrated into Belgrade's existing cultural and historical spirit. Based on the stated general goal, several operational goals were stated, of which the most important are: harmoniously fitting into the natural environment, with a special emphasis on flood protection; the formation of a new public transport system, with a focus on railways; complete regeneration of infrastructure; the protection of cultural objects of particular importance; forming new gathering places; creating a new tourism brand.

In the chapter of the plan regarding rules for detailed regulation and construction, the planned land use was given, divided into surfaces for public and other purposes, and then divided into characteristic units and blocks (Table 1).

Table 1: Land use area [5].

Land use	Planned surface coverage (ha)	%
1. Public land		
Transport	50.14	28
River basin	39.38	22
Public services, public facilities and complexes	9.81	6
Public open spaces and greenery	24,59	14
Infrastructure utilities	0.69	0
Sum 1	124.61	70
2. Areas of other purposes		
Housing and residential area	32.11	18
Commercial zones and offices	20.44	12
Sum 2	52.55	30
Sum 1 + 2	177.16	100

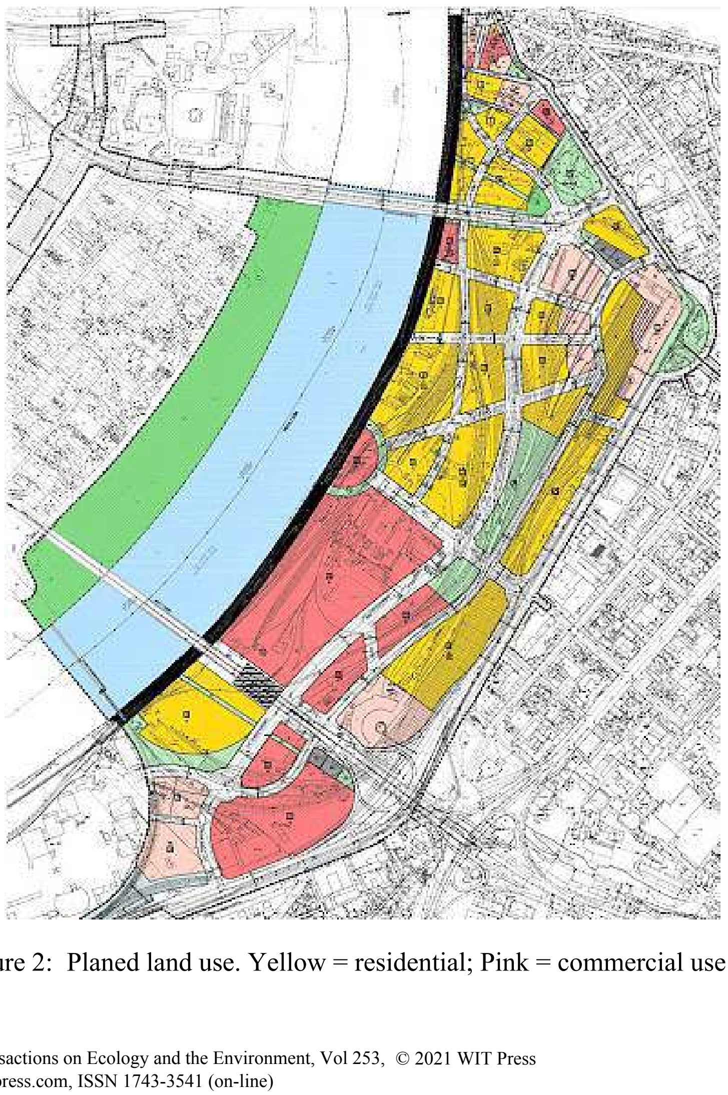

Figure 2: Planed land use. Yellow = residential; Pink = commercial use [5].

In the general division of land use, public land is presented as a 70% share and other (residential and commercial) uses as 30%. However, the border of the plan includes the water surface of the River Sava, greenery and planned streets on the opposite bank (Fig. 2). This means that percentage of public land in the planned development is not exactly as calculated, but much smaller. Besides the already-built residential blocks and shopping mall, with a skyscraper under construction, the only public use is the pedestrian promenade by the river with several playgrounds (Fig. 3). The position and urban design were not debatable, but it soon became a new gathering place for citizens, although the promenade is on a higher level above the river bank, in order to protect it from flooding. But other issues like the position, shape and height of the buildings and the blocked views of the city and its skyline, and the proposal to remove the old tram bridge across the Sava and build a new one, have once again raised protests by citizens' groups.

Figure 3: Promenade. *(Source: http://beobuild.rs.)*

4 CONCLUSIONS

Based on all of the above, there is a single conclusion that the Belgrade Waterfront plan, except for the name, formal content and procedure that followed it, absolutely does not correspond to any other spatial plans for special purposes, but rather has a built-in component that represents a very detailed and specific set of rules, from which about 90% of the area covered by the plan is given directly for implementation. Checking the planning solutions through competitions, analysis, etc. for certain locations offers stability, and highlights any further planning work envisaged, primarily, for possible changes and amendments. However, the urban and architectural competition, as a form, was not used at all in the precondition phase, not even for a single building design. The formal procedure for public insight and hearing the opinion of the citizens was carried out according to the law, but transparency and the possibility of having any influence to produce change was impossible. The professional position was that the urban reconstruction and regeneration of the coastal area was essential and should be carried out in the correct way, but in this case the political establishment took the main role, ignoring the experts. The imported design, with no identity or originality, has become the biggest contemporary controversy in Belgrade. Certainly, the biggest disappointment is the missed opportunity to take advantage of this location for more mixed-use development and including public buildings such as museums, venues for opera and ballet, and concert halls. On the other hand, in these difficult circumstances, the expert team has managed to fulfil its obligation to include as much development as it possibly could for public use. This can be observed in the segments of open green spaces with promenades, in accompanying educational facilities (kindergartens and schools), in the idea for reconstructing the old railway station as a museum, and in streets with infrastructure, some of them with city significance, like bridges, tunnels, flood protection systems and electrical substations.

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SECTION 3
CIRCULAR ECONOMY
AT THE CITY LEVEL

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CIRCULAR ECONOMY IN CHILE: BACKGROUND, LAW AND OPPORTUNITIES

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ABSTRACT

Motivated by the fact that Chile is the largest generator of waste (per person, per day) in South America, and at the same time, it belongs to the region of the world with the lowest rates of recycling, the purpose of this study is to understand the problem that the current linear economy approach brings with it, understand the circular economy approach and the importance of adopting this approach as soon as possible as it can be sustained in the long term. The particular case of Chile is interesting as it is a country that is largely financed by the extraction and export of its natural resources such as copper. The economy needs to be diversified and its dependence on raw materials reduced in order to strengthen other economic sectors. On the other hand, waste management is a major challenge since it is recycled less than the world average and even less than the regional average. Specifically, this publication describes the current situation of the country regarding the circular economy, the state of progress of the respective Chilean legislation and the main courses of action. We also exhibit some examples of successful national companies that have adopted this approach. Finally, the main challenges and opportunities that this paradigm shift presents to consumers and producers are pointed out.

Keywords: circular economy, consumer behaviour, waste, recycle, legislation, business strategy.

1 INTRODUCTION

The economic history of Chile shows the importance that natural resources have had in our economy because we have always been an extractor and exporter of raw materials, mostly minerals [1]. The arrival of Spanish conquerors to our land was driven by the search for gold and silver; however, our relative poverty compared to other countries of the region such as Mexico and Perú, consolidated the exploitation of gold panning activities which permitted the financing of the beginning of colonization in the 16th century. The mining activity was consolidated in the north of the country and organized around three traditional metals: gold, silver and copper. During the 17th century the export of copper to Perú began for the manufacture of cannons, and subsequently during the 18th century, the exploitation of gold and silver acquired relevance and generated an important income for the government. In the 19th century, copper mining used a rudimentary and labor intensive technology, but the investment of large North American companies installed in the country allowed Chile to position itself as the world's leading copper exporter (16.7% of the worldwide production) [1]–[3].

On the other hand, it is important to mention the history of saltpeter in our country, known as "white gold" that began its exploitation in 1830 and lasted 100 years. Saltpeter began to be used in Europe for the manufacture of explosives and the creation of fertilizers. Saltpeter abundance and quality boosted the national industry leading Chile quickly to position itself as the largest exporter worldwide. At the beginning of the 20th century, saltpeter exports reached a 75% share of the country's exports. Even though exploitation was in private hands, a high export tax was applied that allowed the government to retain a large amount of resources for the economy, reaching a relative participation higher than

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50%. Lastly, the Great Depression of 1929 brought consequences to the saltpeter industry, forcing the country to reorganize the industry [1], [2].

Currently, mining activity represents just the 10% of GDP, however, copper alone constitutes 50% of our country's exports. Fig. 1 shows us the relative importance of copper in the country's total exports during the last 15 years. The rest of the exports are mainly made up for the sale of agricultural products, manufacturing (food, wood, pulp and paper, oil refining, chemicals, non-metallic minerals, metallic products), fishing and aquaculture, forest and minerals and wine [4]. This shows us that we continue to be a country that is mainly an exporter of natural resources, showing us therefore, with the understanding that many of these resources are finite, that our economy cannot be sustained in the long term. Chile has the largest copper reserves in the world with approximately 200 million metric tons [5] and, considering that the country´s annual copper production is around 6 million tons [6], our reserves will run out in a period of approximately 30 years. This obligates us to decouple our economic development from the consumption of finite resources, that is, to adopt a circular economy approach.

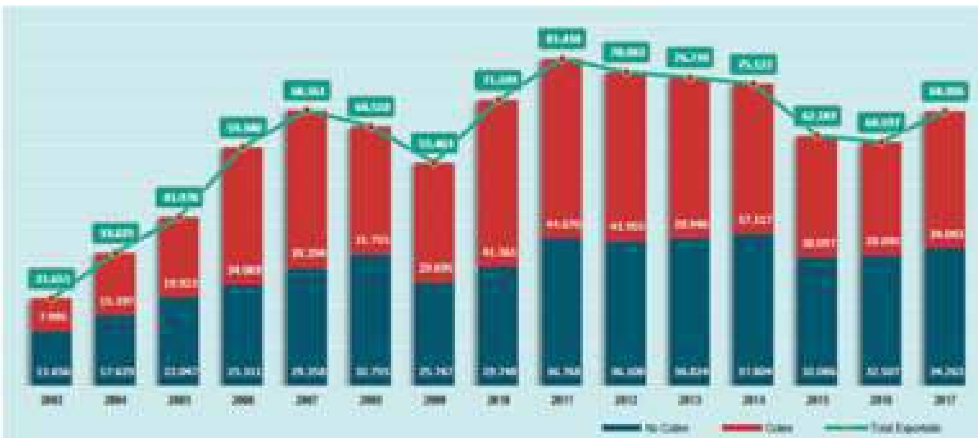

Figure 1: Chilean total exports (2003–2017) (US$ millions) [4].

The purpose of this study is to understand the problem that the current linear economy approach brings with it, to understand the circular economy approach and the importance of adopting this approach as soon as possible as it can be sustained in the long term. Additionally, to understand the state of progress of this approach in Chile.

The present document is structured as follows. Section 2 provides a literature review on the importance of the circular economy, Section 3 the methodology; Section 4 shows the result of the investigation that describes the Chilean legislation in this regard, as well as some successful examples and opportunities we have as a country. Finally, the conclusion is presented in Section 5.

2 LITERATURE REVIEW

The term circular economy was used for the first time by the British environmental economists David Pearce and Kerry Turner in 1990 in their book *Economics of Natural Resources and the Environment*, where they mentioned that the materials of an economy flow in a closed circle [7]. Subsequently, the concept was implemented in Germany in 1996 and then in Japan in 2002 as part of a policy of environmental legislation in waste management, while in China this concept was adopted as a new model for sustainable economic development more than just an environmental policy [8]. In 2010 Ellen MacArthur created the foundation that was named after her with the goal of accelerating the transition towards a circular economy model and for this she works in conjunction with governments, companies and universities [9].

Circular economy is based on the concept of "return and renew" and appears to do away with the culture of linear economy characterized by "throw away and replace" that has operated in the last 200 years, started principally after the industrial revolution and is characterized by generating products through the exploitation of finite resources which, after a period of use, are discarded (resource-product-residue). On the contrary, the circular economy is focused on the efficient use of resources and energy, looking at the productive process more than at their final result. This approach involves topics related to the redesign of products, their components and the use of packaging with biodegradable and safe materials. The most important part of this concept is to re-examine and reorient both the sources of resources and their (re) use to prevent the product from being discarded, and thereby achieve the use of products and materials for the maximum time possible. In this way, this approach seeks the decoupling of economic growth and development from the consumption of finite resources [9].

Worldwide, the indiscriminate extraction and consumption of resources has brought into question the idea of sustainability in the last 50 years [10], [11] emphasizing the importance of the adoption of this new focus for everyone, not just for countries that export raw materials. In the same way, the United Nations has put into discussion the concept of sustainable development with his objectives (SDG). On the other hand, pollution is also a problem that worries us all, generates health problems such as respiratory complications, major risk of cardiovascular diseases and decreases the quality of life and generates environmental effects like droughts, disappearance of species and global warming [12]. Given the above, our production process has to move towards one that uses clean and renewable energy. Here we have a tremendous challenge in creating or advancing these types of energy solutions. Our products have to change as well. We have to think about redesigning products, their components and the packaging in which they are sold and using safe and biodegradable materials. As consumers we have to strive for a responsible consumption and take care of our waste [9].

2.1 Garbage and waste

Planet earth has existed for approximately 4.6 billion years and life for about 3.8 billion years. From the first forms of life until the arrival of man, garbage did not exist because species ate each other, and all waste was in turn a nutrient for the earth or food for others. However, since the arrival of man, garbage has existed, and it is 100% human [9].

The difference between garbage and waste consists in that, on the one hand, garbage is all of what cannot be used again nor recycled in any way; on the other hand, waste is everything that, although it has been used, can still be recycled, for example: glass, paper, aluminium, recycle plastic [13]. Currently not enough is recycled and therefore our dumps or landfills are full of garbage and waste. In the world, an average 0.74 kg of garbage is generated per day per person, in Latin America the average is 0.87 kg per day per person. In Chile, a quantity greater than the world and regional average is generated, that is, 1.26 kg of garbage are produced per day per person. We are the country that generates the most garbage in Latin America on a per capita basis. On the other hand, we recycle only 4% of

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what we generate, a number below the regional average of 4.5% and far below the world average of 13.5% [14].

The garbage produced mainly ends up in landfills. In Chile there are a total of 38 landfills located throughout the country. On occasion, the garbage generated is placed in illegal dumps which are located in peripheral and lower income areas, negatively affecting these places because they must allocate resources to eliminate waste and garbage [15].

3 METHODOLOGY

The methodology used is based on a literature review. Firstly, background information was compiled on Chile's economic history and its strong dependence on resource extraction. Subsequently, information was gathered on the importance of the circular economy approach and the difference between it and the traditional linear economy approach. Both points were presented in the previous sections. Then, a bibliographic review of Chilean legislation related to the circular economy and its state of progress was carried out. Next, some examples of companies that have currently adopted this approach were identified. Finally, some opportunities and challenges for the country were listed.

4 RESULTS

4.1 Legislation in Chile

Chile has had a Ministry of Environment since 2010. This ministry has a Circular Economy office, the first in Latin America, whose lines of work are the following [16]:

(a) Implementation of an Extended Producer Responsibility Law (Ley REP)
(b) Recycling Fund
(c) Circular Economy Roadmap
(d) Grassroot Recyclers Inclusion Policy
(e) Action Plan against Plastic Pollution
(f) Organic Waste Management Strategy
(g) Construction and Demolition Waste (RCD)
(h) Cross-Border Waste Movement

One of the main areas of action considered by the Ministry in order to move towards a circular economy model in the country is related to the implementation of the Extended Producer Responsibility Law (REP). This law seeks to decrease the generation of waste and promote its reuse, recycling and other types of valuation. The main functions carried out include the implementation of programs, plans, policies and regulations to reduce and control the generation of waste, for the circular economy, and for eco-labeling. Likewise, it participates in collaborative actions between the Ministry and competent organizations for the formulation of environmental policies, as well as collaboration in the proposal of actions for citizen participation in the formulation of policies [16]. The REP Law created a recycling fund that is managed by the Circular Economy office, and finances projects aimed at preventing the generation of waste at the community level and promoting their separation, reuse and recycling [16].

In December 2020, a public consultation process on the "Circular Economy Roadmap 2020–2040" was initiated, the goal of which was to increase the current level of recycling from 4% to 65% in 2040 [17]. Since 2018, collaborative work has been done between the private sector, public sector, civil society and academia to determine the main participants and sectors. The proposal prepared has 32 initiatives with 92 actions in four courses of action: circular innovation, circular culture, circular territories and circular regulation [16].

In relationship to the Grassroots Recyclers Inclusion Policy, initiated in august 2016 to promote the inclusion of grassroots recyclers in waste management, three strategic guidelines were considered: environmental, economic and social, and each of them with specific objectives. The initial action plan considered activities that were carried out in the period of 2016–2020 and are currently reformulated for the 2020–2021 period [16].

Continuing with the Action Plan against Plastics Pollution, a labeling system is being developed that indicates the recyclability of the containers and packing of the products [16]. Its desired effect is the promotion of the recycling culture by providing information to consumers. This is a pilot phase project to collect information in order to continue with a larger scale outreach phase incorporating aspects of improvement.

In relation to the management of organic waste, the Ministry of the Environment has a National Strategy for Organic Waste that, during 2020, was under public consultation. The idea of this strategy is to advance from less than 1% current reuse to an overall goal of 66% in 20 years.

In August 2020, the “RCD Roadmap Circular Economy in Construction 2035” was launched and its implementation started. Construction activities create a great demand for raw materials and are a great generator of waste (35% of waste globally comes from construction). This roadmap is a multisectoral initiative that was developed between the Ministries of the Environment, Public Works and Housing that seeks to encourage and promote sustainable waste management under the Circular Economy approach [16].

The last action line of the Ministry is moving forward to achieve the Basel Convention that is related to the “Control of transboundary movements of Hazardous Waste and its Elimination”.

Lastly, in relation to the main laws that are currently in force and that have allowed progress in the generation of waste and/or in promoting a Circular Economy approach, the following can be mentioned:

(a) Law Nº 20879: In 2015 the Ministry of Transport and Telecommunications promulgated “Law 20,879” that sanctions the transportation of waste to illegal dumps [18].
(b) Law Nº 21100: In 2018 the Ministry of the Environment promulgate “Law 21100” that prohibits the delivery of plastic bags in all the national territory, thus prohibiting the delivery of plastic bags in supermarkets and in commerce in general [19]. The fight against plastic has not yet finished, there is currently a project in the Chamber of Deputies to eliminate single-use plastics such as food containers, plates, glasses and silverware.
(c) Law Nº 20920: This law set a framework for waste management, that extends producer responsibility and promotion of recycling. It is known as the REP Law and was promulgated in 2016 by the Ministry of the Environment. It establishes that the producer of “priority products” must take responsibility for the products they sell and their recovery at the end of life to prevent them from becoming waste. The “priority products” are: tires, containers and packaging, batteries, lubricating oils and electrical and electronic equipment [20].

4.2 Some examples

In Chile, more companies are everyday joining the commitment to the environment, adhering to the clean production agreement and subjecting their packaging to a certification process so that their products have an ecological label that identifies them as recyclable packaging. On the other hand, companies are driving important changes by adopting a circular economy approach. Some successful worldwide examples are the following.

4.2.1 Algramo

Algramo is a company whose purpose is to transform the habit of consumption to save the planet. They distribute products of basic necessities in bulk in neighborhood warehouses, with dispensing machines and in reusable containers, that allows a reduction in the sales price. Another line of business corresponds to the sale of products in reusable packing, which completely eliminates the packing of the products and allows a reduction in the sales price [21] (Fig. 2).

Figure 2: Algramo seeks to generate a radical change in consumption habits [21].

4.2.2 Green glass

Green Glass is a company that manufactures glasses from bottles recovered from garbage and bought directly from grassroots collectors. In Chile, at least 1.4 million glass bottles are thrown away in the garbage every day, therefore, the company contributes to the reuse of this waste and additionally contributes to job creation [22] (Fig. 3).

4.2.3 Cambiaso hermanos

Cambiaso is a family business dedicated to tea that, since the 1980s, ventured into the plastic area for packaging its own products. Over time, plastics have transformed into a business unit and they specialize in the production of cleaning bags and packaging products in general. The bags are made with recycled plastic and are biodegradable within 2 years [23] (Fig. 4).

4.3 Opportunities

Adopting a Circular Economy approach creates a series of opportunities, which are described below. First, as a country we could decouple economic development from the consumption of finite resources, which will allow us to diversify our productive matrix and hedge against future price volatilities. In this sense, a joint effort of the entire society is

Figure 3: Example of thematic glasses that Green Glass sells [22].

Figure 4: Example of bags that Cambiosa sells [23].

required to achieve public knowledge of the circular economy concept. In this way, educational entities are key actors in environmental education, research and knowledge transfer aimed at training responsible citizens. At the same time, non-governmental entities play an important role in raising awareness of this concept.

In parallel, there is a great opportunity for companies to adopt this approach. Some of the benefits that are generated are tangible benefits such as profits and savings, and others are intangibles such as recognition, reputation, innovation and collaboration [24]. Additionally, the adoption of this model is directly related to the generation of new jobs. To achieve a circular economy, companies must improve the sustainable productive capacity of the industry, where innovation is a fundamental element. Producers must rethink and redesign their products, components and the packaging in which the final product is sold, working with safe and biodegradable materials during the entire process and collaboration between companies [9].

There are materials that are considered good for circular economy because they can be transformed into raw materials, from waste to resource, some of these are:

(a) Glass: Selected, clean and ground glass allows the manufacture of glass containers exactly the same as the original ones. The manufacturing process of these recycled containers consumes less energy than the original one.
(b) Industrial oil: Used industrial oil is one of the most dangerous wastes that exists. They can be fully exploited for the manufacture of new products or as an alternative energy source
(c) Tires: Used tires, which can take more than a thousand years to disappear, form granulate for infills and as the basis for artificial grass fields and safety floors in playgrounds, as well as for the "recycled highways" of the future, silent and durable.
(d) Plastic: Plastic is a highly recyclable material.
(e) Cork: Is a natural, recyclable and renewable product. The bottle stoppers collected are crushed and the granules obtained are used to make cork products not intended for food, such as materials for construction or for the creation of objects for domestic and artistic use, following the tendency of eco-design.
(f) Aluminium: Material that can be recycled indefinitely and saves up to 95% of the energy needed to produce it from ore. Regarding the saving of polluting emissions, production processes using recycled aluminium generate only 15% of the emissions with respect to an aluminium production based on the mineral from which it comes, bauxite.

Lastly, adopting this approach allows us to transform our consumption habits. There are more and more consumers that are becoming aware of the environment and deciding to buy ecological products that do not pollute and are respectful with the environment. This transformation considers the reflection on our consumption habits and the decisions adopted when buying. In addition, the consumer internalizes the habits of separating waste (as part of the process of its preparation for recycling) and its recycling. In the particular case of organic waste, consumers begin to consider learning and implementing composting, thus preventing garbage and waste from reaching landfills.

5 CONCLUSIONS

Natural resources have always been the basis of the Chilean economy, and currently copper represents 50% of exports. Given this relevance for the country and considering that many resources are depleted, it is necessary to diversify our economy and reduce its dependence on the export of raw materials. In this way, other economic sectors can be strengthened as well as the environmental impacts related to the resource extraction can be reduced. This, added to the environmental problems that we are currently experiencing in the world, indicates the need to transit towards a circular economy approach in which we make the best use of the planet's resources while working to avoid the generation of waste. Let us remember that this concept must consider raw materials, the process and the product, so it goes beyond the simple task of waste management, since it consists of a radical transformation in production methods and in consumption habits.

In Latin America, and particularly in Chile, waste management presents a large gap in relation to the average world, where most organic waste is not composted, and still large amounts of waste are not recycled, ending in landfills or dumps, making waste management a great challenge for the country.

In Chile, in the last 10 years, legislation has advanced to reduce the environmental impact related to waste generation and promote the Circular Economy model. Currently the two main lines of work are, first, the implementation of Law Nº 20,929 (REP) that establishes the framework for waste management, extended producer responsibility and promotion of recycling, and second, advancing in a regulatory framework and other instruments that allow us to transform our economic model towards a circular economy approach. Moving towards a circular economy approach is very complex since it requires many changes which must be accompanied by advances in the country's legislation. In Chile, the regulatory framework is making progress on that front.

Everyday more companies are joining this paradigm shift, as they are facing informed consumers who have greater environmental awareness. Adhering to this change is essential for different reasons: non-renewable resources are running out, the planet is filling with garbage and ecosystems are weakening, and most of the production processes we use are highly polluting.

For all of the above reasons, all sectors and stakeholders must get involved in the circular economy approach as it generates environmental, economic and social benefits. This challenge is just beginning, and we must advance in environmental education. One must not overlook the fact that the circular economy is related to the problem of climate change, since it aims to minimize the amount of natural resources that are used to generate products, and the pollutants that are generated during their production and final waste disposal. In this way, this approach manages to reduce the threats of climate change and the degradation of the ecosystems to transit towards a more sustainable planet.

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REGIONAL RESURGENCE OF WOOL

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ABSTRACT

To sustain authenticity, a holistic approach to preserving arts, crafts, and the fabric of the place must be perpetuated integrally. This research analyzes wool as a sustainable engine for local communities in Transylvania, Romania, and a tool for its artists and creatives to interpret it through different techniques and mediums to contribute to its continued preservation and perpetuation through generations. In Transylvania, the art and craft of processing wool continue to be part of the region's heritage. In order to sustain this practice, both as the basis for the economy and the people's heritage, it is necessary to seek alternatives to engage the older craftsmen while attracting the younger generation. There must be a continuum of practice to transfer knowledge and know-how. The paper is based on a recently completed case study entitled "A Wool Journey: From Fashion Design to Art Installation". The project, which started in 2019, was financed by the Romanian Ministry of Culture and had two main objectives: to create a collection using wool as a foundation fabric for technical and material experimentation, making use of ancestral crafts and symbols from different parts of Maramureș, Transylvania, and to document the entire process of wool processing and manufacturing. The final result was revealed in the form of an art installation that highlighted this journey a journey that reinforced the importance of place. This journey started in Săpânța, home of the Merry Cemetery, a UNESCO heritage site, where the physical fabric of the place lends itself to sustaining the local crafts and craftsman. Therefore wool, perceived in Maramureș as having the same value as gold, soil, wood, and water, is attributed to new valences and focus, becoming a tool for the local community to perpetuate its heritage, necessary to its continuance.

Keywords: wool, heritage, Transylvania, Maramureș, crafts, craftsman, craftsmanship, cultural site, habitat.

1 INTRODUCTION

Living in an age where traditions are starting to fade away and younger generations turn more and more to new opportunities, in Romania, and precisely in Transylvania, entire communities are striving to keep true to their ancestral crafts and customs, by perpetuating them not only locally, but globally as well. Although, in these areas, traditions and customs are part of everyday life, well preserved by generations, technology hasn't totally replaced the ancestral practices, boasting a civilization that today proudly displays a bucolic countryside carved in wood. Some people would call it a "cultural miracle", passed through from generation to generation due to the immense love and dedication people have to their crafts.

Ancestral practices have been passed from generation to generation, such examples include beading, weaving, pottery making, wood carving, embroidery, knitting or crochet, wool processing being of tremendous importance, especially when discussing the region of Transylvania, with a wide mountain landscape and lower temperatures than the South and East of the country.

Romanian symbolism associates wool with prosperity, wealth, and fecundity; wool is the symbol of sun and gold, it is more likely about spirituality than materiality: wool signifies purity and truth. In addition, wool was one of the first fibers available for humans, serving as a primary necessity for protecting the body.

As Szabó mentioned in his book "Wool Story", for the Romanian villagers from Maramureș county (in Transylvania), wool processing was indeed more important than

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going to war, because “while war was killing people, wool was saving them” [1]. Thus, this material has ancestral ties with human evolution, having significant importance globally, mostly in areas with wider mountain landscapes and mild climate.

Sheep and sheep flocks have always been an integral part of the Transylvanian landscape, dispersed around its fields, in a unique interconnection. The land in this area has never failed to loyally and tacitly give a supporting ground, by simply existing, over 3 million hectares covered in rich grass, good for grazing.

Having all the means for successful development of the wool sector in the rural area, it is here where this precious material found its utility, local craftsman or small manufacturers taking it over to generations to come, contributing to its preservation.

Documenting the processes encountered in wool processing and wool crafts, it is of major importance not only for history and social fields, but a continuous source of information, social and economic purposes, and future sustainable development. Moreover, it is an area that could very well represent a strong foundation for economic and touristic development.

“Beyond the story, it is a reality that wool has the same value as gold, soil, wood, and water. Even 29 varieties of seeds, carried by the tail of a ram from one side of the world to another, as biologists say, could save a lot of species of plants and grow biodiversity. So, wool can protect plants and people” [1].

The aim of this research is to highlight the interconnectivity between the craftsman, the craft, and the environment towards a sustainable presence and operation. Cultural heritage, including cultural heritage sites, as well as folklore and archaeological sites and “lived in” museums represent an important part of the whole, each piece completes the other. In order to preserve this interdependency, which stands as the starting point, the sanctuary for local craftsmen and communities, it has to be integrated within the contemporary comfort, as well as discussed and presented to the world. This will not only provide awareness, but also exposure, attracting more lucrative opportunities and sustained development.

2 METHODOLOGY

This research takes a qualitative approach, to investigate non-numeric data, concerning ontological points of cultural heritage/community/local habitat in Maramureș, Romania. It investigates the role of crafts as a sustainable engine for local communities and suggests measures to be taken considering their preservation for future generations. This research aims to present the reality of the place through verified hypotheses, as such this has been achieved in two parts: an archival research of the historical material presented and a case study of the local communities in Maramureș, Romania. The case study had a documentation part (starting from the origins, including sites visits, working and interviewing local craftsmen). The outcome of the documentation was then integrated into contemporary designs and applications. The final results were presented in the form of an exhibition. Combining both the argumentation and a creative, practical solution was considered as the best way to achieve the desired outcome.

3 WOOL IN TRANSYLVANIA

In Transylvania, the mild climate is favorable for the more native type of sheep, “Țurcana” and “Țigaie”, which are proven to be less pretentious, resistant, and adaptable to the environment, says Florica Zaharia in her book, Traditional Textiles from Transylvania [2]. Both kinds of sheep are local races, with moderate wool production capacity, being raised for the wool, meat, and skin. The “Țurcana” type of sheep produces a thick, straight, and long fiber that is generally used for weaving the items serving as interior decoration or heavy blankets. A good sheep could produce up to 3 kilograms of wool during a year, producing up to half the size of inferior quality ones. The color of the wool commonly encountered is white, but occasionally black, brown, or grey can also be found.

Until the mid-20th century, each family had between 5 to 20 sheep, a number that was meant to cover the necessities exclusively for clothing and domestic textiles/objects and meat, the lamb making the traditions for the Easter holiday in Romania. Wool processing was and continues to be a yearly process within a very precise and ongoing circle. Besides each household's wool reserve, there were herds of sheep maintained for wool processing and sale. The complexity of the technological process of wool processing, common in the entire region of Transylvania, did not change over the years and continues in the present, keeping almost the same format.

At the beginning of the 20th century, due to the origination of teasel and spun tools, these operations became partially automatic. The sequence of stages took place annually, in a rhythm that follows the seasons, starting in spring with the wool shearing (Fig. 1) and continuing with its cleaning/washing/scouring in summer (when the temperatures reach 22–25°Celsius and humidity around 10–15%, as seen in Fig. 2, then carding, sorting, combing and spinning in autumn, followed by weaving and knitting in late autumn and during the cold winters. At present, the processing is done according to the needs of each individual or household in a very sustainable manner.

4 WOOL DYEING

Up to around the beginning of the 20th century, traditional textiles dyed exclusively using natural resources, as such, black, brown, and grey, were primarily obtained from "colored" animals and strong primer colors (like red, yellow, or blue) from wild plants growing around the house/yard, or fields, available in the same geographical area. The immense natural richness of Transylvania made these practices easier, giving variety as well as a strong foundation for wool-based crafts/or craftsmanship. Dyeing is a craft, like all other crafts in the region, that has been transmitted from generation to generation, where

Figure 1: Unwashed wool. *(Source: Author.)*

Figure 2: Washed and washing wool. *(Source: Author.)*

mastering them requires extensive and rigorous practice that the local craftsman understood. Nothing was left to chance; rather, every step is researched, practiced, and assimilated in order to be passed on.

Traditional textiles are perceived as true examples of artistic creation and mastership, as their aesthetic appearance can change with the manufacturing and finishes techniques chosen to be used. However, the techniques used for the manufacturing and finishes, as well as the patterns, colors, or textures, are all coming together in a true artistic expression, following precise guidelines that have been in place for generations.

5 WOOL CRAFTS

Preserving ancestral crafts is not only the fundament of a nation but the starting point for contemporary design. One's creative path cannot stand for authenticity and longevity forgetting its culture's fundament. The craftsmen from Maramureș taught us all the secrets learned from their parents and grandparents. What comes from their hands is pure magic, a real work of art created with love, passion and patience. At the same time, it is based on precise knowledge, know-how and experience.

Maramureș, Transylvania is the dream place where amongst an extremely rich landscape, with amazing nature and natural resources, rural areas are fortunate to host talented craftsmen that kept traditions alive through generations. It is true that with years and new industrial developments, keeping ancestral practices alive has proven to be more and increasingly challenging. Nevertheless, one can still encounter practices like spinning (Figs 3–5), weaving, felting, knitting, crochet practice, embroidery, pottery, wool processing, and so on, entirely practiced in the craftsman's household (either inside the house, courtyard, or built-in workshops). And every crafted item that comes out of these magic hands has a particular energy that cannot be repeated twice identically; it is the energy associated to the unschooled rhythm, the one linked to the nature; nothing is imposed but left for self-expression. Creating a suitable habitat, that follows the natural rhythm of nature and community, is it part of a traditional maker lifestyle, one cannot create without the foundation and support of the environment. One such creator cannot subsist outside the personal habitat, part of a wider circle.

Figure 3: Wool spindle. *(Source: Iulian Nan.)*

Figure 4: Wool spindle. *(Photo Credit: Iulian Nan.)*

Figure 5: Wool processing. *(Source: Iulian Nan.)*

6 LOCAL HERITAGE IN CONTINUUM

Working with craftsman from Maramureș, Transylvania, has been the motivation behind this project over a decade ago. This journey of authenticity, connecting to our ancestors and rediscover their crafts, in order to acknowledge, understand and pass on to future generations, is work in progress. Born and raised in this region, I became familiar with the local crafts at an early age and turned it into a main interest to contribute to preserving and conveying to the world, the unicity traditional culture has to offer.

Maramureș is divided into "four countries", the Historic, Lăpuș, Chioar and Codru, each having different characteristics of its traditional costumes, habits, nevertheless, mostly keeping the same practices and techniques, as well as fabrics. Differences are noticeable in the patterns, colours, items layout, and so on. Traditional costumes reflect codes, shapes, and meanings that are common to an entire social group, expressing the communitarian function of traditional art [3]. Consequently, each community has its own particularities when discussing fabric attributes (materiality, patterns, design), which are different from community to community, even if common regional features can be found, says Ana Iuga in her paper, "Contemporary Traditional Clothing in Maramureș" [5].

As such, clothes help people differentiate from each other amongst different communities, and people took extreme pride over this (such examples can be seen in Fig. 6). The difference, though, is not only visible when reflecting on traditional costumes, but also customs, architecture, food, and others, contributing to a diversity well embraced since ancestral times.

Figure 6: Traditional peasant costume from historic maramureș and traditional objects. *(Source: Author.)*

7 A WOOL JOURNEY – A CASE STUDY

"A Wool Journey: from Fashion Design to Art Installation" represents a project [6] initiated in 2019, in order to continue my commitment to promoting Romanian cultural heritage and its authentic design. The goal of the project was to connect with public interested in the meeting of traditions, fashion and textile design, and the cultural heritage of our times.

Having started this journey a long time ago, the desire to connect to my ancestors came as an inherent fact while growing up in the region. I, therefore, believe that preserving ancestral crafts is not only the fundament of a nation but the starting point for contemporary design. One’s creative path cannot stand for authenticity and longevity while forgetting the fundament of its culture.

This project presents the result of a conscious research, visually documented and transformed into a textile installation and exhibition. It had two main objectives: to create a collection using natural fabrics as wool, adding traditional motifs and inspiration from different parts of Romania, but mostly focused on Maramureș (Transylvania), and to document the entire process of processing wool (examples in Figs 7 and 8), creating an art installation that follows this journey and presented in the form of an exhibition. The resulting designs were primarily based on wool, blending traditions, and contemporary design in a personal way. I have been working closely with craftsmen that I grew up with and have had a significant contribution in shaping not only my creative path but also personal identity.

8 SUSTAINING INDUSTRIAL CULTURAL HERITAGE SITES

Craftsmanship plays a significant role in Romania, particularly in Transylvania, but crafts are an integral part of a wider context; they are part of a whole, a system, inside which each element is interconnected, and one could not survive and strive without the other, or at least not in harmony. In other words, we discuss the inevitable balance and interconnection between the three elements, the craftsman, the craft, and the environment in which this takes place. The entire communion follows a natural rhythm; a missing piece leads to disruption which sometimes can play a significant role. As such, cultural heritage in the area is quite complex. Therefore, heritage elements such as cultural heritage sites, as well as folklore and archaeological sites and museums, cannot be left unvoiced. They are an important part of the whole, where each piece completes the other.

The world order is uniquely perceived in a Transylvanian village through abundant and practiced cultural heritage. Surprisingly, this begins with its architecture as the human

Figure 7: Wool yarns. *(Source: Iulian Nan.)*

Figure 8: Wool yarns. *(Source: Iulian Nan.)*

establishment within its surroundings emerge in perfect harmony; each piece of the system is an extension into the other. Consequently, the local villager simultaneously played the architect role, master builder, and decorator of his own space, making a suitable habitat for living and mostly for the creation process that has an important role in their lives. This habitat stands as the starting point, as well as central core and the place of security, the shelter, the sanctuary. In general, this space has mostly perceived as having a feminine valency, as it was a woman's space, while the man was mostly out in the forests and mountains, supporting the household. The interior of traditional houses has a simple plan, with two or three rooms, evolving to more complex structures towards the late 18th century. Being planned for a pragmatic use, more than symbolic or esthetic purposes, the interior incorporates elements of contemporary comfort living amongst heritage pieces, as furniture items, textiles, soft furnishings in the form of woven carpets, rugs, embroidered towels and pottery, heirloom furniture and so on (examples of such an interior in Fig. 9). These are items that have been used with fulfilling results on a continuum bases in a household, and therefore have not been preserved as only heritage pieces but integrated into daily life for generations.

As a result of this fusion, the interior and the exterior space are not separated. A semi-sheltered veranda which lines the façade of the house, called "prispa" (as seen in Fig. 10), is the connecting element that has a function on its own, as well as representing a decorative touch. As part of a strong community, houses are connected amongst each other, being separated by gardens and orchards, or they are scattered on the hills.

Another architectural element that local villagers focuses on is the gate. This represents a passage between the community and the family. It is an example of craft on its own. Usually, it is crafted by local craftsmen, and it hosts an array of symbols dating from thousands of years, each gate being a unique individual work of art, guarding the sanctuary of the home within. As mentioned, the gates are made from wood, true artistic examples, wood is associated with Maramureș and Transylvania since early times. As Takács stated in her publication [7], the definition of cultural heritage is always shifting, followed by an impact on cultural cooperation practices.

Figure 9: Living among crafts. *(Source: Author.)*

Figure 10: Verandas as workshops. *(Source: Author.)*

The definition used by UNESCO since the 1989 Recommendation on the Safeguarding of Traditional Culture and Folklore (http://portal.unesco.org/en) is as follows: "Folklore (or traditional and popular culture) is the totality of tradition-based creations of a cultural community, expressed by a group or individuals and recognized as reflecting the expectations of a community in so far as they reflect its cultural and social identity; its standards and values are transmitted orally, by imitation or by other means. Its forms are, among others, language, literature, music, dance, games, mythology, rituals, customs, handicrafts, architecture and other arts".

Sustained through an interdependence between local industries and craftsmen, the latter assemble their own utter habitat in perfect harmony with nature and blend within the community at large, transmitting further the memory of the place. Traditional practices are therefore supported by "living in" museums, true examples of craftsmanship and cultural heritage, that prominent figures like Maria Zapca (weaver and textile master), Daniel Leș (potter) or Virginia Linul (textiles master) conduct their entire life and activity within and avail to the world an authentic way of living and making that have been practiced by generations. These are part of the cultural fabric of Transylvania, a visual rural landscape that should be preserved by generations to come, not only in terms of ancestral practices but also for sustainable living solutions that have been proven to be effective over time. Showing the results to the world, means sustaining a small community in the 21st century.

9 CONCLUSIONS

This unique land is an authentic ethnographic paradise, traditional costumes that offers true examples of craftsmanship, powerful symbolic motifs, cultural heritage sites and unique habitat solutions, a bonded community powered by spirituality and wisdom, living by harmonious guidelines.

The interdependence of nature and people has created a remarkable atmosphere, an identity of mood that permeates local heritage diversity. Transylvanians attach significance to buildings and to places around the region. The reinforced heritage has played a distinctive role in helping to define the values of society. People around the region take great pride in their unique practices and customs. Do not hesitate to show it to the world, reflecting the rich heritage continued by generations, the quality of life, and the uniqueness of society. The architecture, creative direction, custom, and practices are an integral part of their cultural identity, in which they conduct their lives.

Above all, Transylvania is a land that stands as a unique historical and cultural experience, reinforced by its people who have continuously lived and worked here, have been part of the landscape, and built their own perfect habitat in harmony with nature and community. Nothing is left aside, and everything is integrated, everything finds its place here and has a contribution in enhancing the valences of this amazing place. It is a lifestyle that takes it beyond space and time, and the journey of wool is a means to authentic emotional storytelling.

Consequently, the aim is to continue to preserve local crafts through the production of diverse and actual cultural projects, as well as documenting and implementing the results within relevant and meaningful contemporary practices. To encourage this authentic way of living, immerse in it to make it viable with the contemporary approaches, the following recommendations are inferred:

- The continuous adoption of authentic and traditional crafts as a means for modern inspiration, sustainable local economies, and promotion of living cultural heritage sites.
- Incorporating ancestral crafts into contemporary designs to ensure continuity of both and local aesthetics.
- Allow local craftsmen to utilize existing cultural heritage sites and traditional locations to maintain authenticity or practice and place.
- Discuss similar case studies within international frameworks to exchange know-how and best practices.

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EVALUATING GLOBAL MUNICIPAL SOLID WASTE MANAGEMENT EFFICIENCY FROM A CIRCULAR ECONOMY POINT OF VIEW

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ABSTRACT
The Circular Economy (CE) principles recently set out by the European Union (EU) include additional guidelines for municipal solid waste (MSW) management. More detailed information about material streams must be generated and managed so that the entire system can be monitored from a new perspective. Suitable indicators (and indices from them) must be made readily available, so that they can be used to assess the efficiency that the European Union expects from the sector. This article presents a preliminary critical analysis of the literature and identifies that indicators and indices should be considered to facilitate the evaluation of MSW management under a CE vision. The analysis is combined with a discussion of the situation in various countries, to provide an overview of attempts to implement CE strategies worldwide. Special waste is not dealt with in this article as EU updated the vision of waste management starting from the MSW sector, on which this work is focused.
Keywords: sustainability, circular economy, recycling, integrated waste management, selective collection, quality index.

1 INTRODUCTION

Municipal solid waste (MSW) management in the European Union (EU) is based on well-known principles that include recycling aimed to material recovery as a strategic option [1]. This presents major challenges to most cities in the modern world [2]–[4]. In many countries, especially in developing countries and emerging economies, MSW management models are generally insufficient, with incomplete waste collection coverage and low rates of source-separation and recovery of waste streams, which end up in landfills or dumps [5]–[10]. These final destination sites can cause significant environmental and health impacts: fugitive emissions of biogas play a role in the greenhouse gas balances (globally) and in the odour impact (locally); the leachate generated through waste leaching is difficult to treat; waste pickers working on informal sites inhale pollutants. Thus, improved solid waste management strategies are required worldwide, because this problem will be aggravated in the coming years due to the increased production of MSW. Sustainable development goals (SDGs) – the blueprint of relevant global issues adopted by the UN, has a strong connection with efficient MSW management, and the transition towards Circular Economy can be the major principle for implementation. The CE principles, recently drafted by the EU, address this problem, and give specific attention to material recovery and reuse [11]–[14]. In addition to recyclable materials, the transformation of waste with high calorific value into energy is an option identified in the new EU Green Deal, but may at first sight appear to be controversial; in reality, thermochemical waste-to-energy (WtE) plants allow for energy recovery and their environmental impact can be managed

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adequately only through enhanced expertise. What is clear is that, through energy recovery, landfilling can be reduced significantly not only in mass but also in volume [15]–[17]. The environmental impact cannot be compared to extreme source separation methods (e.g., metals) because of the complex behaviour of some substances in the thermal process (e.g., the percentage of metals in the ash and the stack). However, processing source separated waste needs optimized approaches for avoiding local impact too (an example is composting). The advantages of CE from this perspective therefore require specific analysis.

Fig. 1 illustrates the waste management hierarchy from the most desirable (prevention) to the least desirable (disposal) options. Prevention is the most effective way of dealing with waste as it reduces the amount generated in the first place, thus reducing the impact on the environment and the cost, as a lower amount of waste needs managing.

Figure 1: Municipal solid waste management hierarchy.

Disposal does not extract any value and includes landfill and incineration, which offer no energy recovery in their most simplified versions. It is at the bottom of the hierarchy because the materials become useless and have no value when they are sent to landfill (when no pre-treatment is implemented), and so ideally this would only be a last option. Unfortunately, worldwide, many towns and cities are not able to follow the waste hierarchy and the only option they consider is disposal. Generally, specifically in low-income countries, most of the waste is never collected (it is dumped or burned) and even when it is, most of it is taken to landfill [18]. However, these locations are still expected to move towards a CE management approach. The transition towards a CE can be encouraged through a combination of regulations and incentives [19].

Concerns have been raised about the adequacy of the methodology currently used to analyse the composition of residual MSW, which is the waste stream containing unsorted materials. The presence of recyclable materials that have not been separated at the source must be assessed. For example, in the Italian Trentino Province, where such analyses are conducted, although 29 fractions are used in the characterization, modifications are necessary due to the requirements arising from CE principles [20]. In general, the following classes of materials among the residual MSW should constitute the minimum level of analysis:

- Plastics: plastic packaging waste, PET bottles and HDPE bottles.
- Cellulose-based items: paper packaging waste and similar.
- Glass: glass packaging waste.

- Aluminium: aluminium packaging waste, similar classes and aluminium packaging accessories.
- Steel: steel packaging waste and similar classes.
- The organic proportion of MSW (OFMSW): the percentage (weight) of organic material among the residual MSW should be assessed, both for the OFMSW and for green waste.

Thus, the kind of information that should be collected represents the amount and quality of the valuable material present in the residual MSW. Concerning the characteristics of the above presented list of classes of materials, the sector of MSW management evolved strongly: in order to generate a detailed characterization of residual MSW aimed to check the CE potentialities in the related territory, in some cases the list has been expanded up to more than 20 fractions.

The availability in the literature of indicators and indices that are suitable for considering the EU vision of CE is another issue that must be addressed. This article provides initial comments about the conventional indicators and indices available in MSW management, and considerations about the characteristics that these indices should have to address the new requirements in strong connection with the goal 12 of SGDs. Few studies address the strategies that can be implemented to monitor and improve MSW management from a CE perspective. Thus, we analyse the available indicators and indices and propose those that are suitable for assessing the effectiveness of CE strategies in MSW management. In addition, six international case studies are reviewed to illustrate the situation in different countries and reveal novel options that comply with CE principles.

2 CONSIDERATIONS ON THE INDICATORS AND INDICES FOR MSW MANAGEMENT IN THE LITERATURE

Various indicators are available in the MSW management field, which can be used to describe aspects of MSW management. Indicators for the evaluation of MSW collection systems have been proposed, and focus on performance in terms of distance, time and fuel consumption, vehicle and personnel workload, and costs [21]–[24]. In terms of MSW source separation, quantity and quality efficiency indicators for the various classes have been used in many contexts [25]–[29] and studies comparing the recycling processes for the separated materials have been conducted using Life Cycle Assessment (LCA) tools [30]–[32]. All of the indicators currently available in the literature focus on processing information about the various material flows coming from selective collection (SC), and are aimed at the constant improvement of integrated waste management scenarios. However, only a few studies have considered what improvements could be implemented in the management of residual MSW with respect to the CE principles.

3 INDICATORS AND INDICES FOR EVALUATION OF CE EFFECTIVENESS

The brief analysis reported above indicates that an additional effort must be made to obtain information about:

- The efficiency of SC for each material of interest.
- The quality at the source of the separated materials.
- The economic and environmental sustainability of the waste collection system and of the treatments available for the separated sources.
- The destination of the residues in the adopted treatments.

- Carbon capture and sequestration (CCS) technologies applied to the off gas from energy recovery treatments.
- The development of reuse practices.

The indicators and indices that should be developed (or confirmed) must consider the above listed characteristics. In particular, WtE is not excluded from the scenarios managed according to CE principles: new indicators should acknowledge the implementation of CE practices in residual MSW energy recovery processes regarding bottom ash vitrification and reuse, carbon capture technologies applied to off gas to extract CO_2 as an industrial product, exploitation of off gas from energy recovery processes for district heating and metal recovery from slag.

A selective collection quality index (SCQI) has recently been proposed in the international literature to address the CE vision that includes collection efficiency (and, for each fraction, the type of collection), quality of the source of the separated materials, the presence of a tariff, the influence of tourism [33]. That proposal originated from an Italian case-study. A group of proposed indicators were applied to a specific period to assess the potential of the index. Quantitative results of this case study were obtained, based on the sub-parameters that characterize the proposed index. Decision-makers can then focus on a specific territory and identify the critical SC issues that must be addressed [33]. The SCQI aims at making available an integrated tool that can be used in other areas in Italy and abroad, within the CE context. This limitation depends on the structure of MSW management that is taken into account as a background of the index.

The percentage of thermochemically treated waste with a lower heating value (LHV) higher than a certain threshold, e.g. LHV > 13 MJ/kg, and sent to energy recovery options, can be used as an indicator of the energy recovery management performance of the system. The waste to be considered should be both the one directly used (residual MSW) and the one indirectly used (Solid Recovered Fuel, or SRF) as the input for thermochemical plants. The cited value has been assumed as a decisional threshold in Italy for many years. Indeed, for a long period, waste with LHV > 13 MJ/kg had to be sent to energy recovery plants instead to landfills. The residual MSW stream sent to thermochemical plants for energy recovery could be differentiated into sub-streams, depending on the final destination and the pre-treatment adopted (if any). Checking if the threshold value proposed for addressing the energy strategies in the waste sector is under consideration would be strategic in both cases. Administrations that only send waste with LHV > 13 MJ/kg to thermochemical plants should get a 100% score in this evaluation. Referring to the MSW directly or indirectly used as an input in thermochemical plants, the percentage of waste with recovered ash (bottom ash and fly-ash) could be another indicator. Bottom ash can potentially be used in the cement industry after treatment (a minimal metal recovery can also be performed by an integrated process). Fly-ash can potentially be vitrified and used as a secondary product. Plants where an integrated vitrification is performed (e.g., gasification at a high temperature, including cases of indirect combustion with a vitrifying chamber) should be given a 100% score for this indicator. Integrating these concepts can provide an index that is suitable for analysing the role of WtE in the frame of a CE approach.

In terms of SC of food waste, one CE indicator could be the percentage of this stream sent to anaerobic digestion (AD), which gives two final products: biogas and compost. This is preferable to direct composting, since AD allows for the production of methane, generates less odours and is characterized by higher acceptability by the local population. The biomethane extracted from biogas should guarantee a higher score. If biomethane is produced from 100% of the food waste available in the territory, a 100% score should be

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given for this indicator. Scenarios with biogas could be differentiated by considering the application of a 60% coefficient to reduce the value of the indicator (60% can be assumed as the percentage of methane in the biogas). For example, if food waste has a SC rate of 80%, and 50% is sent to AD where biogas (and not biomethane) is produced, the indicator would have the following values: 80% · 50% · 60% = 0.24. Integrating these indicators can provide a CE index. In case of the extraction of CO_2 from the off gas that remains after biogas upgrading, the scenario becomes more complex. Here, an aspect to be focused on is the fate of the CO_2: it can be either a product or a compound to be sequestrated. This opportunity (extraction of CO_2) is not yet widely adopted; however, in order to avoid future recalibration of the indicators and indexes, an overall index could already include this strategy.

Developed and developing countries currently apply different MSW management approaches. The MSW management model for developed countries is focused on the hierarchy of waste management, as reported in Fig. 1 [1]. In developing countries, the model is generally insufficient with incomplete waste collection coverage, and low levels of source-separation and recovery rates of waste, which thus ends up combined and sent to landfills or dumps. Table 1, summarizes the case studies described below for MSW management worldwide.

Table 1: MSW management in the six countries analysed.

Case study	Main fraction in MSW	Emerging/characterising technology	Reference
Iran	Organic material	Composting process	[34]
China	Food waste	Incineration	[35], [36]
India	Food and inert MSW	Landfills	[37]
Czech Republic	Municipal waste landfill	Composting process	[38]
England	Household waste, food and textile separation waste	Anaerobic digestion	[39]
Russia	Paper	Recycling and landfill	[40]

3.1 Iran

MSW management was officially implemented in Iran only in 2004 when the government established the first regulation of solid waste, which became necessary due to the rapid population growth in urban areas [34]. Iran has a per capita MSW production of 272 kg per year, which has remained almost constant over the past decade. The absence of a specific programme to get a reduction of the production of MSW means that SC is only conducted in some urban areas and citizens lack a proper training in waste separation. The SC collection rate is thus lower than 8% [34]. Considering the high content of food waste in the residual MSW (more than 68%) [34], the absence of defined strategies for recycling may lead to significant emissions of greenhouse gases from the waste sector. Esmaeilizadeh et al. [34] proposed a set of strategies that can help Iran take action towards the implementation of CE principles, including investing in education to raise the awareness of the population about the importance of a proper waste management strategy and SC procedures, making waste hierarchy the basic principle for future waste management programmes, involving experts in drafting waste management plans and make strategic decisions, and considering cost-benefit analyses during the decision-making processes.

3.2 China

China has made efforts to improve the quality of its MSW management system over the last decades. However, recycling is not formally recognized (yet) as an important contributor to MSW management in China. Informal recycling practices are conducted, mainly by waste pickers. The food waste proportion collected in China accounts for about 60% of the generated MSW [35]. According to Liu et al. [35], the environmental performance of the Chinese MSW management system could be maximized if a minimum of between 20% and 30% of food waste were collected separately and treated in AD or composting facilities, and if the products of anaerobic or aerobic treatments were used in agriculture. Incineration is proposed to be the best process for dealing with residual MSW [35], in spite of its low energy content. Of course, the high population density that characterizes many cities makes incineration more appealing. The risk consists in the possibility that building incinerators before optimizing SC could make citizens less interested in source separation. Shanghai was the first Chinese city to implement SC and a dedicated regulation [36]. According to Xiao et al. [36], the economic policies developed by the local administration will have a major impact on the local management of MSW in the future. The Shanghai model may also positively influence the MSW management of other cities in China and worldwide. The food waste percentage in the residual MSW makes it suitable for a biodrying treatment aimed to SRF production. SRF could be used in cement kilns in order to partially substitute coal with advantages also in terms of CO_2 emissions. Indeed, since a fraction of residual MSW is discarded biomass, also SRF is partially renewable. Moreover, the low percentage of SC presently reached makes interesting the option of post-treatment of biodried material for extraction of glass, metals, inert material to be sent into the recycling sector, according to the principles of CE. The scientific literature demonstrates that China is contributing to study the viability of this process, this approach cannot be considered as a characteristic of the Chinese MSW sector yet.

3.3 India

Urban areas in India are characterized by high population densities and high expansion rates that lead to several environmental problems, including the management of MSW [37]. Zooming on a region, according to local estimations, about 557,000 t/y of MSW are dumped in public areas in Delhi. A large proportion of the illegally dumped MSW includes biodegradable MSW (425,000 t/y), paper and cardboard (30,000 t/y) and plastics (38,000 t/y). High quantities of inert MSW (70–95%) and food waste (80%) were identified in various neighbourhoods of the city and represent different socio-economic conditions [37]. Nagpure [37] developed a model to track the characteristics of illegally dumped MSW in selected neighbourhoods (e.g., the spatial frequency of dumping, the waste mass and composition). A comparison of the MSW generated annually in neighbourhoods and that illegally dumped indicates that only 67% of the MSW generated in poor neighbourhoods is sent to landfills, compared to 97–99% in higher income neighbourhoods. Besides the dumping problem, India is known for a significant use of anaerobic digesters at village scale. The technology in use is simplified, but biogas is exploited e.g. for the kitchen of local schools. This energy recovery strategy goes in parallel with material recovery because the digestate can be applied to agriculture. From this point of view, CE appeared in India before the recent perspectives set by EU.

3.4 Czech Republic

In Czech Republic, composting is an important part of the CE implementation and contributes to closing the waste management cycle thanks to the characteristics of its final product. In the case study described by Vaverková et al. [38], the process of composting of food waste is conducted on the surface of a reclaimed landfill site. However, bad composting design or inappropriate management of the composting process could lead to the growth of invasive and undesired plant species. Through a monitoring campaign, 88 plant species were found in various phases of composting. Specific expedients such as the occurrence of the thermophilic phase and sufficient moisture can help preventing the development of invasive weeds. The composting of food waste produced locally should also be considered to avoid the possible presence of the seeds of allochthonous species. Apart from these specific problems, often potential, composting is seen favourably in term of CE in spite of the difficulties of local acceptance. Such difficulties are related to the generation of odours that cannot be easily managed in large plants.

3.5 England

In England, MSW comprises both household waste and waste generated by industry, commercial activities and institutional bodies, provided that the characteristics of the waste produced in non-household contexts are similar to household waste. However, in Nottingham [39] only household waste is regarded as MSW. The authors proposed five indicators that consider the waste management hierarchy: the per capita waste generation, the recycling rate, the SC rate, the recovery rate and the rate of landfilling. Waste prevention ranks highest on the waste management hierarchy and is regarded as the most desirable option for diverting waste from landfill: less waste, less problems. An alternative scenario is proposed that considers food waste and textile separation at the source and the use of AD to treat separately collected organic waste [39].

3.6 Russia

Open landfills were for many years the main option for waste management in Russia, but a large-scale reform of waste management is currently being implemented. The problems of managing existing landfills and dumps are being addressed, along with the optimization of management systems for newly generated waste streams, particularly at the collection stage, which will increase the level of processing. The licensing of waste operators has also been introduced, which will enable the best possible technological options to be chosen when planning solid waste management schemes [40]. Another important development is the introduction of renewable materials and technologies into enterprises, in which a transition to circular business models could be implemented by considering CE principles [41]. Ecological regulations have been introduced, and a model of extended producer responsibility has been developed based on the positive experiences of European countries [40], [42]. The identification of realistic scenarios is important and requires environmental and economic assessments. In a study in Irkutsk [43], an environmentally optimal scenario for waste management has been identified that includes the separate collection and processing of recyclable materials in combination with the preliminary aerobic mechanical and biological treatment of residual waste before disposal, but this scenario is not

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economically viable in real conditions. Energy recovery from waste is the most important factor in waste management in Russia, so it is important to investigate different waste flow characteristics [44]. The Russian Industrial development strategy for the processing, treatment and disposal of industrial waste and MSW for the period up to 2030 has defined one of the main CE resource-oriented indicator – the level of substitution (in percentage) of non-renewable natural resources for recycled ones for application in national economics, thus characterizing the scope of 3R (reduce-reuse-recycle) principle in the country [45]. Specific indicators, measuring the share (or rate) of achieved success towards CE, are considered to be the most valuable and all-purpose instrument for the CE ideology transition as it was mentioned by Kiselev et al. [46] for sewage sludge, but relevant for MSW.

The separate collection of waste has not been fully implemented in Russia, so solutions aimed at obtaining useful products and energy from unsorted organic waste deserve attention. In Paukov et al. [47] the processing of organic unsorted solid waste is proposed by coking them together with oil residues to obtain liquid oil products. Such an approach would enable organic MSW (waste tires, plastic, etc.) to be processed in oil refineries instead of building specialized waste processing plants. The region of Sverdlovskaya Oblast has been recently analysed from the perspective of CE strategies. Although the recovery of materials from MSW was lower than 15% before 2017 [48], this region is considering CE, and involves the contribution of the university sector [49].

Training is extremely important and is a priority in the context of waste management reform, as production and consumption waste management is a very specific area that requires interdisciplinary knowledge. The education system must also quickly respond to the demands of economic development and the prospect of a transition to a new “circular” model. The approach to learning therefore urgently requires changing. Experiences of implementing educational programs focused on waste management are currently limited in Russia, and this issue should be addressed at the regional level. Universities can educate future managers, define new management approaches, develop new technologies for recycling/recovery, and disseminate the principles of CE through the student community.

4 CONCLUSIONS

The majority of the indicators available focus on the valuable sources derived from the separate collection systems. These indicators are useful for assessing a particular system or process, but to put things in perspective and to identify better methods for increasing sustainability more broadly, improvements are required. Specifically, the characteristics of the indicators and indices should consider CE practices, and new indicators should be developed, which focus for example on residual MSW analyses, treatment residues valorisation, reuse practices, CCS technologies, green energy production (including biofuels) and sustainability of the MSW management system as a whole. A problem of the adoption of these indicators in low-income regions is related to the incomplete collection of waste and, more in general, to the absence of a tradition of data generation in the waste management sector. Reliable data generation is compulsory to take advantage of the potential of the indicators and indices.

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SUSTAINABLE DESIGN THINKING AND SOCIAL INNOVATION FOR BEATING BARRIERS TO CIRCULAR ECONOMY

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ABSTRACT
Circular economy is a complex context through the viewpoint of sustainability, design thinking and innovation with environmental, economic, and social dimensions. In this respect, circular economy is part of the crucial components for sustainable development by transforming the culture through design thinking and social innovation whether imposed from the top or initiated at the bottom. According to the sustainable design thinking approach, achieving successful solutions for innovation depends on understanding the barriers and trying to remove them as much as possible. Circular economy and social innovation mainly try to integrate economic activity with environmental, social, and physical well-being by bringing out ideas for transition of cities. In this respect, design is at the heart of circular economy which helps to close resource loops to from linear to circular by integrating circular economy concerns earlier in the design process for sustainable and long-term solutions. This paper mainly considers the theoretical framework and focuses on the circular economy regarding sustainable design thinking and social innovation. In addition, a workshop conducted to bring decision-makers, designers and stakeholders together to focus on how to create a new way of thinking for beating barriers through circular design. The discussions and results of the workshop also presented to help to create sustainable solutions for cities.
Keywords: circular economy, sustainability, sustainable design thinking, social innovation.

1 INTRODUCTION

Circular economy is one of the three pillars of sustainability where transforming the culture through sustainable design thinking and social innovation are crucial for this process. It has a vital role to play for sustainable development of cities whether imposed from the top or initiated at the bottom. Circular economy has a complex context of solution through the viewpoint of sustainability, design thinking and innovation with a perspective built on environmental, economic, and social dimensions. It is a greater way of handling the obstacles and producing solutions with an interdisciplinary approach. In this respect, design is at the heart of circular economy which creates resource loops to move from a linear one to a circular.

Circular economy mainly tries to integrate economic activity with environmental and social well-being by creating new ideas for transition of cities and to create space for bringing issues and related actors together in practice and theory. The circular economy concept emerges from 1985 onward and it has roots in environmental economics [1] where the evolution in environmental awareness derived from this concept. Circular economy is about sustainable development no matter how it was initiated from the top or at the bottom. In this respect, design has a huge impact on circular economy in many aspects considering the whole process. As suggested by Bocken et al. [2] a list of design strategies exist to close resource loops to move from a linear to a circular economy where they are integrated earlier in the design process. Ellen MacArthur Foundation [3] emphasizes that circular economy mainly defined as an industrial system, which considers the end-of-life concept through the use of renewable energy and finally aims for zero waste through design. Prendeville et al. [4] focuses on circular cities and state that although the governments and policymakers

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were willing to include circular economy in their duties, they were not clear about the meaning of a circular city when it comes to practice.

The circular city is mainly defined as a city that implements circular economy principles collaborating with urban stakeholders where design can play an important role to develop environmentally friendly products and services of the city like buildings, infrastructure, and landfills [5]. At that point, the local governments and policy makers try to increase environmental benefits by control of industry for pursuing circular initiatives they do not regard economically advantageous where it is needed to overcome these conflicting situations by top-down and bottom-up approaches with the goal of achieving circular economy [6]. In this case, it is crucial to understand deeply Circular Economy (CE) has a complex philosophy particularly when it comes to cities and related applications. Kirchherr et al. defines Circular Economy as:

> *"…an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus, simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers."* [7].

Cities have a great potential to provide a framework for designers to understand how to lead sustainable development by reducing environmental footprint caused by design and related disciplines. It can also help decision makers, stakeholders, and consumers to understand where their resources come from and where their waste goes to.

2 SOCIAL INNOVATION AND SUSTAINABLE DESIGN THINKING

Social innovation is a wider term with a full range of activities that invent solutions to social problems in a creative as well as positive way [8]. Social innovation includes all sectors like public or private and it is a combination of the logics and social relations conventionally inherent in these sectors [9]. However, according to Hochgerner [10] the concept of innovation was mainly perceived to be the characteristic of economy and technology. Social innovation can be radical depending on the change with regard to existing ways of thinking and it can also be top-down or bottom-up depending on where the challenge starts. In this respect, Manzini [11] states that, design helps people to realize the problems of the production process and to get related with meaningful local activities as consumers linked to the vision. According to him, everyday life innovations create ideas about solving problems in any scale of design and creative communities consider these design-led processes in their bottom-up efforts to find solutions.

Designers as professionals should be involved in these design activities for communities. In this process, designers should work with related actors by bringing them together for sharing ideas and potential solutions. On the other hand, in designing for communities' process, the designer develops solutions after realizing the weaknesses and strengths and social innovation can be identified as the result of various interactions, comprised of bottom-up and top-down processes where hybrid structure is fundamental for sustainable developments.

Heiskala [12] also defines innovation as a new idea that changes social practices to achieve an improvement on social and economic performance, which emphasizes the context specific nature of innovation. On the other hand, Howaldt and Schwarz [13] define innovation as an intervention designed to initiate developments on technology, economics, as well as social practices where design has been extended to the contexts for many scales such as cities, objects and cultures, etc. Morelli [14] emphasizes that designers consider their roles to be complementary to business strategies. He also adds the viewpoint of design needs to be changed for addressing the social problems brought by globalization. In this case, there is an urgent need for the exploration of new areas in design, avoiding from the unsustainable practices behind as design professionals [15]. Fuad-Luke [16] also points out the question whether the creation of well-being rather than the goods of services, be a new aim of design.

According to Buchanan [17] to have a pure vision of design thinking, it is necessary to explore divergent meanings of design both in theory and practice where design thinking can help the social enterprises for being innovative, as well. Design thinking also involves stages such as experimenting and redesigning as an analytic and creative process. It is also an interactive process and design activity has an opportunistic nature that is crucial in the process [18]. As stated by Owen [19] design thinking is as important as science thinking with its contributing value to decision-making process.

Creating a human-centred approach to problem solving involves imagining future scenarios [20] that also underlines the role of design thinking for realizing possibilities and defines it as a mindset [21]. It is argued that design thinking is mainly related to the imaginative act of mind by turning a possibility into a reality and meaning of design thinking sometimes goes beyond designer to the whole culture or a society by referring creative inquiry. In this respect, they emphasized that the professional designers' problem-solving abilities are crucial for the firms, societies and for communities that needs innovations and changes in design thinking which is essential for social innovation. In this respect, the education of designers and planners are crucial for developing a successful design model which considers the needs of communities as well as individuals.

Considering city-scale studies, to reach for a successful social innovation understanding the existing barriers and trying to remove them is crucial. Other factor that creates resistance for the development and social innovation is limited access to the finances needed as well as poorly developed networks [22]. In this case, lack of financial resources and related networks, difficulties of adopting an open innovation paradigm can be defined as the main problems for change for social innovation. Fundraising is the main problem for the NGOs that have great ideas that cannot be applied at any scale [23]. Measuring social innovations and public engagement are also vital for the development as well. Citizen engagement is an important component of social innovation which is more than idea, knowing what works is essential for its successful implementation and dissemination. Evaluations are also crucial for social innovation to find out what works [24].

3 WORKSHOP ON SUSTAINABLE DESIGN THINKING AND CIRCULAR ECONOMY

The traditional understanding of economic activity is mainly based on a linear model which starts with the raw materials and natural resources for products used by consumers and throw them away as a landfill from personal to city scale. This conventional model does not take into account the environmental, social and economic costs related to each step of the circle including extraction, transformation, usage and disposal of resources, which is unsustainable in the long term. On the other hand, circular economy offers a new and developed model in terms of sustainability where the products, processes and resources are maintained for a long term and aimed for zero waste by using closing the loops process.

Concerning the cities, this transition towards a circular economy affects various areas such as local policies, mobility, agriculture, waste management, as well as consumer education. It is also crucial for concerning actors from local governments to all other sectors related to city scale.

As stated earlier, circular economy, sustainable design thinking and social innovation are complex contexts with their interdisciplinary and cross scale structures. In this respect, a one-day workshop has been conducted in Izmir University of Economics, Faculty of Fine Arts and Design to bring local decision-makers and designers together to discuss their ideas in order to identify the local obstacles and barriers for future collaborations on circular design starting from the decision-making process to the applications. At the beginning of the workshop, presentations have been made by the representers of local municipality of İzmir on this subject to explain how planning and design decisions and related applications have been made by the local government and stakeholders of the city of İzmir.

As the second step of the workshop, design professors from the university gave brief lectures on sustainable design thinking and how to improve environmental awareness through design. After having lectures on the sustainability and circular design, design students were also joined to the workshop with their ideas, and they were expected to define the correlations between circular economy and sustainable design thinking in the light of the presentations of the local government and design professionals within the boundaries of their professions from various design scales including urban design, architecture, and industrial design. In this respect, they were also expected to develop possible scenarios and to present their ideas for sustainable future.

Through the study they had a chance to conduct interviews with the local government to analyse the current situation in terms of decision-making processes and how can be developed through participatory design principles. After a daily workshop, the findings were remarkable in terms of sustainable design thinking and improving circular economy via applications which have only been considered in a limited way so far by the politics, decision makers and stakeholders. On the other hand, the workshop was also beneficial for design students by increasing their awareness on how to participate those decision-making processes for their cities as designers and future decision makers.

At the end of the workshop, parameters and actors for Circular Design Thinking were defined in several subtitles and some of those subtitles appeared as the main obstacles and difficulties when it comes to circular design thinking approach (Fig. 1).

- In the first section derived from the daily workshop results, which is defined as **Technology**, the main problem was the lack of feasibility and the weak connection among public services which needs to be strong enough to have a real development for circular design thinking and related applications starting from the local to the whole country.
- Second section of the diagram is entitled as **People**, which is defined extremely crucial in terms of public awareness and participatory decision-making processes as one of the fundamentals for sustainable development. However, according to the discussions of the workshop local governments agreed on that public awareness must be improved by increasing participatory design studies and public information. In this respect, all participants were agreed that these network among the local governments, designers and stakeholders need to be stronger than ever before for sustainable and long-term results.

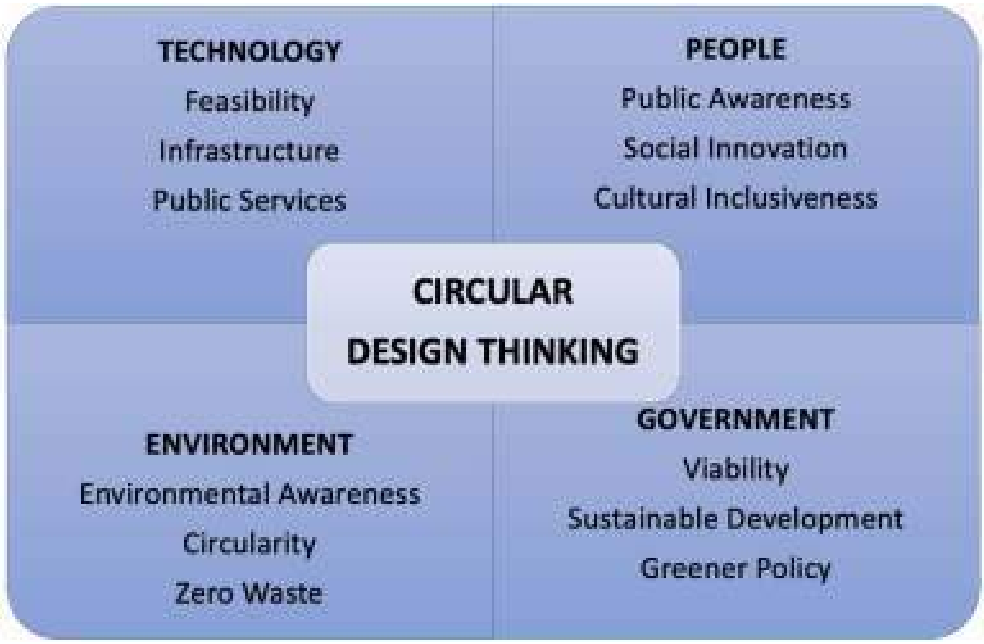

Figure 1: Parameters for circular design thinking.

- Third section was defined as **Environment**, which is the core component from the viewpoint of sustainability and urgently need developments like improving environmental awareness for all actors in cities which lead to the reach goals like increasing circularity and zero waste for cities. As the final section which refers to circular design thinking.
- **Government** has a crucial role to play to achieve those goals. However, this workshop has shown that it is not easy to create a greener policy which leads to a sustainable development and viability. In order to reach the goals defined in these subtitles, there must be a strong and ongoing connections among all kind of actors starting from the decision-making process till the application and eventually end of life for any kind of design related ideas which also needs to be supported via circular economy.

Consequently, the results of this particular study have shown that it must be considered that sustainable design thinking and circular economy is not a simple process that any institution can do alone. Because of its complex nature, there are many obstacles and difficulties, and it requires connections among governments, stakeholders, and related sectors. Cities consist of many features such as infrastructure, utilities, and related services in it. Considering this complicated structure of cities, it is way more important for designers to help local governments and decision-makers to understand the possible results and consequences of their policies and actions.

4 CONCLUSION

Successful networks among all organizations no matter how it flows from bottom to top (or vice versa) and heterogeneity of actors aiming for social innovations are crucial. However, through the discussions, changing the values defined as the most difficult part for this process, although it is much easier to change products and related processes through technical advances. In this respect, sustainable design thinking is a key element to increase awareness and create socially embedded solutions for cities. Designing the capabilities and institutionalizing them will be beneficial for the various organizations as well as individuals to approach new opportunities and possible solutions. Participants of the workshop were also agreed on that there is still a lack of awareness not only for the governmental issues but also for designers where sustainability-based innovations are important for communities in any scale, combining with the collaborations among related actors for design process to turn problems into opportunities and create values.

In this respect, the workshop conducted for this study mainly proved that there is an urgent need for powerful and two-way collaboration (top-down and bottom-up) among the designers, local governments, stakeholders, and related NGOs for the social change and increasing awareness to occur and to diffuse to a community (Fig. 2).

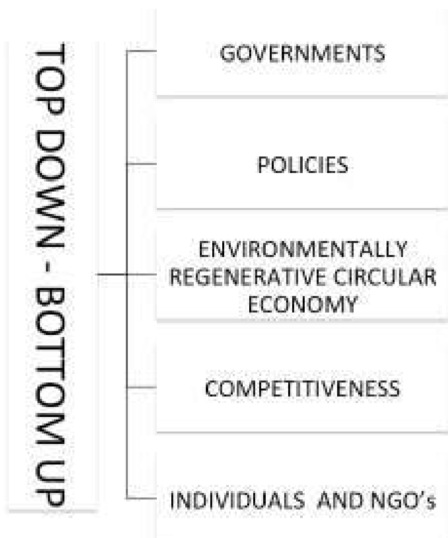

Figure 2: Actors for top-down and bottom-up approaches.

As one of the findings from the workshop, sustainable design thinking and circular economy were defined by the participants as complex contexts of solutions through the viewpoint of sustainability with a systemic perspective built on environmental, economic, and social dimensions and mainly should aim to design out waste to keep natural values in the cycle for resource security and efficiency in any scale, from local to the whole city as in the pyramids below (Fig. 3).

Consequently, circular design concept should spread all over the world in collaboration with the circular economy which aims to redesign everything including cities, products, business models, etc. In this case, although technology is one of the biggest influencers that allows to create new ways of thinking to reach to a smart and sustainable city where the natural resources used wisely in each step, increasing environmental awareness for developing participatory design process is also crucial for any long term and sustainable

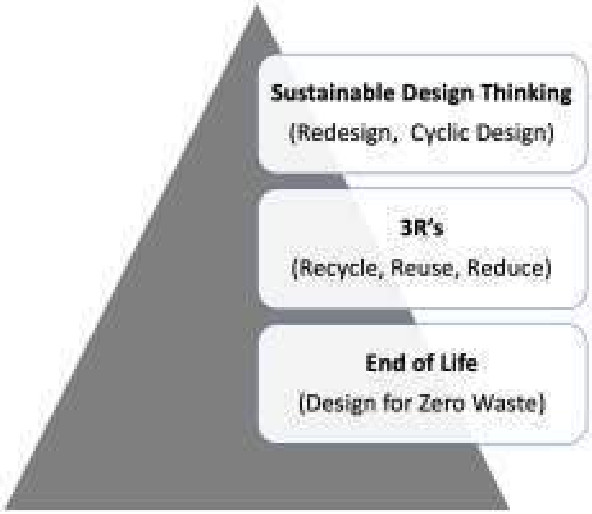

Figure 3: Pyramids of sustainability for cities.

solutions. Having a circular vision, by defining circular strategies and applying those circular principles in city functions are crucial to create a good framework for the circular transition of cities. To sustain this system among the whole city administrations it is also important to build circular awareness and promote a culture of collaboration among all actors to have a sustainable development.

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SECTION 4
URBAN METABOLISM

SPACE NEEDED TO MAKE A CITY SUSTAINABLE AND NECESSARY CHANGES TO REACH IT: THE CASE OF GERMANY

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ABSTRACT

A city concentrates humans, apartments, services, factories, and other facilities. The city is in permanent exchange with its surrounding, receiving food, energy, water, materials and others while delivering products, formation etc. If that whole process would run in a way that it can run in the same way for all future generations, the city would be a sustainable one. As a consequence, it is not adequate to regard only the city scale; the city has to be investigated together with its surrounding. This paper investigates what a sustainable city could be. Starting from the human needs a liveable city is sketched regarding its density and internal organisation, land use, buildings, and their arrangement. The potential of harvesting renewable energies and food per land unit is estimated. The present demand leads to an immense need of land to cover it. To reach sustainability, three different strategies are possible: (a) keep the demand like it is; (b) reduce the demand by increasing efficiency; or (c) reduce the demand by a change of the lifestyle; and cover for (a) to (c) the remaining demand with renewable systems. The highest potential for strategy (b) is in the building sector (refurbishment) and transportation (electrical machines), (c) is touched for food production (widely vegetarian nutrition). Assuming that these changes are already realized, the demand of land for renewable production of energy and food is determined based on corresponding literature and statistical data. For Germany, the need of land exceeds the available land still by 50%. Strategies (a) and (b) led to a big improvement, but without strategy c) the target cannot be reached. That confirms the assumption that the available land for food production and harvest of renewable energies could prove oneself as another limited resource that might be even the dominant one.

Keywords: sustainable city, urban density, transportation network, harvesting renewable energies, space needed for food production and harvest of renewable energies, lifestyle, strategies to transfer cities into sustainable ones.

1 INTRODUCTION

The inhabitants of a sustainable city enjoy spending their lives in a liveable surrounding but with an environmental impact that does not negatively influence the same wish for the following generation(s). These are the first two columns of sustainability, social and environmental; the third one economical is of basic importance but not further regarded in this paper. It is task of our society and policy to make the necessary changes financeable.

It is known that our cities are more or less still far from being sustainable. For the necessary transformation, in minimum much as possible, we have a time frame of only few decades (2050). In literature many different visions of what it should be are to find [1], diverse cities around the planet started with practical initiatives.

The general concept is that the city concentrates of course humans but also apartments, services, factories and other facilities. The city is in strong exchange with its surrounding. The city needs (raw) materials, water, food, energy and others; in return products, education etc. are delivered. Currently that exchange is out of balance in regard to two aspects [2]:

- The needs of the city exceed the potential of the near surrounding to deliver.

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- The exchange is widely not concentrated on the local surrounding but covering the whole planet. That consequence of too cheap transportation contributes worldwide to non-sustainable development.

Most of the literature dealing with sustainable cities is concentrating on the city itself and not including the fact that self-sufficiency can be reached only on the bigger scale city plus surrounding.

This paper deals with both aspects. First the type of city that would deliver best liveability is described in density and organisation. Then the corresponding surrounding is described in land use and size. That matter is very complex; the description will be based on rough estimations and literature. But it will show the dimension of the necessary changes as well as their direction. A comparison with the existing situation will make it further evident.

2 THE LIVEABLE CITY

A city that has no environmental impact but is not liveable would not be a successful solution of the problem. The highest priority is given to the creation of a liveable city but together with the (good) hope that a liveable city delivers also best preconditions for a city with minimized environmental impact.

2.1 Density and internal organisation

A liveable city shall be oriented to pedestrians and cyclists. A pedestrian expects basic services like a bakery, next public travel station in a distance that can be reached inside of a 5 minutes' walk or 3–500 m. To find really a shop to buy a newspaper or some bread, a certain urban minimal density is necessary (how many clients' needs the bakery to survive – all these clients must have their apartments 500 m around the bakery; out of this the urban density can be calculated). In Cording [3] the value of 100 inhabitants per hectare (inh/ha) is cited for a liveable neighbourhood.

A minimal urban density is also a precondition for an efficient public transportation system. Investigations in Newman and Kenworthy [4] and Lefèvre [5] indicate as threshold about 50 inh/ha, better 100 inh/ha. These values refer to the whole metropolitan region, the inner part of a city will have higher densities, the outskirts lower ones. The inner part of (widely as very liveable accepted) Paris has the highest density of all European cities with 210 inh/ha but the metropolitan region has only about 60 inh/ha. For better comprehension for all further investigations in Sections 2 and 7 an urban density of 100 inh/ha is assumed.

It can be seen that social criteria (liveability) and environmental ones (public transportation instead of car oriented) are going hand in hand. Further conclusion is that for further development extension of the cities (and urban sprawl) should be avoided but further densification inside of the existing cities prioritized to reach higher densities.

The organization of the street network and the pedestrian routes should be developed in a way that humans enjoy walking in it. That follows two basic principles:

- The network should often deliver the possibility to decide between different possibilities to continue, left, right or straight forward. Such nodes should be offered once per minute (each 100 m) by the network, but partly still often with separations each 15, 30, 60 m by supplementary nodes only for pedestrians [6].
- The network should deliver sufficient elements of orientation, each 1–200 m (with a walk of in max two minutes all uncertainties are overcome, the next point of

Figure 1: Three different types of pedestrian networks. In a chaotic one (left, made with a random number generator) one would feel lost. Also in a completely ordered one (right) there is no knowledge of being where (lack of reference points). The picture in the middle shows a section of highly walkable Paris Saint-Germain with a lot of small streets and a few bigger streets for orientation [8].

orientation is found). A network that is too ordered would not offer enough orientation; in a chaotic grid the pedestrian would get lost (Fig. 1). The best organisation of the grid would be something between order and chaos [7].

The type of network that corresponds best to both criteria would be one with streets and routes in different width's (hierarchies) that could be clearly differentiated, it follows a Pareto distribution [9]: a few big, central arteries, a medium number of medium distributers and a high number of small and smallest streets forming a very fine network (Fig. 1).

The internal organisation of the network formed by streets and pedestrian/cycling routes is a precondition for walkability. There are decisive further aspects to fulfil that people feel really invited to walk, like sufficient width of sidewalks, clear separation of traffic modes with different velocities (car/pedestrian) etc.; corresponding rating systems describe these indicators [10]. But this is not in the centre of the topic of that paper and not further regarded.

2.2 Land use

To satisfy human needs people need to meet and recover open spaces in their city. To reach big parks and other facilities (stadium etc.) a journey of 30 to 60 min is accepted, they will be located at different places around the city. But besides of that people need for short stay and communication smaller units in the direct neighbourhood (places, pocket parks, public terraces etc.). Semi-public (secondary) territories are dedicated to a defined and limited group of persons (like a house community, sports club etc.). The distribution of these spaces should follow again a Pareto distribution: a few big, central units, more of middle sized (plaza mayor) and a lot of a small sized ones – that guarantees also that everybody will find offers in direct neighbourhood. For all these public and semi-public open spaces, a total area of 12 to (better) 20 m^2/inh is recommended [3]. Together with the assumed 100 inh/ha these are 1,200 to 2,000 m^2 and thus 12 to 20% of the area of the city.

Other 10 to 15% are necessary for central units like hospitals, schools, supermarkets, administration, culture, religion, etc. [11]. For circulation and parking further 25 to 35% of the area are used, industries fill another 20 to 25% of the area [11].

All together are already 60 to 80% of the area allocated to open spaces, central units and industries. Only the remaining space can be filled with buildings. A major part of these buildings will be used as apartments but a certain part (about 3.5 m^2/inh [11]) should be reserved for retail and small services (kindergarten, dentist, bakery, cafe, restaurant etc.), they will be concentrated in the ground floors. With this offer, about in minimum 10% percent of the inhabitants could find their workplace in the own quarter [12], the corresponding mixed use reduces daily transfer inside of the city and invites inhabitants to stay inside of the quarter.

2.3 Buildings and their arrangement

In German cities each inhabitant has an apartment area of about 35 to 40 m^2 available. With 100 inh/ha the total net floor area of apartments would be 3,500 to 4,000 m^2. A factor of two can roughly be assumed between net and gross floor area (stairs, walls, public floors etc.) leading to a demand of 7,000–8,000 m^2 gross floor area. Supplementary the area for retail and little services would need 350 m^2 net and 700 m^2 gross floor area. Together with the assumption that we can fill about 3,000 m^2 with buildings, this rough estimation leads to an average number of storeys of three. That is a good message, the threshold where the technical effort (fire protection, elevators etc.) and energy demand (sealed facades and mechanical ventilation because of wind pressure etc.) jumps to a high level is at about five to six storeys – we are not obliged to construct sky-scrapers.

In a neighbourhood with three to six storey-buildings the area for retail and little service would comprise about one third to a quarter of the ground floor area, giving still space for apartments also on ground level.

Apartments should have a very good access to daylight and deliver an attractive view out of the window. It is known that areas of usage are still in daylight until a depth that corresponds twice the room height, with a height of 2.7 to 3 m that leads to an alighted area until about 6 m depth. Daylight from the sky reaches a building from all sides, with windows in opposite facades and a central part (floor, bathroom, kitchen etc.) in the building's core the recommended building depth is about 14 to 16 m.

For good daylight access buildings should not shade each other and not block the way from the light source sky through the windows into the apartments. Optimal would be a building distance that is in minimum twice the building's height – but with that the available area can't be filled with enough apartments. As a compromise the building distance should be – wherever possible – in minimum equal to the building height; that ensures in minimum for the upper two third of the apartments good conditions.

The classical building block structure fulfils best all these requests. It guarantees a high urban density, the highest daylight access, offers internal courts as private and semi-public territories, quiet back sides for sleeping. The continuing facades along the streets deliver good orientation and identity for a walking person. The inner part of Paris is an example for such a structure (see Fig. 1) but similar quarters are to find in all big European cities. That statement may sound personal and subjective but a view to the city map and the quarters with the highest rents (as an indicator for attractiveness) shows that such quarters are preferred.

3 WHAT WE NEED FOR DAILY LIFE – ENERGY AND FOOD

In MacKay [13] the energy demand of an average middle European inhabitant is investigated and assessed. To facilitate the task and results presentation, the demand per day and inhabitant was used. Assessed is the end-energy demand, not the primary energy

Table 1: Current energy demand of an average middle European inhabitant [13].

	Energy demand (kWh/d inh)	Type of energy	Remarks
Heating	40	Thermal	Coal, oil, gas
Flights	30	Mechanical	Chemical energy (kerosene)
Car	40	Mechanical	Chemical energy (fuel and diesel)
Others	90	Nearly all electricity	Comprises lighting, electric devices, agriculture, energy that is needed to produce all goods that are bought and their transportation
Total	200		

(because there are too many different possibilities). Consequently, it is to differentiate between different forms of energy; thermal, mechanical or electricity, see Table 1.

The total of 200 kWh/d inh is necessary to ensure the current life-style. For comparison, one litre of fuel contains about 10 kWh of energy; the daily demand per inhabitant corresponds to 20 l of fuel.

The food should deliver daily about 3 kWh [13] to the body of an average human. The production of this food needs energy as well as land. The energy demand for the food production is assessed with 15 kWh/d inh and is already included in Table 1 under "others" [13]. For the demand of agricultural land see the following Section 4.

4 SPACE NEEDED FOR FOOD AND AGRICULTURAL PRODUCTS

The total agricultural area in the world corresponds quite well to 2,000 m^2/inh what is a square of 45 x 45 m. Practical experiments show that this enough to feed a person [14] – *if* the nutrition would be widely vegetarian. With the present high consumption of (industrial produced) meat, the need of land to feed the animals increases that threshold remarkably. As a consequence, to serve the meat eating society, the import of agricultural products from abroad is at a high level and increasing permanently. Supplementary land is grabbed at other places of the world, bringing the food production as well as their fair distribution to the world population out of balance.

For the final topic to investigate the space needed for the surrounding of a sustainable city two aspects can be noted:

- The existing agricultural area in Germany lays in fact in the range of 2,000 m^2/inh. In principle it can be self-sufficient. Products that need a warmer climate (bananas, citrons etc.) could be exchanged with wheat or potatoes.
- Currently Germany is far from that target, *a drastic change* in the manner of production (deindustrialized, decentralized, organic etc.) as well as in the German's consumption behaviour (less meat) would be necessary.

5 SPACE NEEDED FOR RENEWABLE ENERGY SYSTEMS

Renewable energies are coming (besides tide and heat from the hot core of the planet earth) in last consequence all from solar radiation. In Germany a square meter of land receives about 1,000 kWh per year or 2.74 kWh/d m^2. The yearly offer would already cover the energy demand of one inhabitant for 5 days, in total 73 m^2 of land would be sufficient. That very optimistic statement does not withstand a deeper investigation. Because of physical reasons renewable energy systems cannot transfer 100% of the solar radiation into another

Table 2: Energy density (possible harvest) of renewable energy systems [13]. All values correspond to the solar offer in Germany of (in average) 2.74 kWh/d m².

Renewable energy system	Energy density (kWh/d m^2)
Electricity	
PV modules	0.4
Wind turbines onshore/offshore	0.05/0.07
Thermal energy	
Wood pellets	0.005
Solar collectors	1.8
Chemical energy	
Energy plants – biodiesel	0.01

energy form like electricity or mechanical energy; the possible harvest is described by the energy density, see Table 2.

To decide about practical application it must be noted that these renewable energy systems have besides their energy density supplementary specialities.

Electricity can easily be transported over big distances thus it can be produced everywhere. PV modules have the highest energy density (about 15% of the solar radiation is transferred) but cover the land completely; a second usage is hardly possible. A competition energy or food should be avoided; PV modules should be placed where agriculture is not possible. In first priority these are suitable surfaces in the cities, the buildings roofs, coverage of parking's etc. Wind turbines can only be placed with a certain distance to each other to avoid that the second one is in the wind shadow of the first one. That leads finally to the quite low energy density. But turbines are vertical, between them agricultural use is possible furthermore without problems. Because of dimension and noise wind turbines cannot be installed inside of cities, in first priority they should be placed in suitable areas in the surrounding or on the sea.

Thermal energy in form of heat cannot be transported over long distances and not be stored over long time, thermal losses would dominate. Thus, it must be produced on-site, in the cities and used in a short time. On the other hand, solar collectors have a very high energy density and should be applied inside of that limits. Another possibility is to produce (with sustainable forestry) material in the surroundings, to transport it into the city and to burn it there. But the energy density (of wood pellets, e.g.) is very low. Plants do accumulate only very few of the incoming solar radiation as material in their own body.

Chemical energy can be gained with special energy plants (soya, rape, palm oil, etc.). Besides the low energy density is a further problem the increasing occupation of land for the production; a competition with food should be avoided, there are other sources for regenerative energy production.

6 STRATEGIES TO REDUCE ENERGY DEMAND AND TO COVER IT WITH RENEWABLES

For the transfer of the society into a sustainable one three different basic strategies are possible, they are noted here only in regard to energy but their philosophy is valid for all other aspects like land use and resources:

(a) No change in the current lifestyle and replace the fossil energy by renewable one.

(b) Reduce the energy demand by increasing the efficiency of the systems. Replace the remaining (fossil) energy demand by renewable energy. Strategies a) and b) are the pure technical answer.
(c) Change the lifestyle into a less energy consuming one. That change can be realized only if it will be accepted in the society. For this, a discussion is necessary, what are our real needs and what do we need to satisfy them. Ideally nobody should have the feeling that one loses quality of life. Replace the remaining (fossil) energy demand by renewable energy.

Strategy (a) is the most comfortable one regarding our lifestyle. Germany has an area of 357,000 km^2 and 85 million inhabitants; that corresponds 0.42 ha of land per inhabitant. If the current life-style is taken like it is the energy demand would be 200 kWh/d inh. If that amount should be replaced even by the most effective renewable energy system, PV modules (it is obvious that this is not possible, but details are neglected for a moment, the target is to gain an impression about the minimal demand of land for renewable energies if strategy (a) would be the only one), $200 \times 85{,}000{,}000/0.4/1{,}000{,}000 = 42{,}500$ km^2 of land would be necessary to serve Germany. That area corresponds nearly to the area for settlement and transportation (15% of Germany, see Table 4) – that land is not available supplementary. If the whole demand is assumed to be covered by wind turbines onshore already 340,000 km^2 would be necessary, that is about the whole area of Germany – but we cannot cover it completely.

Evidently, strategy (a) alone leads not to the target, strategies (b) and perhaps (c) are necessary. In fact, an efficiency revolution is possible in two fields, heating and land based transportation (see Table 3).

Table 3: Possible reduction of energy demand of an average middle European inhabitant [13] and replacement by renewable energies without changing lifestyle. The reduction is exclusively reached by higher efficiency, for the situation "before" see Table 1.

	Energy demand (kWh/d inh)		Reduction	Renewable energy
	Before	After		
Heating	40	10	Thermal insulation of buildings	Thermal (wood pellets, bio gas etc.)
Flights	30	30	Only strategy (c)	Chemical (bio kerosene)
Car	40	16	Transfer to electrical machines	Electricity
Others	90	80	Transfer to electrical machines for transportation of products, LED for lighting and mainly strategy c)	Electricity
Total	200	136		

The heating demand can be reduced drastically down to 1.5 kWh/d inh by constructing new buildings in the passive house standard, with high thermal insulation and (during cold seasons) mechanical ventilation with heat recovery. Building refurbishment cannot reach in general the same standard but should be near as possible to it. It might be that in total 10 kWh/d inh can be reached for all buildings, an increase in efficiency by a factor of 4. A

European directive [15] brought this initiative already into power, all new erected buildings have to be nearly-zero-energy-buildings and the building stock shall be refurbished.

Combustion machines in cars and trucks have a very bad efficiency tank to wheel of only about 15%. Electrical machines are much more efficient but cars may be heavier because of the load of the batteries. Latest electrical cars on the market need finally about 40% of the energy of combustion ones, an increase in efficiency by a factor of 2.5. And, supplementary, fossil fuel can be replaced by renewable electricity.

The energy demand for transportation of products would be reduced in the same way. Also, the replacement of older systems by modern LED would decrease the demand for lighting. In total it can be assessed that the demand for "others" in Table 2 can be reduced to 80 kWh/d inh.

Electricity and thermal energy do not directly present an alternative to replace the chemical energy that is used for airplanes. The only way seems to be the production of bio kerosene in form of hydrogen or methane, the efficiency electricity to gas (electrolysis) is about 50%, the energy density would be 50% of the values for electricity in Table 2 thus 0.2 kWh/d m² for PV modules and 0.025/0.035 kWh/d m² for wind turbines on-/offshore.

Table 3 shows that by increasing efficiency a reduction of the energy demand by about one third is possible. But, obviously, even for that the available land is not sufficient to produce all the energy as renewable one. The conclusion is that without strategy (c), a change in the lifestyle, the target cannot be reached.

7 THE SURROUNDING

Table 3 shows that after the transition to higher efficiencies for heating and transportation the demand per inhabitant would be 10 kWh/d thermal energy (heating) and 156 kWh/d electricity (2 kWh electricity are needed to produce 1 kWh of bio kerosene thus $2 \times 30 + 16 + 80$).

For deeper investigation of the role of the surrounding it is helpful to return to the findings of Section 2. Here it was stated that an urban density of 100 inh/ha is a good precondition for liveability as well as for sustainability. The 10,000 m^2 of that hectare are dedicated to different usages, for the buildings 3,000 m^2 are available. It can be assumed that 50% of the corresponding roof area (1,500 m^2) have a good orientation to be covered with PV modules. That leads to the request that the *buildings should have about the same height and number of storeys* to avoid that the roofs shade each other and cannot be used for PV modules. Again, the inner part of Paris is a good model, but also Masdar city [16] as an example of modern architecture and urban planning. With these 1,500 m^2 of PV modules 600 kWh/d could be earned what satisfies the energy demand of about four of the 100 inhabitants. Further production of energy (mini wind turbines, mini biogas etc.) and food (urban gardening) are very welcome and have an absolutely positive social impact but would not remarkably contribute to cover the demand. All the rest of energy and food has to be produced in the surrounding and brought to the city.

Like already mentioned in Section 6, in Germany per inhabitant 0.42 ha land are available, for 100 inhabitants 42 ha. Table 4 shows the land use as well as the available area for 100 inhabitants. For food the need of $2{,}000 \times 100/10{,}000 = 20$ ha (see Section 4, widely vegetarian) is available. If for energy is assumed (a bit too optimistic) that the whole agricultural area could have a double use with wind turbines and that the forest is used for the renewable production of wood pellets only about two third of the energy demand could be covered. For the remaining third there is no further land in Germany.

Table 4: Land use of Germany in percent and corresponding area for 100 inhabitants. A possible second use for renewable energy production and the corresponding generation are shown further as well the comparison with the demand after the increased efficiency in heating and transportation.

Land use	%	Area for 100 inh (ha)	Second use	Energy generation (kWh/d)	
				Electricity	Thermal
Agriculture	50	21	Wind turbines onshore	10,500	
Forest	30	12.6	Wood pellets		630
Settlement and transportation	15	1 (city) + 5.3 (surrounding)	PV modules on building's roofs	600	
Water bodies	2.5	1.05			
Others	2.5	1.05			
Total land	100	42	Total generation	11,100	630
			Total demand	15,600	1,000
			Not covered	35%	37%

It must be noted that the scenario presented here in Section 7 is a view into a possible future but even then the available land is overstressed by a factor of about 1.5. The real situation is still far from that. The current ecological footprint of Germany (and all other comparable countries) is estimated between 2.5 and 3 [17].

Fig. 2 illustrates the situation for the capital Berlin. It has 3.5 million inhabitants. The available land (0.42 ha/inh) comprises 14,700 km^2 or a circle with a radius of 68 km. To have a sustainable Berlin all food and all energy have to be produced inside of that range. The reality is far from it, even after an increase in efficiency in heating and transportation another 50% of land would be necessary for the resulting reduced energy generation, what would correspond to a circle with a radius of 83 km. That land is not available, it would already overlap with the equivalent circles of the bigger neighbour cities in Germany and Poland (Szczecin, Magdeburg, Leipzig).

8 CONCLUSIONS

In literature and speeches the term sustainable city is widely used. Often it concentrates only on the city scale, without detailed investigation from where the missing renewable energy, food and products should come. Initiatives on-site like urban gardening, mini wind turbines etc. are very welcome but can by far not cover the need.

To be justice to sustainability it is necessary to regard the topic on a larger scale, the city and its surrounding. Only here the city's remaining demand for energy and food and partly other products can be fulfilled.

The main target of this paper is to show that there is another important limited resource that has to be regarded on the development to sustainability – the available land. Food production and especially the harvest of renewable energies need big areas; their amount can be determined or in minimum estimated. In countries with high population density like Germany it might be the dominant resource that determines the amount of food and energy that can be provided to the city.

The investigation shows that with the present lifestyle surrounding land would be necessary that corresponds to a multiple of Germany. Germany and its cities are far from

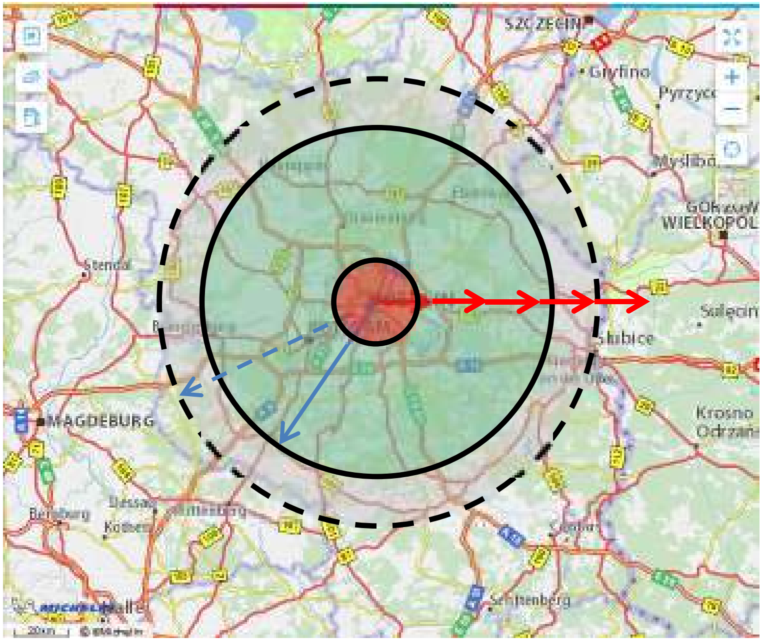

Figure 2: Space availability for sustainable Berlin. The city corresponds to a circle with a radius of 10.5 km (red), the available land a circle with 68 km radius (green, arrow and circle with continuous line). Inside of that range all food and all energy should be produced for a sustainable city. Even after an increase of efficiency in heating and transportation supplementary another 50% of land would be necessary, corresponding to a circle with a radius of 83 km (grey, arrow and circle with dotted line). The red arrows mark a scale of 20 km distances. *(Source: Map based on [18].)*

being sustainable (the same holds for all other developed countries too). Even with a strong increase in efficiency for heating and transportation the need of land would correspond to 1.5 times Germany.

To reach the target and to become really sustainable, a sequence of concerted measures is necessary. The technical part is called in Rifkin [19] the third industrial revolution (this term is very pleasant, a revolution is something that includes a strong movement forwards and a strong change; it sounds much better than an adaptation to climate change and, in fact, it is a revolution).

In first priority, the demand side is to reduce by increase of efficiency and change of lifestyle:

- Food: Widely vegetarian nutrition, less meat. Avoid industrial production.
- Transportation: Replace combustion machines by electrical machines. Less flights, more railways. Less car, more public transportation, bicycles, walking. Avoid, if there is a local alternative, products from far away.
- Heating: Thermal insulation of building stock. New buildings are erected as nearly-zero-energy-buildings.
- Lighting: Replace older systems by LED.

In the second priority (but to realize simultaneously!) replace the fossil energy production by renewable one:

- Change the structure of generation and grid from a centralized one into a decentralized one where energy is produced and used at all places at the same time.
- PV modules have the highest energy density. Their best place is on the suitable areas of the building's roofs in the cities. To avoid shadowing, buildings should have about the same height and number of storeys.
- Wind turbines can be installed in the surroundings, a double use with agriculture is possible.
- For the remaining demand of chemical energy electrolysis (electricity to gas, hydrogen or methane) can be used.
- Forests can be used for sustainable production of material that can be burned to heat buildings.

Roughly, Germany as well as the developed countries have to reduce their demand for energy and land by a factor of about three. About one third can be saved by an increase in efficiency, especially in heating and transportation. Another third has to be contributed by a change in the lifestyle (with the feeling that the basic needs are in minimum as satisfied as before). The last third can be covered be renewable systems in the surroundings of the city. But to reach that, each potential for renewable energy production must be used. That means, that we should see PV modules on all roofs, wind turbines everywhere in the landscape etc. Only then we will have a successful change to a sustainable society.

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WATER SUSTAINABILITY: A CASE STUDY USING SOCIAL AND ECONOMIC METABOLISM PERSPECTIVE

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ABSTRACT

The search for sustainability, which is understood as a situation that ensures the basic needs of the present while guaranteeing these exact needs for future generations, is present in each of the agendas of the highest authorities of the different countries around the world. In this same context, the study of efficiency in the use of aquatic resources and the interconnections between water use and socio-economic variables within a society will provide enormously beneficial information for studying the sustainability of this element. The main objective of this research is to know the principal uses of water and its interactions with socio-economic factors within the Spanish State. For this purpose, we use the MuSIASEM methodology, a technique capable of identifying and taking the economic, social, cultural, political, technical, and environmental dimensions in a precise analysis. Therefore, this method can study this element extensively, enriching the research through multivariate techniques, such as the HJ-Biplot. This study proves the effectiveness of the MuSIASEM methodology and the multivariate technique HJ-Biplot in the practical case of the Spanish State during 2018. We concluded that the complementation of both methods achieves an efficient and exhaustive study of the relationships and individual behaviour of the different social, economic, and water use-related variables. After that, these results can be used to study how to reduce the consumption of water resources in the Spanish State and achieve a fair and respectable consumption for both humanity and the planet.

Keywords: MuSIASEM, HJ-Biplot, sustainability, sustainable development, Spain, water use, water-energy-food nexus.

1 INTRODUCTION

Since some years ago, scientists around the world have been warning of the climate change consequences. Rising temperatures, biodiversity loss or ecosystem changes are some examples that have been forecasted by numerous studies, leaving as a consequence a hopeless future for the generations to come.

In this context, water sustainability is one of the biggest problems caused by climate change. In 2005, the Spanish Government elaborated an inform called Preliminary Assessment of Climate Change Impacts on Spain [1], trying to predict what essential changes will be produced by climate change in this country in the coming years. In addition to many other things, this study talks about a sharp decline in the country's water resources, emphasising that some of them could even disappear. Also, water is an indispensable element for life as we know it. Not only is it needed directly by people daily to survive, but everything that surrounds us needs water to be carried out, from the food consumed daily to cars or clothes.

Consequently, the quest for water sustainability is becoming an increasingly vital necessity. In 2014, the Food and Agriculture Organization of the United Nations (FAO) defined the Water-Energy-Food Nexus (WEFN) as the element responsible for linking the interactions between humans and natural systems. This concept encompasses socio-economic and biophysical resources needed to achieve social, environmental and economic objectives related to water, energy and food [2].

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In this way, FAO and other scientific research recommend using the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) approach to study this nexus. This accounting method, developed by Giampietro and Mayumi in 2000 [3], can integrate quantitative information obtained through different models based on various dimensions and scales of analysis [4]. Thus, MuSIASEM is able to take into account environmental and social-economic dimensions in a single analysis.

Therefore, the nexus study can provide very revealing information about the sustainability of natural resources in a territory. Numerous studies based on the MuSIASEM approach have already been carried out in other parts of the world, such as China [5], Chile, Brazil and Venezuela [6] or Ecuador [7]–[9]. In addition, there is research in the latter country where multivariate techniques are also applied to enrich the MuSIASEM research, such as the HJ-Biplot or the use of GWPCAs [10]. Likewise, numerous studies have also been carried out in Europe applying this methodology, such as in the United Kingdom [11] or Romania, Bulgaria, Poland and Hungary [12]. Recent research using the MuSIASEM technique can even be found in Spain [13], [14]. However, most of these investigations are carried out by an approach in which energy and its use is the main subject of study. This research will attempt to situate another element of the WEFN in focus, trying to achieve a novel and enlightening approach to water sustainability in Spain in 2018.

2 MATERIALS AND METHODS

2.1 A case under study: Spain

Spain is the fourth most populated country in the European Union and is one of the strongest economies in the world. It also has a regressive or bulbous pyramid, characteristic of developed countries [3]. Spain occupies most of the Iberian Peninsula of Europe and two island territories and two cities in North Africa. It is surrounded by the Cantabrian and Mediterranean Seas and has some direct access to the Atlantic Ocean. Territorially, the country is divided into 17 autonomous communities plus two autonomous cities located in North Africa (Ceuta and Melilla). These 19 territories have a certain legislative autonomy that is unusual in neighbouring countries. Thanks to this decentralisation, Spain can boast multiculturalism that is not typical of such a small territory.

Due to its geographical situation and climatic and cultural differences, Spain is an extremely interesting country to analyse using the MuSIASEM technique. By studying sustainability in such a diverse country, many valuable conclusions can be drawn to develop further and improve the use of aquatic resources in this territory. In this way, Spain has been divided into 18 territories; 17 Autonomous Regions and one domain consisted of two Autonomous Cities: Ceuta and Melilla. Likewise, it has been preferred to analyse only the part related to water use within the WEFN since, as previously explained, Spain's geographical situation makes it a highly interesting country to analyse this element. Both the socio-economic variables and the variables related to water use have been obtained from data provided by the Spanish national statistics institute for 2018.

2.2 MuSIASEM: Multi-scale integrated analysis of societal and ecosystem metabolism

The first method used in this study to analyse water sustainability in Spain in 2018 is the MuSIASEM approach. This model can deal with different hierarchical levels and scales, making it a highly useful technique for studying possible links between variables in other areas [3]. Also, the MuSIASEM method can recognise and characterise the existing metabolic pattern in the socio-economic system, providing extensive information on the different elements (flow and funds).

This technique is essentially based on applying four main theoretical ideas; the flow-fund model, the multi-level/multi-scale accounting, the multi-purpose grammar and the impredicative loop analysis [4]. The flow-fund conceptual model, developed by Georgescu-Roegen in 1971 [15], allows the socio-economic processes of consumption and production of goods and services to be represented in biophysical terms. On the one hand, the funds are those elements that do not vary throughout the study; in other words, they are used, but they are not consumed and tell us "what the system is made of". On the other hand, the flows represent "what the system is doing", and they tend to change during the study, appearing or disappearing [4]. Furthermore, multi-level accounting represents the different hierarchical levels of analysis (level n, n-1, n-2, etc.), while multi-scale accounting refers to the different types of variables involved in the analysis (biophysical, economic, etc.) Also, the grammar provides a description based solely on the relations between semantic categories. Thus, a set of relations is created between formal and semantic categories, due to which grammar is semantically open (the same term can be defined in several ways). Finally, it is convenient to formalise this grammar in quantitative terms by eliciting a set of congruence relations between the characteristics of the parts and those of the whole. These links imply that the characteristics of the components must be compatible with those of the total and vice versa but need not define a linear causal relationship between them [4].

Twenty-one MuSIASEM variables will be analysed for 18 individuals or territories at three different levels (n, n-1 and n-2) in this study. First, a general level n will be defined, where the variables that affect society will be found. Subsequently, there is a level n-1, divided into two large groups known as paid work (PW) and household (HH). The first sector, PW, is responsible for generating the entire GVA or GDP of a society. In contrast, the second sector, HH, not only does not produce any economic value but is also responsible for consuming these values [13]. However, both sectors make equal use of the element water to exist and develop. Finally, a level n-2 is defined where the paid labour sector (PW) is further subdivided into two sectors: the economic sector (EC) and the government sector (GOB). In this way, a division is made between the public and the private sector.

2.3 HJ-Biplot method

To extend and enrich the analysis of the WEFN in Spain, following the MuSIASEM approach, it has been decided to use multivariate techniques, applying the HJ-Biplot method to the database. This method, proposed by Galindo in 1986 [16], is just a variant of the biplot methods proposed by Gabriel in 1971 (GH-Biplot and JK-Biplot) [17]. However, unlike these methods, the HJ-Biplot can achieve maximum representation for both rows and columns when represented on a low dimensional vector dimension. Thus, the HJ-Biplot method can perform a multivariate representation of row and column markers chosen so that they can be superimposed on a standard reference system obtaining maximum quality of representation [18].

Formally, a biplot is a graphical representation of an initial data matrix, X (IxJ), employing markers $a_1, a_2, \ldots, a_I$ for the rows of X and $b_1, b_2, \ldots, b_J$ for the columns of X, such that the scalar product $a_i^T b_j$ approximates the element x_{ij} as well as possible. Furthermore, considering the markers $a_1, a_2, \ldots, a_I$ as the rows of a matrix A and the markers

$b_1, b_2, \dots, b_J$ as the rows of another matrix B, it is possible to state that: $X \cong AB^T$. Also, the starting matrix with dimension IxJ, where, in general, the I rows correspond to the individuals and the J columns to the variables, and with a rank r, must be approximated to another with a lower rank q (q < r). This will be achieved through the Decomposition into Singular Values (DVS) and Singular Vectors of X [19]: $X = UDV^T$, where X (IxJ) is the original data matrix with rank r, U (Ixr) a matrix whose column vectors are orthonormal and contain the eigenvectors of XX′, V (Jxr) is the matrix whose column vectors are orthonormal and contain the eigenvectors of X′X and D (rxr) is the diagonal matrix containing the eigenvectors of X. Moreover, U and V must be orthonormal, i.e. UU′ = V′V = 1. In this way, the factorisation is guaranteed to be unique since this is not always the case. Therefore: $X = AB^T = UDV^T$.

Table 1: Resumé of the variables MuSIASEM used. *(Source: Own elaboration.)*

Variable (unit)	Complete name	Calculation	Flow or Fund	Description
THA (hr)	Total human activity	Population × 8,760 hours per year	Fund	Total of hours of human activity in a society
HA_i (hr)	Human activity in sector i	People employed per sector × hours of work per week × 52 weeks of work per year	Fund	Total of hours spent in each sector
GVA (€)	Gross value added	Taken directly from INE	Flow	Added value generated by an economy in one year
GVA_i (€)	Gross value added in sector i	Taken directly from INE	Flow	Added value from the various sectors
ELP_i (€/hr)	Economic labour productivity for sector i	GVA_i/HA_i	Flow/Fund	Added value per hour of working time in activity i
GWU (l/hr)	Gross water use	Taken directly from INE	Flow	Gross use of water appropriated by society, including losses and unaccounted-for water.
NWU_i (l/hr)	Net water use for sector i	Taken directly from INE	Flow	Net water use according to the different sectors.
WMR_{SA} (l/hr)	Water metabolic rate, average of the society	GWU/THA	Flow/Fund	Total amount of water used per hour of human activity
WMR_i (l/hr)	Water metabolic rate for sector i	NWU_i/HA_i	Flow/Fund	Amount of water used per hour of human activity spent in each sector

In this case, the matrix that will be analysed (IxJ) is formed by 18 individuals (territories within Spain) and 21 MuSIASEM variables, which are shown in Table 1. The BiplotbootGUI package [20] in Rstudio will be used as a development tool for this technique. The result is a Euclidean map in reduced dimension (2D) where the variables or columns are represented by vectors and the individuals or rows as points in the same reference system. For this reason, the geometric interpretation of this representation is based on simple geometric concepts; the cosine of the angle formed by two vectors indicates the degree of correlation between these variables, the smaller the angle, the higher the correlation ($\cos\theta \propto r$); the distance between individuals indicates the dissimilarity between them, the greater the distance, the greater the dissimilarity; lengths of column vectors indicate the standard deviation of the variables, the longer the vector, the more variability the variables collect and, therefore, the more information it will provide.

3 RESULTS

3.1 MuSIASEM analysis: Graphical description

This section will obtain graphical representations of the 21 variables individually to interpret the results better.

3.1.1 AH, VAB and UW variables

At all levels of study, it can be observed that all variables related to water use, human activity and gross value added to have a greater weight in the territories with a more significant number of inhabitants. The four Spanish regions with the most significant number of inhabitants (Andalusia, Catalonia, Madrid and Valencia) occupy the first four positions in these 13 variables. These territories represent the most populated areas with the largest populations in the different sectors and the regions that produce the most money and consume the most water within the Spanish territory.

THA, HA_{HH}, HA_{GOB}, GWU, NWU_{PW}, NWU_{HH} and NWU_{EC} have their maximum in Andalusia, while HA_{PW}, HA_{EC} and GVA_{GOB} have their maximum in Catalonia. Finally, the variables NWU_{GOB} and GVA and GVAEC take their maximum value in the community of Madrid (see Figs 1 and 2).

Moreover, all these variables have their minimum in Ceuta and Melilla, La Rioja and Cantabria. All of them have their minimum in the autonomous cities of Ceuta and Melilla, except VAB_{GOB} and NWU_{GOB}, which have them in La Rioja and Cantabria, respectively. Thus, it is confirmed that the territories with lower populations have a lower weight in these indices.

Therefore, it is confirmed that the variables related to HA, GVA and WU are directly related to the number of inhabitants in the territories or exercising a specific activity. This reasoning makes sense since the greater the number of inhabitants, the greater the human activity, the greater the GVA, and, in turn, the greater the water use.

3.1.2 ELP variables

Suppose we now study the variables related to economic labour productivity. In that case, we can see that these three variables take high values in the same four territories: Madrid, the Basque Country, Catalonia and Navarre. In ELP_{PW} and $ELP_{GOB,}$ the maximum is found in the Basque Country, while in ELP_{EC} the most is located in Madrid (see Fig. 3).

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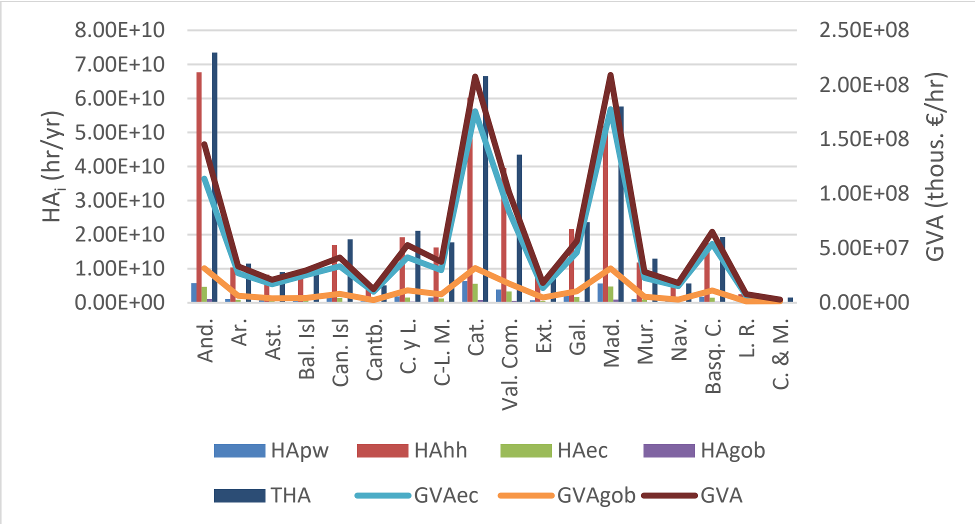

Figure 1: HA and GVA variables of the different territories of Spain.

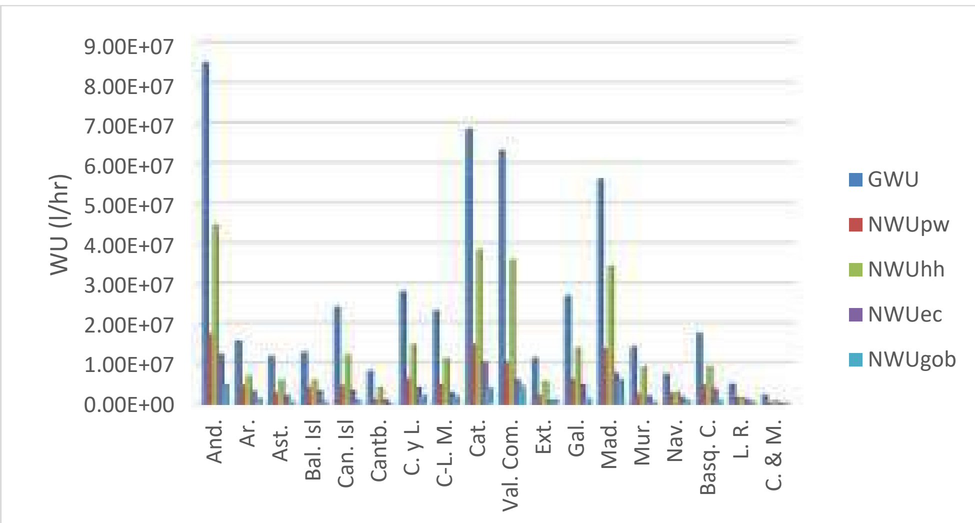

Figure 2: WU variables of the different territories of Spain.

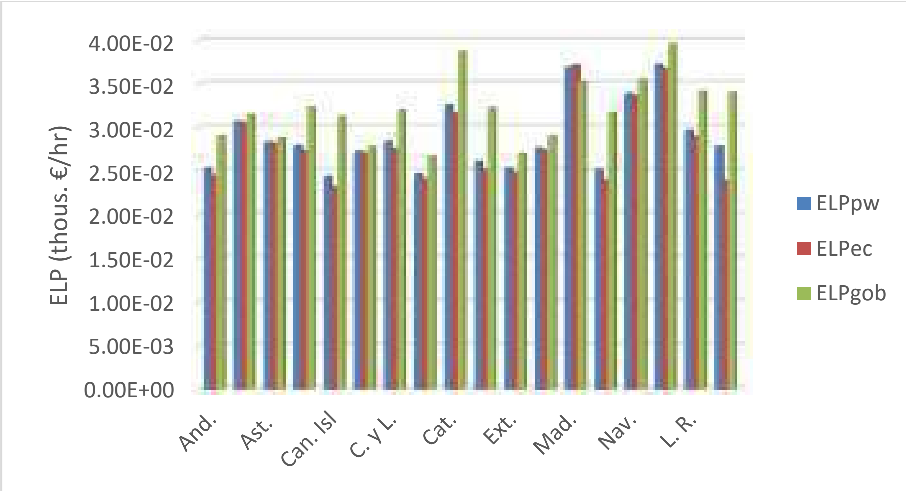

Figure 3: ELP variables of the different territories of Spain.

3.1.3 WMR variables

Finally, we must study the variables related to the metabolic rate of water. In this case, unlike the previous ones, we do not see the uniqueness in terms of the territories in which these values are maximum, but rather it depends significantly on the variable in question.

The territories with the highest values for the WMR_{SA} variables are La Rioja, Cantabria, Ceuta and Melilla and Valencia. In contrast, the territories of La Rioja, Navarra, Aragón and the Balearic Islands have high values for the WMR_{PW} and WMR_{EC} indicators. Finally, WMR_{HH} takes high values in Valencia, Cantabria, Murcia and Castilla y León while WMR_{GOB} in La Rioja and Navarra (see Fig. 4).

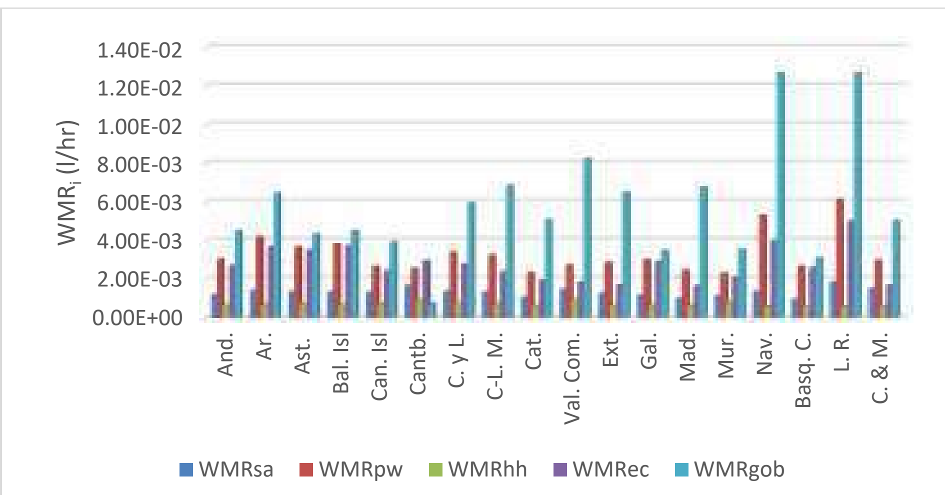

Figure 4: WMR variables of the different territories of Spain.

3.2 HJ-Biplot method

After having thoroughly analysed the 21 MuSIASEM variables, it is possible to complement and considerably extend the study of these data by applying a multivariate technique such as HJ-Biplot to the database (18 individuals and 21 variables). In this way, the first thing that can be observed is that the first three axes can capture 90% of the total variability of the analysis and the first two axes more than 80% (see Table 2). Consequently, it is possible to assume that a two-dimensional solution will be sufficient to explain the various characteristics of the data set.

Table 2: Eigenvalues and % variance explained.

Axes	Eigenvalues		% of variance	% Cumulative variance
1	15.11		63.98	63.98
2	7.7		16.59	80.57
3	5.82		9.44	90.01

On the other hand, by plotting the variables and individuals in the same two-dimensional reference system, we can observe results similar to those obtained with the previous analysis. First, we see a clear dependence between the variables related to HA, WU and GVA. All these variables, located on the left side of the representation, have a solid and direct correlation, forming small angles between the vectors. In the same way, Fig. 5 shows a strong dependence between the ELP variables in the upper part of the representation. All these variables form small angles to each other and are therefore strongly and directly correlated. Finally, we can see how the rest of the variables are somewhat more scattered on the right side of the representation. In addition, we can see how the WMR_{EC} and WMR_{PW} variables are strongly correlated with each other.

If we then look at the groupings formed between individuals and assuming that the shorter the distance between them, the greater the degree of similarity, we see how three clusters can generally be formed. The four territories will create the first of these, with the most significant inhabitants in Spain (Andalusia, Catalonia, Madrid and the Valencian Community). This first cluster is located on the left side of the representation. We can see how while Madrid and Barcelona are located above axis 2 very close to each other, the other two are located below the axis somewhat further away. This is quite significant since these four territories are placed quite far away from the rest, especially Madrid, Barcelona and Andalusia, so it is expected that these territories share specific characteristics and differ significantly from the rest.

On the other hand, we can find a second cluster formed by the territories of the Basque Country, Navarra, Aragón and La Rioja in the upper right part of the graph. All these territories share the same geographical location; they are all located in the north-eastern part of the Iberian Peninsula (see Fig. 6). Finally, the rest of the territories form a third cluster located in the lower right part of the representation. Within this grouping are territories such as Galicia or Castilla y León, which are located very close to the centre of coordinates and, therefore, do not contribute much information to the analysis. In the same way, Fig. 5 shows how the variables WMR_{GOB}, WMR_{SA} or WMR_{EC} have shorter vectors than the rest of the variables and, therefore, contribute less information to the analysis. However, in general, it can be assumed that all variables are perfectly represented in this 1–2 plane.

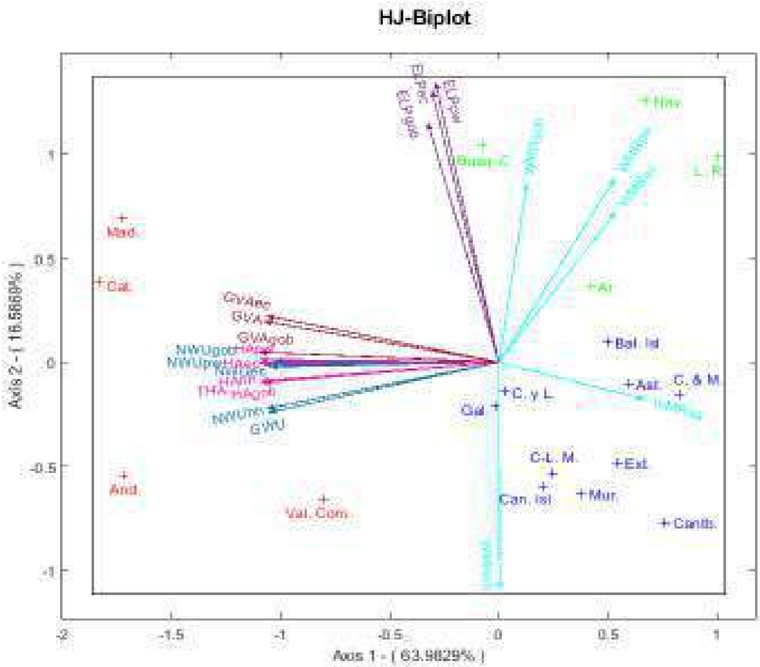

Figure 5: HJ-Biplot representation of the 18 territories and the 21 variables.

Figure 6: Clusters of Spain.

Finally, the interaction of the 18 individuals and the 21 MuSIASEM variables should be studied. In this case, the results are entirely similar to those obtained with the analysis of the descriptive statistics of the 21 variables individually. Thus, a greater weight of the variables related to water use, human activity, and gross value added is visualised in the populations of the first cluster, i.e. the populations with the most significant number of inhabitants. Secondly, we see how the variables related to ELP are at their highest in the Basque Country, Navarre, Madrid and Catalonia, as previously deduced. In addition, the representation shows how certain territories of the third cluster, such as Cantabria and La Rioja, have high values in most of the WMR-related indicators.

4 DISCUSSION

Thanks to the multivariate HJ-Biplot method, we have considerably enriched the MuSIASEM analysis of water sustainability in Spain. The application of the multivariate method to the database (18x21) allows us to represent in the same two-dimensional plane both the MuSIASEM variables and the territories within the Spanish state and the interactions between both groups.

This combination of methods reveals, in the first place, the fact that the four territories with the largest populations behave similarly. The first cluster of individuals takes high values in all variables related to water use, human activity, and gross value added. Moreover, these variables are strongly and directly correlated. Secondly, we can see a clustering of the three variables related to ELP. All of them have a strong dependence and take high values in the territories of Madrid and Catalonia, in the first cluster, and the Basque Country and Navarra in the second cluster. Finally, the variables related to WMR in paid work and the economic sector are highly correlated. However, the rest of the variables in this group are somewhat more separated from each other, denoting certain independence.

If we focus on water use in Spain, which is the ultimate goal of this research, we can draw several implications. First, we can see a typical result in all the variables except the variable relating to the household; the maximum in all these variables is in La Rioja. In addition, Navarre occupies second place in the WMR_{PW}, WMR_{EC} and WMR_{GOB} variables. On the other hand, WMR_{HH} has its maximum in Valencia, followed by Cantabria, which also occupies second place in WMR_{SA}. Observing these results, it can be seen that certain territories have high values in the indicators related to WMR but low values in the rest. This shows the existence of certain territories where excessive and disproportionate water expenditure is being made in specific sectors that could be easily solved without considerably disrupting the functioning of society. The first clear example of this would be La Rioja, which consumes the most litres of water per hour of human activity in four out of five variables related to WMR. Other examples could be Cantabria in the WMR_{SA} and WMR_{HH} variables, the Balearic Islands in PW and the EC sector, or Castilla y León and Murcia in the HH sector. This should be studied later in a more extensive investigation to analyse why certain areas consume more water within Spain and whether it is possible to reduce this expenditure.

This analysis also shows no evidence of a solid and direct correlation between the metabolic rate of water consumed in the labour sector and the economic productivity of labour. This clashes head-on with previous research on energy use in different territories. In 2001, Jesús Ramos-Martín showed how in Spain, a strong correlation between the variables ELP_{PW} and EMR_{PW} can be verified, the latter being the variable in charge of representing the exosomatic energy rate for the paid labour sector [13]. During this research, it is shown that the hypothesis formulated by Cleveland et al. [21] and Hall et al. [22] about the correlation between these two variables is also true for the case of Spain. Therefore, a direct relationship between hourly electricity consumption in paid work activity and the amount of GVA generated in this sector per hour of human activity was demonstrated, associating higher energy expenditure with higher economic productivity of labour. However, the results obtained during this study imply that this situation cannot be generalised in the case of water in Spain, since there is no strong and direct correlation between the WMR_{PW} and ELP_{PW} variables.

5 CONCLUSIONS

Taking into account all the considerations obtained throughout the research, it is possible to draw certain conclusions that are worth mentioning and recapitulating:

1. Both techniques are capable of perfectly studying the sustainability in a given territory. In this way, a successful study on water use in Spain in 2018 has been carried out.
2. The MuSIASEM approach manages to define the database that will be subsequently explored effectively. Thanks to this analysis, it is possible to get a detailed report of the territories that excel in specific indicators, denoting the socio-economic characteristics and water use in those territories.
3. The MuSIASEM grammar opens the way to a new way of exploring sustainability in the different countries of the world, inspecting as many levels and elements as desired.
4. The HJ-Biplot analysis has considerably expanded the knowledge about sustainability in the territory under study. This new approach offers in a much more visual, straightforward way the different interactions between places and indicators and the internal correlations existing in both groups.
5. The use of both techniques has meant a different approach, but at the same time, a sample of absolute concordance, obtaining widely coherent and equivalent conclusions.
6. Most of the research on sustainability using the MuSIASEM approach has been done by focusing on energy use in a given territory. However, this study shows how water is a perfect candidate to be studied with this technique.
7. A strong and direct correlation between the metabolic rate of water in paid work and economic labour productivity in this same sector cannot be assumed.
8. Many of the territories in the third cluster, such as Cantabria, La Rioja, Murcia, Ceuta and Melilla or Castilla y León, have high values for the WMR variables but low values for the rest of the variables, which can be interpreted as an excess of water expenditure that could be easily solved without considerably disrupting the functioning of society.

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URBAN METABOLISM AS AN APPROACH TO ACHIEVE RESOURCE EFFICIENT COMMUNITIES: A CASE STUDY OF AL SHAKHLOBA, BURULLUS LAKE, KAFR EL SHEIKH, EGYPT

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ABSTRACT
Efficient use of natural resources has become increasingly important due to the pressure resulting from population growth, increased demand for resources, and globally unprecedented waste generation habits. Therefore, exploring the flows of urban resources (i.e. water, energy, land and materials) could help one to reach a better understanding of the complex processes of entry and exit of such resources. This study analyzes the inflows and outflows of one of the resources – namely energy – within the Egyptian community "Al Shakhloba village". This study aims to formulate a model that simulates and optimizes the resources flows in communities by means of the urban metabolism approach; study human interaction with energy use in one of the small Egyptian communities through the use of interview questionnaire; and identify the current state for the energy flow. The main conclusions and recommendations of this case study can improve energy resources management in Shakhloba village, in order to convey a vision to decision-makers about how to manage energy resources within the scope of achieving sustainable development. In addition, it shall contribute to sustaining a more efficient use of energy resources.
Keywords: urban metabolism, energy, energy consumption, energy efficiency, resource efficiency, Shakhloba village, Egypt.

1 INTRODUCTION

Recently, enormous amounts of resources are being consumed within human settlements and their physical impact on the natural environment, such as urban and rural sprawl, housing demand, transportation and basic infrastructure, is rapidly increasing. Thus, the need for efficient management of resources to reduce societal environmental impacts, in parallel with applying the objectives of sustainable development, is crucial in addition to incorporating the concept of resource management within the stage of urban and rural design into especially marginalized productive communities. The main characteristics of communities are the consumption of large quantities of natural resources and the production of larger amounts of waste and pollution, throughout the life of these projects [1]. However, the currently adopted pattern of their use shall deplete the resources, causing such natural resources to be scarce. In addition, this shall contribute to the degradation of ecosystems, and make the prices of natural resources increasingly fluctuating. The ultimate test would be to achieve an optimum balance between delivering greater value and more services and using fewer resources [2]. Recently, several concepts and terms have emerged that have often preoccupied the world around the concept of environment and sustainability, thus the concept of urban metabolism has been brought to light.

The concept of 'Urban Metabolism' (the flow of resources – i.e., materials and energy – through a community) can be used to outline the notion of how to improve citizens' access to essential services (a focus on collective well-being), while managing their resources rationally, and producing minimum or recyclable waste. Urban metabolisms must shift from 'linear' to 'circular', which necessitates integrating new methods of managing the flow of

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resources within the community. This concept must be adopted to assist strategic planning at local government level. Local governments should quantify communities' inputs (e.g., energy, biomass) and outputs (e.g., waste and emissions), and use such data to develop resources efficiency strategies [3]. Urban Metabolism has promoted quantitative approaches to urban and rural resource flows assessment and served as an inspiration for bright design ideas for sustainable communities [4], [5], consequently, allowing for the identification of leverage points for resource-efficiency interventions. This concept has been widely applied to various disciplines in order to assess cities' sustainability in relation to resource consumption and waste generation. The idea that urban environments are similar to metabolic systems has given rise to the reconsideration of how environmental, social, and economic factors intertwine to shape urban phenomena [3].

2 URBAN METABOLISM APPROACH

In order to explain the concept of urban metabolism, we have to define the concept of metabolism itself. Metabolism is the sum total of the chemical processes that occur in living organisms, resulting in growth, production of energy, elimination of waste material, etc. [6]. For instance, one's metabolism is the way through which the chemical processes in one's body use food efficiently to generate new cells and provide you with energy.

2.1 Definition of urban metabolism

The concept of Urban Metabolism has re-emerged after being overlooked for many years, due to the growing population and the importance of conserving natural resources. Interestingly, there is no consensus in the literature on the foundations of the concept. For instance, Kennedy et al. [7], Wolman [8], Marx [9, p. 556], Odum et al. [9, p. 555] (Table 1) give different definitions of urban metabolism.

Table 1: Different definitions of urban metabolism. *(Source: The authors.)*

Authors and year	Definitions
Agricultural chemists (19th century)	Understanding the cycle of organic matter and nutrients and fertilizer [10].
Karl Marx (1883)	Describing the exchange of materials and energy between society and nature [3].
Abel Wolman (1965)	Process of supplying material, energy and food to a hypothetical city [8]. Wolman published the first explicit application of the metabolism concept to the urban sphere.
Odum (1970)	Conceptualization of energy flow [9].
Fischer-Kowalski and Walter Hüttler (1999)	Sum of Material and Energetic Inputs = Sum of Outputs + Changes in Stock [11].
Huang & Hsu (2003)	Process of transforming all the materials and commodities for sustaining the city's economic activity [12].
Kennedy et al. (2007)	Collection of complex sociotechnical and socio-ecological processes by which flows of materials, energy, people, and information shape the city, service the needs of its populace, and impact the surrounding hinterland [7].

Taking into account the bio-based metaphor "metabolism", a community bears resemblance to an organism in terms of intaking, digesting, and releasing materials while exchanging energy with the external environment [13]. Wolman was the first to describe a community as an organism with metabolic processes [8]. Gradel (1999) also adopted the same concept stating that communities are analogous to organisms [14]. Thereby, examining the metabolic flows of communities enables us to consider the rates at which resources are being depleted and wastes are being produced. As for Built Environment, the metabolic flows represent raw materials, energy and water which are transformed into building stocks with an outflow of waste energy and water [8]. On the one hand, urban metabolism is based on an analogy of an organism's metabolism with inputs and outputs [15]. A community is highly intricate if compared to a single organism, whereas each system element can be viewed individually with inflows and outflows. Then these individual elements can be overlaid with one another more congruently as an ecosystem [16]. Urban metabolism can be defined as a model to facilitate how to describe and analyze the flows of materials, energy, people, and information shape within cities. It offers a metaphorical framework within which we can study how natural and human systems interact.

2.2 Urban metabolism framework

The current city metabolism configuration, which is mostly linear, can be represented by the organism metaphor. Cities obtain the majority of their materials (such as biomass, water, construction material and energy requirements) from the sparsely inhabited rural areas, yet such materials are not efficiently utilized. The disposable waste can be in any form solid, liquid or gaseous. Thus, the current linear metabolism makes the cities vulnerable, owing to their dependency on the resources, which burdens the local resource supplies and adversely impacts the natural environment during the processes of resource extraction and waste disposal. On the contrary, an ecosystem metaphor of cities represents resource efficiency and closed loops in which all outputs are potential inputs, thus offering a stronger prospect for achieving urban sustainability. A circular metabolism is quite similar to a natural ecosystem with efficient consumption, recycling and reuse of resource flows. Urban metabolisms are facing a complicated challenge, namely shifting from linear to circular perspective, where waste can be used as a resource [3]. The processes needed to flow resources within communities are affected by the human element, its consumption, behavior and various activities, in different sectors such as housing/services/transportation, etc. The human-related elements affect gaseous emissions, and liquid and solid waste, and this gives an indication of resource efficiency. Fig. 1 shows a proposed model for resources efficiency.

3 ENERGY EFFICIENT COMMUNITIES

The potential to reduce urban flows is governed by many factors, including but not limited to: urban management and planning, compactness, urban morphology and urban form (Fig. 2). The aforementioned factors shall significantly establish the Resource Use Pattern. These factors not only determine the way the population moves and lives, but also define the need for maintenance (particularly, buildings and roads deterioration rate, and the quality of and way in which services are provided). Poorly planned cities can cause constant waste of resources [17].

3.1 Energy situation in Egypt

Egypt is a highly rich country in terms of natural resources. The country's natural resources include: Natural gas, oil, coal, precious stones, and massive reserves of fossil energy sources. Egypt's reserves are estimated to be about 4,189 billion barrels of oil and approximately 77,200 billion cubic meters of natural gas, as the reserves are in the form of both mainland and coastal deposits [18]. Over 90% of the Egyptian electricity is generated exclusively from

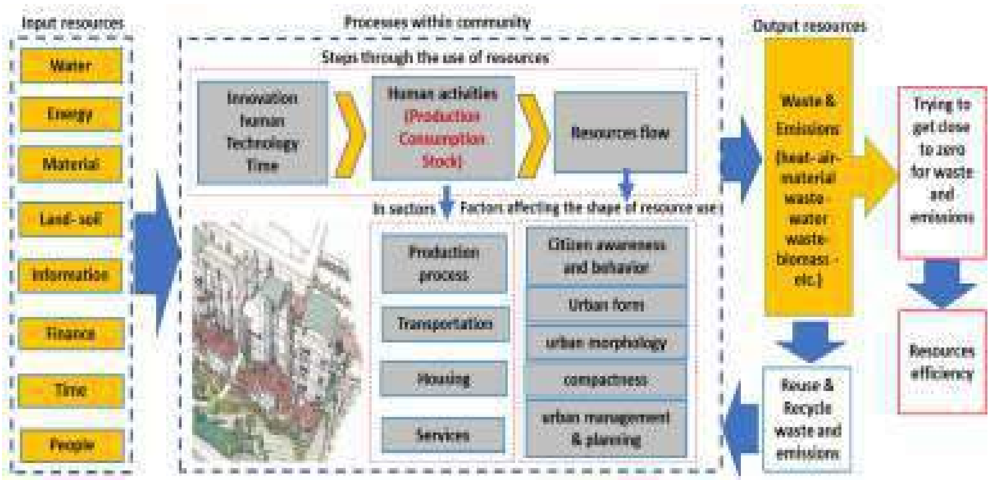

Figure 1: Urban metabolism model to resources efficiency.

Figure 2: Factors affecting resource use.

oil and natural gas. Meanwhile, the major obstacle that Egypt faces, especially in the energy sector, is the increasing population growth rate, which is estimated to be 1.3% annually, which means increasingly higher demand, which shall eventually expedite the rate of depleting the country's major resources [19].

From both energy and environmental perspective, it is crucial to use biomass as a renewable source of energy. Using the biomass can reduce the increasing depletion rate of fossil fuel, resulting from the rapid increase in energy consumption (Fig. 3). The following are the four main types of biomass energy: Agricultural residues (dedicated bioenergy crop residues), municipal solid wastes, animal wastes, and sewage sludge. The computed potential biomass quantity and its theoretical energy content were based on statistical reports, literature reviews, and personal investigations. The results show that Egypt produces a considerable amount of biomass, whereas the total theoretical energy content is estimated to be 416.9×10^{15} J. The dry biomass produced from bioenergy crop residue sources has been estimated at about 12.33 million tons/year, of which 63.75% is produced from rice straw. This source represents the highest percentage (44.6%) among the total theoretical potential energy in Egypt, followed by municipal solid wastes, which could produce up to 41.7% (corresponding to the annual amount of 34.6 million tons). Meanwhile, the remaining theoretical potential energy could be produced from animal and sewage wastes. The estimated biomass with its considerable potential energy content represents an important renewable energy source in Egypt [21].

Figure 3: Total energy consumed (million KW/h) [20].

4 METHOD AND PROCEDURES

Concerning resource management policy, there is little or no information about the actual consumption of different energy resources. Thus, in order to address this current gap in identifying how different communities perform regarding energy resource consumption patterns and respective intervention priorities, the study strongly focuses on in-depth discussions with stakeholders (including residents, civil organizations, users and local municipality) and household/parcel audits to account for energy resource flows on the demand side. Furthermore, the study tracked the energy resource flows from source to sink, investigating the upstream and downstream processes. The research depends on an interview questionnaire of inhabitants for data gathering. Since the interviews require a great amount of time and effort and due to the conditions created by the Corona virus, in addition to the fact that the researched society is homogeneous, the researcher took an available sample of 5% of the researched society, that is, about 77 buildings/parcel, out of the total researched community of 1,536 buildings/parcel. The heads of households of these buildings were interviewed to collect data after testing the research tool. Some descriptive statistics coefficients (frequencies/percentages/arithmetic means/standard deviations) and inferential statistics (Spearman's correlation coefficient) were used.

First, the fishing community, its nature, characteristics, diverse resources, characteristics of the inhabitants and their daily activities, were identified through research and observation, in addition to interviews with some of the fishermen and the leader of fishermen for the area. Second, various issues, energy resources, and potentials on the ground were identified through transect walks. Third, different archetypes (to cover all existing land uses) were identified using GIS maps of land use, building heights, building conditions, and construction materials and knowing all processes within the community. Hence choosing sample parcels (buildings) for identifying energy resource flows. Fourth, within the sample parcels, demand of the investigated energy resource at the household/unit level was quantified and other related attributes of energy flows were documented using interview questionnaire; this was in addition to assessing waste (food/animals/birds/sewage sludge) output from buildings. Finally, a statistical analysis was carried out to obtain results for energy uses in the selected population.

5 CASE STUDY (SHAKHLOBA VILLAGE)

Despite the greater consumption of energy in cities, one of the fishing communities was selected as a case study for several reasons, including:

- Lack of a clear vision to manage the flow of energy resources in these communities to preserve them for future generations. Such communities are vulnerable due to their resource dependency on their current linear process, which imposes stresses on local resource supplies and negatively impacts the natural environment.
- Fishing communities are very important and have a potential to be turned into self-sustaining communities; they are characterized by energy consumption used for boats movement (fishing and transport of people), and the wide use of furnaces to grill fish in those areas. These areas are also characterized by various energy resources that are not visible to the community, such as the waste resulted from raising poultry and fish (Fig. 4). This can be converted into energy, making the village self-sufficient in energy consumption. These resources require more efficient management.
- These communities share a similar lifestyle (Fig. 5), the same function, and the same energy consumption and flows.

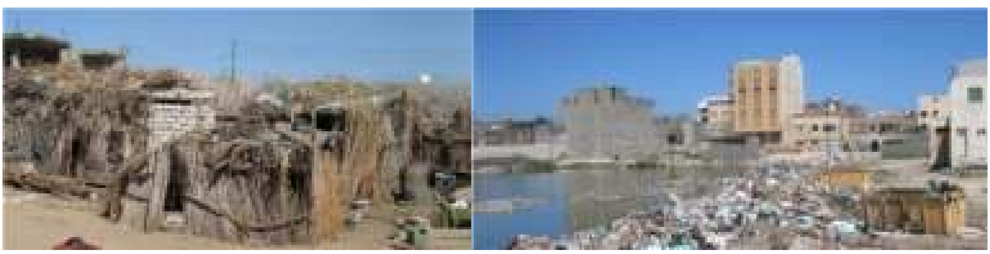

Figure 4: Showing negligence of existing resources in fishing communities.

5.1 Case study: Shakhloba village

The village is being one of its most exquisite spots located south of Lake Burullus. Its administrative subordination is the Sidi Salem Center, Kafr El Sheikh Governorate, Egypt (Fig. 6). Its total area is about 60 acres. The population of 17,000 comprises mostly fishermen and boat builders; the number of buildings is about 1,536 [22]. It is known among local travelers for its alluring landscapes, delicate ecosystem and migratory birds; it is considered a destination for tourism.

Shakhloba is directly overlooking the lake; it is located at the end of a small channel from the Nile that flows into Lake Burullus. The village has two entrances, one through land and the other one through the sea. It is divided into two parts, eastern and western mainlands, separated by a waterway and connected by bridges. The reason for the name of the village is due to the gathering of quantities of fish called "Shakhlout" that come from the Mediterranean Sea and stay in this place. The village is isolated due to its location from the rest of the villages, and therefore it has preserved its identity and traditions, as well as the

Figure 5: Life style in fishing communities in Egypt.

Figure 6: Location and layout of Shakhloba village. *(Source: Google Earth, 2021.)*

distinction of its inhabitants with the hospitality and welcoming visitors from all over the world, as it is considered a tourist attraction.

5.2 Characteristics of Shakhloba village

The architectural, social, economic and environmental aspects greatly affect energy consumption and flows within communities. Some of these aspects are explained below according to the field and statistical study.

5.2.1 Social aspects

The field and statistical study revealed the strong relationship between social factors, the behavior and needs of the population, and the flows of energy and biomass inside the village. It became clear that most of the village residents raise poultry inside buildings, whether on the roof, courtyards, or a separate room in the building. The percentage of the population that raises poultry is 83.1% of the total selected sample, but the waste produced by these birds is not exploited, so it turns out that 98.4% of those who keep poultry inside the residential units dump their waste in the Burullus lake and on the streets. As for food waste, they use it to feed their poultry, and residents who do not keep poultry dump food waste into the lake.

5.2.2 Architecture aspects
The identity of fishing communities and the shape of buildings has changed. Initially, the fisherman used local building materials in the wrong way, but he took into consideration his needs and the needs of the fishing profession. But when money was available to the fishermen, they began to change the housing units to make it more suitable for them. The residents' needs affected the design of residential buildings, regarding the change of building materials (from local materials to concrete buildings) to be able to raise the heights of the buildings into two to three floors, which affected the flows and energy consumption significantly. Figs 7 and 8 show the change of buildings and the design of residential buildings within the village.

Figure 7: Old typical fisherman's housing.

Figure 8: Current typical fisherman's housing.

5.2.3 Environmental aspects

The lake includes a noteworthy number of environments, with swamps and sand plains prevailing, and constitutes an ideal habitat for 135 land and water plant species as well as an important stop-over point for migrating birds [23]. The lake is considered a wetland of international importance for birds, despite the simplicity of the village's nature. However, residents suffer from lake pollution and neglect. Agricultural drainage water accounts for 97% of the total inflow to the lake (3.9 billion m^3 per year), followed by rain water (2%) and groundwater (1%). Sixteen percent of the lake's water evaporates and 84% flows into the sea. According to a biodiversity report by the Egyptian Environmental Affairs Agency, the lake is a natural habitat for 33 species of fish, 23 species of reptiles, 112 species of birds, and 18 species of mammals. Fish species in the lake have declined significantly since the beginning of the 20th century when 52 different species were recorded. This is mostly due to the inflow of agricultural drainage into the lake resulting in lower salinity [24].

5.2.4 Economic aspects

The economy in the village is based mainly on fishing. Fishing is the main source for life and income. This village is distinguished by its specialization in the craft of fishing. After fishing journey ends in the lake, the second stage comes, which is the stage of fishermen taking the fish they got during the day from boats to auction to sell. Where sellers exist from inside and outside the village. Other work that the fishermen depend on, making all types of fishing nets, various boats and scuttle.

5.3 Results and discussion

The energy resources in the village are classified into solar energy, wind, electricity, natural gas, biomass and petroleum, and the energy consumed in several sectors are shown in Table 2. The following is a study of the energy resources in the village through the official authorities and the field study of the village.

5.3.1 Electricity

Electricity is used in all sectors (residential, commercial, services, economic activities, transportation). The total electricity consumption per month is 509,482 kilowatts. Through the field study, it was also found that there are continuously power cuts in the village, especially in winter seasons.

5.3.2 Natural gas

Through the statistical study, it was found that the village fundamentally depends on gas due to the lifestyle and needs of its inhabitants. Fish grilling takes place continuously inside the village, as well as baking bread in the ovens. The average gas consumption per month for the buildings sample is about 5 cylinders, which is about 150 liters of gas per month for the building. The percentage of buildings with an oven is about 93.5% of the selected buildings.

5.3.3 Biomass

There is a variety of resources of biomass in the village, such as reeds, Nile rose plant and bird droppings on the lake. Locals harvest reeds and use them to make mats which are used for a variety of purposes in the nearby community [23]. The village also contains many bird, animal and food waste, which can be converted into energy to obtain gas. The average Egyptian food waste is 73 kg per year [25], so the food waste in the village must be about 103,416.7 kg per month, in addition to poultry droppings and sewage, which is drained into the lake because there is no sewage network.

Table 2: Energy consumption within the village. *(Source: Field Study & North Delta Electricity Distribution Company & leader of fishermen.)*

Resources of energy	Sectors	Energy consumption	
		Energy uses	Total consumption per month
Solar Wind Electricity Natural Gas Biomass Petroleum	Residential	Lighting	367,563 kW of electricity+ 230,400 liters of gas
		Appliances	
		Cooking	
		Water heating	
		Space heating & cooling	
	Commercial	Lighting	46,969 kW of electricity
		Appliances	
		Space heating & cooling	
	Services (Education/ Administration/ Health/ Religious/ Recreation)	Lighting	6,550 kW of electricity
		Appliances	
		Water heating	
		Space heating & cooling	
	Economic activities	Fishing	240,000 liters of petrol + 27,000 liters of diesel
		Fish farms/Fish auction area	88,400 kW of electricity
	Transportation	Maritime transport	900 liters of diesel
		Road transport	810 liters of diesel
Total consumption			509,482 kW of electricity + 240,000 liters of petrol + 259,110 liters of diesel

Note: These statistics are without road electricity and diesel consumption of fish farms due to unavailability of data.

5.3.4 Petroleum

This village is also known by its high consumption of petroleum in many sectors (transportation, economic activities); the total diesel consumption in the village is about 271,110 liters per month, while the total consumption of gasoline in the village is about 240,000 liters per month. This is in addition to the consumption of gasoline used by private cars, where the percentage of those who own private cars is about 5% of the selected sample, and the total consumption of gasoline for personal cars is about 6,795.5 liters per month.

Through the field study and statistical analysis, it was found that:

- The results of the study showed that there was a positive relationship between the building area and the rate of electricity consumption (the value of Spearman's correlation coefficient = 0.350 and significant at 0.01), also there was a direct relationship between the number of floors and the rate of consumption (where the value of the Spearman correlation coefficient = 0.440 and significant when 0.01).
- It was found that issues related to resources and their use occupy an important aspect in the lives of the population, as 88.3% of the buildings sample suffer from electrical energy problems such as interruptions and high prices; 75.3% complain about problems related to lake pollution and the spread of waste, and 86.9% of the buildings sample suffer from the lack of a sewage network.
- The population has a desire to help manage resources better, as the percentage of approval for separating the waste and placing it in the designated places, if available, is about 100% of the heads of household sample. The sample agreed by 80.5% to use solar energy to obtain electricity, due to the high electricity prices at the present time with the low level of income.

6 CONCLUSION

This paper confirms that the urban metabolism approach can be used for a better management of resources within communities for sustainability. It also confirms taking into consideration the importance of the impact of human behavior and activities on improving resource flows to reduce emissions and waste within communities, which reduces the negative impact on the environment. Through the field study, it was found that there is increasing awareness of the population on the importance of good resource management and desire to achieve resource efficiency to improve their lives. Also, it turns out that there is enormous amount of untapped resources that can be converted into energy, for example, converting biomass from various wastes into energy used in buildings, in order to preserve the environment from pollution and emissions and turn output resources into input resources again within the community. The main recommendations lie in improving the management of energy resources in order to convey a vision to decision makers on how to manage energy resources within the scope of achieving sustainable development. Particular attention should be given to neglected small communities that do not have clear management of resources.

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GREENING THE GREY: IMPLEMENTING GREEN URBAN SOLUTIONS, AS ADAPTATION RESPONSE TO CLIMATE CHANGE, IN A PILOT PROJECT IN LEGAZPI, BASQUE COUNTRY, SPAIN

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ABSTRACT

This paper focuses on the implementation of green urban infrastructure solutions (GUIS) in an urban pilot project in Legazpi, Gipuzkoa (Spain). It shows the environmental benefits derived from an overall GUIS project, in terms of climate change adaptation, such as ameliorating stormwater runoff, reducing urban hot spots and improving urban air and water quality. The design process followed in this project started with a community engagement with the residents of Legazpi. A series of international case studies of GUIS were presented. The conclusions of the community engagement informed the final design and construction project. A selection of GUIS were implemented including permeable paving with high albedo finishing materials; bio-retention areas; stormwater retention tanks; and a vegetated pergola. During the design phase, the contribution of the applied GUIS to climate change adaptation was analyzed. It shows that proposed GUIS contribute to reduce the runoff by 25%, the urban temperatures by up to 20°C, and sequester the 7% of the CO_2 emissions from the site. The paper includes lessons learned and the barriers identified when implementing these GUIS. It demonstrates that implementing GUIS in an urban renovation project in Legazpi, are effective to mitigate climate change consequences. Larger projects and more experience are needed in both the construction sector and the technical professionals, to move from pilot projects to common practice.

Keywords: green urban infrastructure, climate change adaptation urban solutions, sustainable urban drainage system, urban greenery, nature based urban solutions, stormwater management, green streets, low impact development, environmental benefits, water sensitive urban solutions.

1 INTRODUCTION

This paper implements GUIS in a pilot project and analyses what a green urban intervention contributes to climate change adaptation. The International Paris Agreement in 2015 [1], achieved an international compromise of main countries around the world to strengthen the global response to the risks of climate change. In addition, the IPCC Climate Change Report of October 2018 [2], called for urgent actions in order to limit climate change impacts. This paper analyses how GUIS contribute to reduce the risks of climate change and suggests more ambitious and rigorous green urban interventions should be carried out.

Several initial questions were asked: do these GUIS reduce the impacts of climate change, do they meet expectations in terms of climate change adaptation, under what terms are they met? This paper provides some clarity on the suitability of GUIS. It analyses the degree to which these environmental benefits are achieved by implementing GUIS into an urban project in a small Basque municipality, Legazpi, of less than 8,500 inhabitants. The project is part of a LIFE European Project (Good Local Adapt) [3], which includes public engagement in order to understand the needs of the residents and to identify the GUIS that better respond not only to climate change but also to citizen's needs. The engagement process included the selection of GUIS implemented in the project: permeable paving and

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high albedo finishing materials; bio-retention areas; stormwater retention tanks; and a vegetated pergola. The paper includes the analysis of the contribution of these GUIS to ameliorate the impact of climate change in three main areas: The reduction of runoff (by 25%), and consequently the reduction in the risks of floods. The reduction of urban heat island, by lowering the urban surface temperature (by up to 20°C). The contribution to air and water quality by CO_2 sequestration through the new greenery (sequestering the 7% of the CO_2 emissions attributable to that area). This paper includes the lessons learned from the implementation of GUIS, and helps to inspire other urban designers to follow a more rigorous design process. It also highlights the barriers found during the project and it concludes advocating for larger and urgent GUIS projects, in order to meet the compromises of the Paris Agreement.

2 PILOT PROJECT DESIGN PROCESS

The design process included the following stages:

1. Community Engagement – a two-part community engagement process, that identified the needs of the residents and assessed the GUIS to be incorporated into Stage 2 (design).
2. Design – integrated the GUIS selected through the engagement process. These included permeable paving and high albedo finishing materials; bio-retention areas; stormwater retention tanks; and a vegetated pergola. These GUIS were installed into the project site.
3. Analysis – the contribution of such GUIS to climate change adaptation, in terms of reducing the stormwater runoff, ameliorating urban heat island effect and contributing to water & air quality were analysed during design.
4. Construction – the selected GUIS were implemented and built on the specific site of Legazpi.
5. Review – includes the lessons learned, conclusions and discussion.

3 COMMUNITY ENGAGEMENT

The community engagement was divided in two major sessions: S0 and S1. The first one, focused on more general concepts of climate change and adaptation solutions. It was held in four neighbourhoods of Legazpi (San Inazio, San Marin, Arantzazu and San Jose). The second session, focused specifically on the site and the solutions to be implemented, was held in the San Inazio neighbourhood. The two main sessions were divided in two sub-sessions, the first one (S01) focused on analysis; and the second (S02) focused on the opportunities to improve their neighbourhoods. The first session S0 was undertaken utilizing both face-to-face participation and digital participation (through an on-line platform). The objectives of the engagement were to raise awareness regarding the consequences of climate change at a local level, to identify the needs and opportunities of both traditional and innovative adaptation solutions, and to compare and prioritize with the citizens the specific GUIS solutions being proposed for use at a local level. In the first sessions S01, residents identified their needs on a neighbourhood map. In session S02 a set of GUIS around the world were provided and participants prioritized their opportunities in a map (Fig. 5) or voting (raising hands). The digital consultation method were statements according to which participants had to express a degree of agreement (from total agreement to total disagreement). In the first sub-session S1.1, of session 2, the needs for the specific site were discussed, and in sub-session 1.2 participants selected their GUIS preferences to be implemented on the specific site. Fig. 1 shows the participation diagram followed during the first main engagement sessions (S01, and S02). Fig. 2 shows some of the sessions.

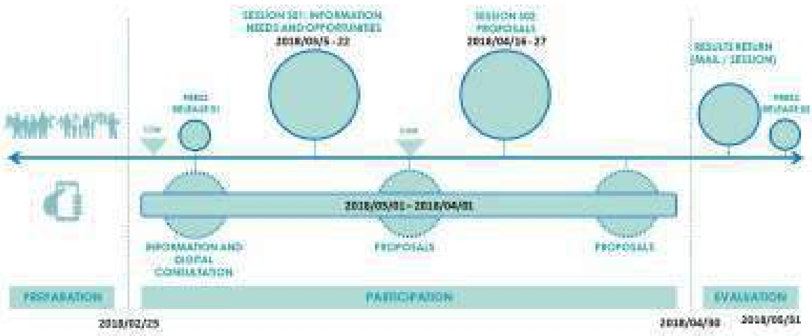

Figure 1: Participation diagram with the three phases: preparation, participation and evaluation. Above the line, is the face-to-face participation main milestones. Below the line, are the main digital participation milestones. *(Source: Image by the authors.)*

Figure 2: The participation process (left S0.1; right S1.2). *(Source: Images by the authors.)*

3.1 Participation indicators

3.1.1 Participation by number and means

Overall, 168 people participated in all four sessions (Fig. 3). The majority of participation was face-to-face, while digital, and online consultation, had a significantly lower participation rate.

FOUR SESSIONS	Session 0 S0.1	Session 0 S0.2	Session 1 S1.1	Session 1 S1.2	TOTAL FACE-TO-FACE	TOTAL DIGITAL	TOTAL
Number of participants	39	47	48	29	**163**	**5** (S0)	**168**
Women (%)	47%	55%	52%	45%	**50%**	**80%**	**50%**
Men (%)	53%	45%	48%	55%	**50%**	**20%**	**50%**

Figure 3: Number of participants by gender. *(Source: Image by the authors.)*

3.1.2 Participation by gender

From a gender perspective, participation in all four sessions has been quite balanced, with 50.01% women and 49.99% men participating.

3.1.3 Participation by age

Average age of participants was over 65 (by visual observation in face-to-face sessions), while in digital participation the average age was between 30 and 45 years old.

3.1.4 Participation by stakeholder group and residential origin

In all four sessions, participants were mostly local residents.

3.2 Results of the community engagement

3.2.1 Citizens' prioritized climatic risks in the demonstrative neighbourhoods

In session S01 participants prioritized the climatic risks as: floods, followed by droughts and heat waves. They identified on a map where these risks are more pronounced in both public space and buildings.

3.2.2 Citizens' input on needs and opportunities for adaptation in public space

The needs and opportunities for climate change adaptation design solutions in public space according to participants in the different sessions are summarized below, in order of priority (Figs 4 and 5). The results are summarized in Fig. 6.

3.3 Evaluation and conclusions

3.3.1 Participants' evaluation

Participants had the opportunity to evaluate the engagement sessions. Ten evaluations were completed and overall, the engagement was well received. Out of the 10 evaluation sheets gathered from the sessions, 60% thought the sessions were an informative way to approach climate change design solutions, and that they would recommend this type of community engagement for similar plans and projects. Additionally, 100% of participants agreed facilitators communicated clearly and were easily understood, and that was communicated in a respectful way between the participants. They also made a few recommendations on how to improve the sessions (Fig. 7).

3.3.2 Conclusions on the overall community engagement

The community engagement achieved the expectations as the three initial objectives were met. This was mainly due to the active engagement of those who participated and defined specific proposals which were considered by the city and the design team for implementation in the subsequent design project.

NEEDS AND OPPORTUNITIES FOR ADAPTATION IN PUBLIC SPACE IN LEGAZPI ***(from higher (1) to lower (4) priority)***
1. Need to increase shade with more natural solutions (trees and vegetation); but maintaining current parking lot numbers.
2. Need to decrease impervious surfaces and create SUDS (Sustainable Urban Drainage Systems), in order to reduce current humidity affecting dwellings adjacent to streets.
3. Opportunity to introduce community gardens (was not interested)
4. Need to increase shadow through hard urban elements (was not interested)

Figure 4: Needs and opportunities for adaptation in public space. *(Source: Image by the authors.)*

Figure 5: Participants identified their needs and opportunities in their neighbourhoods' maps (S0). A diagram summarizes the outcome of session S1.1. *(Source: Images by the authors.)*

	Session S0.1	Session S0.2	Session S1.1	Session S1.2
SUMMARY OF RESULTS	• Needs identified • Climatic risks prioritized	• GUIS examples • Opportunities identified on map	• Specific Needs & Opportunities for the site identified	• GUIS selected for the site • Consensus achieved
	• Awareness for CC raised			

Figure 6: Summary of the results from the engagement sessions. *(Source: Image by the authors.)*

	Agree	In between	Disagree
1. This session has been useful.	60 % (6)	40% (4)	0 %
2. Facilitators have communicated in a clear and easily understandable way.	100 % (10)	0 %	0 %
3. Participants have talked with respect.	100 % (10)	0 %	0 %
4. I would recommend this type of processes.	60 % (6)	40 % (4)	0 %

Figure 7: Participants' evaluation of the engagement. *(Source: Image by the authors.)*

At the same time, participants had the opportunity to see case studies from other parts of Europe and their potential replicability in their municipalities. Surveys showed participants' awareness for climate change and its consequences was raised, and they also valued the engagement process.

The involvement of municipal technicians and political representatives as part of the stakeholders should also be highlighted. This is important to promote the later application of these measures in pilot projects, as future project actions, such as the design project defined in the following section.

4 IMPLEMENTATION OF GREEN URBAN INFRASTRUCTURE SOLUTIONS IN THE PILOT PROJECT OF LEGAZPI, BASQUE COUNTRY

Based on the input from the community engagement, the design team implemented the identified GUIS in the design project including permeable paving with high albedo finishing materials; bio-retention areas; stormwater retention tanks; and a vegetated canopy. A soil permeability study was included in the project which was key to reconsider preliminary design of GUIS. This study showed that the soil characteristic was impermeable (mainly clay), which changed the solution of directly infiltrating rainwater into the soil, to including a stormwater tank. Thus, the rainwater was guided, collected and retained into the tank to reuse it for irrigation or cleaning of streets. The design included a new 1.5 m wide pedestrian area, 9 new trees, and respected existing parking lot numbers. This last aspect was indicated as mandatory by residents during the engagement process. The scheme of the proposal is summarized in the following Fig. 8.

Figure 8: Scheme of the main GUIS implemented in the project. *(Source: Image by the authors.)*

4.1 Permeable pavement and high albedo finishing materials

The design proposed a new permeable pavement to avoid current generation of puddles (indicated in the community engagement as a problem) and with high albedo materials to reduce the heat island effect. Moreover, the new pavement, made of porous concrete, is mostly placed on the existing asphalt, due to the impermeability of the existing soil, and the rainwater is guided to the stormwater tank (Fig. 9).

4.2 Bio-retention areas

The project includes 9 new bio-retention areas which integrate 9 new trees (5 birches and 4 liquidambars), combined with esparto grass and gramineous grass. Again, due to the impermeability of the terrain, the overflow rainwater of these bio-retention areas is connected to the stormwater tank (Fig. 10).

Figure 9: Permeable pavement construction system during the work. *(Source Images by the authors.)*

Figure 10: Bio-retention areas and trees. *(Source: Drawing by the authors and images by Ruben Cañadas, municipal architect.)*

4.3 Stormwater tank

Due to the impermeable ground, rainwater is collected and guided to a stormwater tank made out of reinforced polyurethane cells, covered by EPDM water proof membranes and vegetated soil. The volume of the tank is 41.85 m^3, calculated to retain a medium rainwater event of 25 l/m^2 (Fig. 11).

4.4 Vegetated canopy

The project includes a vegetated pergola, made out of wood, which integrates a new moss roof and wall system, which is tested in the project. The waterproofing of the canopy is by a bituminous roof proofing membrane, a biodegradable coconut layer and the moss plants and substrate (Fig. 12).

5 CONTRIBUTION OF GREEN URBAN SOLUTIONS TO CLIMATE CHANGE ADAPTATION

The paper also analysed the contribution of proposed GUIS to ameliorate the impact of climate change, in terms of the reduction of runoff, the reduction of urban heat island, and the contribution to air and water quality.

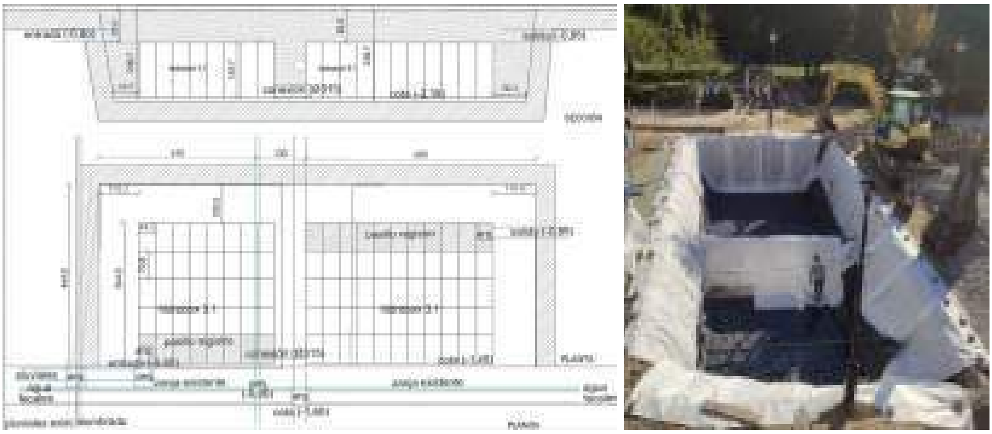

Figure 11: Construction process of the stormwater tank. (Source: Drawing by the authors and image by Marc Rips, Ekinn.)

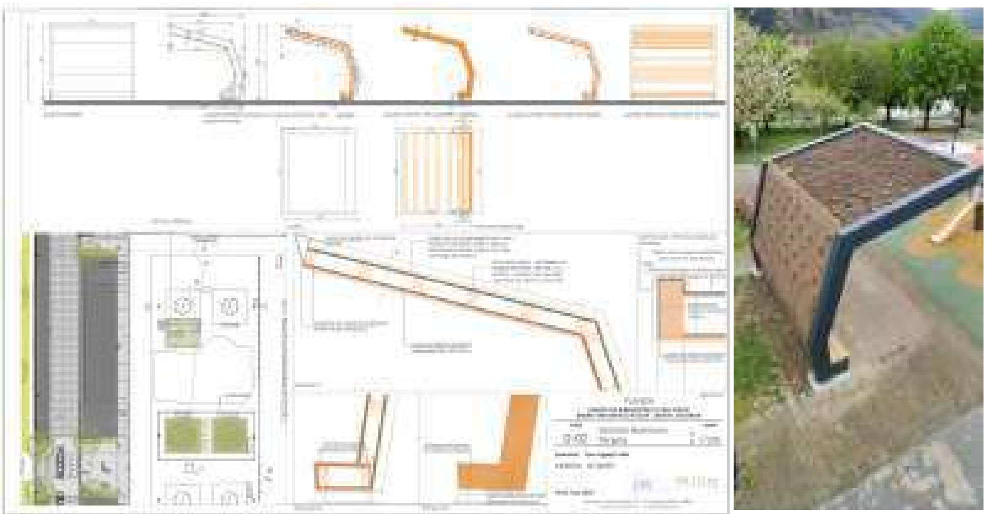

Figure 12: Vegetated canopy. (Source: Drawing by the authors and images by Ruben Cañadas.)

5.1 Contribution to the reduction of runoff from the site

GUIS contribute to retaining and collecting rainwater runoff. Green roofs retain between 20–30% rainwater [4]. Green walls retain 50–75% and can reach 100% [5]. By implementing green roofs, green walls and green streets solutions stormwater runoff can be reduced by 13% [6] A global green urban infrastructure strategy can retain 90% of a city's runoff [7].

The pilot project proposed 23.3 m^2 of vegetated roof (in the vegetated pergola), 26 m^2 of bio-retention areas, and a 41.85 m^3 rainwater tank. Considering these GUIS areas and based on mentioned research studies, this paper estimates that an average of 25% runoff reduction was achieved.

5.2 Contribution to the reduction of urban heat island

The contribution of GUIS to reduce the urban heat island effect is based on relevant publications. For example, in urban parks, for every 100 m^2 of vegetation, air temperature is reduced by 1°C, and that by increasing the ratio of green area to built area by 10% a 0.8°C reduction is achieved (Dimoudi and Nicolopoulou [8]). Similarly, Central Park in New York reduces the nearby temperature by 2–5°C (Rosenzweig et al. [9]), and Shinjuku Gyoen Park in Tokyo reduces the urban heat island effect by 2°C and decreases the temperature in adjacent areas within the range of 80–90 m from the boundary (Honjo et al. [10]). Vegetated courtyards reduce air temperature approximately 4–5°C (Reynolds [11]), and vegetated roofs reduce air temperature between 0.5–2°C (The City of Toronto and Ryerson University [12]). The following Fig. 13 also shows this capacity of greenery to reduce urban surfaces temperature (up to 20°C).

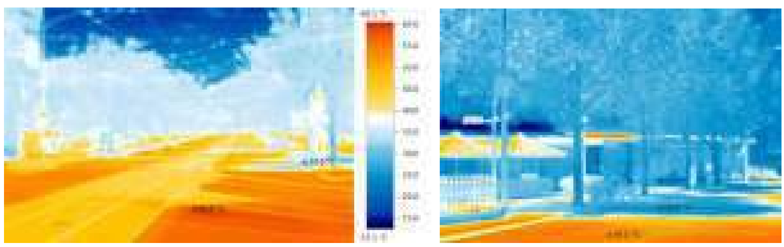

Figure 13: Urban surface temperatures under the sun or under the shadow of trees [13].

This contribution of the vegetation to reduce the urban heat island effect has a direct influence on the reduction of CO_2 emissions, since it reduces the energy demand of buildings as explained below.

5.3 Contribution to the reduction of CO_2 emissions

The contribution of urban greenery to CO_2 emissions, due to the reduction of the energy demand of buildings, can be estimated to be around 10–15% [14]–[18] However, in the Legazpi's pilot project, proposed urban greenery doesn't significantly affect to the nearby buildings. Thus, this paper estimates the reduction of CO_2 emissions through the capacity of the greenery to sequester CO_2. Based on the data from Schaefer et al. [19]; it estimates that grassy plants from the bio-retention areas and vegetated canopy would trap 281.63 kg of CO_2/per year; and climber plants from the canopy would trap around 153.1 kg of CO_2/per year. Additionally, according to McPherson et al. [20] the proposed 9 trees, with a diameter less than 7 cm, would trap around 0.18 kg of CO_2/year.

Therefore, the combined contribution of the proposed GUIS to the sequestration of CO_2 is 434.89 kg of CO_2/per year is shown in the following Fig. 14.

Considering that the CO_2 emissions of Legazpi is around 154,241 tCO_2e [21], for a municipality of 42.17 km^2 [22]. A quick calculation suggests that Legazpi emits 3,657.6 tCO_2e/km^2; which is 3.66 $kgCO_2e/m^2$. The pilot area of 1,675 m^2, would mean it

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ESTIMATION OF THE CO2 SEQUESTRATION IN THE LEGAZPI PROJECT				
		surface (m2)	sequestration (kg/m2) [18]	CO_2 sequestration (kg/year)
LEGAZPI	Grassy plants	64.3	4.38	281.634
	Cilmbers	23.3	6.57	153.081
		number (ud)	sequestration (kg/ud.year) [19]	
	Young trees	9	0.02	0.18
	TOTAL			**434.895**

Figure 14: CO_2 sequestration by the GUIS of the project. *(Source: Image by the authors.)*

corresponds a 6,126.48 CO_2e emissions to that area. Since the proposed GUIS contribute to sequester 434.91 kg of CO_2, which means a 7% of the CO_2 emissions attributable to the site area. However, this pilot project only increased the urban greenery by 4%. Thus, these results show the limitations of urban greenery to significantly reduce CO_2 emissions by sequestering it.

The overall results of this section shows that GUIS are effective to reduce the urban heat island and stormwater runoff of a specific area (Fig. 15). They can also achieve more modest results to reduce CO_2 emissions. It concludes that more ambitious urban greening interventions should be addressed in order to achieve better climate change adaptation results.

CONTRIBUTION OF PILOT PROJECT'S GUIS TO CLIMATE CHANGE ADAPTATION	
REDUCTION OF RUNOFF	25%
REDUCTION OF URBAN HEAT ISLAND	UP TO 20ºC
REDUCTION OF CO_2 EMISSIONS	7%

Figure 15: Summary of the contribution of GUIS to CC adaptation. *(Source: Image by the authors.)*

6 CONCLUSION AND DISCUSSION

This paper highlights the potential of GUIS as an effective climate change adaptation solution. It implements GUIS in a specific pilot project in Legazpi, Basque Country. It outlines the design process highlighting the community engagement to both select the GUIS applicable to the site and to raise awareness regarding the consequences of climate change at a local level. A series of findings on how these green urban interventions contribute to climate change adaptation is provided, in terms of reducing the urban stormwater runoff and the risk of floods; as well as the influence on the urban heat island effect and CO_2 sequestration.

Results demonstrate that by the proposed GUIS on the site (Legazpi), 25% of runoff could be reduced; urban surfaces temperatures reduced by 2°C and up to 20°C; and 7% of the CO_2 emission sequestered. This pilot project shows that GUIS are effective for climate change adaptation. Specially to reduce runoff and urban heat island effect, and in a more modest way to reduce CO_2 emissions.

This implementation of GUIS in the pilot project of Legazpi, provided valuable lessons for future designs. For instance, the convenience of including elements that allow more space for the roots of trees in the bio-retention areas; as well as the recommendation to include a drain pump for the stormwater tank, or an irrigation system for the vegetated pergola. Another valuable aspect was the community engagement during the design phase. The engagement process provided a better understanding of the needs of the citizens in the project, and reflected priorities of the residents in the GUIS implemented in the project. The design process is useful to get community support for an urban project.

The project identifies the main barriers encountered when implementing this type of GUIS, and it shows that there are still many challenges which are summarized below:

1. The little experience in this type of projects of all agents involved in the project: the design team, the construction company, and the municipal technicians.
2. The skepticism and distrust towards new urban solutions (GUIS); which reflect the need to continue working and promoting them to increase the experiences of all the agents involved. This would generate more confidence in GUIS.

The authors suggest larger green urban projects should be promoted in order to meet the commitments made in the International Paris Agreement. This effort should be accompanied by training courses on green solutions for all the agents involved in these types of projects from designers, developers, to builders, planners, municipal technicians, and decision makers.

The paper emphasizes that this type of green urban infrastructure design process is effective for adapting to climate change, creating consensus within the community and developing a more resilient urban space. It advocates to move from pilot projects to common practice. Finally, it urges to promote this type of GUIS in larger scale projects in order to increase the experience and confidence in GUIS.

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SECTION 5
THE COMMUNITY AND THE CITY

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MEASURING PARTICIPATION: A COMPARATIVE STUDY OF CITIZEN ENGAGEMENT PROCESSES IN URBAN PLANNING

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ABSTRACT

While there is a growing practice of engagement processes in urban planning, with diverse strategies and actions, there are still many questions regarding the evaluation; the gap being how to conclude that a process has been successful or not, and in what terms. In this context, this paper analyses a series of international reference models over the last fifty years, including levels of participation (Arnstein, UN-Habitat, IAP2), key performance indicators (IISD), evaluation guidelines (IOPD) and quality standards and indicators for community engagement (NSfCE, OGP, UNICEF). Based on this analysis, the research proposes an evaluative framework specific for citizen engagement in urban design and planning processes. The framework includes consists of six standards, with quantitative and qualitative indicators to consider both a process's outputs as its outcomes. The standards are: scope (level of engagement, process planning and structure), inclusion (diversity and quantity of stakeholders by gender, age, stake-holder type and others), mechanisms (typology, diversity and outreach), communication, building capacity (raising awareness and understanding), and impact (contribution to the urban plan). The research applies the framework to conduct a comparative study among cases of engagement processes in municipal-scale urban planning in the Basque Country, Navarre and Cantabria, in the north of Spain. Six case studies include small- and medium-sized towns and cities with a wide range in scale, from 4,000 to 350,000 people, and both pre-COVID and during-COVID experiences. Results reveal tendencies, common benefits and challenges. Conclusions allow for a better understanding of the matter and expect to be useful and transferable to future urban planning-related engagement processes in order to overcome initial preconceptions, avoid false expectations, and better design and undertake them to increase their social impact and contribution to the urban plans they are framed within.

Keywords: citizen engagement, public participation, urban planning, inclusive urbanism.

1 INTRODUCTION

International and European standards for engagement in decision-making processes have evolved considerably in the last years, with numerous binding and non-binding documents reinforcing the notion that participation is a right that should be regulated and implemented, as well as existing good practices and benefits need to be highlighted and shared [1].

Diverse strategies and actions are used to a lower or higher extent of public participation, from basic information to full empowerment, including both digital and in person means. Regarding these last two, while technology provides economical and effective ways to engage citizens, when decision-making is required on large issues, there is no substitute for offline face-to-face engagement [2, pp. 7–8]. Consequently, engagement processes combine different actions or mechanisms in order to achieve their specific engagement goals.

Nevertheless, there are still many questions regarding the evaluation of these processes. According to Hanover Institute, standardization of public engagement evaluation and

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effective measurement approaches and tools are still in early stages, as it is difficult to quantify the impact of public engagement efforts, especially when they can comprise such a wide variety of initiatives. It is important to make a difference between process outputs and process outcomes and, although the evaluation of the first is more straightforward than the evaluation of the second, sophisticated evaluation methods tend to focus on the latter [3].

When it comes to urban planning, following this trend, there is a growing practice of engagement processes and similar lack of evaluation. In particular, the little research targeted on the use of co-design as a joint planning process between experts, the local community and stakeholders, suggests increased tendency of citizen awareness and understanding of urban development depending on the level of citizens' power in the process [4].

In this context, this paper focuses in the evaluation of citizen engagement processes specific to urban design and planning, addressing the question of how to conclude that a process has been successful or not, and in what terms; that is, according to what standards or criteria. The methodological approach begins with an analysis of engagement models and evaluative frameworks, to develop a specific one for urban design and planning, apply it in a series of case studies and extract conclusions to inform future practice.

2 ANALYSIS OF INTERNATIONAL ENGAGEMENT MODELS

2.1 Reference engagement models analysed

Over the last fifty years, since Arnstein's 1969 influential Ladder of Citizen Participation, different citizen engagement and public participation models have appeared worldwide. As democratic societies across the globe increasingly commit to collaborative governance, public participation has thereby emerged as a rich arena, including the "deliberative wave" that has gained ground since 2010 seeking ongoing, continuous and open dialogue and engagement between the public and public decision-makers [5]. Within the different existing engagement models, this paper analyses the following eight (Table 1): Arnstein's 1969 Ladder of Citizen Participation, UN-Habitat's 2007 Forms of Participation in an Urban Strategic Planning Process, the IAP2 Spectrum of Public Participation, the International Institute for Sustainable Development's (IISD) 2012 report on measuring community indicator systems, the International Observatory on Participatory Democracy (IOPD) 2013 Guide to Evaluate Participatory Processes, Scotland's 2016 National Standards for Community Engagement, the Open Government Partnership (OGP) 2017 Participation & Co-Creation Standards, and UNICEF's 2019 Minimum Quality Standards and Indicators for Community Engagement.

Arnstein's 1969 Ladder of Citizen Participation [6] is considered one of the classic and most influential participation theories [7, p. 4]. Understanding citizen participation as a categorical term for citizen power, Arnstein proposes a provocative typology of eight levels of citizen participation based on the power relationship between what she refers to as the *haves* and the *have-nots*. Arranged in a ladder pattern (for illustrative purposes), the first two rungs relate to nonparticipation, being manipulation and therapy. Rungs 3, 4 and 5 are degrees of tokenism: informing, consultation and placation. At the top of the ladder, as degrees of citizen power, there is partnership, delegated power and citizen control. Arnstein describes each level, with specific examples, tools and caveats.

Within the notion of levels or degrees, and more related to urban planning, UN-Habitat presents seven Forms of Participation in an Urban Strategic Planning Process [8]: information, consultation, consensus building, decision-making, risk-sharing, partnership

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Table 1: Analysis of eight reference engagement models.

Author/Organisation	**Model/Document**	**Levels of engagement**	**Tools/ Mechanisms**	**Standards/ Criteria**	**Indicators/ Actions**
Sherry Arnstein, 1969	A Ladder of Citizen Participation	8 levels. Provocative and critical	Tools and caveats for each level		
UN-Habitat, 2007	Forms of Participation in an Urban Strategic Planning Process	7 forms of participation + concept			
IAP2 – International Association for Public Participation, 2007	Spectrum of Public Participation	5 levels, with goals and promise to the public	Tools and techniques by level	Principles, core values and code of ethics	
IISD – International Institute for Sustainable Development, 2012	Measuring the Performance and Impact of Community Indicators Systems				Key performance indicators (KPI)
International Observatory on Participatory Democracy (IOPD), 2013	Guide to Evaluate Participatory Processes	4 scenarios (similar to levels) with roles and values by level		Specific evaluation criteria	Indicators and evaluation instruments
The Scottish Government, 2016	National Standards for Community Engagement (NSfCE)			7 standards	Indicators for each standard
Open Government Partnership (OGP) 2017	OGP Participation & Co-Creation Standards	Uses the IAP2 Spectrum (5 levels)		2 main standards: basic and advanced	Requirements for each standard
UNICEF, 2019	Minimum Quality Standards and Indicators for Community Engagement			6 core standards + 10 other standards	Actions and indicators for each standard

and self-management. These forms reflect three basic rights of citizens: the right to be informed (materialized through access to information), the right to be heard (materialized through consultations and consensus building), and the right to affect those activities which directly relate to people's living conditions (realized through inclusion in decision-making, risk sharing, partnership and self-management). Individual phases and stages call for different levels of participation and not all the stages require direct public participation. However, all these forms create a continuum, a gradual development of participation from the lowest- to the highest-intensity stages. UN-Habitat highlights urban consultation as the most important and effective means of stimulating participation and civic engagement in strategic planning. The framework describes each form of participation and when it occurs within the Urban Planning and Management Framework (UPMF).

In a similar way, also following this notion of levels, the IAP2 (International Association for Public Participation) provides its Spectrum of Public Participation [9], ranging from inform to consult, involve, collaborate and empower. The spectrum was developed to support and define the public's role in any public participation process. Essentially a matrix, it shows that differing levels are legitimate and depend on the goals, time frames, resources, and degrees of concern in the decision to be made, identifying the level to be chosen based on the specific goal of the project and the promise being made to the public. [7, p. 25]. The spectrum also includes example techniques or tools for each level. Moreover, the overall IAP2 framework provides Core Values, to define the expectations and aspirations of the public participation process, and a Code of Ethics on the actions of practitioners. It is widespread in North America, with different institutions following and adapting the spectrum to their specific realms (i.e., the US EPA for environment-related projects and the Facility Engagement for Canadian Medical Staff Associations, MSA). In 2009, together with the National Coalition for Dialogue & Deliberation (NCDD), the Co-Intelligence Institute, and other leaders in public engagement, the IAP2 developed a series of seven Core Principles for Public Engagement: careful planning and preparation; inclusion and demographic diversity; collaboration and shared purpose; openness and learning; transparency and trust; impact and action; and sustained engagement and participatory culture [10].

Though not detailed in this paper, there are other models following a graduation of engagement, ranging from three to twelve levels. The European Center for Not-for-profit Law (ECNL) explains how the tools and mechanisms adopted by countries to implement and foster participation differ based on three main levels of engagement: information, consultation and active engagement through dialogue and partnership [1, p. 46]. On the other hand, Scott Davidson developed the Wheel of Participation for and with the South Lanarkshire Council to define and encourage levels of citizen participation for community planning and development. Based on four degrees (to inform, consult, participate and empower), the wheel presents, in all, twelve different levels, three in each degree [5, p. 8].

Shifting attention from engagement levels to specific evaluation tools, and though not an engagement model in itself, the International Institute for Sustainable Development's (IISD) 2012 report [11] provides a useful understanding on indicators as a tool for evaluation, reflection, learning and improvement. The report concludes a well-defined set of key performance indicators organized within a coherent evaluation framework can help Community Indicator Systems (CIS) to divide broad evaluation questions into more specific and manageable pieces, overcome vested interests and subjective biases, and provide hard empirical evidence of program performance and impact that can be used to engage stakeholders and to inform future planning and implementation.

In this line towards support for evaluation, the International Observatory on Participatory Democracy (IOPD) developed in 2013 a Guide to Evaluate Participatory Processes [12]. Building from its previous 2006 guide and similar to the levels defined in the previously described models, the guide indicates four gradual participatory scenarios: information, communication (or dialogue), debate and decision. Additionally, it provides specific evaluation criteria, methodologies and indicators for five key areas: process coordination, participants, subject, method and consequences.

Responding to the need for standardization in evaluation mentioned in the introduction, Scotland's National Standards for Community Engagement (NSfCE) [13] are clear good-practice principles designed to support and inform the process of community engagement, and improve the result. Originally launched in 2005 and revised 2015/2016, the standards provide detailed performance statements to achieve quality results and impact. The seven standards are: inclusion, support, planning, working together, methods, communication and impact. Each standard includes a short headline statement, a set of indicators to show progress towards meeting each standard, and some examples of good practice, within different sectors (health, social care, urban planning, budgeting, etc.). The National Standards are designed for public sector bodies and elected representatives, third sector organisations and community groups, and the private and independent sector. In this context, in 2017 the Scottish Government, together with Architecture & Design Scotland and NHS Health Scotland, developed the Place Standard tool [14] to structure conversations to assess the quality of a place; be it well established, undergoing change, or still being planned. Viewed alongside digital engagement tools, the value of the Place Standard is how it facilitates face-to-face conversations [2, p. 4].

Likewise, the Open Government Partnership (OGP) published in 2017 its Participation & Co-Creation Standards [15]. The guidelines are based on evidence and experience and build on the IAP2 Core Values. The standards are divided into two overarching sections outlining basic requirements (the standard all countries are expected to meet) and advanced steps (the standard countries should strive for). Countries are expected to improve the quality of each cycle of the national OGP process, complying with more of the advanced steps outlined in these standards and moving from consult to collaborate on the IAP2 Spectrum. The standards are further organized around three essential elements of a participation and co-creation process: dissemination of information, spaces and platforms for dialogue and co-creation, and co-ownership and joint decision making.

Last within the analysed models, UNICEF presented in 2019 its Minimum Quality Standards and Indicators for Community Engagement [16]. Though specific for humanitarian assistance, the model is useful for other fields such as urban design and planning. Standards are organized into four sections to cover both core standards as well as support implementation, coordination and integration, and resource mobilization. Each standard includes quality criteria, detailing the minimum targets needed to achieve quality community engagement with a series of actions, listed as bullet points below each criterion. They are meant to be flexible and should be selected or adapted to local contexts as needed. The model also includes indicators, meant to trigger internal institutional review processes to study whether internal data collection, monitoring, evaluation, research, and learning tools and processes align with the community engagement minimum standards.

2.2 Similarities, differences and gaps among the analysed models

Many of the analysed models follow Arnstein's proposal of a gradient in participation, be it three levels (ECNL), four (IOPD), five (IAP2), seven (UN-Habitat), eight (Arnstein) or twelve (Davidson). Other than Arnstein's first two levels of nonparticipation, all analysed models place information at the basis for participation, followed by consultation. From there, names vary in a somewhat similar way referring to a higher intensity engagement level: involve, collaborate, consensus building, dialogue, debate, active engagement. Last, at the highest-intensity end of the range, models include: empower, decision-making, risk-sharing, partnership, self-management, delegated power and citizen control. The most notable difference in terms of levels is in the approach: while Arnstein provocatively refers to consultation as tokenism (a symbolic effort to be inclusive in order to give the appearance), the UN-Habitat highlights its importance and effectiveness. Except for Arnstein's, the rest of analysed models present the different levels legitimating them depending on the goals that are wished to be met.

All of these models present examples of engagement tools or mechanisms within each level, which is useful when designing a process, once the level of engagement is decided.

Some analysed models provide principles (IAP2) or quality standards and criteria (IOPD, NSfCE, OGP, UNICEF) to better design, plan and assess engagement processes. While each model has its own structure and uses different terms, there are similarities as to the areas the different standards cover. For instance, many refer to the process, as coordination (IOPD) and planning (NSfCE, UNICEF). Standards also relate to inclusion (NSfCE, UNICEF) and participants (IOPD); methods (IOPD, NSfCE), tools (IAP2) and activities (UNICEF); communication (NSfCE, UNICEF); and outcome, described as impact (NSfCE) and consequences (IOPD). Furthermore, some models provide indicators as a practical tool for evaluation (IISD, IOPD, NSfCE, OGP, UNICEF).

While these standards are flexible enough to be valid across different contexts and settings, they require to be fine-tuned in order to further apply them to the specific realm of urban design and planning. Citizen engagement in urban planning includes a variety of specific concepts and topics, and, at the same time, these are usually quite technical, thus, requiring an important effort to make them understandable to the general public. Moreover, it offers the opportunity for design-based methods typically used in the field, suitable to citizen engagement in the form of collaborative design or co-design methods between technicians (architects and planners), stakeholders and citizens, as "experts in experience".

3 CITIZEN ENGAGEMENT EVALUATIVE FRAMEWORK FOR URBAN DESIGN AND PLANNING PROCESSES

The proposed evaluative framework specific for citizen engagement in urban design and planning processes builds on the previous analysis. It consists of six standards, each relating to a specific goal and criteria and including a set of three main indicators to assess the extent to which the criteria are accomplished. Table 2 summarizes the six standards and indicators.

The first standard, scope, includes a first indicator on the level of engagement, targeted and achieved. Considering the different engagement models analysed, the framework uses the following four-level range: information, consultation, consensus building (which includes other models' levels of involve, dialogue, debate, collaborate, etc.) and decision-making (which includes partnership, self-management, empower, etc.). The second indicator relates to the process planning as some of the analysed models suggest. Last, the third indicator relates to the structure of the process by urban design and planning key topics (housing, public space, mobility, etc. included in Table 4).

The second standard, inclusion, looks at the targeted and participating stakeholder types and to participants' quantity as well as diversity by gender, age, stakeholder-type, location, family-work reconciliation and language.

Table 2: Proposed evaluative framework for citizen engagement in urban planning.

Standard	**Indicators**
1. Scope	1.1 Level of engagement.
	1.2 Process planning.
	1.3 Structure by urban design and planning topics.
2. Inclusion	2.1 Stakeholder types.
	2.2 Quantity of participants.
	2.3 Diversity of participants.
3. Mechanisms	3.1 Typology of engagement mechanisms (by levels).
	3.2 Diversity of engagement mechanisms (by levels).
	3.3 Outreach by engagement mechanism.
4. Communication	4.1 Typology of communication mechanisms.
	4.2 Diversity of communication mechanisms.
	4.3 Outreach by communication mechanism.
5. Building capacity	5.1 Participants' understanding of the planning process.
	5.2 Participant's awareness of urban planning key topics.
	5.3 Participants' assessment of the engagement process.
6. Impact	6.1 Contributions to the plan (by urban planning key topics).
	6.2 Support & consensus (by urban planning key topics).
	6.3 Incorporation of engagement contributions into the plan.

Mechanisms and communication, the third and fourth standards, focus on typology, diversity and outreach by engagement and communication mechanisms used in the process, the first organized by engagement levels. While mostly based on process outputs through quantitative indicators, they also allow for a qualitative analysis and assessment.

The last two standards relate to the process' outcomes in terms of building capacity (raising awareness and understanding of the plan) and impact (contributions, support and consensus by urban planning key topics). Although supported by quantitative indicators, the analysis of these two standards is mostly qualitative.

4 CASE STUDY ANALYSIS

4.1 Case study selection of engagement processes in municipal urban plans

The case study focuses in six engagement processes within municipal urban plans in the Basque Country, Navarre, and Cantabria, in the north of Spain.

1. Bilbao, Basque Country: Engagement in the Advance phase of the Municipal Urban Development Plan (MUDP) [17].
2. Santander, Cantabria: Public consultation previous to the MUDP [18].
3. Getxo, Basque Country: Engagement in the MUDP Advance phase [19].
4. Irun, Basque Country: Engagement in the Advance phase of the MUDP Modification in the railroad area (ViaIrun Master Plan) [20].
5. Zumaia, Basque Country: Engagement in the Information phase of the MUDP [21].
6. Cendea de Cizur, Navarre: Engagement in nine small towns within the municipality [22].

The selection of the case studies is due to five main reasons: similar planning scale (municipal-scale) and phase (plans' early stages), diversity in municipality's scale (with populations from 4,000 to 350,000), geographical proximity, first-hand information and COVID impact diversity (with both pre- and during-COVID experiences). The last case study, Cendea de Cizur, is the only one not directly related to a MUDP but to more specific urban design and infrastructure issues relevant for a municipal urban strategy. It is included because of its smaller scale to provide empirical data, as it is a 4,000-inhabitant municipality consisting, at the same time, of nine smaller towns ranging from 60 to 3,000 residents.

4.2 Main results from the comparative study

4.2.1 Scope

All six case studies target and achieve the same level of engagement, consensus building, all including the previous levels of information and consultation. While all go far beyond the minimum legal requirements for engagement in urban planning in the Basque Country, none attain the highest-intensity level of decision-making and empowerment.

In terms of process planning, the case studies relate to the plans' early stages; be it at the earliest phase (Santander, Zumaia, C. de Cizur) or at the Advance Phase, prior to the plan's Initial Approval (Bilbao, Getxo, Irun). The first approach is useful in providing first -hand initial information to later develop alternatives and proposals. In turn, the second approach is useful to contrast and complement the plans' first proposals, before the Criteria and Objectives document and the development of the Initial Approval document.

As for process structure by urban planning topics, the five MUDP case studies include the six topics directly related to urban planning land-uses: housing, mobility, public space, economic activity, facilities and services, and landscape and natural environment. Urban regeneration, which is gaining momentum in Europe, is incorporated either on its own or within housing or patrimony. The largest cities and towns (Bilbao, Santander, Getxo, Irun) also include a first topic on regional and urban strategy. All case studies comprise cross-cutting topics, such as patrimony, inclusion (including gender, age-diversity and safety), and sustainability and climate change. A few also cover innovation (with caveats about what it really entails in urban planning) and the most recent case includes health, whose relationship to urban form has been argued for years, becoming increasingly relevant with the pandemic.

4.2.2 Inclusion

Case studies target mostly to local residents. Stakeholder typologies are completed by local associations, people working or studying in the municipality, as well as visiting. To a lower extent, municipal technicians and politicians. Santander and Zumaia adapted their stakeholder typology to include occasional residents (week-ends and holidays).

Comparing quantity of participants relative to population (number of participants per 1,000 residents), instead of by absolute values, suggests a potential relationship with scale (Fig. 1). Results show a tendency of higher participation in lower population towns (dashed line) with a spike in the less populated case study. While this may be useful to avoid false expectations, other factors are obviously key for attaining a higher number of participants, such as communication and engagement mechanisms, and further research with more empirical data needs to be conducted to affirm a relationship between scale and quantity of people engaged.

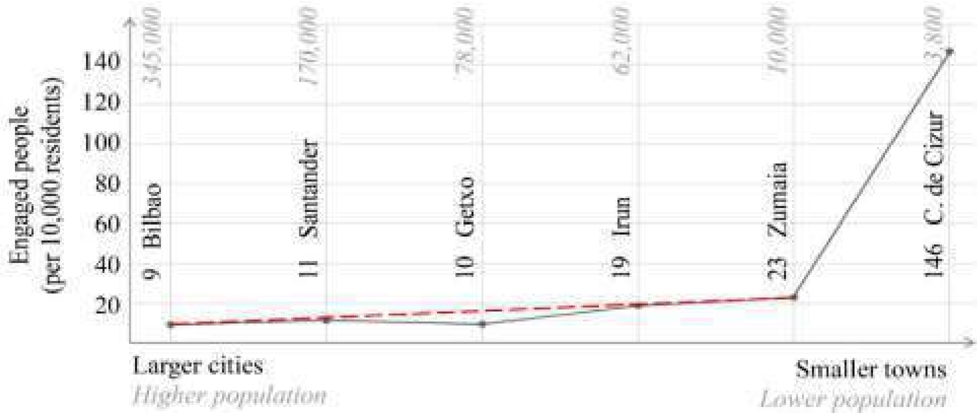

Figure 1: Quantity of participants: engaged people per 10,000 residents.

Looking at diversity by gender (Fig. 2), results show an overall higher participation of men than women in the largest cities (Bilbao, Santander, Getxo and Irun). The pattern shifts in the smaller towns of Zumaia and C. de Cizur, with women participating in a very similar percentage as in the overall population (around 50–52% being women). Looking at specific engagement mechanisms, on average, face to face events gather more men than women, suggesting the need to overcome this. At the same time, digital consultation usually provides a more even participation between men and women. This could explain the shift in gender equality in Zumaia, where, due to the pandemic, engagement was mostly digital and by interviews, whereas in the other case studies, face-to face meetings and sessions had a higher relevance. Further research could be developed in terms of culture and politics, and its impact or reflection in women's roles and expectations, arguing Santander, Getxo and Bilbao are more conservative, and Zumaia and the smaller towns within C. de Cizur more progressive.

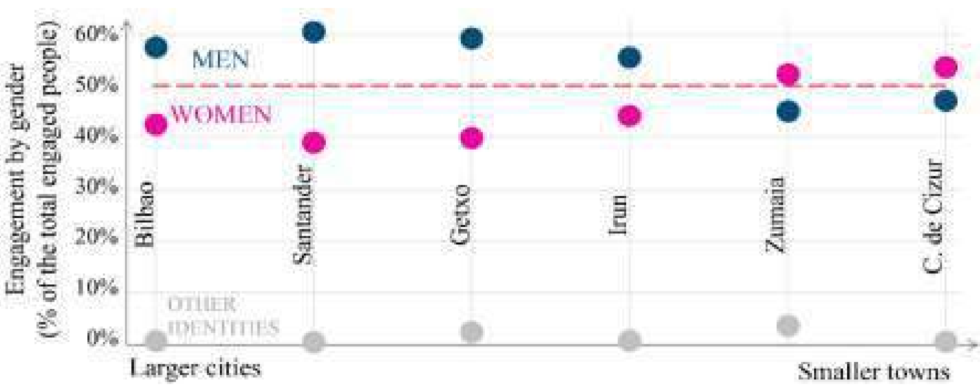

Figure 2: Diversity of participants by gender.

4.2.3 Mechanisms

All six case studies include informative, consultive and consensus building engagement mechanisms, combining them in different ways, as reflected in Table 3. The pandemic, affecting the processes in Zumaia and Santander required significant adaptation; delaying, suspending or adapting in person means (depending of the specific health situation at the moment). Zumaia, specifically, had to basically rely on digital consultation and interviews.

Table 3: Typology and diversity of engagement mechanisms by level of engagement (Standard 3, Indicators 3.1 and 3.2 in Table 2).

Information mechanisms	**B**	**S**	**G**	**I**	**Z**	**CC**
Website	■	■	■	■	■	■
Informative brochures/leaflets	■	■	■	■		■
Informative videos	■	■	■		■	
Informative lectures	■	■	■	■	■	■
Exhibitions	■	■	■	■		
Individual informative meetings	■		■	■		
Consultation mechanisms	**B**	**S**	**G**	**I**	**Z**	**CC**
Digital consultation	■	■	■	■	■	■
Paper consultation	■			■		■
Telephone interviews				■		
In person interviews			■			
Consensus building mechanisms	**B**	**S**	**G**	**I**	**Z**	**CC**
Sessions/workshops with neighbours	■	■	■	■		■
Focus sessions (experts/by topics)	■	■	■	■		
Sessions with children/youth	■	■	■	■	■	
Urban walks/citizen walks		■				
Advisory Committee	■		■	■	■	

In overall, results suggest the combination of different mechanisms is needed to achieve diversity. Particularly, the larger the target population, the higher diversity of mechanisms. Digital consultation generally gathers the highest number of participants and an even participation among men and women. While not building consensus per se, it is very useful to visualize consensus among participants. Paper consultation and interviews increase the diversity, despite being time-consuming. As for consensus building mechanisms, specifically when working in groups with collaborative design methods, they generally gather less people but are more effective in building awareness, understanding, trust and consensus, and in gathering more in-depth contributions to the plans. Focus sessions allow for specific views by topics and specific stakeholders, while sessions with children and youth in schools and universities are an effective way to alter the otherwise common gaussian curve in engagement by age. In this sense engaging people over 65, remains a challenge.

4.2.4 Communication

Communication is key to reach out to the public. While websites are a minimum, more active means such as municipal magazines/newspapers and continuous press releases and posts in social media show spikes in number of participants in digital consultation. Continuous communication is most relevant, the larger the target population is. Bilbao and

Santander, for instance, offered several press releases throughout the processes, with an impact of over 130 and 100 media appearances each. In turn, the smaller town of C. de Cizur, where the only communication means were WhatsApp and informative brochures distributed to every household, resulted in the highest quantity of participants per capita, by far (Fig. 1). In terms of social media, while some projects developed their own profiles, other used the municipality's, with similar or even better results, as these already have a set of followers.

4.2.5 Building capacity

Case study results confirm an increase in understanding and awareness of the planning process. According to the participants' assessment (undertaken in all pre-COVID cases), the majority affirms the process increased their understanding of the process. With slight differences within the case studies, the urban planning topics that arouse the highest awareness and interest among participants are, in general: mobility, housing and the natural environment, followed by public space, facilities and patrimony (Table 4, darker colours).

Table 4: Awareness, contribution and consensus by planning topics (Standards 5 and 6).

	Urban planning key topics	**Awareness** (Ind. 5.2)	**Contrib.** (Ind. 6.1)	**Consensus** (Ind. 6.2)
	Regional and urban strategy	1	3	2
Spaces	Landscape and natural environment	3	3	4
	Mobility	5	5	3
	Public space	2	4	3
Buildings	Housing	4	3	1
	Economic activity	1	2	2
	Facilities and services	2	4	3
Cross-cutting	Urban regeneration	1	1	3
	Patrimony	2	3	3
	Inclusion	1	2	4
	Sustainability and climate change	1	2	5
	Innovation	1	1	3

4.2.6 Impact

All case studies gathered contributions from all urban planning topics, although topics that collected a higher number of contributions were generally mobility, public space and facilities (Table 4, darker colours). Of course, quantity does not mean quality. Processes mixed closed-ended questions to validate specific items or proposals (expressing results in consensus bars) together with open-ended questions, at times using collaborative maps.

Results reveal, in general, higher consensus and support in sustainability and climate change, followed by natural environment and inclusion. The topic that usually includes a higher diversity of opinions (hence, lower consensus) is in all cases housing (except C. de Cizur, where it didn't apply). It is followed by economic activity and, to a lower extent, regional and urban strategy. In all, results suggest citizens tend to agree more around cross-cutting topics (sustainability and climate change, inclusion, patrimony) and space (be it for nature, mobility or public space). In turn, they tend to agree less when it comes to buildings, particularly housing (the largest share of buildings in Municipal Urban Development Plans).

5 CONCLUSIONS

The evaluative framework developed from the analysis of international models, together with its application to the case studies presented, allows for a better understanding of different considerations, outputs and outcomes related to the success or achievement of a given urban planning-related engagement process. The research lies within the consensus building level, as none of the cases attain higher, more ambitious citizen empowerment levels. Further research in the development of the framework needs to overcome challenges in obtaining some of the indicators (i.e. the incorporation of engagement contributions into the plan). At the same time, there are external factors that influence the processes, such as legislation, political will, economic resources, participatory culture, and, potentially, a municipality's scale. Additionally, despite a clear scope and planning, processes require adaptability to unforeseen circumstances such as the pandemic.

Nonetheless, the framework and comparative study attempt to go beyond demonstrating the different cities' commitment to public engagement, to provide empirical data and suggest similarities, variations and tendencies within the analysed case studies. This expects to be useful and transferable to future urban planning-related engagement processes. Among others, in order to overcome initial preconceptions, avoid false expectations and better design and undertake them, considering the targeted level of engagement, quantity and diversity of participants, engagement and communication mechanisms and outcomes in terms of building citizen capacity and impact and contribution to the plan. In all, to foster a more inclusive urbanism, with a higher social impact and enriched by citizen contribution.

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POTENTIAL OF THE PUBLIC SPACE TO PROMOTE ENVIRONMENTAL BEHAVIOR

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ABSTRACT
It is widely recognized that individual environmental behavior plays an important role in curving climate change but it remains unclear how it could be promoted. This paper studies the potential of the public space enabling action. We use an explanatory social mechanism approach to examine what distinctive features of the public space facilitate the implementation of different strategies aimed at overcoming internal and external factors *or barriers* hindering action and how they do it. A fictitious intervention serves as an example to explain the link between space and action. Our deep and fined-grained analysis points out that *accessibility features* of the public space and *situational features* facilitating its use are preconditions for the implementation of all the revised strategies. Visual accessibility facilitates the implementation of social norm-based interventions involving active participation, creating the conditions for other strategies to work, while physical accessibility represents an opportunity to implement availability-based interventions by providing quickly and easy access to the promoted products and services. Situational features refer to the physical characteristics of the space, influencing the nature and scope of the intervention by determining space and infrastructure constraints. Accessibility and possibilities for use lead to multiple forms of social exchange. All the reviewed strategies deal in one way or another with different forms of communication, positioning information as the strategy with the widest range of action. The public space also facilitates civic-based strategies aimed at increasing the participation of citizens on decision-making at administration level. Finally, priming and salience-based strategies can be used to create full *lived-in* experiences, reinforcing action through sensation and perception processes. The study shows the potentiality of the public space curving climate change towards more sustainable cities and societies through the implementation of a wide range of interventions aimed at making environmental behavior visible and accessible to all.
Keywords: public space, environmental behavior, behavioural change, participation, communication, sustainable cities.

1 INTRODUCTION

Limiting the impact of global warming on human and natural systems requires the upscaling and acceleration of ambitious mitigation targets through actions to reduce GHG emissions, thus posing challenges associated with changes in behavior [1]. The still limited and incomplete studies on the effectiveness of interventions involving different types of environmental behavior [2] coupled with the observed differential effect an intervention may have according to the target group [3] and the difficulties faced by practitioners in bringing possibilities for action closer to people, have resulted in little progress towards behavioral changes.

A vast body of literature exploring the drivers of human behavior has identified a significant number of internal factors (e.g. environmental knowledge) and external factors (e.g. availability) promoting or hindering environmental behavior [4]–[6]. According to Steg and Vlek [6], interventions should be tailored to the factors influencing the adoption and maintenance of the targeted behavior in order to achieve the best possible outcomes, but the relative influence of the different factors on individual's decisions in different situations is uncertain since decision-making and behavior are the outcome from multiple motivations. While giving feedback about the performance of others may result in energy

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conservation in a metallurgical company [7] results may be vary depending on the frequency and content of feedback provided to households [3]. In the same way, while it has been found a strong association between environmental attitudes and environmental behaviors in the context of consumption [8], attitudes might not be relevant in the work place [9]. Previous research has reported positive results when combining different strategies to achieve behavior change [3], [4], thus confirming the inconsistency and bias in individuals' decisions and highlighting the need of the use of multiple interventions and strategies towards more effective results in promoting environmental action.

While the discussion thus far has mainly focused on the identification of determinants for action and the effectiveness of specific strategies in specific settings, far too little attention has been paid to study the conditions that facilitate the promotion of environmental action through a wide range of interventions on a large scale. Moreover, how to bring a wide range of possibilities for action closer to people reminds uncovered. In addition, participatory approaches aimed at gaining people's involvement and commitment along with contextual factors influencing environmental behavior need more attention [6]. This article aims to help fill those gaps by inquiring about the implications of the public space on facilitating the adoption of environmental behavior. In doing that we use the mechanisms-based approach [10] that makes it possible to formulate deep explanations of the relationship between features of the public space and behavior.

At the center of our effort is the observation that the public space is the arena that brings people together and makes possible a wide range of activities, thus creating opportunities for the spread of environmental behavior through social contagion. According to Carmona et al. [11], public space refers to the *physical* space where *social* activities occur. We study the role of features of the public space facilitating the implementation of different interventions aimed at tackling internal and external factors influencing behavior and the micro-level pathways leading to potential success.

This study seeks to contribute to the literature on behavior change and public space in several ways. First, it shifts the focus from the relative effectiveness of specific strategies addressing specific factors influencing behavior to the conditions that facilitate the implementation of a wide range of interventions, thus increasing the possibilities for action. Second, based on in-depth qualitative analysis, we provide theoretical – practical insights into the link between public space and behavior change. In doing this, we deliver a wide range of possibilities that practitioners can use to bring action closer to people and highlight the role of the public space towards sustainable societies and cities.

The paper provides a brief overview of internal and external factors influencing behavior; reviews the most influential strategies encouraging behavior; presents a set of features of the public space; and analyses how those features facilitate the success of different strategies encouraging environmental behavior. Finally, we draw conclusions and discuss our findings.

2 FACTORS INFLUENCING ENVIRONMENTAL BEHAVIOR

One basic distinction can be made between internal and external factors influencing behavior. Internal factors involve individual capabilities [4], motivations [6] and preferences [12]. External factors refer to conditions outside the control of the individual that might facilitate or hinder environmental behavior, the latter understood as *behavior that harms the environment as little as possible, or even benefits the environment* [6]. Literature dealing with the effective promotion of environmental behavior suggests undertaking specific steps towards success, starting with the identification of behaviors with a significant impact on the environment, and finishing with the assessment of the

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effectiveness of the interventions. That literature has pointed out the importance of the identification and subsequent overcoming of factors *or barriers* to action as a key step toward success. Greater success in overcoming barriers might be achieved through the design of interventions responding to tailor made strategies tackling the identified barriers [4], [6], [13], [14]. In this line of work, we first present some of the most popular internal and external factors influencing behavior, followed by strategies to cope with them. After that, we present a set of characteristics and diversities of the space necessary to understand its role facilitating the implementation of the different strategies.

2.1 Internal factors influencing behavior

***Motivation*:** Refers to the reason and internal stimulus for a behavior, implying motives for it and intensity [5].

***Values*:** The values shape much of the individual intrinsic motivation and can be influenced by different actors, factors, contexts, and past experiences [5].

***Attitudes*:** They refer to the persistent positive or negative feeling about some person, object or issue. Attitudes can be strongly influenced by the associated costs in terms of time, effort, money [5] and benefits [15].

***Beliefs*:** Refers to beliefs about the difficulty of taking certain actions or about the consequences for self, others or the environment [4].

***Self-interest*:** Refers to the expected costs and benefits by performing the behavior [15].

General predisposition: Refers to a person with flexibility in order to perform different environmental behaviors, unlike someone willing to perform only certain behaviors [4].

Environmental knowledge: Implies the familiarity with the environmental problem and its causes [5].

***Environmental awareness*:** Refers to the consciousness of the impact of human behavior in the environment. It deals with the link between knowledge and perception of threats and effects, which in turn shapes individual's beliefs, values and attitudes as a response to emotional reactions like fear, sadness, pain, anger, and guilt [5].

Practical and technical knowledge: Implies to know *how* to lower the environmental impact [5].

Perceived behavioral control: Refers to the perceived possibility to perform the behavior [15] and the ability to bring change [5].

***Personal commitment*:** Is the communicated willingness to take environmental action [5].

***Responsibilities and priorities*:** Refers to the priority given to the individual´s responsibilities, being the own well-being and the well-being of the family the highest priority [5].

***Perceived feedback about ecological behavior*:** Refers to the necessary positive reinforcement in order to continue performing the behavior [5].

Social and cultural factors: Refers to the mutual influence between individuals and the societies in which they live [16].

Habits and inertia: Habits refer to the way behavioral choices are made. They are reconsidered when the context changes significantly [6]. Inertia is rooted on habit, acting just as in the past [17].

***Injunctive, personal norms*:** Injunctive norms involve perceptions of which behaviors are typically approved or disapproved, most individuals doing what they think is socially approved [18].

Descriptive norms: They involve perceptions of which behaviors are typically common, most individuals doing what is most popular [18].

2.2 External factors influencing behavior

Institutional factors: Includes a large number of governance-related issues facilitating or hindering environmental action like *government regulations and policies*, *monetary incentives*, *physical infrastructure* and *available technology* [4]. While the impact of attitudes and knowledge on individual behavior is uncertain, they might have great impact on citizenship action supporting institutional change [5].

Economic factors: Refers to rational decisions to maximize utility where certain outcomes might be perceived as losses or as unfair [19].

Availability/supply: Refers to the possibility to access products and services necessary to perform the desired behavior [6].

Convenience: Refers to the degree of difficulty to perform the behavior.

Quality: Refers to standards of quality [12].

External factors like economic considerations are intertwined with internal factors. For instance, when the behavior is very costly, individual motivations are not relevant when making decisions [6]. Behavior is the result of the interaction between internal and external factors, where internal factors might create an initial predisposition to act, but the result might be shaped by external factors [4].

3 STRATEGIES TO INFLUENCE ENVIRONMENTAL BEHAVIOR

Once the internal and external factors influencing the desired behavior have been identified, intervention strategies can be developed to address each of them. What follows is a selection of strategies addressing internal and external factors towards behavior change.

Information: According to Stern [20], information is an intervention in the personal domain that can influence individual's basic values, beliefs, attitudes, motives and feelings, where the outcome is the result of the interactive effects of the different interventions. For instance, information about alternatives for action might increase individual's environmental knowledge. New knowledge can result in changes in attitudes, which in turn might influence behavior [6]. The *skill* to apply that knowledge, might lead to immediate action [21].

Information is likely to be more effective when presented at the point of decision, when it provides feedback about the obtained benefits, when people similar to the target group model the message or when it comes from a trusted source. It is also particularly effective when it is reinforced by requesting public commitment or when it highlights the social support for the behavior and gets the involvement of the people [20]. Tailored information prevents information overload and it might be more effective when addressing the personal situation of the individuals, demonstrating clear results and being aligned with their core values and beliefs [1].

Environmental campaigns might have an identifiable component of persuasion [22]. Persuasive messages are characterized by being specific and concrete, having a core idea, being credible, highlighting the individual ability to perform the behavior and its benefits, conveying the idea that the behavior is something good that everybody does, and creating a vision of a desirable future [23].

Social norms: Individuals tend to do what is socially approved as well as is common or popular. The use of injunctive norms implies to highlight what is typically approved or disapproved, referencing the *right thing* to do. The use of descriptive norms implies to

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highlight what others typically do. Norm-based interventions might be more effective when the descriptive and injunctive messages are aligned, being the information about what others do the most powerful guiding behavior, increasing its effectiveness by making it salient [18]. Descriptive norms about what others do can be communicated via feedback, visual cues or direct observation.

Commitment: This strategy includes the definition of explicit goals, pledges and promises in order to elicit implementation intention. Asking for written, oral, public or private commitment might encourage action, as individuals are motivated to keep their promises and meet their goals due to social pressure [2], [23]. If participants are enrolled in the desired energy program *in situ* immediately after making commitment, the result might be even better [2]. Commitments work best if they are meaningful, written, made public, and require some effort, increasing the social pressure to be consistent [23].

Priming and salience: Individuals react to information that is made accessible in their mind via *priming* and to which their attention is constantly drawn via *salience*. The salience strategy implies constantly to draw the individual's attention, while priming implies the use of subconscious information and sensory cues. Prompts and reminders about energy conservation placed next to light switches might be effective, while displays highlighting the good quality of foods might prime individuals to buy organic food [2].

Role models/modeling: This strategy implies a careful choice of the person or *messenger* responsible for encouraging the desired behavior. Information is more effective when the individual suggesting the action is perceived as similar [2].

Availability, quality and convenience: This strategy includes actions aimed at providing easy and fast access to good quality products and services and/or providing the optimal conditions to perform the desired behavior. The intervention might tackle the well-identified barriers of time, effort and costs, but also it might consider efficiency options [13].

4 THE PUBLIC SPACE

The concept of public space refers to the sites and settings where public life occurs. It is a *neutral* arena where all kind of social public activities and events take place. There is therefore a strong relationship between space and society [11]. Public spaces range in form, scale and functions, ranging from squares to street corners [24]. In this section, we introduce a set of features and diversities of the public space necessary to understand its potentiality to facilitate action. This is followed by an in deep analysis that explains how those features facilitate the implementation of different environmental strategies.

***Accessibility*:** The public space is closely associated with *accessibility*, i.e. *the capacity to enter and use a space*. According to Carmona et al. [11], at least three forms of accessibility must be considered. First, *visual access* allows individuals to evaluate the place before they enter it, including the level of comfort, acceptance and safety. Second, *symbolic access* refers to animate (e.g. particular groups) or inanimate (e.g. particular kinds of shops) cues in the environment that might indicate the type of people that are welcome in that place and/or the kind of activity that is expected to perform, including the ability to pay. Third, *physical access* refers to the physical availability of a given place to all social groups, including use of the environment, implying that it should be open to the "freely" (responsible freedom) chosen and spontaneous actions of all its users. Physical access also presupposes accessibility in terms of public transport [11]. Inviting and easily accessible public spaces encourage people to move from the private to the public environment [25].

***Situational features*:** Human behavior is *situational* i.e. it is embedded and shaped by physical, social, cultural and perceptual context. The physical environment influences

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individual's decisions in at least three ways. First, the physical environment determines what individuals can do or do not in strictly practical terms. Second, the physical environment determines the surrounding opportunities available to the individuals. Third, the physical environment influences the likelihood of individual action, where some choices are more likely than others depending on the characteristics of a given setting [11].

Opportunities for exchange: The capacity to enter and use a given public space opens the opportunity for multiple forms of socio-cultural and economic transactions to occur, which are key elements in defining a successful place [26]. Socio-cultural transactions include practices of communication, interaction and intermingling, where the public space can be used as an information stage for social learning and personal development through activities involving leisure, entertainment and gaining information. The public space also can function as a forum for political action and representation, involving activities that account for the existence of a civil society and citizens [11]. According to Arendt's interpretation, it is the *polis* where citizens could participate freely and equally in debating and resolving issues through grassroots collective actions [27]. Economic interactions might involve consumption practices [11] propelled by a wide offer of activities, products, and services such as street markets, cinemas, restaurants, and cultural animation programs among others [26].

***Opportunities for sensory experiences*:** Public spaces are associated with *sense of place* and *lived-in* experiences, i.e. the way individuals experience and perceive places through sensation and perception processes. Sensation refers to all human senses. The vision is the dominant sense, codifying what lies before us and providing more information than the other senses combined. The acoustic experience includes all surrounding life, creating opportunities for emotionally rich experiences and gathering of information [11]. Seeing and hearing other people entails participation in social activities in a very subtle way that can lead to other forms of contact as individuals are inspired to take action by seeing others in action [25]. Depending on the situation, the rest of the senses might enrich the live-in experience, which is codified through perception processes. Perception concerns to the understanding of the live experience. It implies *cognitive* processes involving the gathering, organizing, keeping and making sense of information; *affective* processes involving feelings; *interpretative* processes involving associations between past and present experiences, and *evaluative* processes defining if something is good, bad, valuable or desirable. Despite perception processes occur at individual level, similarities in socialization and past experience in combination with the present environment might lead to the creation of a collective imagery and common place experience [11].

5 ANALYSIS

We use a fictional example to illustrate and explain how the different features of the public space facilitate the implementation of different strategies encouraging action. In line with literature dealing with the effective promotion of environmental behavior, we use an intervention with a significant impact on the environment to perform the analysis. Living car free has been identified as one of the actions with the potential to substantially reduce annual individual emissions [28]. We therefore use fictitious interventions aimed at the promotion of the bike as a means of transport to explore the relationship between public space and environmental action.

***Accessibility*:** A bike workshop consisting of a basic unit where people have access to information and tools to repair bikes could serve as a trigger for action. The opportunity to observe a few individuals repairing bikes in a public space might catch the individual's attention. To catch the eye of individuals is three-fold: to establish *visual contact* with them, to encourage them to *get into* and to show what others do. Since not every individual might have a broken bike at that time, their immediate involvement can be facilitated by offering the opportunity to rent bikes in the setting, increasing the number of participants and the likelihood for action. Calling for higher participation might send out the message that use and repair of bikes is *popular* and *approved*, thus *the right thing* to do in accordance to social norms – based strategies. Printed or visual information communicating the extensive use of bikes in happy neighborhoods and cities might reinforce the idea that biking is something good that many people do. Additionally, every time that a certain number of bikes is successfully repaired and/or rented, the song of a bird might play, stressing the popularity and acceptance of the action. The presence of a group of people might create baseline conditions for the implementation of other environmental strategies.

When the intervention aims to reach a wide audience, it is important to avoid cues in the environment restricting access. For instance, offering only fancy bikes for rent in a fancy environment, might suggest that both rent and reparation are expensive, inhibiting the participation of low-income sectors. On the contrary, cues in the environment might indicate *symbolic access* to certain groups when role model-based strategies are used to address a target group. Many steps, inadequate surfaces and/or a lack of easy *physical access* by public transport may prevent action, as a broken bike is heavy and difficult to transport and it must be fixed as soon as possible.

Along with the opportunity to fix and/or rent a bike, every weekend a green market can be organized where people can find a variety of bike-related products like bicycle lamps, or reflector vests, but also bicycle bells imitating animal sounds and wheel-shaped cookies. To have easy and fast *physical access* to a wide variety of good and competitively prices products might tackle the external barriers of quality, availability and convenience in terms of time, effort and costs, thus facilitating availability-based strategies. An overview of the linkages between *accessibility* features and the implementation of different behavior strategies is provided in Table 1.

***Situational features*:** The physical characteristics of the space influence the nature and scope of the intervention by determining space and infrastructure opportunities and constraints. Enough and adequate space for intervention would enable the realization of the planned activities, as the installation of the repair units and information boards while a space that it is very small or flooded with fixed urban furniture might impede or limit the implementation of different strategies. A generous space can stage a wide range of events and/or activities supporting the main intervention like the creation of supportive atmospheres, which in turn open an opportunity for more and major interventions, thus expanding the scope for action and increasing the likelihood for it. For instance, if the physical characteristics of the setting make it possible, the fix and rent bikes offer could be expanded by offering bike taxi services, with the consequent increase of related activities, needs and action, like the organization of more public events or the need of more and higher quality bikes, or bike path expansion (Table 2).

Opportunities for exchange: Depending on the physical conditions of the space and particular objectives of the practitioners, different information-based interventions to gain and convey information might be considered. That includes a wide range of leisure, entertainment and cultural activities that take advantage of an individual in a state of openness and rest to promote the use of the bike, like the organization of quiz games, raffles, theatre plays, exhibitions and guided bike tours among others. Many types of information might be involved in the different activities, ranging from general environmental information to detailed information on how to fix a bike, addressing different internal and external factors influencing behavior. For instance, information

Table 1: The linkages between *Accessibility* and behavioral strategies.

Accessibility	Strategy	Intervention	Aim	Factors/ barriers
Visual access	Social norms	Main intervention – Involving active participation (e.g. people fixing bikes) secondary interventions – Rental (bike) service – Visual/printed information – Sound	– Attract people – Visual contact – Encourage participation – Show/spread behavior – Setting a quorum for the implementation of other strategies	Internal
Symbolic access	Role model	– Cues in the environment – Targeted intervention (e.g. fancy bikes in a fancy environment for fancy people)	Attract the target group	Internal
Physical access	All strategies	– Barrier-free access – Adequate surfaces – Easy access by public transport	– Facilitate action – Enabling individual's action	Internal
Physical access	Availability	Physical availability and convenience (e.g. green market)	Provide quick and easy access to products, services	External

Table 2: The linkages between *Situational features* and behavioral strategies.

Situational features	Strategy	Characteristic	Aim	Factors/barriers
Physical characteristics	All strategies	– Enough/adequate space – Infrastructure	Enabling the realization of the planned activities	Internal/external
Opportunities/options	All strategies	Idem	Expanding the scope of action	Internal/external
Probability/likely to occur	All strategies	Idem	Increasing the likelihood of action	Internal/external

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highlighting the social support for the bike elsewhere might encourage the use of the bike through norm compliance, while information about the economic and health benefits of biking might encourage its use through perceived personal benefits. In the same way, information about places where affordable bikes are sold, might overcome inconvenience. Information can be given in different ways, including personal communication, audio-visual material and cues from the environment.

Creating an atmosphere of community through the organization of social events facilitates commitment-based strategies, where individuals might be motivated to make writing, oral or public commitment and to keep their promises as a reaction to the social pressure. Commitments in situ facilitate the performance of the action on different time and space. Some individuals might promise to buy a bike in the green market organized in situ while others pact to participate in the next weekly workshop in order to acquire knowledge on bikes or to save money to buy a bike in the future or to promote the use of the bike at home.

Priming and salience – based strategies placing emphasis on the presentation of options to participants can be used to reinforce success. For example, attractive and visible at eye level *to go* labels about comparative cost and benefits of different means of transport where the use of the bike is listed at the top, might persuade participants to take action. Salience interventions can include a wide range of types of information that can be conveyed in different ways, including temporary advertising like posters and brochures or through everyday products like T-shirts, caps, cups or pens that the participants can use and hold.

Green markets could support commitment, priming and salience – based strategies by providing the opportunity to take immediate action by acquiring product that facilitate or support the environmental action but also could be used as a framework to implement availability – based strategies. Here, participants might have access to multiple bike-related products, services and barter trade practices, the latter giving participants the opportunity to give a bike helmet in semi-use condition in exchange for bicycle lamps. Depending on the opportunities offered by the physical conditions of the space, different interventions may be designed with the aim to attract different target groups, which in turn might increase the exchange of experiences and enhance the positive effect of the *domino effect*. For instance, the bike intervention can be complemented by a green food intervention where people can buy on site but food is also distributed by cargo bikes, thus involving new stakeholders like farmers and urban gardeners, who in turn will attract more participants.

Regular organization of events might lead to frequent contact between regular participants in the activities of the place, which in turn might facilitate civic – based strategies involving high levels of organization. Public participation might address *institutional* factors hindering action. For instance, organized civil society can promote the required funding to encourage mass buying of bicycles, an effective bike-loan system or a plan for the development of cycle paths and pedestrian zones fully integrated with public transport, firmly placing environmental action on the governmental agenda. An overview of the linkages between *opportunities for exchange* and the implementation of different behavior strategies is provided in Table 3.

Opportunities for sensory experiences: The status of neutrality of the public space facilitates the openness of the individuals to their surrounding environment. Thus, the creation of a supportive and persuasive ambience for the bike workshop might enrich the *live-in* experience where the interactive effects of the different interventions will shape individual's decision through sensation and perception processes involving rational and emotional responses as well as value judgements. Sensory experiences might be maximized

Table 3: The linkages between *Opportunities for exchange* and behavioral strategies.

Opportunities for exchange	Strategy	Intervention	Aim	Factors/barriers
Communication/interaction	Information	– Leisure, entertainment and cultural activities to spread different types of tailored/persuasive information in different ways (e.g. personal communication, audio-visual material and cues from the environment)	– To gain/convey information – Facilitate action	Internal/external
Communication/interaction	Commitment	– Organization of social events to create an atmosphere of community	– Facilitate/reinforce compliance in different locations and time	Internal
Communication/interaction	Priming and salience	– Cues in the environment (e.g. labels, posters, t-shirts)	– Make information accessible and visible – Facilitate/reinforce action	Internal
Financial	Availability	– Financial and barter-trade practices through social events, services and activities	– Provide quick and easy access to the desired products and services – Facilitate action	External
Communication/interaction	Civic	– Regular organization of social events – Civic actions	Enhancing: – High levels of organization – Citizen participation in decision-making	External

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Table 4: The linkages between *opportunities for sensory experiences* (OSE) and behavioral strategies.

OSE	Strategy	Intervention	Aim	Factors/barriers
To see	Social norms	– Intervention including active participation (e.g. people fixing bikes)	– Attract people – Encourage participation – Show/spread behavior – Produce a positive knock-on effect/ sense of community/ – Trigger affective, cognitive, evaluative responses	Internal
	Role model	– Multiple interventions (e.g. elderly people fixing bikes)	– Trigger affective/evaluative responses	Internal
	Information	– Multiple interventions (e.g. accurate information about financial advantages)	– Trigger cognitive/evaluative responses	Internal
	Commitment	– Multiple interventions involving cues from the environment (e.g. others making a commitment to buy a bike)	– Trigger cognitive/affective/evaluative processes – Facilitate commitment and compliance	Internal/external
	Priming and salience	– Multiple interventions involving cues from the environment (e.g. products with a bike design)	– Trigger cognitive/affective processes – Facilitate commitment and compliance	Internal
	Availability	– Availability of products and services (e.g. bikes to sell or rent)	– Facilitate action	External

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by strategies aimed at the creation of an experience that seduce all the senses. To see people fixing bikes attracts people to the setting, where visual information about the negative effects of the use of cars on elderly and children might elicit a positive emotional response towards action. Accurate information about the financial advantages of biking might facilitate conscious decisions to take action, while cues from the environment in the form of priming, salience and availability-based strategies trigger commitments concerning present and future actions. In the same way, strategies dealing with the other senses might complement the collective place experience. A comprehensive *live-in* experience might influence both the sense of community and people's sense of well-being when doing *the right thing*, i.e. *well-being by well-doing*, which in turn increases the likelihood of individual's action following the social contagion (Table 4).

6 CONCLUSIONS AND DISCUSSION

This paper has explained the potential of the public space in promoting environmental behavior. We anticipated that different features and diversities of the public space facilitate the implementation of different strategies aimed at overcoming factors hindering action. Our exploratory analysis provides support for this hypothesis. The first conclusion is that the public space offers ideal conditions for the implementation of all the revised strategies alone or in combination, giving the opportunity for maximizing the effectiveness of public interventions through the combination of strategies. Furthermore, it allows the implementation of strategies aimed at attracting different target groups, thus providing conditions to make environmental behavior visible and accessible to different groups in society.

Second, we found that the implementation of all the reviewed strategies is feasible only when the access to the public space and its use is possible. Accessibility enables individuals to participate actively in different activities. Additionally, it facilitates the spread of different kinds of information. Visual access facilitates the success of social norms-based interventions dealing with activities involving active participation, which can be used as a *hook* to catch the individual's attention and further involvement. The initial group of people attracted by the ongoing action in the setting might create baselines conditions for the implementation of other strategies. Physical access in terms of public transport creates ideal conditions for the implementation of availability-based strategies by providing quick and easy access to the promoted products and services. A barrier-free design of pavements and infrastructure might support the success of the action by providing easy physical access and mobility in the setting. Just as accessibility is a precondition for each individual participate in the action, the physical conditions of the particular setting enable the realization of the planned activities in practical terms, thus pointing out *accessibility features* and *situational features* as preconditions for action. Situational features related to physical conditions of the public space influence the nature and scope of all the included environmental strategies by determining space or infrastructure constraints. A relatively large space allows the implementation of a wide range of strategies and corresponding activities, which in turn have a direct influence on the opportunities for action available to participants and therefore increases the likelihood of action.

Third, all the revised strategies to promote environmental behavior deal in one way or another with different types of information and communication practices, leading to the conclusion that the typical *opportunities for exchange* condition of public spaces plays a key role spreading action. The following three observations support that assertion: (i) The public space provides ideal conditions to convey information effectively. For instance, the information is presented at the point of decision, trusted sources and specific messengers can be used to model the message, it facilitates priming and salience strategies, which in turn facilitates different types of commitment, and it allows multiple possibilities to present accurate, tailored and persuasive information according to the target group. (ii) Different interventions convey a wide range of different types of information, each addressing different factors influencing behavior. For example, information highlighting the social support for the desired behavior encourages action through norm compliance, while information about of the advantages of the behavior encourages action through perceived benefits. (iii) All kind of social events involving leisure, entertainment and cultural activities like theatre plays and exhibitions create conditions for the flowering of multiple forms of communication and interaction, including personal communication, printed and audio-visual material, and cues from the environment. Communication also occurs through events involving financial transactions like green markets. Furthermore, the public space is the arena where advanced forms of communication facilitate civic-based strategies aimed at increasing the participation of citizens in decision-making in environmental matters. Our analysis confirms the relevance of information-based strategies in promoting action and positions information as the strategy with the widest range of applications in the public space.

Another important conclusion is that the public space provides the opportunity to create a persuasive atmosphere that fulfils at least two important functions facilitating action. First, a visually attractive atmosphere can help recruit participants. Here, audio-visual elements can be used to attract the attention from long distances. Second, it supports the success of all the revised interventions by creating an in situ full experience that prompts to action through social contagion but also through sensation and perception processes involving rational and emotional responses. Here, every medium that appeals to the gratification of the human senses can be used to enrich the live-in experience. It is worth noting that priming and salience – based strategies are particularly relevant for creating a persuasive ambience, playing an important role supporting the success of strategies that works with specific groups and targets, like actions involving commitment.

Our study allows for other preliminary observations. It suggests the temporal dimension of the strategies in terms of time and space. For instance, social norms-based strategies making visible that something is popular might encourage immediate action, while taking action may take longer when giving information about how to do something. In the same way, commitment based strategies might encourage action in real time or in the future. These findings call for attention for the action time implications of the different strategies, where immediate action should be priority. Permanence is a different dimension of time, where frequent encounters between people with similar interests or backgrounds might lead to higher levels of citizen participation, which enable citizens to have an impact on decision-making at administration level. To this end, the responsible use of the public space for the better service of citizens must be guaranteed. Using the example of the bicycle workshop, local regulations on the use and activity of the public space might impede or limit the installation of necessary permanent infrastructure for its daily operation and further development. Potential limitations can range from the lack of safe storage areas for tools, the lack of public toilets or restrictions on audio-visual content to a ban of the use of the public space for civic action, highlighting the importance of institutional conditions in facilitating action.

While this work explored socio-functional aspects of the public space, factors typically associated with the architectural and artistic tradition, as spatial arrangements and qualities of the space might also play an important role facilitating action. A place that provides ideal stay conditions in terms of spatial arrangements, urban furniture and aesthetic order calls for joint-actions. Here, protection against weather conditions is especially relevant for action, since nobody is supposed to take action under adverse environmental conditions. It is also worth mentioning that interventions aimed at promoting environmental behavior could also serve to meet three of the five needs that people seek to satisfy in a given public space according to Carmona et al. [11], named passive engagement, active engagement and discovery, accompanying the function of providing comfort and relaxation.

The authors want to note that the use of a fictitious intervention to perform the analysis points to an important limitation of this study. Dealing with one fictitious intervention in an undefined location, limits the generalizability of the findings. This however, enabled the authors to carry out an exhaustive analysis of the potentiality of the public space in facilitating very diverse strategies to promote environmental behavior. Future studies might want to focus on real life case studies to understand the unique challenges of each strategy in specific locations, including an effort for understand what represent an adequate space size for the success of the different strategies. Future research also calls for the development of standardized methods to evaluate the combined effect of different strategies on individual's behavior, including the places and times for action.

To conclude, we would like to highlight the potential of the public space to attract and involve a wide diversity of individuals by the use of combined strategies, avoiding the need to be environmental oriented as a precondition to take action.

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PROPERTY MANAGEMENT OF AFFORDABLE HOUSING: A RESILIENCE PERSPECTIVE

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ABSTRACT

The COVID-19 incident has forced us to think carefully about the vulnerabilities in the city's public administration and to prepare for future risks. In China, urban and rural communities are the basic units of social governance. Affordable housing is a category of social housing provided by the Chinese government for the benefit of low-income urban families, and its property management services often suffer from insufficient funding sources, thus aggravating the problem of supplying its property services. Therefore, faced with risks, the vulnerability of this type of community is more pronounced than that of normal communities, so its property management resilience should be given high priority. Property management is a part of community governance. From a resilience standpoint, in normal time, it should not only deal with securing the supply of property services, formulating emergency measures, strengthening the stock of emergency supplies, and improving the maintenance of emergency facilities; in crisis, but it should also deal with the deployment of emergency supplies, emergency operation of public utilities, and enhancing the maintenance of emergency facilities. This paper aims to clarify the rights, responsibilities, and public nature of affordable housing, analyze the functions that each entity should play in property management services, and then explore solutions to the misalignment of rights and responsibilities in its property services, thus increasing property resilience in community governance and improving community resilience.

Keywords: affordable housing, property management, resilience, public goods.

1 INTRODUCTION

China's housing system is based on five pillars: housing finance, land, taxation, housing indemnification and housing supply. The indemnification housing system is divided into affordable housing, low-rent house, and public rental housing.

The marketisation process of Chinese society has witnessed the withdrawal of the *Danwei* system from the historical stage. Following the *Danwei* housing, the implementation of the affordable housing system has once again made housing a form of social welfare. On the one hand, it guarantees their fundamental right for living, but on the other hand, the unconscious "expansion of rights," due to these protected groups' misconception of the policy, has made affordable housing encounter an unprecedented institutional dilemma. Based on the system origin and property ownership model of affordable housing in China, this paper provides an insightful analysis of the rights and obligations of affordable housing stakeholders. The case study of Beijing's Yulong Mingju clarifies the dilemma of the affordable housing system due to the misalignment of rights and obligations and proposes strategies for different interest groups to break through the dilemma from the perspective of resilience.

The impetus for future innovation in the affordable housing system will inevitably have to come from the healthy interaction between the government, property management enterprises, property management associations and property users in the process of practice. The ultimate goal of indemnification housing is to meet the housing needs of vulnerable groups, which are often diversified and multi-layered. It isn't easy to fully achieve this goal through purely intergovernmental administrative directives and must be accompanied by

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innovative and locally adapted government working methods, the regulation of industrial standards and the increased participation of residents' self-government.

2 RESILIENCE OF PROPERTY MANAGEMENT

The term "resilience" is derived from the Latin word "*resilio*," which was first proposed by the Canadian ecologist Holling, who argued that the behaviour of ecosystems could be defined by two different attributes, namely resilience and stability, and distinguished between engineering resilience and ecological resilience [1]. The meaning of resilience refers to a system exposed to disaster/risk maintaining its basic structure and function through effective resistance, absorption, and adaptation to the risk, and recovering from the disaster. As the concept of resilience continues to evolve, while there are different definitions of resilience, some commonalities exist: namely, an emphasis on resilience's ability to adapt to changes in the external environment and to learn from disasters, as well as the system's multiple equilibria and self-organisation.

A United States Commercial Real Estate Services (CBRE) study on "Resilience and Property Management" concludes that property managers need to develop resilient property management strategies in advance to withstand unexpected risks, which include accurately assessing the safety hazards of their properties and developing comprehensive disaster plans and measures [2].

3 AFFORDABLE HOUSING SYSTEMS AND MODELS IN CHINA

The public (social) housing system guarantee is provided by the government for middle- and low-income families. It is of a social welfare nature. China's existing indemnification housing system is divided into three categories: affordable housing, low-rent house, and public rental housing.

3.1 Affordable housing system in China (see Table 1)

In June 1991, the Notice of the State Council on Continuing the Reform of the Urban Housing System in a Positive and Prudent Manner (No. 30 [1991], State Council), which for the first time introduced a concept similar to that of "affordable housing," making it clear that housing could be not only commercial but also indemnification. In the Decision on Deepening the Reform of the Urban Housing System (No. 43 [1994] of the State Council) of the State Council in July 1994, "affordable housing" was first explicitly introduced in a policy document. Notice of the Ministry of Construction, the National Development and Reform Commission, the Ministry of Supervision, the Ministry of Finance, the Ministry of Land and Resources, the People's Bank of China and the General Administration of Taxation on Issuing the Administrative Measures for Affordable Houses (No. 258 [2007] of the Ministry of Construction), regulating the construction costs, funding sources and supply standards of affordable housing, which marks the initial formation of China's affordable housing system [3]. The Circular of the State Council on Further Deepening the Urban Housing System Reform and Accelerating Housing Construction (No. 23 [1998] of the State Council) marks the formal integration of affordable housing into China's indemnification housing system [4].

Table 1: History of the development of the affordable housing system.

	Legal documents	Contents	Significance
1	Notice of the State Council on Continuing the Reform of the Urban Housing System in a Positive and Prudent Manner (No. 30 [1991], State Council)	Article 4. "Housing construction shall implement a tripartite system of joint investment by the State, collectives and individuals, actively organize the building of houses with pooled capital and co-operative housing, vigorously develop economical and practical commercial housing, and give priority to solving the housing problems of homeless households and those in housing difficulties."	The first time introduced a concept similar to that of "affordable housing," making it clear that housing could be not only commercial but also indemnification.
2	The Decision on Deepening the Reform of the Urban Housing System (No. 43 [1994] of the State Council)	The "fundamental purpose and basic content of the reform of the housing system" states that "an affordable housing supply system of a social indemnification nature will be established for low- and middle-income families."	"Affordable housing" was first explicitly introduced in a policy document.
3	The Administrative Measures for Affordable Houses (No. 258 [2007] of the Ministry of Construction)	Establishes regulations on the construction costs, funding sources and supply standards for affordable housing.	Marking the initial formation of China's affordable housing system.
4	The Circular of the State Council on Further Deepening the Urban Housing System Reform and Accelerating Housing Construction (No. 23 [1998] of the State Council)	China will establish and improve "a multi-level housing supply system with affordable housing as the core," and at the same time proposes to make the affordable housing system the main way to solve residents' housing difficulties, gradually replacing the traditional welfare housing system.	Marking the formal integration of affordable housing into China's indemnification housing system.

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Table 2: Legal provisions of the shared ownership model for affordable housing.

	Legal documents	Contents
1	General Principles of the Civil Law of the People's Republic of China	Article 78. Property may be owned jointly by two or more citizens or Legal Persons. There shall be two kinds of joint ownership, namely co-ownership by shares and common ownership. Each of the co-owners by shares shall enjoy the rights and assume the obligations respecting the joint property in proportion to his share. Each of the common owners shall enjoy the rights and assume the obligations respecting the joint property. Each co-owner by shares shall have the right to withdraw his own share of the joint property or transfer its ownership. However, when he offers to sell his share, the other co-owners shall have a right of preemption if all other conditions are equal [6].
2	Property Law of the People's Republic of China (Order No. 62 [2007] of the President of the People's Republic of China)	Article 94. A several co-owners of a commonly owned real property or movable property shall enjoy the ownership of the real property or movable property according to his shares. Article 95. A joint owner of a commonly owned real property or movable property shall enjoy the ownership of the real property or movable property on a common basis [7].
3	Measures for Building Registration (No. 168 [2008] Order of the Ministry of Construction)	Article 13. The registration of a co-owned building shall be jointly applied for by the co-owners. The registration of changes to the ownership of a co-owned building may be applied for by the relevant co-owners, but the building registration as a result of changes to the nature of co-ownership or changes to the shares held by co-owners shall be jointly applied for by the co-owners. Article 25. The building registration authority shall write out and issue the certificates of ascription of right in a building to a right holder according to the record in the building register book. The certificates of ascription of right in a building shall be the proofs of a right holder's enjoyment of rights in a building, including a Certificate of Ownership of a Building, Certificate of Other rights in a Building, etc. Where the building, the registration of which is applied for, is a co-owned building, the building registration authority shall note the word "co-owned" on the certificate of ownership of a building [8].

3.2 Legal provisions of the shared ownership model for affordable housing

Shared ownership is a property rights system arrangement in which the costs and benefits are shared between exclusive groups. Shared ownership housing (see Table 2), in short, means that families with low-to-moderate income housing difficulties who cannot afford to buy a home in a lump sum can jointly own the property rights of that home in proportion to their individual and government contributions [5]. Current international shared ownership housing policies include shared ownership housing and shared equity housing in the UK, and community land trusts housing and limited equity cooperatives housing in the US, and co-ownership housing in Australia.

3.3 Qualification of affordable housing purchasers

Notice of the Ministry of Construction, the National Development and Reform Commission, the Ministry of Supervision, the Ministry of Finance, the Ministry of Land and Resources, the People's Bank of China and the General Administration of Taxation on Issuing the Administrative Measures for Affordable Houses (No. 258 [2007] of the Ministry of Construction), Article 25 to apply for purchasing an affordable house, an urban low-income family shall simultaneously satisfy the following requirements:

1. It has registered permanent residence in the city or town where the house is located;
2. Its household income is below the low-income family line as determined by the municipal or county people's government; and
3. It has no house or the currently dwelling space satisfies the housing difficulty standards as determined by the municipal or county people's government.

4 RIGHTS AND OBLIGATIONS OF AFFORDABLE HOUSING AND ITS PUBLIC NATURE

The perception of residents' rights in relation to housing is based on the formation of housing ownership. With the implementation of the affordable housing policy, the government has assumed residential responsibility for those unable to afford commercial housing. At the same time, these groups are given the basic right to occupy social housing. However, these groups that were sheltered believe that these housings are government-owned and are public goods for which the government should be responsible. So, they believe they are not obliged to pay the property management fees, causing many conflicts after they live.

Residents who do not pay property management fees or who believe that the government should take over property management are "expanding rights" after basic rights have been fulfilled. First, a new relationship of dependency has been established between affordable housing dwellers and the government when those were granted access to affordable housing and was the underlying motivation for "expanding rights" of affordable housing dwellers. Secondly, affordable housing residents' claim for "expanded rights" requires the conditions for its triggering and its legitimacy. The newly established status of "affordable housing dwellers," characterizing the symbol of "vulnerable groups," is a factor of legitimacy that allows the demand for "expanded rights" to take place. In other words, under the political discourse of safeguarding and improving people's livelihoods, " vulnerable group" shapes the "legitimacy" of the action of "expanding rights." Thirdly, the spatial aggregation of vulnerable groups has become an organizational condition for forming the demand for the "extension of rights."

Affordable housing dwellers with similar lower economic conditions have been gathered together into the community from all around the city. That kind of spatial concentration stimulated dwellers to a certain degree of “right consciousness,” thus creating the motivation, desire, and requirements to claim “expanding rights.” In a word, affordable housing dwellers use not only their identity symbols but also the concentrated spatial community shapes “expanding rights.”

4.1 Rights and obligations of affordable housing under the shared ownership model

4.1.1 Rights

1. Possession and use rights

Affordable housing owners have the right to occupy and use the housing with restrictions. This is reflected in the fact that they are not allowed to destroy the function of the housing, rent out the housing without permission and other acts that do not comply with the regulations of the affordable housing with shared ownership.

2. Income rights

Affordable housing with shared ownership model is available for trading in the market after certain conditions are met. Affordable housing in Beijing is co-ownership by shares, which entitles the co-owners to share the housing proceeds. It is important to note that affordable housing under this model does not give the owners the right to rent, and accordingly, the government does not have the right to rent affordable housing, and the government is not allowed to charge the owners rent.

3. Alteration and repair rights

There is no right to alteration or repair of the home for those owners. Property Law of the People’s Republic of China, stipulated that the reconstruction or alteration of a buildings and its appurtenant facilities requires the consent of the owners whose exclusive part accounts for more than two-thirds of the floor area and at least two-thirds of the total number of owners. However, under China’s existing ownership proportion arrangement for affordable housing, which is generally 30/70 or 50/50, almost one-third of the housing ownership will be enjoyed by the government, regardless of the ownership proportion arrangement in which the protector is placed, which means that if the government does not agree to make alterations or repairs to the housing, then the alterations and repairs to the housing cannot be carried out.

4.1.2 Obligations

1. Home maintenance obligations

The government and the protected person shall share the maintenance costs of affordable housing under shared ownership in proportion to their own contributions. Article 98 of the Property Law stipulates that all or some of the co-owners shall share in the maintenance and repair costs of the house in accordance with their share of the capital contribution.

Article 98. As for the management expenses or any other liabilities of a commonly owned property, if there is any stipulation on it, such stipulation shall apply; if there isn’t any stipulation on it or the stipulation is not clear, the expenses shall be borne by the several co-owners on the basis of their respective shares or commonly borne by all joint owners.

2. Property management fees paying obligations

Property services include greening, sanitation, maintenance, and repair of houses and ancillary facilities in the community. The property management fee is a daily fee paid by the owner or the actual user of the property to the entrusted property management agency, based on the occupation and use of the house.

Under the shared ownership model, the government is in a special position and is not obliged to bear the cost of property management. The government should not be jointly and severally liable for the payment of property management fees by other co-owners to avoid being caught in civil disputes and being a passive subject of liability. Meanwhile, the owners' ownership percentage does not affect their house use, as the government has ceded the right to use the house to the owners. Because of the nature and use of the property management fees, the actual occupier of the house, i.e. the owners, should be obliged to pay the full cost of the property.

4.2 The public nature of affordable housing and its property management services

4.2.1 Property management services of affordable housing are partially excludable and non-competitive

The counterpart of public goods is private goods. Samuelson divides goods into purely public and purely private goods, and he argues that public goods have significant non-exclusive and non-competitive characteristics in relation to private goods [9].

Quasi-public goods have limited non-competitive and partial excludable, as well as externalities and natural monopolies, and are social goods between private goods and pure public goods [10]. Quasi-public goods are divided into two categories: those with a non-exclusive and competitive character, i.e., common-pool resources, and those with an exclusive and non-competitive character, i.e., club goods (artificially scarce goods). Quasi-public goods are generally congested, i.e., when the number of consumers increases to a certain threshold, there is a positive marginal cost, unlike pure public goods where the marginal cost is zero for each additional person. When a quasi-public good reaches a "limited capacity," each additional person will reduce the utility of the initial consumer.

Does affordable housing, as a type of indemnification housing, have the attributes of a quasi-public good? The answer is yes.

Firstly, the land used for affordable housing is allocated by the State to developers for free and is built without profit. The selling price is considered by the municipal and county people's governments according to the cost price and is guided by the government. Secondly, unlike public rental housing and low-rent housing, the ownership rights of which belong entirely to the government are of a strong public nature. Affordable housing is a project that government initiative to solve the housing problems of the middle and lower-income groups and to offer part or all of the ownership rights to these groups at a price lower than the market. Hence, some of the affordable housing is fully self-owned, and some is jointly owned by the homeowner and the government. As its ownership is not fully occupied by a single household, it cannot be used as a property investment asset. Thirdly, the supply of affordable housing is aimed at the majority of the low and middle-income groups but not fully covered, so it has a partially excludable. Fourthly, the allocation process for affordable housing is a vetting system, and access is non-competitive as long as income conditions are met. On the other hand, people who do not belong to these groups cannot qualify for access, and such exclusivity is a club good. However, the quantity of affordable housing in China is currently limited. The supply is less than the demand, and the marginal cost of increasing the number of consumers is positive and congested. In other words, affordable housing is competitive within the club of "low and middle-income groups." In summary, affordable housing is a quasi-public good with limited non-competitiveness and is partially exclusive.

4.2.2 Property management services of affordable housing are partially excludable and non-competitive

The nature of affordable housing determines the public or quasi-public product nature of its later property management. This is because, on the one hand, affordable housing property management serves that are partially or fully owned by the government; on the other hand, it serves low- and middle-income people in towns and cities who are most in need of care and who do not have sufficient payment capacity to purchase property services on the market.

Affordable housing property services are aimed at owners of affordable housing residents, so it has an exclusive feature. Still, owners of affordable housing communities can enjoy property services simply by paying below the market rate. Moreover, in general, within a certain range, an additional owner's property consumption does not bring an increase in cost to the property company, and the marginal cost is zero, which has the characteristic of non-competition.

4.2.3 Efficiency losses of affordable housing property management services

Affordable housing services are non-excludable in terms of consumption, and most people have a "free-rider" mentality, hoping that others will bear the costs. To provide this entirely through market mechanisms would lead to inefficient allocation of resources.

5 CASE STUDY: YULONG MINGJU COMMUNITY IN HUAIROU DISTRICT, BEIJING

Beijing began building affordable housing in 1998 and has been applying the limited shared ownership model.

Measures for the Administration of Affordable Housing in Beijing (No. 27 [2007] Order of the People's Government of Beijing Municipality) stipulated that affordable housing cannot be listed and traded for five years, and full ownership can be acquired after five years. Beijing municipal commission of housing and urban-rural development the Notice on Issues Relating to the Listing and Sale of Purchased Affordable Housing (No. 225 [2008] Order of Beijing municipal commission of housing and urban-rural development), stipulated the steps for the sale of affordable housing after five years and the distribution of proceeds.

The beneficiary acquires affordable housing ownership in the limited shared ownership model through payment of the housing price. However, the right to transfer and dispose of the property is restricted. The housing cannot be traded for five years after purchase and can only be repurchased by the government at a price determined by considering the purchase price and other discount factors. After five years of purchase, the recipient acquires full rights to the property, subject to taxes and land premiums. In this model, the ownership of the house is granted exclusively to the person under protection. It mainly belongs to the building's differentiated ownership. The right to gain and dispose of the house is restricted and the circulation transfer can only be done in a particular scope by legal means.

The Yulong Mingju Community is an indemnification housing project in Huairou District in 2008, 97.5% of the housing are affordable housing, located in the west of Chengezhuang Village, Yanqi Town, Huairou District, south of Zhonggao Road, covering an area of 5.97 hectares, with a construction area of 75,868 square metres and 9 storeys. The total number of households in the area is 978, of which 954 are affordable housing and 24 are low-rent housing. The average size of the households is about 64 square metres. It is evident that this is a larger residential community and requires a professional property management company to take responsibility for the utilities, landscaping, hygiene, security, and environment. The construction of Yulong Mingju was financed by the government and the property management company was selected by the government's Housing and Urban Development Bureau after completion. The property management fees are lower than those of commercial properties and are basically based on market-based principles.

However, some residents could not agree with the fees and have had some friction with the property management company. So, since they moved in, it has been quite difficult for the property management company to charge. Quality of management is difficult to ensure due to low property funding. In response, the property management company has also reduced the level of property services. The owners' committee also failed to do an excellent job of communicating effectively between themselves in this process. Hence the vicious circle (Fig. 1), due to their dissatisfaction with the level of property services, residents are refusing to pay their property fees. In three years, close to 70% of the residents did not pay their property fees. Finally, the property management company withdrew from the community, and the property services are underpinning management by the government, which includes only the most basic waste removal. It can be seen that due to the lack of property management services, the community has long suffered from a lack of greenery, community safety concerns, poor quality of hygiene and environment, and unsecured infrastructure.

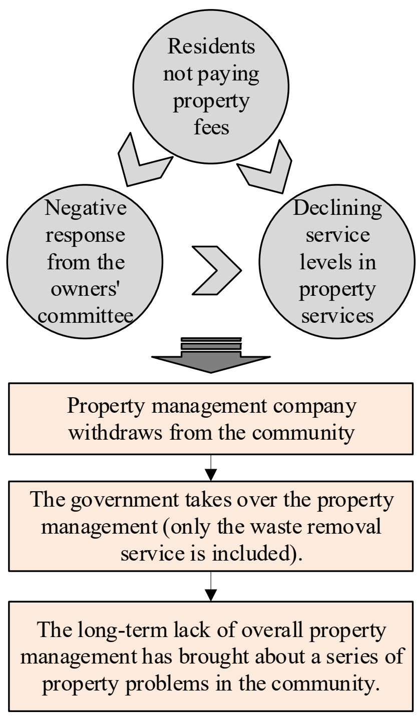

Figure 1: Vicious circle.

Under the shared ownership model, residents own part of the affordable housing, enjoy the right to possession and use, and are responsible for part of the home maintenance costs and all property management fees (Fig. 2). When there is not the owners' committee in the community for self-governance, residents should pay their own property management fees on time under the property management company's rates. When a community has formed an owners' committee for self-governance, the committee should decide which approach the property management should take. The first is to choose to outsource all the property management services to a property management company; the second is for the owners' committee to organise residents to undertake the property management services themselves, charging only for the basic operation and damage of the facilities; and the third is to share the property management services with the property management company on a pro-rata basis, with the property management fees to be decided by the committee in consultation with the property management company. All three ways are charged by the owners' committee. Whether there is an owners' committee, the government is not obliged to undertake property management services in it.

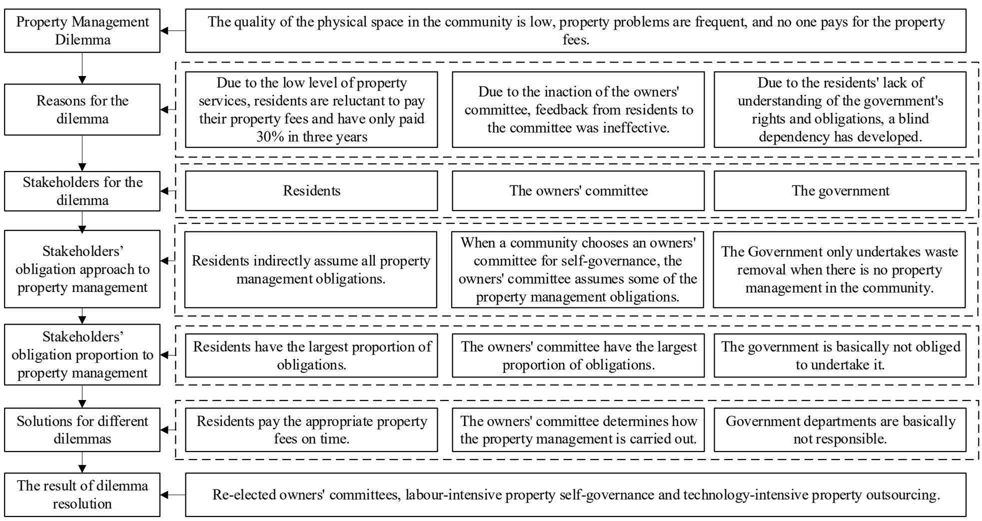

Figure 2: Processes of resolving property management.

6 RESOLUTIONS OF MISALIGNED RIGHTS AND RESPONSIBILITIES OF AFFORDABLE HOUSING PROPERTY MANAGEMENT SERVICES FROM THE PERSPECTIVE OF RESILIENCE

6.1 Government should safeguard financial resilience, awareness resilience and data resilience

1. Financial Resilience: The government gives financial support to affordable housing's management properties to ensure the daily operation.

Although the government is not obliged to bear the cost of property management, as affordable housing with the nature of public welfare and public goods, the property management of affordable housing has a strong positive externality, so it cannot rely entirely on the market operation. The government must give appropriate financial policy support to affordable housing properties to subsidise the negative externality losses caused to property companies by the government's price-limiting actions. For example, those enterprises that undertake property management services for affordable housing are given relevant tax relief, and the income tax and business tax rates of those enterprises are reduced; the income tax or business tax paid by property management enterprises for affordable housing is collected first and then returned proportionally.

2. Awareness resilience: The government clarifies the rights and obligations between the government and affordable housing residents through advocacy and education.
    1) Resilience of rights and obligations in property management supply: The rights of affordable housing residents are totally dependent on the local government, and the identity of affordable housing residents becomes a tool and condition for them to claim their subsequent rights. Residents continue to demand property management services from the government because they have developed a one-sided understanding of the rights and obligations relationship between themselves and the government, elevating their rights outside the framework of existing policies.
    2) Risk Awareness Resilience: The government should strengthen the risk awareness of affordable housing residents through appropriate Party-building activities and news media advocacy tools. This includes raising risk awareness and conducting guidance and training on risk skills.
3. Data resilience: Government monitoring communities through big data platforms.

The infrastructure, population, and grid data of the affordable housing communities are shared with property management companies, community managers, community committees, and residents through big data visualisation guiding the decisions of the property management companies and community committees, and also raising residents' awareness of risk response in a relational manner.

6.2 Property management companies should ensure physical space resilience and property charging resilience during normal and emergency periods

Physical space resilience: Property management companies should conduct a comprehensive inspection and assessment of the security protection of existing properties before risks strike and upgrade or renew them as necessary to enhance their resilience, including the resilience of building performance, infrastructure, disaster prevention and mitigation spaces and facilities. For one, there are no private parking spaces as residents of affordable housing have low incomes. In this case, the property company should first survey the demand for parking spaces in the community, then make full use of the space to set up parking spaces, and guide residents to park in an orderly manner to improve the resilience of emergency access.

Property charging resilience: Property management enterprises and building manager committees, the Housing Authority signed a tripartite agreement to clarify the form and content of services, charges, etc., to enhance the resilience of property management, which enables evidence-based if disputes. Moreover, the cost of property services must not exceed 60% of the average property fee in general commercial housing communities, with the shortfall relying on financial subsidies and the profits of commercial operators to make up.

6.3 Property management service recipients should raise awareness of rights and responsibilities and risk awareness

Awareness resilience of rights and responsibilities: Led by the street office, residents of each housing unit should elect a building manager, who forms a building management committee, which holds regular building manager meetings to discuss major issues regarding property management. The building managers' committee should establish a covenant for residents to help them shape a spirit of self-government and self-discipline and pay their property fees on time.

Risk Awareness Resilience: Residents should actively cooperate with the government and community committee on safety and disaster reduction education; consciously participate in risk-based skills training (including skills training on fire, earthquake, first aid, etc.); park vehicles in an orderly manner and maintain adequate escape life routes; consciously maintain community discipline and public space to enhance the resilience of disaster reduction and isolation space.

6.4 Property management associations should ensure the resilience of access and regulatory mechanisms

Access mechanism resilience: Property management association to assess the qualifications of property management companies being selected, setting property servicing standards by their actual situation, and enabling self-election to improve the access mechanism in property management.

Regulatory mechanism toughness: The Property Management Association improves the regulatory mechanism resilience, for example, after monitoring property users and property enterprises, enterprises that do not provide the corresponding services according to the contract after repeated warnings, revoking the qualification certificate and informing and criticising them; and giving criminal liability or informing and criticising property users who do not travel their obligations according to the contract.

Taking the first Community Environmental and Property Management Committee in Chengdu as an example, it was organised and established under the leadership of the Community Party Committee, recommended by the residents' representatives and set up under the Community Residents' Committee, mainly to do the coordinate work between property service companies and residents committees. It's not only to supervise the performance of the committees' duties, assist in convening residents' meetings, initiate residents' self-governance, but also to resolve conflicts. Finally, these means promoted the smooth development of property management, promoted residents' participation in property management affairs in an orderly and rational manner, and at the same time, realised community members participatory governance of self-management, self-education, self-service and self-monitoring.

7 CONCLUSION

In the initial stage of the affordable housing policy, the number of affordable housing was more important to meet the housing gap of the vulnerable groups. As their numbers increase and most of the housing-disadvantaged groups are provided with affordable housing, the importance of their numbers begins to diminish and the sustainability of affordable housing and the resilience of property management services becomes a key issue to be addressed at this stage. The property management dilemma in the Yulong Mingju community is indeed an unconscious "expansion of rights" due to the residents' confusion about their rights and obligations, which also reflects the shortcomings of the affordable housing policy and the lack of multi-stakeholder participation in the process of policy implementing.

Therefore, the resilience of property management in affordable housing must be led by the government, with the implementation of co-government and co-management among the government, property management enterprises, property users, and property management associations. In the practical application process, these tools need to be integrated and appropriately adjusted to the characteristics of different affordable housing communities, ultimately improving community resilience, safeguarding the lives of residents in times of normality and emergency, and improving their standard of living.

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SECTION 6
SOCIAL, CULTURAL AND ECONOMIC ASPECTS

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SUSTAINABILITY OF HOUSING TYPOLOGIES IN HISTORIC SITES

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ABSTRACT

Only few people in Mexico are researching about historic housing typologies. Architects, historic preservation scientists, urban planners and sociologists are basically the disciplines concerned about such topics. In addition, several researchers mention the importance of preserving industrial heritage, including houses of workers. But there are barriers to understand the importance of housing typologies in contemporary societies. The main goal of this paper is to analyse the people's points of view and to understand a social construction of industrial heritage; especially about those unique houses situated in historic sites, in order to understand meanings and how catalogued buildings are recognized. Also, housing typologies somehow impact society's perception on historic preservation. Besides, urban places affect how people feel. It is through the use of a survey and a questionnaire that cultural heritage sites can be analysed to know behaviours and opinions related to historic recognition and preservation facts. The objectives of the survey are to demonstrate the architectural influences from abroad in Mexican historic sites, also to find out about social interaction among workers and the administrators of the factories they work for, furthermore architecture and typology of buildings in company towns like Ferronales suburb, most common materials used in railway stations and company houses for workers, relevant land use changes in industrial sites and preservation concepts used in industrial heritage preservation. The questionnaire includes issues about preservation, comprising characteristics such as gender, age, educational level, origin, architectural concepts and urban facts, railway housing and local culture, meaning of historic sites, historic places and memories (breath of the places). Furthermore, a qualitative multivariate statistical method was used to enhance the conclusions. The results and conclusions include a typological analysis and the interpretation of social construction of industrial heritage sites.

Keywords: housing typologies, sustainability, industrial heritage, historic preservation.

1 INTRODUCTION

The company town concept was first used in England at the beginning of Industrial Revolution. The first factories needed a considerable number of workers and the best solution was to settle neighbourhoods closed to them. This idea allowed architects and designers to create several urban solutions to the company towns. So multiple designs appeared trying to solve the complex relationship between the factory and houses for workers. Designs depended on geographic location and types of factories. Some of the most important factories in Mexico – established during the 19th century – used to be textile factories. Such factories needed water flows in order to function properly. The current always varies spatially as well as the factories installed nearby.

Mills were built nearby or inside the factories using the streams to produce energy. Generators helped out to make the machines work in an efficient way so workers could produce, for example, wool and fabrics in textiles factories. So, the design of the factories depended on the natural site they were established at. This situation was relevant because specific sites also conditioned the factories, on the way they had to be built. This is also the case of construction materials. The usage of regional construction materials used to be a rule in architecture. Of course these phenomena changes, depending on time. But this theory is mentioned in this paper because regional materials ruled somehow building typologies, which is the main topic of this document.

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Some stone structures of factories appeared as a natural extension of the surroundings. Designs made with stone in factories produced a vertical shape of windows and main entrances at the beginning. This theory helps to understand housing typologies in historic sites. Besides, vertical windows were used to create pattern in multiple sites. After Industrial Revolution, the shapes of windows and entrances of buildings were still vertical. But slowly during the 20th century and modern movement, this situation changed. So, vertical windows tend to be related to historic buildings of a traditional shape and manufacture – and also to handmade buildings.

The created patterns in most of the company towns designs offer attractive landscape architecture. Sometime regional limestone was used as facing masonry in main buildings of company towns, but brick was the most common material in housing for workers in Mexico. In fact, aesthetics of historic sites have to do with historic patterns. Additionally, in order to study housing typologies in historic sites it is convenient to understand how people look at them. So, a survey and a questionnaire were applied to recognize social construction of industrial heritage.

2 METHODOLOGY

Historic sites usually comprise features that make them special, in aesthetic terms. There are several reasons to preserve a historic site. Among them, recognition of quality by users is an essential characteristic. How can such appreciation from people be documented? For example, the Latin American Tower has become a symbol in the historic centre of Mexico City for more than 60 years. People have learned to live with the presence of the tower that it feels like part of the urban context. Even though, it is situated among historic buildings and viceroyalty places. So, nowadays it is convenient to recognize that newer architecture integrates somehow with the past. This is related to what George Kubler mentioned as continuous change across time in *The Shape of Time.* He says: Calendrical time indicates nothing about the changing pace of events. The rate of change in history is not yet a matter for precise determinations: we will have advanced if only we arrive at a few ideas about the different kinds of duration [1]. In fact, no one would intend to demolish the Latin American Tower nowadays because it has become a symbol of Mexico City. This example also shows how postmodern architecture learned to incorporate itself within a historic site.

The first research instrument applied for this paper was a survey. It was implemented to 100 architecture students. The first question was: Under your point of view What is the main foreign architectural influence on industrial sites in Aguascalientes? The second item was: Explain briefly how social interaction was inside industrial heritage of Aguascalientes. The third item of the survey was: Can you identify architectural typologies of industrial heritage? The fourth item was: How do changes in land use impact industrial sites? And the fifth item was: Explain a relevant concept you know about industrial heritage.

The second research instrument gave consistent results from 5 inquirers, but some of the inquirer's results (one out of six inquirers) were not considered reliable. In the cases from the second to the sixth inquirers the results were validated and that included a total amount of 500 hundred inquiries. The inquiry forms were applied on line and sent by the inquirers' social media. A statistical mode was used to calculate the value that appeared most often:

$$x(i.e, X = x)$$

As we can observe in Fig. 1, from 500 questionnaires 100 were applied by each inquirer and subdivided into four groups. Subsequently, a statistical mode was used to obtain the number of respondents required for the Burt's matrix. The questions used by the inquirers included the following items: (1) Age of inquired people: Young (13–17), adults (18–60) and senior (+61). (2) Gender: Man or woman. (3) Educational level: Basic studies, graduate or post-graduate. (4) Origin: Mexican or foreigner. (5) Understanding the concept of industrial heritage. (6) Recognition of Ferronales suburb. (7) Preferences about Ferronales architecture: Wood windows, porches, tree lined streets or stone-paved streets. (8) Preferences about wood windows. (9) Value appreciation of: Ferronales suburb, Tres Centurias Park or the Mexican Smelting Co. Also, preferences about them: history, colours, successful companies or technology. (10) Contribution of industrial heritage to improve landscape architecture. (11) Memories (breath of the places) about Tres Centurias Park: trains, progress, pollution, manufacturing decline and significance of the place.

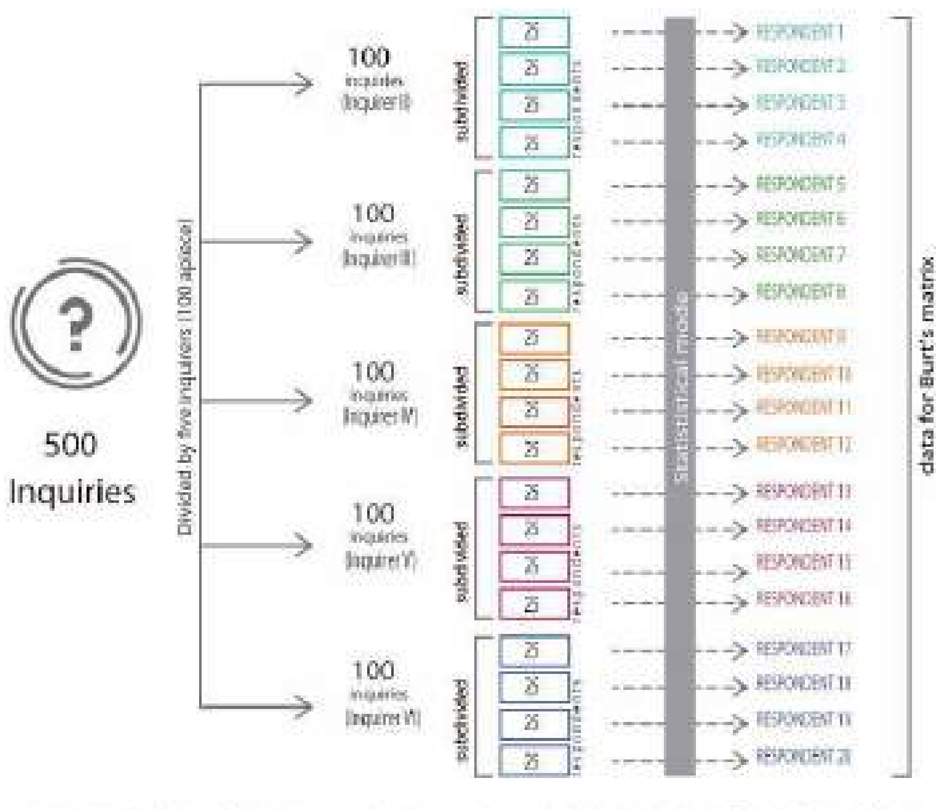

Figure 1: From 500 questionnaires 100 were applied by each inquirer and subdivided into four groups. Also, a statistical mode was used to obtain the number of respondents required for the Burt's matrix. *(Source: Author.)*

3 RESULTS

The results of the survey showed the following opinions in item number one: Under your point of view What is the main foreign architectural influence on industrial sites in Aguascalientes? Some of the students mentioned types of materials used in factories and houses and the way factories used to function. They also recognized architectural influences brought from Europe and from the United States, but also England had to do with it because the first factories were first established in that country. But also, functionalism shaped some industries during the 20th century. Materials and double shed roofs also came to Mexico to be used in a lot of factories, and in some cases *Art Deco* was used in some other factories.

The answers for the second item: Explain briefly how social interaction was inside industrial heritage of Aguascalientes, showed significance results. Some mentioned communities of workers settled down near the factories. In the case of the railway company in Aguascalientes, numerous residences were designed as housing for workers near the train station and the railway workshops.

About the third item: Can you identify architectural typologies of industrial heritage? The answers were related to materials, architectural styles and types of spaces. But also, some answers were associated to horizontal windows, the use of glass and concrete in several industrial buildings from the 20th century.

The fourth item's main goal was to explain how changes in land use influenced in industrial sites. Basically, thanks to railway and road systems the main cities of Mexico started to grow, and in a lot of cases there were changes from lands devoted to agriculture to lands for cities.

The fifth item asked for an explanation of relevant concepts students knew about industrial heritage. Taylorism was detected in some of the answers. Also, the concept of reversibility, which was frequently, used in contemporary restoration works. And finally industrial heritage – related to preservation of unique buildings. Yomna says: Over the course of history, architecture played an important role in manifesting the identities of cities; as each era had its unique architecture that represents the culture and ideologies of people, as well as their values and traditions [2], and industrial heritage is one of them.

The results of the questionnaire applied were concentrated on a matrix. Then a Burt's Matrix was used to apply a qualitative multivariate analysis. A correspondence analysis was the best option to study the results. A complete explanation about how to use this method can be consulted in the author's paper: *Urban mobility and qualitative research in historic places* [3]. The results of the Burt's matrix for this paper can be observed in Table 1. About the concept of industrial heritage, only 45% said they understood the meaning of it, but as a contrast 90% said they could recognize Ferronales suburb. The answers of people about their preferences for Ferronales architecture were: 75% preferred the tree lined streets and 25% porches. Also, wood windows were preferred (100%) over some other materials. All inquired people considered that industrial heritage was valuable and should be preserved. So, it is important to start working with preservation of the built legacy. Caroupapoullé mentions that the contribution to knowledge is the design and development of a research-led strategic framework for the future development of World Heritage Sites that develops current theories and methods [4]. Also, city planning can contribute a lot with it.

Likewise, 100% of the people inquired said the place was appreciated for local culture. Also, they all agreed industrial heritage contributed to local landscape architecture. But still there is work to do about preservation of original typologies and to recognize successful actions done in some other historic sites. For example, Broseta suggests improving the management of protection and urban renewal of historic districts: disseminating the good examples and practices in preservation and refurbishment, including digitalization, regarding typologies and constructive techniques [5], which is a respectable point of view.

The last question was also very interesting because it referred to the "breath of the place". The idea was to detect reminiscences and memories of the people about significant

Table 1: Final Burt's matrix of data obtained from the results of the inquiries.

			Gender		Age			Educational level			Origin		Understanding industrial heritage		Recognition of Ferronales Suburb		Preferences about Ferronales architecture				Preferences about wood windows		Value appreciation of industrial heritage		Ferronales value for local culture				Contribution of industrial heritage to landscape		Breath of the place				
			Male	Female	Young (13-17)	Adult (18-60)	Senior (61 or more)	Basic studies	Graduate	Post-graduate	Mexican	Foreigner	Yes	No	Yes	No	Wood windows	Porches	Tree lined streets	Stone-paved streets	Yes	No	Yes	No	History	Colours	For its production	For its technology	Yes	No	Pollution	Trains	Progress	Manufacturing decline	Significance of the place
			a1	a2	b1	b2	b3	c1	c2	c3	d1	d2	e1	e2	f1	f2	g1	g2	g3	g4	h1	h2	i1	i2	j1	j2	j3	j4	k1	k2	l1	l2	l3	l4	l5
Gender	Male	a1	4	0	0	4	0	0	4	0	4	0	2	2	4	0	0	1	3	0	4	0	4	0	4	0	0	0	4	0	0	3	0	0	1
	Female	a2	0	16	0	16	0	2	14	0	16	0	7	9	14	2	0	4	12	0	16	0	16	0	16	0	0	0	16	0	0	13	0	0	3
Age	Young (13-17)	b1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Adult (18-60)	b2	4	16	0	20	0	2	18	0	20	0	9	11	18	2	0	5	15	0	20	0	20	0	20	0	0	0	20	0	0	16	0	0	4
	Senior (61 or more)	b3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Educational level	Basic studies	c1	0	2	0	2	0	2	0	0	2	0	1	1	2	0	0	1	1	0	2	0	2	0	2	0	0	0	2	0	0	2	0	0	0
	Graduate	c2	4	14	0	18	0	0	18	0	18	0	8	10	16	2	0	4	14	0	18	0	18	0	18	0	0	0	18	0	0	14	0	0	4
	Post-graduate	c3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Origin	Mexican	d1	4	16	0	20	0	2	18	0	20	0	9	11	18	2	0	5	15	0	20	0	20	0	20	0	0	0	20	0	0	16	0	0	4
	Foreigner	d2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Understanding industrial heritage	Yes	e1	2	7	0	9	0	1	8	0	9	0	9	0	8	1	0	4	5	0	9	0	9	0	9	0	0	0	9	0	0	6	0	0	3
	No	e2	2	9	0	11	0	1	10	0	11	0	0	11	10	1	0	1	10	0	11	0	11	0	11	0	0	0	11	0	0	10	0	0	1
Recognition of Ferronales Suburb	Yes	f1	4	14	0	18	0	2	16	0	18	0	8	10	18	0	0	5	13	0	18	0	18	0	18	0	0	0	18	0	0	14	0	0	4
	No	f2	0	2	0	2	0	0	2	0	2	0	1	1	0	2	0	0	2	0	2	0	2	0	2	0	0	0	2	0	0	2	0	0	0
Preferences about Ferronales architecture	Wood windows	g1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Porches	g2	1	4	0	5	0	1	4	0	5	0	4	1	5	0	0	5	0	0	5	0	5	0	5	0	0	0	5	0	0	5	0	0	0
	Tree lined streets	g3	3	12	0	15	0	1	14	0	15	0	5	10	13	2	0	0	15	0	15	0	15	0	15	0	0	0	15	0	0	11	0	0	4
	Stone paved streets	g4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Preferences about wood windows	Yes	h1	4	16	0	20	0	2	18	0	20	0	9	11	18	2	0	5	15	0	20	0	20	0	20	0	0	0	20	0	0	16	0	0	4
	No	h2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Value appreciation about industrial heritage	Yes	i1	4	16	0	20	0	2	18	0	20	0	9	11	18	2	0	5	15	0	20	0	20	0	20	0	0	0	20	0	0	16	0	0	4
	No	i2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ferronales value for local culture	History	j1	4	16	0	20	0	2	18	0	20	0	9	11	18	2	0	5	15	0	20	0	20	0	20	0	0	0	20	0	0	16	0	0	4
	Colours	j2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	For its production	j3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	For its technology	j4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Contribution of industrial heritage to landscape	Yes	k1	4	16	0	20	0	2	18	0	20	0	9	11	18	2	0	5	15	0	20	0	20	0	20	0	0	0	20	0	0	16	0	0	4
	No	k2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Breath of the place	Pollution	l1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Trains	l2	3	13	0	16	0	2	14	0	16	0	6	10	14	2	0	5	11	0	16	0	16	0	16	0	0	0	16	0	0	16	0	0	0
	Progress	l3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Manufacturing decline	l4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Significance of the place	l5	1	3	0	4	0	0	4	0	4	0	3	1	4	0	0	0	4	0	4	0	4	0	4	0	0	0	4	0	0	0	0	0	4

facts of the place. In this case, 80% of the inquired people answered trains and its sounds were remarkable, and only 20% mentioned a notable significance of the place for the city.

It is convenient to mention that all the inquired people were adult people, between 18 and 60 years old. This occurred because the questionnaire was applied on line due to the national emergency caused by COVID-19. Under normal circumstances, inquirers could have applied the questionnaires on a square or a park (for example), or some other place, but inquiring any type of people they encountered.

4 DISCUSSION

A multivariate analysis is very helpful as a qualitative method. Some variables are crossed with facts that help researchers make significant deductions. Even though the inquirers were young people (from 18 to 22 years old) in this case, the results show most of the inquired people were students from several universities (90%). But this doesn't mean they completely understood the concept of industrial heritage, so only 50% affirmed they knew something about it. Likewise, university students preferred urban facts about the historic site, like the tree lined streets. Indeed, such students considered the site worthwhile to live at.

Understanding industrial heritage has to do with a strong recognition of Ferronales suburb, also in the cases mentioned in this paper. This is helpful in order to promote an entire typological record to encourage preservation of the historic site. This means most educated people agree with preservation of historic architecture and urban contexts. Also, they agree historic architecture has important values and contributes to local culture and landscape.

Referring to origin of the inquirers, they were basically Mexican. Even though the Ferronales suburb has railway houses with a typical American style, no Americans live in the place anymore. It can be found in historical archives of Aguascalientes that first owners of Ferronales houses were Americans, but they decided to move away from Ferronales due to railway enterprise problems. This situation happened more than 100 years ago.

Also, an interesting relationship between preferences about Ferronales architecture (tree lined streets) and contribution of industrial heritage to landscape demonstrates that nature could be part of historic sites, and sustainable city designers can help with this type of integration. In fact, the tree-lined streets with a combination of historic one-story houses make Ferronales suburb a unique place to live in Aguascalientes.

There's also a combination of factors that show an interesting relationship between Ferronales value for local culture with preferences about wood windows. In Aguascalientes almost anybody uses wood windows in houses nowadays. It looks like such construction material became out of use through the times. So, young people relate the artefact (wood windows) to their imaginaries about historic houses.

Finally, another interesting inference has to do with the concept of industrial heritage and its relationship with some types of buildings. During the last two decades this concept has been developed and some countries from Europe are very interested in recovering architecture from industrial revolution phases, especially Spain and England. In Latin America, some governments and academics are concern about preservation of this type of architecture, mainly from the second phase of industrial revolution. This was from 1870, at the time invention of electricity made possible assembly lines in factories, to 1969, right when programmable controllers changed production lines. During this phase, good architecture was built – related to industry – including housing for workers, which is the basic issue of this paper. At the end, not a lot of people are concerned about preservation of industrial heritage, but there is good expectation people will understand this type of heritage during the next years.

5 CONCLUSIONS

Windows and entrances arrangement have to do with proportions. Somehow window arrangement has contributed to improve exterior perspectives in historic sites. If someone takes a look at windows and entrances in Carranza Street in Aguascalientes City, it can be observed that dimensions are variable. In the case of religious buildings (Figs 2 and 3), opening 1, 17 and 21 show a proportion of 1:2; in fact they are the biggest openings. Also, the south city block facing shows several big openings but they are related to newer architecture and altered historic buildings. In addition, intermediate size can be classified with openings 6, 8, 30 with a proportion of 1:1.5, also openings 11, 28 and 38 with a proportion of 1:2. Moreover, the opening 28 correspond to a religious building. The opening 41 has an intermediate size, but keeps a proportion of 1:1.

Figure 2: Typology of Carranza St. openings (windows and entrances, north city block facing). *(Source: Author's research, 2021. Drawing made and edited by Alejandro Acosta Collazo and Alejandra Díaz de León Esparza. Photographs by Jéssica González Reyes, September 14th 2021.)*

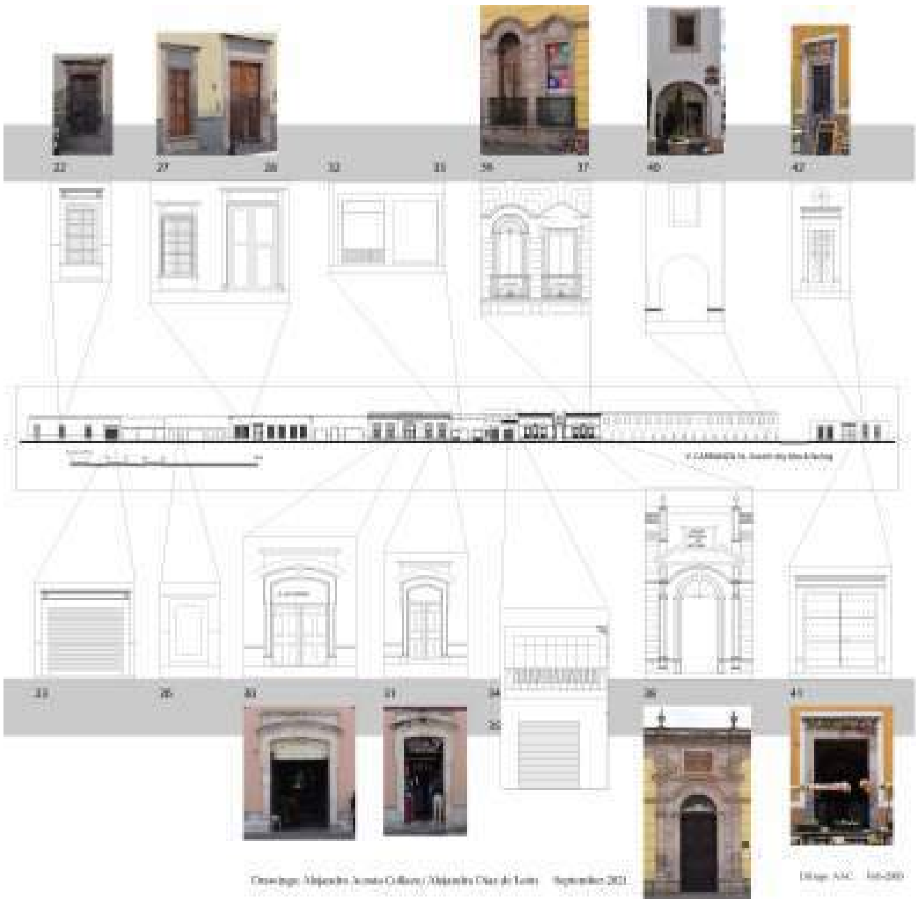

Figure 3: Typology of Carranza St. openings (windows and entrances, south city block facing). *(Source: Author's research, 2021. Drawing made and edited by Alejandro Acosta Collazo and Alejandra Díaz de León Esparza. Photographs by Jéssica González Reyes, September 14th 2021.)*

The most common openings are the small ones. This is the situation of openings 2, 7, 10, 12, 20, 22, 27, 31 and 42. Actually, they keep a proportion of 1:2 (see Figs 2 and 3). Another classification for these small openings is the proportion 1:3, especially in openings 18, 19 and 36. Also, it is possible to identify small openings with a proportion of 1:2.5 (see opening 37 in Fig. 3). One opening with a proportion of 1:1.5 (opening 15) was found and another opening with a proportion of 1:4 (see opening 9 in Fig. 2) was also found.

Openings of main facades of historic buildings sometimes change because of commercial stores or businesses. They rent them, remodel their spaces and remove walls or structures. The reason of choosing these city blocks was because in the whole city centre they have a high concentration of historic and unique buildings (including houses). Even though the street is considered a World Heritage Site, several transformations on windows and entrances have occurred, as a consequence the proportion of such openings have

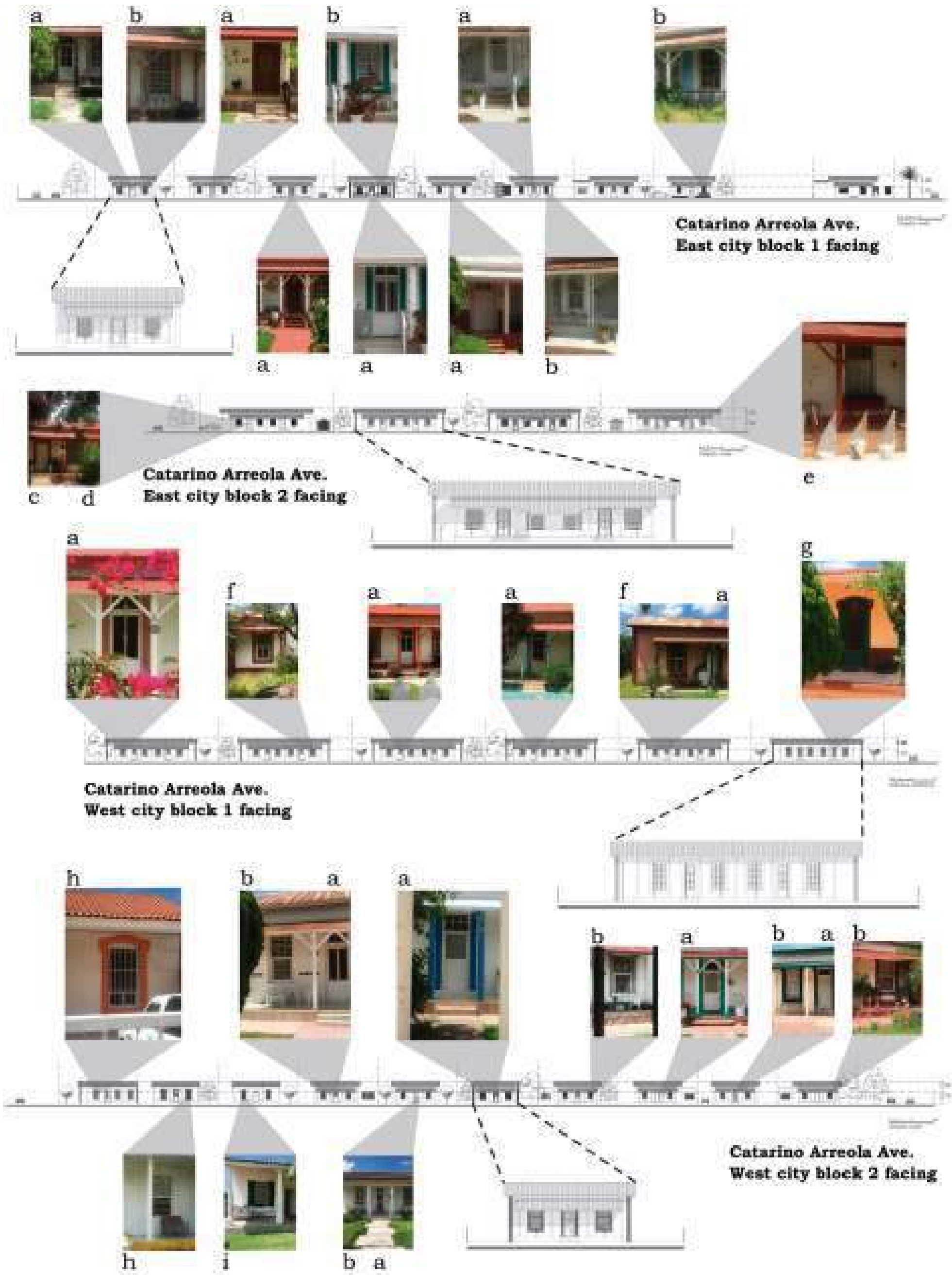

Figure 4: Typology of Ferronales suburb. Catarino Arreola Ave. openings (windows and entrances). *(Source: Author's research, 2021. Drawing made and edited by Alejandro Acosta Collazo and Fernanda Pérez Sifuentes. Photographs by Carmen Paulina Muñoz Rangel, September 19th 2021.)*

changed from a vertical position to a horizontal position, especially during the second half of the 20th century.

In Ferronales suburb, the analysis of the place and typologies demonstrated that Aguascalientes red bricks and limestone were used to shape entrances and windows. In Fig. 4 it can be observed that typologies differ in measures, but they all have vertical shapes. Dimensions of typologies are as follow: (a) 1.40 × 2.15 m (15 entrances), (b) 1.40 × 1.75 m (eight windows), (c) 1.14 × 2.25 (one entrance), (d) 1.44 × 1.72 (one entrance), (e) 1.60 × 1.95 m (one window), (f) 1.60 × 1.85 m (two windows), (g) 1.40 × 3.22 m (one entrance), (h) 1.60 × 2.80 m (one window), and (i) 1.40 × 2.34 m (one window). It can be observed that the most common entrance is (a) with a proportion of 1:1.5, and also, the most common window is (b) with a proportion of 1:1.25.

Nowadays, they are building a cinema complex too close to Ferronales suburb, so inhabitants are concerned about possible land use changes and the consequences of building parking lots nearby. This situation may affect the original houses for workers and may change dramatically the typical typologies. Government administrators and social actors should understand that preservation of historic sites could be instrumental in rising cultural distinctiveness.

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TOWARDS SOCIALLY SUSTAINABLE WATERFRONT URBAN REGENERATION: THE CASE OF ZAYED PORT DESIGN, ABU DHABI

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ABSTRACT

While the urban waterfront is crucial to shaping the city image, it also contributes to the quality of life of the city's inhabitants and visitors. The Waterfront of Abu Dhabi city, the capital of the United Arab Emirates (UAE), has witnessed influential changes in the last 20 years. This research aims at discussing the relationship between urban form and social sustainability in a very recent urban regeneration of a waterfront project in Abu Dhabi city, the Zayed Port's waterfront project. The attainment of the social sustainability principles in the urban regeneration project was explored through examining the existence of these principles through an established theoretical framework. The theoretical framework included the main social sustainability principles of compactness and density, mixed-use and social mix, mobility, equitable access and spatial integration, safety and security, identity of place, and community participation. The utilized qualitative/quantitative tools of the case study method encompassed Space Syntax analysis of the urban form through relevant DepthmapX simulation variables. The assessment results revealed the gaps and potentials related to the application of these principles in the proposed design of the urban regeneration waterfront project of Zayed Port. Based on these outcomes, a set of social sustainability enhancement strategies has been recommended. The applied method with its tools as well as the revealed outcomes is envisaged to be significant to consider in the current and future urban regeneration designs of waterfront projects in the UAE's cities distinguished with their long waterfronts such as Dubai, Sharjah, Ajman, and other cities, to assure the achievement of social sustainability principles in this important type of urban development.

Keywords: urban regeneration, social sustainability, waterfront, Zayed Port, Abu Dhabi, UAE.

1 INTRODUCTION

Urban areas are always in a state of physical, social, environmental, and economic transformation [1]. Some of these transformations lead to a state of urban degradation that requires urban regeneration process to deal with. The practice of urban regeneration starts with identifying the major areas of concerns and the possible future challenges, then, it tackles the physical conditions enhancement, social improvement, and economic progress of the targeted urban area [2]. Waterfront urban development and regeneration, in specific, are representing valuable endeavor for urban communities stemming from common aspects of old ports areas such as the availability of vacant land and the potential of attracting new investment and cultural development. All over the world, various waterfronts urban areas have been regenerated from brown fields to commercial, residential, and recreational areas. While the main attention has been paid to the environmental and economic dimensions of most of the urban waterfront regeneration plans, the social dimensions have recently become increasingly important in urban policies [3].

Since its establishment as a federal state, the United Arab Emirates (UAE) has witnessed continuous urban development efforts which recently aimed at achieving sustainable development. Abu Dhabi, the capital city of the UAE, with its port and long waterfronts has been in the center of the contemporary efforts of waterfront regeneration in the country. Waterfronts in the UAE lay by the coast of the Arabian Gulf and have been

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historically considered the oldest sources for economic activities of the Emirati residents including trade, pearling, and fishing. With the aim to facilitate better living conditions, many of the current urban regeneration projects in Abu Dhabi city appear beside the water.

Abu Dhabi Urban Planning Council has issued the Abu Dhabi Public Realm Design Manual in which a chapter is dedicated to the urban planning ‘guidelines’ related to the Waterfront development [4]. As shown in Table 1, these guidelines define the needed amenities for waterfront development hierarchy with the overall aim to assure high-quality waterfront developments, make them accessible destinations for both residents and visitors, and provide diverse public space designs that celebrate and strengthen local heritage of Abu Dhabi. Table 1 illustrates the guidance for the types of the served users, the needed features and/or amenities, the service radii, and the level of service that provides benchmarks for the percentage of the accessible waterfront frontage for each hierarchy level [4].

In this research, a conceptual design alternative for Zayed Port in Abu Dhabi city was assessed from a social sustainability point of view to define the shortcomings and potentials associated with the design and to provide future insights for enhancing the attainment of socially sustainable urban waterfront regeneration projects, not only in this and other similar projects in the city, but also in other waterfront cities in the UAE.

2 RESEARCH PROBLEM AND METHOD

While the waterfront urban regeneration is receiving global attention from researchers and scholars, locally in the UAE, there is almost no literature that have reviewed the sustainability of recent local waterfront communities in the country, especially from a social sustainability point of view. Usually, social impacts have contextual features, and they represent complex social relations or dynamics. The Zayed Port Pier urban regeneration design [5] was selected as the case study of this research as it is one of four major ports in the Emirate of Abu Dhabi and it is a prominent project reflecting the very recent trend in considering sustainability in waterfront urban regeneration in the country.

Established in 1968, Zayed Port is located in the northeast section of Abu Dhabi city (Fig. 1). The Port covers an area of about 535 hectares, with 21 berths and a total berth length of 4,375 meters. The port is characterized by its containment of a traditional Dhow harbor, and its continuous fish trading tradition of earlier times. The site is overlooking the Al Lulu Island, and the port is located beside Al Corniche from the South and the Southwest directions. While from the Northwest direction the port is overlooking the Louvre Museum in Al Saadiyat Island.

The design of the urban regeneration of the Zayed Port Waterfront Pier by the Sasaki Architects [5] is conceived as a fully integrated mixed-use district tied by a series of pedestrian-oriented public spaces and a world-class waterfront promenade. As shown in the mixed land-use plan of the design (Fig. 2), a circular-shape hotel complex anchors the west end of the redevelopment site and overlooks Abu Dhabi city, Al Lulu Island, and the Arabian Gulf, while the middle blocks of the redevelopment plan combine three hotels, meeting and ballroom facilities, retail spaces, and residential apartments into one district. Besides its local residents, expectedly from middle class stratum, the Zayed Port Waterfront Pier project is intended to serve a mixture of users including tourists, visitors from surrounding areas. Also, the plan will offer various jobs opportunities for all factions of the society.

To assess the Zayed Port Pier urban regeneration design from a social sustainability perspective, the research first initiated a theoretical framework for the main principles and indicators of socially sustainable urban waterfront regeneration. This theoretical framework

Table 1: Waterfront urban planning guidelines in Abu Dhabi [4].

Users	Features/amenities	Locations	Service radius	Level of service (% of accessible waterfront frontage)
Residents of the Emirate	-Limited waterfront development. -Provides public access to important waterfront landscapes.	Dictated by the presence Emirate significant waterfront features, natural landscapes, and locations of Emirate importance.	100 km +	40–60%
Residents of a municipality	-Large promenade. -Iconic design. -Focal point of the urban area. -Passive recreation. -Event space. -Large gathering nodes. -Major beach and conservation areas.	Dictated by the presence of coastline adjacent to a major urban city center.	40 km	5–10%
Residents of a city	-Narrower promenade design than regional/municipal level. -Access to city's most important beach areas. -Beach preservation and development. -Passive recreation.	Dictated by proximity to densely developed urban areas.	10–15 km	10–15%
Residents of a district	-Trail access. - District-oriented beach access. -Smaller promenade/boardwalk design. -Passive recreation.	Dictated by proximity to medium density developed areas, centrally located along a district's edge.	5–10 km	10–15%
Residents of a local neighbourhood	-Trails integrated into the neighborhood. -Neighbourhood-oriented shoreline access. -Small boardwalks in central areas. -Passive recreation.	Dictated by proximity to neighbourhood center.	0.5–2 km	10–15%

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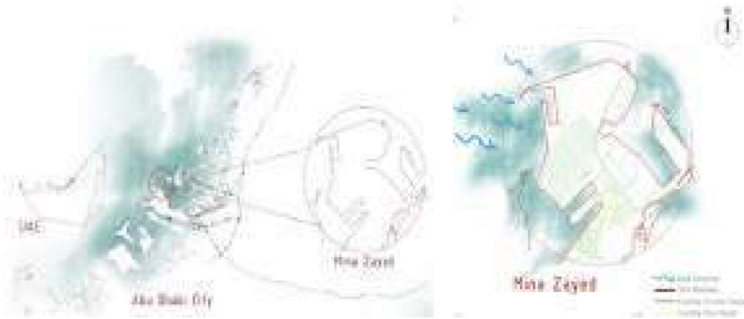

Figure 1: The location of Mina Zayed in Abu Dhabi City.

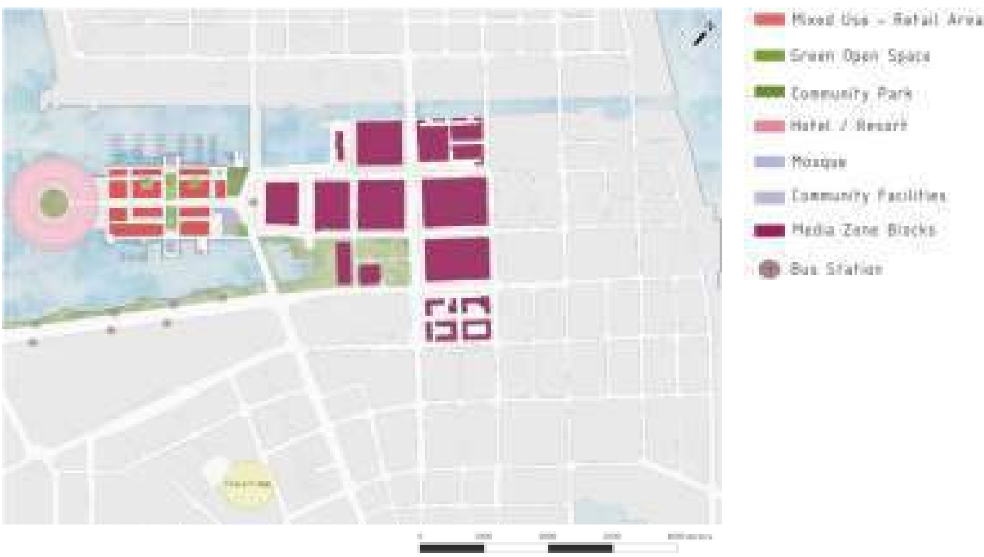

Figure 2: The Land-use Plan of Mina Zayed Waterfront Pier – the development of the services designed by Sasaki Architects. *(Source: Based on [5].)*

was mainly derived from two sources: the relevant global literature, and some relevant case studies. Then, this framework was used to assess the proposed design of Zayed port and ultimately a set of future design guidelines and recommendations has been developed out of the results of this assessment. In terms of the main investigation tools of the applied case study method, the design CAD drawings of the Zayed Port urban regeneration project were explored and analyzed against the defined target social sustainability principles using quantitative/qualitative tools especially Space Syntax analysis through DepthmapX simulation software, as a reliable tool for investigating social impacts of urban forms [6]. In DepthmapX software, the produced *Integration* values for the whole urban system (Rn), calculated through Angular Segment Analysis, were used to assess the spatial integration measures of the design. Meanwhile, *Choice* values were used to assess accessibility measures of the urban form of the design. Meanwhile, catchment distances were calculated using the values of *Step Depth* which follow the shortest angular path from the selected segment to all other segments within the whole urban system [6]. In addition, some qualitative tools were applied, as relevant, to probe some qualitative social sustainability principles and indicators of the waterfront urban regeneration such as Identity and Sense of Safety and Security.

3 PRINCIPLES OF SOCIALLY SUSTAINBLE WATERFRONT URBAN REGENERATION

In general, the social dimensions of urban waterfront planning and regeneration refer to the different ways of experiencing and using the edges of sea to make an understanding of their qualities for the community. To initiate a matrix of principles for socially sustainable waterfront urban regeneration that could be used to assess related designs, the research consulted a wide variety of relevant literature, local guidelines, and some case studies aiming at developing a comprehensive set of relevant principles and indicators. Still, due to the nature of the literature about social sustainability, this conceptual framework might have unintentionally missed out some of the principles and/or indicators. As briefly detailed below, these principles included main seven principles as follows: Compactness and Density, Mixed-Use and Social Mix, Mobility, Accessibility, Safety and Security, Identity, and Community Participation.

First, Compactness and Density of the built environment is a widely acceptable strategy through which more sustainable urban forms could be achieved. This is because compactness leads to urban connectivity, which minimize the need for transport of people, products, and materials. It also leads to less use of urban land due to increasing the density of development and activity [7]. The Floor-Area-Ratio (FAR), calculated by dividing the total floor areas of the buildings by the gross area of the development site, is suggested as a measure of urban form compactness and indicating the development density [8].

Second, Mixed-Use and Social Mix enhance the condition of social sustainability through giving the residents the opportunity to meet their needs within their locality. In this way, the people would become less dependent on private automobile trips and will be more encouraged to walk toward their desired destinations. This would also strengthen the social ties and networks among the residents through stimulating their interaction in a way that enhances the life quality and social equity of the local community [9]. On the other hand, social mix and mixed land-use are interdependent and promote each other. Actually, social mix aims to encourage the interaction between different social stratum in the same community and to ensure the accessibility to equitable urban opportunities. Social mix helps to provide the basis for healthy social networks and social capital, which are the driving force of socially sustainable communities [10].

Third, Mobility, with the provision of its different modes including walking, cycling, public transport, and private vehicles, is an essential social sustainability principle. It is important for a socially sustainable built environment to encourage walking and cycling through providing a safe, attractive, and well-maintained walkways and cycling networks. The interconnected public realm enhances the mobility of people by providing comfortable and continuous access for walking, cycling, and other modes of transport with their different design strategies [4]. One of the most important services which highly contributes to the neighborhood's level of mobility is public transportation. While there are different types of public transportation – i.e., train, tram, bus –, their applicability depends on various factors including the population and/or development density [11]. Meanwhile, private cars mobility network should be allowed but with less permeable configuration and with applying traffic calming measures to control the impact on pedestrian and cyclists [12].

Fourth, Accessibility is highly required in waterfront developments for their attractive and vibrant public destinations. Within the developed waterfront area itself, catchment distances to locally provided services and public transportation nodes between 400 m and 800 m are recommended. Furthermore, it is better to centrally locate the local services and facilities and to be near to a main transport node. Ease of access into local services and facilities for elderly, children and disable people, should also be considered. The stop intervals of public transport nodes within the development area should be within a t distance of about 200 m–300 m. On the other hand, the waterfront development should have Spatial Connectivity and Integration both internally and externally with the surrounding urban context. Integration could be achieved through a reasonably permeable grid that results in linkage of the urban spaces [13].

Fifth, Safety and Security entail the provision of safe, secure, and accessible spaces for all members of the waterfront development residents and visitors. Compact and inclusive urban development plans could cater to security and safety measures for all. Additionally, traffic calming measures, visual surveillance, and the provision of a safe and connected mobility networks should all be achieved in public areas through the urban development plan [14].

Sixth, Identity represents what is unique about a community's culture, heritage, and natura assets, in the development urban and architectural design of buildings, streets, streetscapes, green spaces, plantings, etc. Outstanding features of natural and man-made heritage of the developed waterfront area should be considered in the design [4].

Seventh, Community Participation is acknowledged in the contemporary planning development as it helps accomplish a sustainable development design. As the professionals and users are two quite different groups in terms of educational background, ways of thinking, "taste," and many other aspects, a participatory process can bridge this gap resulting a design based on an adequate understanding of the public's needs and preferences [15], [16].

4 SOCIAL SUSTAINABILITY ASSESSMNET OF THE DESIGN

Density and Compactness: The overall site area is about 51 hectares and the total floor area of the buildings in the urban regeneration design is about 560,000 m^2. The calculated floor-area-ratio (FAR) of the urban regeneration design, as a measurement of the urban form compactness of the project, is 1.65. This figure indicates a high dense and compact value.

Mixed-Use and Social Mix: The masterplan of the Zayed Port Waterfront Pier project is a compact mixed-use development, which consists of residential, commercial, and service facilities. The mixture of uses includes three hotels, meeting and ballroom facilities, retail space, apartment blocks, green open spaces, community facilities, and media zones, as illustrated in Fig. 3.

Still, some of the required services and facilities, such as schools, clinics, and toddler play areas, are not provided in the master plan of the project. On the other hand, social mix is expected due to the diversified services and facilities in the project as discussed earlier. Residential dwellings are also provided with a variety of areas but are apparently targeting the requirements of middle-class social stratum.

Mobility: The Zayed Port Waterfront Pier masterplan connects the different provided facilities in the site from Northwest, Northeast, and South directions by convenient pedestrian walkways and footpaths that integrate the whole waterfront redevelopment area (Fig. 4). Additionally, the design of the 5-meter-wide pedestrian lanes in the main streets are mostly shaded and artificially lit following a typical city Avenue urban design typology.

Figure 3: The ground floor plan of Zayed Port Waterfront Pier. *(Source: Based on [5].)*

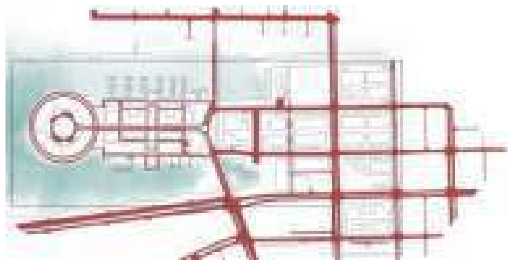

Figure 4: The Zayed Port Waterfront Pier Street pedestrian access [5].

Dedicated cycling lanes are not considered in the masterplan, but they are shared with pedestrian lanes. The design is not showing dedicated facilities and parking areas for cycles. For Public transportation, the proposed tram will link Zayed Port facilities to the designed multi-modal transit facility in Abu Dhabi city. Visitors who will arrive by tram to the Transit Plaza of the Waterfront Pier can easily then be guided to points north and south along the pier promenade. There is only one main line for public transportation which is serving the whole Waterfront Pier project. Meanwhile, bus stops are not available indie the project site.

Accessibility: The services and facilities in the Zayed Port Waterfront Pier project are open for the public with no restrictions. For the walkable catchment distances, the Step Depth Angular Segment Analysis in DepthmapX simulation tool show variant values for the different provided services and facilities in the study area. Fig. 5 illustrates two of these simulations results for the community parks and mosques.

About 60% of the site is not within the 400 m catchment distance for the community parks located in the Northwest of the project. Almost the same result is recorded for the mosques. On the other hand, the 800 m catchment distances for the local shops, retails, restaurants, and public services seems mostly achieved. For the accessibility analysis of the public transportation nodes (Fig. 6), the locations of the bus stops are not easily accessible by most residence of the project, as they are located along the corniche (Fig. 6(a)). Fig. 6(b) illustrates the catchment distance simulations, using Step Depth Analysis in DepthmapX, for the Transit Hub, tram stops, and bus stops, in and around the Zayed Port Waterfront

(a) (b)

Figure 5: Segment analysis-step depth: The accessible distance for the community park and Mosques in The Zayed Port.

(a) (b)

Figure 6: (a) Public transportation access from Transit Hub; and (b) Segment analysis-step depth: The accessible distance for the transit nodes.

Pier and other surrounding segments within the urban system. Unfortunately, it is revealed that about 20% of the urban regeneration area is not located withing the walkable catchment distance of 600 to 800 m.

Accessibility requires spatial connectivity and integration among the residential, commercial, recreational, and civic uses of the project. The *integration* values were analyzed in DepthmapX for the whole urban system (Rn) (Fig. 7(a)). The obtained values show that the roads in the Waterfront Pier project are not perfectly integrated, where the main arteries around the basic services and facilities have recorded low *integration* values, while the most integrated road is located far from the mixed-use area. This makes the public services and facilities in the Southwest part of the project are not easily accessible by the visitors.

Additionally, the availability of accessibility routs leading to the designed services and facilities within the study area was analyzed through simulating the *Choice* values in DepthmapX software for the whole urban system (Rn). According to Fig. 7(b), the most “chosen” arteries (highlighted in red) are the one located between the media zone and the community center, and another one located in the Northeast side of the Waterfront Pier. Both roads are far from the mixed-use areas of the project.

(a) (b)

Figure 7: Angular segment analysis: (a) Integration-Rn, and (b) Choice-Rn.

Safety and Security: The design of the streets considers the provision of safety buffers to isolate pedestrian walkways from vehicular movement but, on the other hand, there are no separated cycling paths, which is a safety concern. Visual surveillance in the public realm would be positively affected by the provision of mixed-use mixed commercial and residential areas where the shops ensure a sufficient population in the street in the daytime and the residential use ensures a natural surveillance during the nighttime. The masterplan is designed to in a way where public spaces are easy to overlook and to oversee. But with the lack of appropriate catchment areas, residents’ presence in the streets might not be enough for the provision of visual surveillance. On the other hand, the measures of inclusive design that consider the needs of children, the disabled, and elderly people are mostly achieved in the design. The good consideration of visibility through effective artificial lighting enhances the sense of security.

Identity: Whereas the Zayed Port location contains important natural and heritage assets of the Arabian Gulf, the design seems not considering these assets sufficiently to help create a distinctive identity either in the masterplan of the port design or the architectural design (Fig. 8).

Community Participation: Actually, the current proposal does not directly involve the community in shaping its vision and concepts. But, as mentioned by the designer, Sasaki’s architect, the Zayed Port design helps the community to engage in various shared social activities through the provision of public spaces, plazas, tourism area, yacht club, public landmarks, and mosques.

(a) (b)

Figure 8: Zayed Port Waterfront Pier aerial view [5].

5 DISCUSSION: RETHINKING THE DESIGN OF ZAYED PORT WATERFRONT

The outcomes of the investigations managed to assess the defined social sustainability principles in the examined case study. This gives confidence in the applied method and tools which might help enhance the assessed design and any other urban regeneration design for similar waterfront development cases. For the case of the Zayed Port urban regeneration project, the assessment reveled 5 potential enhancement strategies that would make the regeneration design more socially sustainable. These are: first, redefining the land-use of the project to provide all the missing local community facilities and services in the design, such as clinics, schools, play areas, etc. In addition, the number of some provided facilities such as mosques, etc., need to be increased in some locations as revealed in the analysis, to cover the need of these services in all areas of the project. More variety of housing types is also needed. Traditional activities related to the Port, such as a fish market, could be added near to the Marina. As the project also attracts tourists and visitors, some city scale services such as a vegetable/fruit market, and handmade carpets market, might be good additions to the land-use of the design.

Second, improving modes of mobility by enhancing the pedestrian network, adding dedicated cycling infrastructure, and more importantly applying the relevant code for the streets' typical cross sections according to each street category (boulevard, Avenue, Street, Alley (*Sikka*), etc.) as per The Abu Dhabi Urban Street Design Manual [17]. Minimizing the cars' right of way would enhance other more sustainable mobility systems of pedestrians, cyclists, and public transportation. This would give the residents and visitors the ability to choose the mode of movement and commuting that best fits each one of them. In new urban districts, like the project in hand, it is preferable to place car parking and service delivery belowground to save the public street realm for use of people. Meanwhile, the streetscape design of the Zayed Port Waterfront Pier development should be designed to enhance thermal comfort by creating a network of safe, comfortable, and continuously shaded routes.

Third, improving accessibility through developing the design of the street network to be more integrated with the surrounding urban context. In addition, applying Transit Oriented Development through providing the services and facilities around the public transportation hub, would enhance accessibility. Enhancing pedestrian accessibility through meeting the required catchment distances might require adding dedicated pedestrian pathways, known as *sikkas* in traditional urban development of Abu Dhabi. To enhance accessibility to public transportation nodes, bus routes need to penetrate the redevelopment area with nodes within walkable distances to the residents. This will encourage a greater number of residents to consider bus/tram-trips as a viable solution to their travel needs.

Fourth, enhancing visual identity of the project in a way that sustain the local culture of the Port by better reflecting the history of the waterfront area as an old Dhow harbor. The notion of 'authenticity' should be reflected in the urban form and building design that naturally blend daily activities with culture and the street life. Achieving this in the project requires more reliance on local urban forms, construction materials, open spaces that resonate with the local climate conditions and other distinctive attributes that are tied to local traditions of Abu Dhabi as a Port city. Moreover, adding dedicated spaces such as floating parks containing an array of seasonal activities, including areas for traditional performance, play, and quiet rest places, that are overlooking the Arabian Gulf, might also help enhance the visual identity of the project.

Fifth, enhancing the level of community participation by involving community members in the design decision-making processes of the project. Engaging the local public, as part of the design strategy, would allow people to be involved directly in shaping the project's visions and ideas, and consequently better design decisions will be reached.

6 CONCLUSION

The Zayed Port Waterfront urban redevelopment is perceived as a sustainable initiative, that will revive the old port district to become a new social and civic hub in Abu Dhabi city, i.e., a place where it is enjoyable for people to live, work, shop, visit, and spend time with family and friends. As social sustainability is a vital pillar in these types of projects, adhering to social sustainability principles is essential in the design to help restore the vibrancy and enhance the quality of life for people. By that the urban redevelopment project will be a place that is scaled to people, providing safe pedestrian environments and open space for vivid and safe public life. Most importantly, it will be a place grounded in the unique culture and values of its people and spatially integrated with the waterfront and the Port.

The study aimed at assessing the current urban regeneration design concept of the Zayed Port from a social sustainability point of view. Accordingly, a conceptual framework for the main seven principles of social sustainability and their indicators was briefly established and consequently used as a tool of assessing the original urban form of the urban regeneration design. The utilized qualitative and quantitative tools, especially Space Syntax simulation, proved valid in defining the shortcomings of the proposed design in relation to the examined social sustainability principles. These were related mainly to the mixed-use plan, modes of mobility, accessibility, safety and security, visual identity, and public participation. Based on the assessment findings, a recommended set of social sustainability improvement strategies has been identified encompassing valid, reliable, and highly contextual design guidelines that could meet the needs of people in this geographic and cultural context, and hence enhance their quality of social life and well-being. If applied, it is envisaged that these strategies would enhance the design of the urban regeneration project of the Zayed Port Waterfront to be a more socially sustainable project. In addition, appropriate consideration of social sustainability principles would mutually reflect on other sustainability measures. For example, the socially sustainable mixed-use design can improve the energy efficiency through the development of the public transportation node around the high-density areas and providing proper catchment distances for walking and cycling, etc.

Finally, it is hoped that the outcomes of this research would pave the way for futuristic urban design scenarios that will lead to a more socially sustainable urban forms of waterfronts developments in the UAE and maybe in other Gulf Cooperation Council

(GCC), Arab, and Middle Eastern cities that share many socio-cultural and environmental circumstances and contexts.

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CHALLENGES OF TURKISH HERITAGE IMPACT ASSESSMENT PRACTICES: CASE OF CANAL ISTANBUL, TURKEY

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ABSTRACT
Heritage impact assessment (HIA) which has been implemented internationally after the Vienna Memorandum aims to contribute to both development initiatives and conservation principles. However, Turkish impact assessment practices still display inactive relationships with cultural heritage although the country developed alongside prior global experiences. Istanbul pioneered planning interventions and large-scale urban regeneration in Turkey, which has been the country's primary connection to global markets. Due to Istanbul's reputation as an investment centre defined by the government, the balance between conservation and development has become shallow. While Turkey introduced legislative measures from European perspectives, the country began to drift apart in terms of the logic behind HIAs since 2005, when the urban regeneration era commenced. In this context, Istanbul Canal exemplifies the Turkish approach of HIA, at the intersection of conservation and development, grounded exclusively in Turkish legislation. Established on the Canal Istanbul Environmental Impact Assessment (EIA) practice, this study investigates the challenges encountered by Istanbul's cultural heritage, due to the hierarchical structure of the planning system, the adoption of international conservation and management principles, and the EIA–HIA processes and procedures. It considers that the deep-seated problems within the Turkish conservation–planning structure can be attributed to the ineffective HIA, and the results could contribute to the improvement of impact assessment mechanisms.
Keywords: Canal Istanbul, conservation, cultural heritage, heritage impact assessment.

1 INTRODUCTION

Heritage impact assessment (HIA), defined as the process of evaluating potential impacts of any development on cultural properties [1], can be dated back to the National Environmental Policy Act (NEPA) dated 1969 [2] when environmental impact assessment (EIA) was introduced to the world. Among the conditions which led to the creation of an impact assessment framework, not only the natural environment but also archaeological values are defined within the scope of the affected environment. Destruction of archaeological sites from large scale developments, especially dams and highways were included within The Reservoir Salvage Act in 1960 [3], and by the National Historic Preservation Act (NHPA) [4], the effects of developments on cultural properties were recommended to be considered. Similarly, it was 1967 when UNESCO's international campaign to safeguard Abu Simbel and 1968 when Recommendation concerning the Preservation of Cultural Property Endangered by Public or Private works [5] called attention to preservation of heritage against development proposals. Influenced by international practices, Turkey also had rescue operations commenced in 1966 in the Lower Euphrates Basin where the Keban Dam Project was proposed by the State Hydraulic Affairs. There had been surface investigations, documentation of cultural heritage and excavations conducted by multi-disciplinary team from multiple universities [6]. Therefore, it is possible to call the 1960s as a decade of the first steps towards HIA taken by archaeological impact assessment (AIA).

In addition to AIAs, visual impact assessments (VIA) became widespread in the 1970s. In 1972 The Convention Concerning the Protection of the World Cultural and Natural

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Heritage was adopted and it was followed by the first United Nations Conference on Human Settlements [7] that reveals the breakdown of social relationships and traditional cultural values due to the rapid urbanisation, Recommendation concerning the Safeguarding and Contemporary Role of Historic Areas [8] that connects social, economic and cultural ties within the historic environment and considers harmonisation of new buildings and visual integrity. In 1976, a visual resource management system that encourages VIA methods for a better decision-making process in landscapes was established by the US [9]. While AIA and VIA were added to the EIAs, Turkey put legislation on conservation areas.

Both the 1980s and the 1990s are important as nature conservation-based impact assessment practices began to evolve into wider frameworks by the concept of sustainability. Furthermore, regulatory measures for the EIAs were increased and cultural heritage was recognised as an impact assessment topic. Charter for the Protection and Management of the Archaeological Heritage [10] specified development projects as one of the greatest threats and it draws attention to the implementation of AIAs together with the appropriate legislation. This was discussed in the First National Symposium on Protection and Evaluation of Archaeological Conservation Areas 1991 [11] Some countries such as France and the UK, also put archaeological and cultural heritage into their EIA regulations whereas Turkey followed the EU's perspective, and the first Turkish EIA legislation was introduced.

Known as the strategical thinking period, from 2000 to 2010 there was a search for harmonisation of impact assessment with conservation not only worldwide but also in Turkey. After the European Strategic Impact Assessment (SEA) Directive, the first connection between spatial planning and EIA in Turkey was set via MATRA [12] which aims to adopt EU directives into the Turkish impact assessment system. However, these initiatives have also faced many amendments to support development. In the field of conservation, on the other side, management plan and HIA practices started parallel with the global perspectives such as the cultural impact assessment framework of INCD [13] and Vienna Memorandum [14] which again focused on the impact of contemporary development on world heritage sites by the historic urban landscape approach. Hence, the 2000s was the last phase for HIA to be recognized globally until 2011 when Guidance on Heritage Impact Assessments for Cultural World Heritage Properties was published by ICOMOS.

Since 2011, HIA has been used as a conservation and management tool for historic environments. The efforts to establish the two-way link system of impact assessment–planning–conservation on the other hand still fall behind the times compared to EIA. However, the ICOMOS Guidance is still the main document for HIA practices globally. Turkey, on the other hand, has not provided any legal basis for the use of an international approach, and it has become a challenge to carry out HIAs actively within the current planning–impact assessment–conservation mechanism. Although there are 17 cultural and 2 cultural and natural world heritage sites, there is not any national guidance for the HIA that affects enhancement of 21,023 national conservation areas [15] effectively.

Hence, this study focuses on the Istanbul Canal EIA experience, the report of which was prepared based only on the Turkish legislation. As the deep-seated problems between the Turkish conservation–planning structure can be attached to the primary difficulties associated with a practical HIA, the challenges of HIA are examined in terms of problems within the hierarchical structure of the planning system, the adoption of international conservation and management principles into practice, and the EIA–HIA procedures and processes. While the EIA practice of the Istanbul Canal Project lists all weaknesses in the Turkish HIA, it reveals the requirements for an effective HIA as well.

2 CANAL ISTANBUL

Canal Istanbul, which is alleged to be a project from the Ottoman Era, was proposed by Prime Minister Erdogan in 2011 [16]. Promoted as a water transport project to preserve Bosphorus, the Canal Istanbul Project includes not only the creation of an artificial waterway, but also the erection of new developments along the canal. The canal was designed to follow the route of existing water resources of the city that include Küçükçekmece Lake, Sazlıdere Dam and Lake Terkos, respectively [17]. It is 45 km long, 20.75 m deep, and 275 m wide at the narrowest portion. In addition to the canal, the Black Sea and the Marmara Sea are each proposed container ports, and one marina serves as a logistics centre. Apart from the canal and associated facilities, following Law 6,306 regarding the Transformation of Areas Under the Disaster Risks, 33,498 hectares surrounding the canal has been designated as a "reserved residential development area" [18]. Although Canal Istanbul (Fig. 1) and the so-called New City (Fig. 2) are outlined together, they are produced and presented separately.

Figure 1: Model of Canal Istanbul and the New City [16].

Figure 2: The plan of the "new city" together with Canal Istanbul [17].

The objective of the canal project considers the preservation of Bosphorus as a natural value, and the Historic Peninsula, as a prominent cultural heritage site in Istanbul by decreasing the number of ships [19]. The location of the project and the proposal of the new city reveal the alternative path that targets the use of protected natural values of Küçükçekmece Lake and Sazlıdere Dam, whose ecological and biological habitats [20] would be lost for the canal. Additionally, the Marmara Sea would become deoxygenated [21], and together with the new urban expansion, loss of agricultural land and deforestation would accelerate.

3 HIA CHALLENGES OF CANAL ISTANBUL

3.1 The hierarchical structure of Turkish planning system

The project, which is a top-down decision, serves cross-purposefully in terms of its objective with the upper-scale Istanbul plan. It also represents Turkish planning instruments, and institutions that define the decision-making system for the approval of government-led projects. The 1/100,000 scale Istanbul Environmental Plan, 2009 is the spatial development framework of the city that puts basic decisions for development and conservation plans. It was prepared according to the EU development perspective and the National Development Plan, which focuses on the balance of economy–ecology for a liveable city [20].

Based on the sustainability of natural values as thresholds and population projections, the carrying capacity of Istanbul for 2023 is determined to range between 16 and 18 million people by the plan, and the main planning principle is described as *The spatial development to be in harmony with the natural and cultural environment, respecting the cultural heritage, taking care of the needs of future generations* [20]. Therefore, the plan aims to control the population, stop the tendency of urban sprawl towards the north and supports multi-centred linear development along the east–west axis on the Marmara Sea.

According to the 2009 Plan, the area between Sazlıdere Dam and Kucukcekmece Lake, where the canal is located, should refrain from new development and it should remain as a controlled zone [20]. However, Canal Istanbul and the New City propose population of 500,000 on the north–south axis where the protected areas of environmental sustainability, including cultural heritage sites emphasized by the 2009 Istanbul Environmental Plan exist. Hence, the project is not only a canal project but also a new settlement venture, where a new canal passes through [22]. As the compliance of transportation decisions with land use plans and the process of demand management has not been managed well until present times [23], the acceptance of the project against the upper scale plan has been accepted without considering any objections.

Furthermore, neither the EIA report nor the plan of the new city, refers to the conservation decisions proposed by the 2009 plan. In addition, 1/5,000 scale plans were prepared based on the new city do not indicate any decisions related to the cultural heritage sites. Contrary to the 2009 plan, lower scale development plans defend changing the linear macro form of the 2009 plan. None land use analysis map of 1/5,000 plans, recognises conservation areas. Instead, there are labelled "empty land" and "other land" in plans. Hence, if the project is implemented, cultural and natural values will risk extinction.

While the spatial decisions of Canal Istanbul are inharmonious with the approved upper-scale purposes, dilemmas introduced by planning laws and institutions specify the decision-making process of the project. There are seven legislations, regarding planning instruments for creating spatial plans, projects, and the implementation of EIA and SEA (and HIA), some of which were changed for the sake of the Canal Istanbul Project. The MEU is the primary

Table 1: Turkish legislation for HIA practices and their role in Canal Istanbul.

Legislation and authority	Aim	Role in HIA of Canal Istanbul
Law on the Protection of Cultural and Natural Assets (1983) – Ministry of Culture and Tourism (MCT)	To determine the definitions related to movable and immovable cultural and natural assets that need to be protected	Consultation: cultural heritage conservation decisions
Environmental Law (1983) – Ministry of Environment and Urbanisation (MEU)	To protect the environment, in line with the principles of a sustainable environment and sustainable development.	None
Land Development Law (1985) – MEU	To ensure all lands and settlements are met the appropriate planning, science, health, and environmental conditions.	Project design: Construction of waterways (Change in Law-by-Law no. 6,704)
EIA By-law (1993/2014) – MEU	To regulate administrative and technical procedures and principles to be followed in the Environmental Impact Assessment (EIA) process	Assessment of effects on cultural heritage "Archaeology Report".
Law of Transformation of Areas Under Disaster Risks (2012) – MEU	To determine the procedures and principles regarding improvement, liquidation and renewal in areas that are at risk of disaster and to create a healthy and safe living environment	Legitimization of proposed developments
By-Law on Spatial Planning (2014) – MEU	To determine the procedures and principles for the construction and implementation of spatial plans and decisions that protect and develop physical, natural, historical, and cultural values, and support sustainable development	None
SEA By-law (2017) – MEU	To integrate environmental elements into the preparation and approval process of plans/programs that are expected to have significant impacts on the environment in line with the sustainable development principle to ensure environmental protection.	None

actor for the impact assessment and approval of the project and the plan (see Table 1). Although By-Law on Spatial Planning (2014) [25] includes conservation of heritage, high-level sustainable development, and procedures of spatial decisions, no role for the relationship of spatial decisions for Canal Istanbul was determined. Instead, there have been changes to the Land Development Law (1985) [26] affecting the construction of the canal, and the Law of Transformation of Areas Under Disaster Risks No. 6,306(2012) [27] remains the basis for the plan of the new city to be developed in conservation areas. In addition, even though “sustainability” is mentioned, both in the Environmental Law, and SEA regulation, neither of them constitutes an essential effect on the decision-making process of Istanbul Canal.

3.2 The adoption of international conservation and management principles

Directly related to the problems within the Turkish planning system, there has been lack of coordination between spatial (conservation) plan and management plan of cultural heritage areas. The Law on the Protection of Cultural and Natural Assets (1983) [28] comprises documentation and identification of heritage buildings and sites, approaches for physical protection of cultural heritage, and preparation of conservation plan. Management plan on the other hand was added into the law after it was introduced by the World Heritage Centre, and the management framework has been applied only for WHS in Turkey. Likewise, the perspective of managing change, assessing impacts of changes, and their specialization cannot be built on solid ground as the current conservation-management mechanisms in Turkey goes without the available capacity to shape HIA. As the conservation, management and HIA approach of Canal Istanbul relies on national guidance, it points to the issues regarding the adoption of international principles.

As “the physical location of a place is part of its cultural significance” [29], the axis chosen for the canal includes the significant number of cultural heritage sites. Küçükçekmece Lake and Sazlıdere Dam have attracted attention since the early ages of settlement history. Yarımburgaz, which is in the northwest of Küçükçekmece Lake, is a Middle Pleistocene Period cave formed approximately 1,000,000 years ago [30]. It is not only the most critical archive reflecting the prehistoric cultures of Istanbul, but also one of the first human settlements in Europe, dating to 600,000 BC [31]. Apart from Yarımburgaz Cave (Fig. 3), there are cultural properties from the Hellenic, Roman, Byzantian, and Ottoman periods of Istanbul, most of which are protected by the cultural heritage conservation law. However, as there is not any conservation-management plan for them, they are considered as any material asset located in the development area, and rather than the HIA report, “archaeology report” has been prepared as an annexe to the Canal Istanbul Project Report.

Figure 3: Yarimburgaz Cave. *(Source: Tay Project, 2000.)*

At the southeast corner of the Küçükçekmece Lake, there is an archaic settlement of Rhegion, which was part of Byzantion [32], and the ancient city of Spradon dated back to the late Roman era is in Küçükçekmece district [33]. Similarly, the Filiboz and Kurudere archaeological sites, Azatli Gunpowder factory, Resneli Farm, and another ancient settlement near Dursunkoy [34] exist on the route to the northern part of the Canal Istanbul Project.

Along with the remains of walls, castles, and blockhouses planned as a perimeter line to defend Istanbul [35], the stratification and richness of heritage are prominent. While the Istanbul Environmental Plan considers cultural and natural heritage as a whole and proposes their absolute conservation; Canal Istanbul treats the areas as an empty land.

According to the Operational Guidelines of the Implementation of the World Heritage Convention, the sites of combined works by man and nature as illustrated by Yarimburgaz Cave are defined as "cultural landscapes" and in ICOMOS' HIA Guidance [1], broadly classified as: archaeology, built heritage or historic urban landscape, historic landscapes, intangible cultural heritage, and associations. However, cultural values located within Canal Istanbul and the new city have been categorized as natural, visual, and cultural landscapes. They are listed in the archaeology report as archaeological areas, historic/other areas, and listed areas. Rather than expressing distinctive characteristics and heritage values of the area, the long excavation history is provided in the archaeological report. Therefore, the absence of international conservation terminology in HIA of the canal comes forward as another issue.

Furthermore, regarding the number of affected heritage assets between the project website, the EIA study, and the archaeology report. For example, while there are 32 blockhouses in the EIA report, 41 are listed in the archaeology report. Since these studies include only the borders of Canal Istanbul, and not the new city, the list of heritage properties and potential heritage assets have been devalued. There are 129 areas and/or buildings, 111 of which are listed in the total area of the project, and the plan [20]. The project declares that the Yarımburgaz and Bathenoa sites are not within the project area, although they overlap with the canal route [35]. Moreover, the possible archaeological resources, such as the area closest to the Ağaçlı Village, which will be affected by fill area [36], are oversimplified, and not considered within conservation or impact assessment studies. Hence, the primary approach of Canal Istanbul to the cultural heritage displays inconsistencies about the meaning, inventory, and potential of heritage values and fails to comply with international approaches.

3.3 The EIA–HIA procedures and processes

As the existing system of Turkish conservation planning and management include complex structures regarding the wide range of legal instruments [37], current EIA and HIA practices are already ineffective. This is contrary to the integrated process of conservation, management, impact assessment, and project development [38], [39]. In addition, the necessity for qualified and experienced HIA teams [1], [40] and their active relationships with project owners and conservation bodies [13], [41], [42] are not met by the HIA or EIA of Canal Istanbul. As a result, the desired standards for managing change and conservation of cultural heritage do not converge on impact assessment.

The ideal impact assessment process has twelve steps, six of which are part of the comprehensive impact assessment: description of the project, affected environment and alternatives; definition, prediction, assessment, and mitigation of impacts; production of impact assessment report; review of the impact report/study; consultation and participation; and final decision [43]–[45]. For the HIA, however, values of the affected cultural heritage site and significance assessment [1], as well as cultural, indigenous, and social assessments are prerequisites for a proper study [46]–[49]. Since the Turkish HIA system has not been established, HIA studies are conducted under EIA, in concordance with characteristics of development or features of an affected environment as being only "the world heritage". Therefore, if development is applied for financial support from international institutions, the impact assessment team will follow the guidelines of the institution, and if the affected environment is listed as a world heritage, documents and suggestions by UNESCO and advisory bodies will be respected.

The process and the approach of HIA for the assessment of Canal Istanbul are unique as HIA, which is an archaeology report, has been prepared based on ICOMOS' Guidance and Turkish High Council for the Conservation of Cultural Property's "Principle decision on the protection of immovable cultural assets affected by the dam areas" [17]. Contrary to the expected, as mentioned, impact analysis does not show proper HIA features. For instance, in comparison with the best practices [50] and cultural heritage standards for investments [49], regarding description and protection of the affected heritage environment, the Canal Istanbul HIA study fails to identify heritage values advised by ICOMOS [1].While the scope of HIA should be guided by cultural heritage [46], procedures are not clearly defined or explained by either the Canal Istanbul EIA Report or the Archaeology Report.

On the grounds of discrepancies in the pre-assessment stages, significance assessment and impact assessment phases have led to undesired results for heritage values. These two technical procedures constitute the core of HIAs. According to Lambrick et al. [51], and Historic England [52], while the significance of cultural heritage is assessed, sensitivity to change should be determined, and the effects of all proposed changes on each heritage value and element should be studied in detail. To understand the features of cultural heritage, it is necessary to represent the setting in which heritage values have evolved historically [53]. However, the archaeology report provides basic information on some assets but not the significance. Hence, the domino effect of previous stages increases exponentially, and application of the overall impact assessment advised by ICOMOS [1] is open to discussion.

In the impact assessment process, all potential effects and development proposals should be considered [50], [54] and direct–indirect, negative–positive, long-term effects within the project phases should be evaluated [51]. In this context, the heritage impacts of not only the canal project but also the docklands and other land developments, originating from New City should have been considered by HIA (Fig. 4). Nevertheless, there is very little information concerning the impacts of the canal. Furthermore, the grading scale for the value of the

Figure 4: Cultural heritage sites within affected environment of Canal Istanbul and the New City.

heritage asset and significance of the effect proposed by ICOMOS contains 5- and 6-point scales whereas they are 3- and 4-point scales in the report. As a result, the matrix provided by the archaeology report, based on ICOMOS Guidance [1], exhibits an unusual approach. In addition, general proposals, such as following the conservation council's advice, and preparation of a management plan were disregarded by the council [55]. Hence, there is no framework within HIA to pursue the project–cultural heritage relationship for Canal Istanbul.

HIA studies conducted for the project also question degrees of reliability and transparency. Consulting with and receiving opinions from the public from the initial steps of a project and impact assessment studies to determine affected properties and communities, is considered a standard approach [1], [40], [49], [50], [53]. Similarly, implementation of successful mitigation measures to reduce or remove identified impacts depends upon consultation with the public authorities, local communities, administrations, NGOs, and cultural heritage professionals [48], [56]. Moreover, for the review of the HIA, the secondary team composed of these actors [53] and agreement with affected people [47] are expected to be considered by heritage impact studies. In the Canal Istanbul experience, however, passive participation was represented in all stages of the impact study, that only public authorities were asked for judgment, which limited influence on project design. Documentation of the participation by local people and additional actors was provided by attaching meeting minutes to the main EIA report. Based on these notes, participation was considered only to be answering questions, which exemplifies avoiding interactive activities and demonstrates a lack of transparency throughout the process.

4 CONCLUSIONS

This study outlined the recent challenges of HIA practices in Turkey derived from the Canal Istanbul Project. Three prominent challenges were discussed in relation to the hierarchical structure of the planning system, the adoption of international conservation and management principles, and the EIA–HIA procedures and processes. Although the HIA background in Turkey can be described as an imitation of the world's conservation and EIA practices, the inter-relationship of three challenges based on problems within planning, conservation, and impact assessment mechanisms lead to an ineffective HIA approach for Turkey. When HIA problems of Canal Istanbul are analysed, it is recognized that the canal and new city proposals contrast sharply with Istanbul's Environmental Plan, which was respectful to heritage sites. Even if the Canal Istanbul Project and the new city plan were created in the same context, they were not presented together, culminating in only one impact assessment study. The shallowness of the heritage protection approach by these two developments continues in the EIA and HIA processes as well. Additionally, misinterpretation of international conservation and HIA principles has benefitted Canal Istanbul which puts development pressure on heritage areas. The failure of the HIA study in terms of description of cultural significance, impact assessment, and lack of participation and management appears to have been performed intentionally. Despite its identification of the tension between conservation and development in Turkey, Canal Istanbul case highlights the need for contemporary changes for the management of heritage sites, supported by an integrated conservation–impact assessment framework.

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INVESTIGATION OF THE SENSE OF COMMUNITY LEVELS: VARIABLES, DIMENSIONS AND SPATIAL ANALYSIS APPROACH

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ABSTRACT
Neighborhood sense of community is considered both a theory and a value in the community and social psychology. It has been examined significantly in a wide range of research. However, there is a need to investigate the effect of several independent variables on the sense of community-level change. Consequently, this study attempts to advance the relationship between the sense of community and some factors such as the built environment, the historical background, and the socio-economic conditions in three selected neighborhoods. Besides, in this paper, spatial analysis and observation have been done to identify each neighborhood's main features and residents' engagement level through quantitative analysis and GIS analysis. To reach that aim, an updated methodology composed of a mixed method Consisted of a quantitative survey and a qualitative observation of the built environment features by adding a spatial analysis. Appling this updated methodology to four neighborhoods in Alexandria city, Egypt. This will be achieved through in-depth statistical analysis for the four neighborhoods, followed by GIS analysis for two neighborhoods to correlate the quantitative approach with the quantitative spatial analysis approach for the sample. The findings support the notion that there is a strong correlation between the sense of community and the built environment. The results show, a significant correlation with some demographic factors like age, monthly income, and the importance of community attachment and identity on measuring sense of community. Finally, this study highlighted that the public participation practices increase the residents' attachment to the community, which emphasizes the concept of a sense of community responsibility towards their neighborhood.
Keywords: sense of community, built environment, GIS, Alexandria, Egypt, statistical analysis, public participation, citizen's empowerment.

1 INTRODUCTION

Explaining the meaning of community, its components, and needs is a significant topic to study. Worth mentioned that researchers aiming to develop a definition of the community should consider both people and place. The place is where people live and are affected, and the people might include the total population of any geographic place or one or more distinguishable smaller groups of people. The complexity of community life could be identified through the community cultural assessment as an essential tool in developing well-designed strategies that meet the needs and interests of the community and its inhabitants and understanding the formal and informal networks people use for communicating. It is crucial to highlight that communities are dynamic and continuously growing as people move in, move out, become more educated, enter new phases of their lives, or face different challenges [1]. Citizens, politicians, and social researchers used the sense of community as a keyword to identify the relationship between people and their built environment's social structure [2].

In a conceptual framework of community psychology, the idea of community and the psychological sense of community are strongly associated with each other. They are also linked to other concepts, such as participation, empowerment, community development, neighboring, social cohesion, community identity, and quality of life [3].

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Recently, the sense of community is decreasing at the neighborhood level in many researchers' studies in the Global South. This decrease is usually linked with the built environment's quality [4]. Lately, the quality of Alexandria's neighborhoods has decreased. Several factors are proofing that such as noise, air pollution, and the poor quality of the public transportation system [5]. In 2010, the UNDP report stated that Alexandria contains 29 informal areas, which representing about 2.9% of the informal settlements of Egypt. Also, about 1.4 million persons, representing about 35% of Alexandria residents, live in these informal areas. In addition, the number of informal buildings has been increasing in the city's neighborhoods [6].

2 SENSE OF COMMUNITY

There is a growing understanding of the advantages and significance of the sense of community in the urban environment in the literature. Definitionally, the sense of community has been described in different ways and through several researchers' contributions. The most accepted model of sense of community comes from psychologists David McMillan and David Chavis, who applied factor analysis to clarify the four main elements of sense of community: membership, influence, integration, and fulfilment of needs, and shared emotional connection. Through these elements, they described the sense of community as "a feeling that members have of belonging, a feeling that members matter to one another and to the group, and a shared faith that members' needs will be met through their commitment to be together". They also created the Sense of Community Index (SCI), which became one of the most applied quantitative measures in analyzing the sense of community in the social sciences field [7].

Furthermore, Kim and Kaplan investigated the physical relationship between the sense of community and urban form and generated adequate measures to test the social and physical dimensions of a sense of community. Their aim was mainly to create a multidisciplinary and distinctive approach to a survey instrument that measures the sense of community. Thus, their framework was divided into four main domains as follows: 1 – Community or place attachment, concerns with residents' connections to their community; 2 – Community identity, refers to personal and public identifications with a specific community with its character; 3 – social interactions, is described as a formal and informal social opportunity in which residents participate to the quality of their relationships; 4 – pedestrianism implies that a community is designed for walking and encouraging street side activities [8]. Furthermore, these domains are divided into some subcomponents, and each subcomponent contains some factors which can be applied and examined the physical attributes and social qualities of the selected community [8], [9].

3 METHODS AND TOOLS

This study aims to investigate the effect of some determinants (the built environment, the history of the place, and socio-economic conditions) on the sense of community level. Furthermore, it aims to monitor the physical features of the built environment in the selected neighborhoods and how they affect the sense of community. Consequently, the researchers adopted a methodology, integrating a quantitative survey to examine the sense of community index in four neighborhoods (statistical analysis). Using a spatial analysis was then investigated in two neighborhoods: having a high sense of community and having a low sense of community. This is to examine the spatial distribution of open spaces, social activities, educational activities, and main health services to try to interpret the reason behind the high sense of community and low sense of community.

3.1 Study context

The four selected neighborhoods present different socio-economic conditions, historical background, and physical built environment; Kom El Dikka, Kafr Abdo, Sidy Bishr Kibly, and Syouf Kibly. Kom El Dikka is considered one of the oldest neighborhoods in Alexandria, its residents lived in a low economic condition, but they had a huge historical and cultural heritage. It is associated with many distinctive cultural and historical events. Kom el Dikka's significance goes to the presence of Sayed Darwish's home, the most famous Egyptian composer who lived and grew up in the area. Kafr Abdo, a residential neighborhood for wealthier Egyptians, including professionals, and foreigners living in Alexandria, is considered one of the most high-class neighborhoods but suffering from removing some of its ancient historical villas and establishing new buildings which threatening the quality of the place. Sidy Bishr Kibly and Syouf Kibly are two attached neighborhoods; they began to appear from 1950 to 1960. In this period, Alexandria attracted many immigrants from nearby rural areas either for work or education, so many neighborhoods appeared in this period for this immigration and natural growth of the city. However, they were not with the same quality old Alexandria. They suffer from the low quality of their informal housing and the rail line and are considered low economy neighborhoods – their location and context shown in Fig. 1.

Figure 1: Map shows the administrative boundaries, the social economic conditions, and the location of the three neighborhoods. *(Source: Authors.)*

3.2 Sense of community index (statistical analysis)

The adopted survey (quantitative method) has been used to measure sense of community as a dependent variable. Besides, the statistical analysis aims at analyzing the relation between the dependent variable (sense of community) and the independent variables (built environment, socio-economic conditions, and historical background).

3.2.1 Measuring the independent variable (sense of community)

The used survey (sense of community measure) was a composed measure designed based on David McMillan and David Chavis SCI (1986) and Kim and Kaplan theoretical dimensions (2004).

3.2.2 Measuring the dependent variables

The built environment is measured through an observation table of the physical attributes of the built environment. It consists of physical factors suggested by Kim and Kaplan theory, as well as built environment variables (transport, safety and danger, privacy and crowding, participation and empowerment). This observation is divided into three sections Aesthetics, streets and services and buildings. It is a Likert scale tool (bad or not exist = 1, fair = 2, good = 3). Besides, the social economic conditions and the history of the neighborhood have been identified using quantitative data and maps and used in the selection of the case studies.

3.2.3 Sample and data collection

A random sample of 218 participants from the three neighborhoods was selected based on the Launch Epi Info 7 software. The online survey used the Kwik Survey application. It was shared through different websites such as Facebook, Twitter, and LinkedIn. It has been shared in Arabic and English and targeted different places and people in the selected neighborhoods. The sample included in the final analysis was a total of 218, Kafr Abdo 51, Kom El Dikka 21, and Sidy Bishr and El Seyouf Kibly 146. The survey consisted of 30 questions and divided into three major sections as follow.

Section 1: General personal information

It includes a question regarding gender, age, children's presence, ownership status, level of education, employment status, income, and length of residence. The objective of this part is to know the influence of demographic factors on the respondent's sense of community to know their different ways of thinking.

Section 2: Evaluation sense of community

It is divided into three parts, including the people's opinion about their social interaction within the community, their community attachment and identity, and their community' physical factors (Pedestrian). The responses' answers are in the form of a Likert scale (the five Likert scale varies from 1 to 5, as 1 = strongly disagree, to 5 = strongly agree. This part's targeted objective is concluding the values of sense of community in different neighborhoods and comparing their results to know the impact of cultural factors, social spatial character, physical factors, and their relationship with neighbors on the sense of community.

Section 3: General comments

It includes general comments and thoughts of the survey's respondents. The objective of this part is to conclude recommendations about sense of community. Also, identify the needs of residents towards their community in order to increase its sense of community.

3.2.4 Survey and built environment observation results

The data were analyzed using SPSS version 18. First, a descriptive analysis of survey results has been done to identify the percentage of sense of community in each neighborhood. A General Linear Model (GLM) – multivariate analysis – has been used to examine the association between sense of community and social-economic conditions, history of the neighborhood, and the built environment (physical attributes). This approach was adopted according to [10]. Subsequently, the researchers identified the positive or negative relations between the physical observation and the survey result. Finally, a descriptive analysis of significant variables – resulting from the multivariate analysis – has been done to give more detailed results.

The validity and reliability of the survey have been checked and the measure was found to have excellent internal consistency with a Cronbach's alpha of 0.843. Then, the correlation and internal cohesion between items of the survey has been calculated for a sample of 40 (about 20% of all the sample).

The survey results illustrated that the sense of community in Kafr Abdo is moderate to low (the highest SOC), but it is low to moderate in Kom El Dikka and Sidy Bishr and El Seyouf Kibly. Concerning sense of community domains, community attachment and identity is the most effective in measuring sense of community, then Social interaction, and finally pedestrian. The domain of community attachment and identity is moderate to low in Kafr Abdo, low to moderate in Sidy Bishr and El Seyouf Kibly, and in the case of Kom El Dikka, the result is somehow strange the percentage of high equal the percentage of low community attachment and identity. The social interaction is low to moderate in the three neighborhoods.

The pedestrian is moderate to low in Kafr Abdo and Kom El Dikka, but it is low to moderate in Sidy Bishr and El Seyouf Kibly. As shown in Fig. 2.

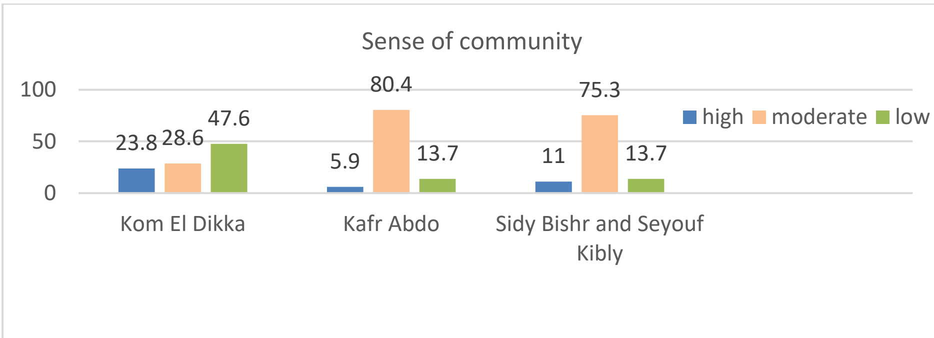


Figure 2: Charts identify the percentage of sense of community in each neighborhood. *(Source: Authors.)*

The built environment is measured through an observation table of the physical attributes of the built environment. This observation is divided into three sections: Aesthetics, streets and services, and buildings. Each factor has been evaluated, then the total of the section and finally the total of the three sections. The quality of the built environment in each neighborhood in descending order is Kafr Abdo 89%, Kom El Dikka 75%, and Sidy Bishr and El Seyouf Kibly 47%. The built environment in Kafr Abdo is high (68%) to moderate (32%). Nowadays, the neighborhood suffers from the removal of historical villas and the construction of new buildings with different styles that are not well connected to the past. Kom El Dikka is moderate (59%) to high (37%). This neighborhood's problems are mainly included in the maintenance of buildings, respect of buildings lines and proportions. Nowadays, the residents in this neighborhood started a development project to make their neighborhood a better place and applied the concept of public participation. Sidy Bishr and El Seyouf Kibly is low (68.5%) to moderate (21%). Their problems are almost common the decrease of aesthetics pleasantness, harmony, walkable streets, continuity in buildings. The presence of cars crowding, a huge number of informal buildings with no respect for human scale, and the maintenance of streets and services. Furthermore, a correlation has been done to examine the significance of physical attributes. The physical attributes that are insignificant are the presence of local and unique characteristics, mixed-use neighborhoods, community services, and affordable housing.

In addition, the researchers studied the relationship between physical attributes and the level of sense of community. The scatter chart, in the case of high sense of community in each neighborhood, illustrates a direct correlation (positive relation) between SOC and quality of physical attributes. In the case of low sense of community in each neighborhood, an inverse correlation has been illustrated. That means positive relationship between SOC and the quality of physical attributes (built environment). It should be noted that the slop of forecasting line (Y2-Y1/X2-X1) is not the same in the two cases; in the case of high SOC the slop is 0.84 but in the second case the slope is 0.42. So, the first relationship is more effective. As shown in Fig. 3.

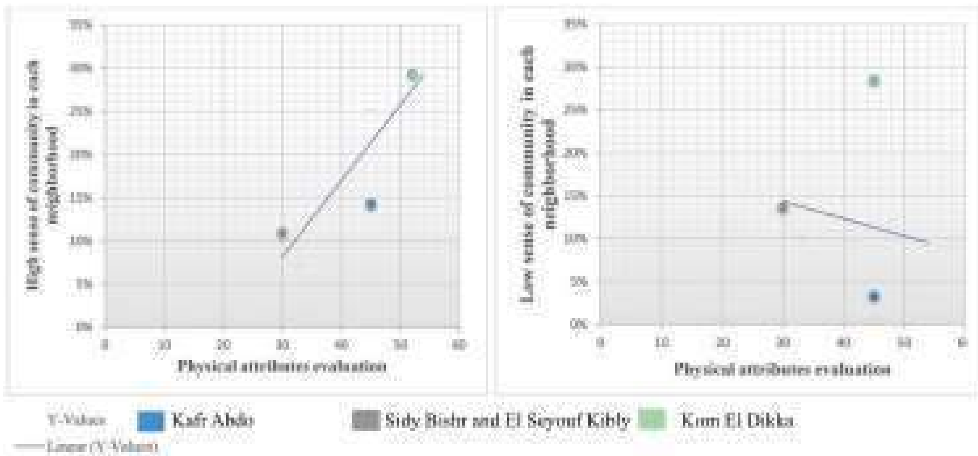


Figure 3: Scatter charts identify the relation between high SOC and physical attributes, Low SOC and physical attributes. *(Source: Authors.)*

Furthermore, multivariate analysis has been done to test the relationship between the sense of community and all the various independent variables. This accomplished through using a series of four models, each model adjusting for additional variables and mutually adjusting for all other variables in the respective model. The final model (model 4) presents a significance only for the monthly income, the age, and the built environment. As shown in Table 1.

3.3 Spatial analysis: tools for community mapping

In the previous part, Demographic variables included gender, age, marital status, socio-economic status were examined, followed by correlating the sense of community to the physical attribute of built environment. Therefore, it will be followed by a Spatial analysis in order to investigate the relationship between Public Open Space (POS), Community and sports club, nursery, schools, shops and sense of community in residents of two selected neighborhoods, Kafr Abdo and Kom el Dikka, one having high sense of community and the other one has low sense of community. In addition, the Two chosen Neighborhoods exhibit different socioeconomic conditions, and physical built environment: Kafr Abdo and Kom El Dikka, but both neighborhoods are old. Kafr Abdo is considered as a high socio-economic residential neighborhood, the area has been developed between 1900 and 1930. Kom El Dikka is the oldest neighborhood at heart of the central business district of Alexandria, the area is established between 1800 and 1900, low socio-economic one but rich in historical and cultural heritage. This spatial analysis is examining the sense of community exhaustive

Table 1: Multivariate analysis linear regression models. *(Source: Authors.)*

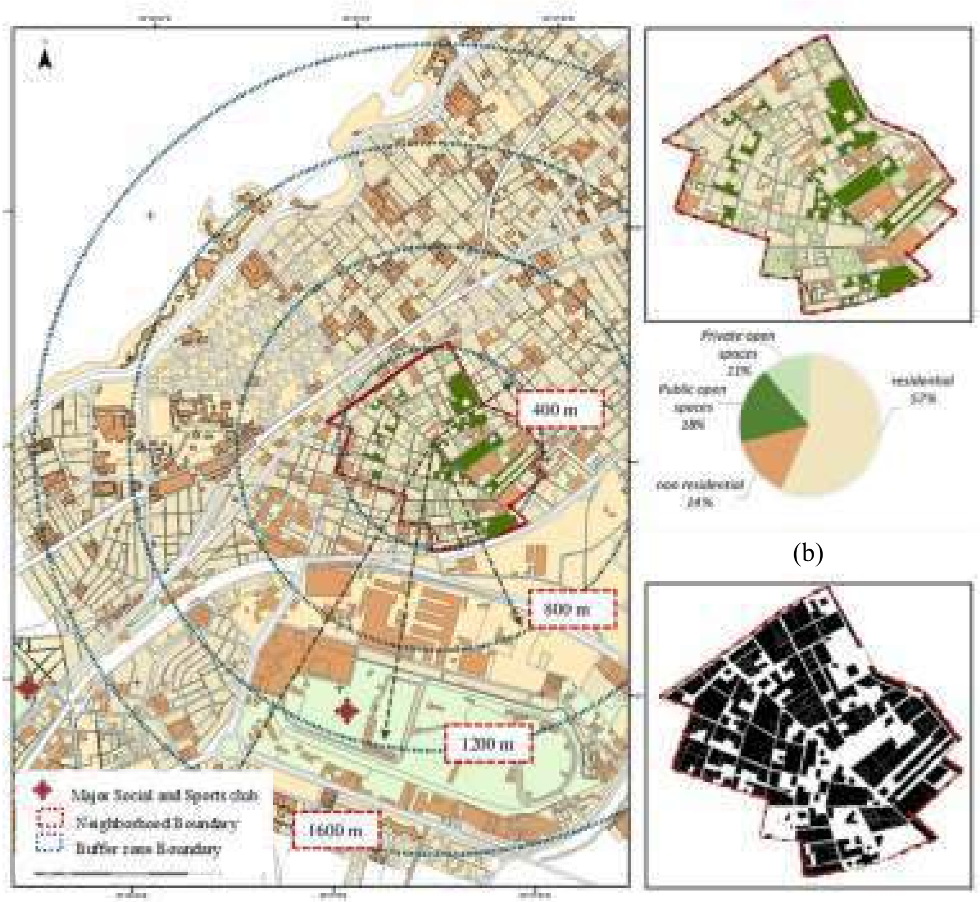
	Model 1		Model 2		Model 3		Model 4	
	β	**p Value**	**β**	**p Value**	**β**	**p Value**	**β**	**p Value**
Age	–0.354	<0.001*	–0.308	0.001*	–0.300	0.001*	–0.297	**0.001***
Have children	–0.128	0.142	–0.113	0.185	–0.119	0.168	–0.116	0.175
Your current residence	0.035	0.617	0.054	0.434	0.044	0.524	0.048	0.486
Level of education	0.087	0.249	0.048	0.519	0.085	0.251	0.074	0.319
Current employment status	0.046	0.556	0.052	0.490	0.040	0.604	0.043	0.573
Monthly income	0.179	0.011*	0.158	0.022*	0.182	0.009*	0.175	**0.011***
How long have you lived in your current residence	–0.473	0.637	–0.050	0.504	–0.042	0.574	–0.045	0.546
Previously moved from another neighborhood	0.595	0.553	0.019	0.799	0.017	0.827	0.014	0.850
Economy	–	–	0.225	0.001*	–	–	–	–
History of neighborhood	–	–	–	–	–0.189	0.009*	–	–
Built environment observation	–	–	–	–	–	–	0.210	**0.003***
R^2	0.127	0.173	0.159	0.126				
F	3.376*	4.314*	3.883*	4.111*				
P	0.001*	<0.001*	<0.001*	<0.001*				

measure focusing on people-place relationship [11]. Identifying and creating the conditions that foster and strengthen sense of community within residential neighbourhoods in terms of the built environment. According to previous researcher a stronger sense of community has been associated with Public spaces, such as parks and piazzas, are another element of the built environment that may foster sense of community by facilitating chance encounters between neighbours [12]. Less surface parking areas, as high vehicular traffic and car parking negatively affected perceptions of helpfulness and area friendliness and safety [13]. Higher levels of commercial floor space to land area ratios, lower levels of land use mix [10], [14]. Finally, living in neighbourhoods perceived as safe and interesting [12]. Therefore, spatial analysis was applied using. Geographic Information Systems (GIS) to obtain POS size, the number of open spaces within participant's neighbourhood, whether it is public parks, or private garden or major sports and social complex, analysing the percentage of non-residential which will include educational services, religious, utility buildings, administrative and commercial building to the percentage of residential units, and the network distances from center of neighborhood and the previously mentioned. 'Neighbourhood' was defined as a 5, 10, 15, 20 min walk from the center of neighborhood. Accordingly, a road network buffer 400 m, 800 m, 1200 m and 1600 m was used to capture the neighbourhood within a 10 to 20 min walk [15].

3.3.1 Data collection

All the Geospatial data used is collected by the central agency for Public Mobilization and statistics (CAPMAS) and General Organization for physical planning (GOPP).

As shown in Fig. 4(a)–(c), In Kafr Abdo neighborhood, it is obvious from the spatial analysis that the neighborhood is easy to access within walking distance, and the neighborhood has a variety of open spaces, public open spaces, and private gardens, especially with ¼ mile walking distance. Within a radius of ¼ mile, there are educational facilities (nurseries, schools), Religious Facilities (mosque and churches), Administrative facilities (bank, companies), commercial facilities (shops), and utilities (police stations). In addition to the residential use, this means that the residents' basic needs are fulfilled within walking distance; also, according to the questionnaire, the results of the domain of pedestrian in Kafr Abdo were moderate (66.7%) to high (29.4%). Also, Kafr Abdo has an 89% in the researchers' observation of the neighborhood's physical attributes. The evaluation of the streets and services section includes the assessment of some significant points such as mixed mixed-uses, community services, local public parking and transportation, Walkable streets

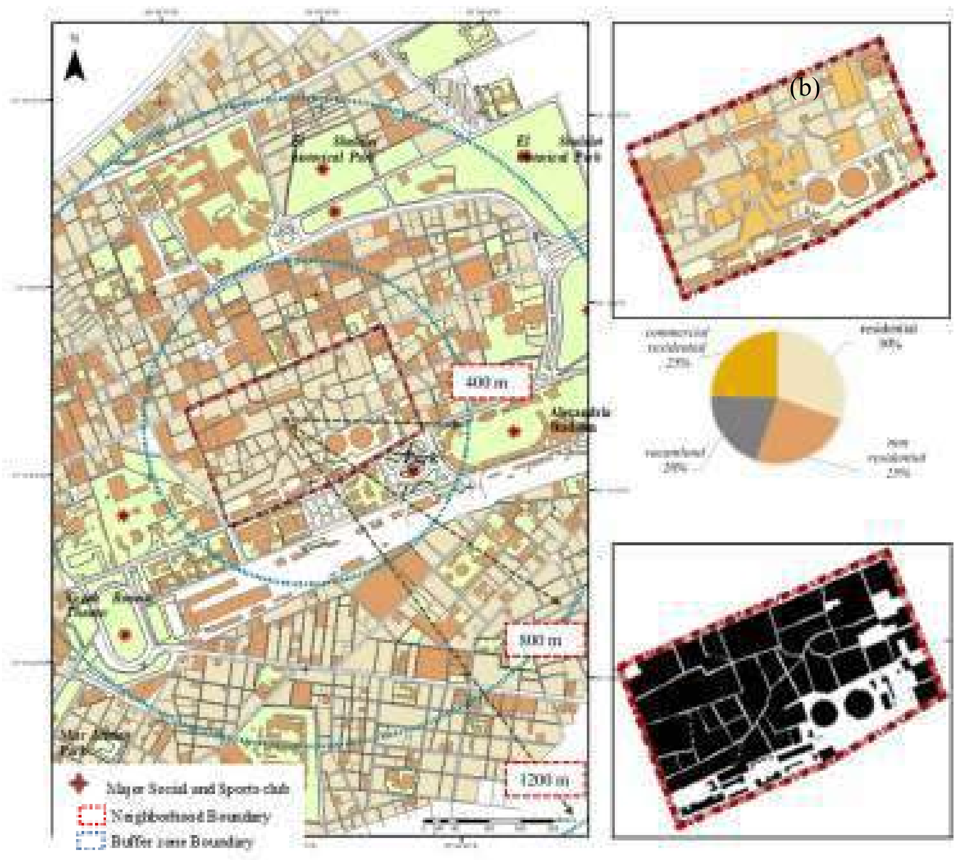


(a) (c)

Figure 4: (a) Representing spatial analysis for Kafr Abdo neighborhood and surrounding context, with in the following radius 400, 800 and 1600 m; (b) Representing percentages of land use; and (c) Representing built up area to open spaces within boundary of Kafr Abdo neighborhood.

with good sign system which encourage pedestrian activities such as street vendors, and the presence of squares, parks, services, shops, recreation facilities and play areas in their right place. That also exists within ½ mile radius, and with ¾ mile, the residents can reach major sports and social complexes in Alexandria. The spatial analysis shows that the open spaces represent 29% of the total area of neighborhood, which is considered adequate, and it was mentioned clearly in Section 3 of the survey (participants' comments). They stated that their neighborhood is characterized by open spaces and greenery, which give uniqueness, and that is why they are not satisfied by any change or transformation in their neighborhood. So, now, the percentage of built-up to open spaces is almost 70% to 30%, which is considered a moderate percentage.

While as shown in Fig. 5(a)–(c), in Kom El Dikka neighborhood, it is obvious from the spatial analysis that the neighborhood is easy to access within walking distance, with in the radius of ¼ mile there are educational facilities (nurseries, schools) Religious Facilities



(a) (c)

Figure 5: (a) Representing spatial analysis for Kom El Dikka neighborhood and surrounding context, with in the following radius 400, 800 and 1200 m; (b) Representing percentages of land uses; and (c) Representing BUILT up area to open spaces within boundary of Kom El Dikka neighborhood.

(mosque), commercial facilities (shops), utilities (police station, water company)in addition to the residential use, and a high percentage of mixed commercial residential use this means that the basic needs of the residents are fulfilled with in a walking distance, according to the questionnaire, the results of the domain of pedestrian in Kom El Dikka were moderate (57.1%) to low (28.6%). Also, Kom El Dikka has an 75% in the researchers' observation of the neighborhood's physical attributes.. but within ¼ mile there is lack of open spaces, only one newly developed park adjacent to the southern edge of Kom el Dikka and there is Also Alexandria Main Sports stadium. Within ½ mile radius there is another two main parks; El Shalaet Park and Misr station parks and a Greek Roman theatre (it is Archaeological site). Analysing the ¾ mile the residents can reach mixed uses and residential uses. The spatial analysis shows that the neighborhood suffers from lack of open spaces within its boundaries, which is considered insufficient to the residents because of the neglection of the value of this historical place. However, the residents tried to participate in the protection of their neighborhood and did an attempt to increase the percentage of green areas, so that percentage of built up to open spaces is 80% to 20% with is and theses 20% are left vacant and some of them are privately owned, so the residents suffers from high percentage of built up area. These means that the percentage of open spaces and their quality and also shops were significantly and positively associated with sense of community.

4 RECOMMENDATIONS

Based on the research observation, the survey results, the resident's comments, and the statistical analysis, the authors identified the current situation. Then, they proposed some recommendations about enhancing and protecting the physical attributes to increase the sense of community in each neighborhood, as shown in Table 2.

Table 2: The researchers' recommendations. *(Source: Authors.)*

Neighborhood	**Recommendations**
Kafr Abdo	1. The establishment of civil associations to protect the neighborhood's local character and action should be taken from residents to protect their community and make decisions about their neighborhood. 2. The presence of strict laws prevents the destruction of historical buildings. 3. The presence of a good public transportation network to reinforce their common significance and foster a shared sense of place.
Kom El Dikka	1. The decisions makers should encourage empowerment and public participation in decision-making. 2. The financial support for Kom El Dikka Development Association. 3. The studies on this neighborhood should be applicable, and the government should stop the exploitation of Kom El Dikka from some fake associations. 4. The maintenance of this historical place.
Sidy Bishr and El Seyouf Kibly	1. Buildings in the same place should respect the concept of harmony and human scale. 2. Settings should be designed to enable and facilitate the activities that people plan to execute within them. This highlights the need for participative planning to identify potential users'' needs, preferences, and intentions. 3. The maintenance of streets and services and the presence of a good streetscape.

5 CONCLUSION

This research attempts to study the impact of the built environment on the sense of community and some variables related to the community's social experiences. Also, it aims at investigating the local residents' activities and their perception of the built environment, and their sense of community using community mapping. The sense of community was influenced by monthly income, age, and the majority of the built environment's physical attributes. The significance of the sense of community domains in descending order is community attachment and identity, social interaction, and pedestrian. Furthermore, this study attempts to analyze the spatial pattern of neighborhoods and how it affects the sense of community; from the analysis, it was obvious that the public spaces within the neighborhood had the most significant value. It is more effective than the public spaces in the surroundings. This is detected in Kafr Abdo, with a higher sense of community than Kom El Dikka. Also, the quality of public spaces and services provided in the neighborhood to the residents. In Kafr Abdo, the variety of shops and services they provide is totally different from that existing in Kom El Dikka. Moreover, the non-residential uses that vary is significant to the sense of community of locals. The most significant is the educational facilities, as in Kafr Abdo for instances, the percentage of educational facilities that range from a variety of nurseries and schools provide sufficient fulfillment for the residents, this is not fulfilled in Kom el Dikka neighborhood, in Kafr Abdo represent 32% of total non-residential uses, while in Kom El Dikka 11%. Followed by the shops that allow the gathering, in kafr Abdo are much higher than in Kom El Dikka 40% to 10%. Finally, the police station that provides a sense of safety and security to neighborhood and Kafr Abdo is higher than in Kom El Dikka. Both neighborhood can provide their daily needs within walking distance as proved by the spatial analysis, but the quality of streets is better in Kafr Abdo than in Kom El Dikka, and all the aspects related to walkability as an aesthetic factor, the pavement width, street width is much better in Kafr Abdo than in Kom el Dikka. Therefore, it is highly important to provide a good quality of public spaces, various mixed uses, and commercial shops at the ground level, increasing social aspects and gathering points, safety, and security. Using the spatial analysis with the survey is very important as each one highlights important facts that need to be linked together for better improvement for the sense of community.

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IMPACT OF LIGHTING ON CHILDREN'S LEARNING ENVIRONMENT: A LITERATURE REVIEW

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ABSTRACT

Research studies show that the physical learning environment influences the performance and wellbeing of children, supporting their development into adulthood. Lighting is a critical aspect of this physical environment. We highlight the relationship between human functionality and lighting, showing what key roles lighting plays in an optimum key environment, providing specific references to the importance of lighting for visual capabilities, body temperature, and healthy living through vitamin D production. We elucidate how lighting is a major driver for children's performance and functioning, by enabling their visual, cognitive and behavioral skills through concentration, alertness, and maintenance of children's moods. Research has also identified methodologies used to establish this relationship, which include qualitative, quantitative, mixed-method, and quasi mixed-method; and parameters such as using the progression of test scores in standardized tests, concentration over time, user behavior, and mood as the test parameters. Study results of academic performance through reading performance (accuracy, speed, and expression) under conditions similar to everyday life show that exposure to higher correlated color temperature (CCT) light leads to greater improvement in children's task-switching performance, though no impact was seen on their sustained attention. This was also established by Mott et al. as the Oral Reading Frequency (ORF) scores of students, with the lighting of 6500K and 1000lx showed increased student ORF scores compared to students receiving 3000K and 500lx. Results exploring user behavior and mood test parameters indicate that blue-enriched light increases student concentration and cognitive performance (processing, speed, concentration, and memory). Here we highlight research/ studies about the importance of lighting for comfort, through varying lighting scenarios; and how student behavior, learning capabilities, and cognitive skills can be improved through lighting choices.

Keywords: lighting, children, learning, environment, wellbeing, performance testing.

1 INTRODUCTION

Childhood provides the opportunity for children to develop lifelong skills that will support them throughout their adult lives, later on. There has been educational research focused on providing insights into the various aspects of the student learning environment, such as: learning tasks, materials, time on task, teacher's instructional behaviors, and student–teacher relationships. There remains a need for focused, systematic research into the influence of the physical aspects of students' learning environment, by measuring various factors such as air quality, noise levels/music, plants, and lighting, reported to influence childrens' performance and wellbeing [1]. Lighting was reported to be an important factor that affects student learning and growth in the classroom environment [2], [3], so this review will present the collective findings on the impact of daylight on the learning environment, plus how to enhance lighting to influence the behavior and cognitive learning capabilities of children.

2 HUMAN FUNCTIONALITY AND LIGHTING

The functioning of humans is enabled and directed by light; light enables visual capabilities, systemizes body temperature, reduces the chances of myopia and enables healthy living through the production of Vitamin D [1]. Human functionality is therefore heavily hinged on daylight. The Environmental Protection Agency (EPA) estimates that an average American spends 87% of time indoors, 7–8% outdoors and 5–6% in an automobile (Fig. 1) [4]. This

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data strongly suggests that the indoor and outdoor environment plays a major role in human development and functionality, and creates a healthy environment that will be key to achieving children's development and potential.

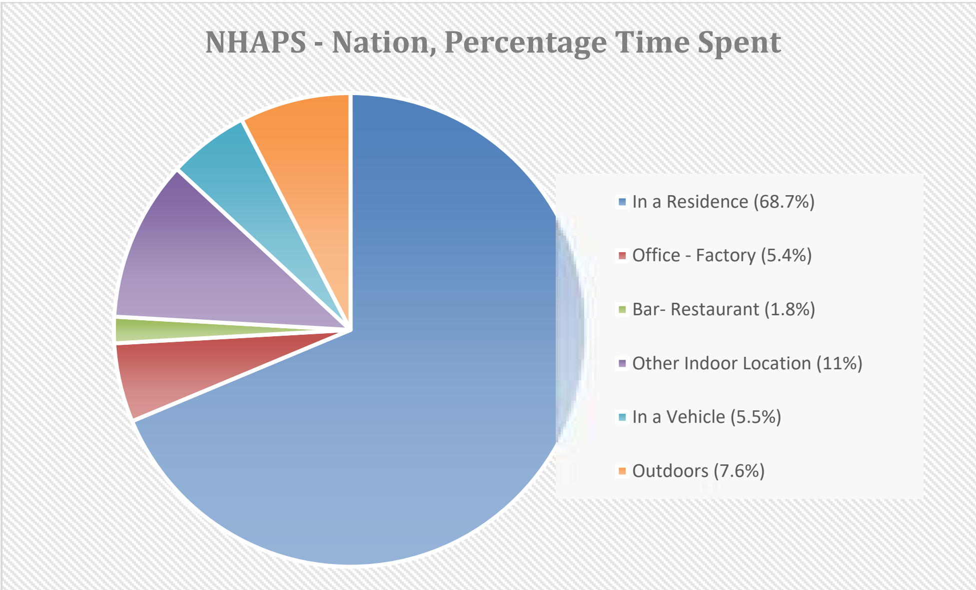

Figure 1: National US percentages for time spent in various places [4].

2.1 Lighting and the learning environment

In seeking to establish that human function is heavily hinged on lighting, We believe that one of the major questions for this review is to understand the key roles that light plays in an optimum learning environment. Hansen et al. [3] define the learning environment as the combination of the physical environment (the classrooms); the learning activities which take place in this environment during school hours, and the behavior of the students which would affect or might affect these activities. According to research by Boyce et al. [5], lighting (natural and artificial) has been a major driver of childrens' school performance and functioning, with windows providing natural daylight as well as a view, and artificial light further enabling children's visual, cognitive and behavioral skills inside [1]. Research by Govén et al. [6] has proven the effectiveness of blue lighting to help maintain moods during the day, leading to better concentration and alertness in adolescents who appear sleepy, due to going to sleep late. Additionally, lighting was proven effective in the development of cognitive, behavioral, and visual skills; especially from tracking materials and book visually.

3 METHODOLOGIES AND PARAMETERS FOR STUDYING LIGHTING IN LEARNING ENVIRONMENTS

Several methodologies and parameters have been used to determine the effectiveness of lighting in the learning environment. Methodologies vary from Qualitative; to Quantitative; to Mixed Methods (the use of both quantitative and qualitative, merged and connected); and

Quasi Mixed (use of qualitative and quantitative research without merging them). Meanwhile, the parameters used included (Fig. 2):

(a) Using academic performance as a test parameter (this involves testing the progression of test scores and concentration over time, using standardized tests).
(b) Using behavior and mood as test parameters to study the impact of lighting on behavior, mood, and the use of lighting in the classroom to measure attentiveness, task and off-task behaviors [3].

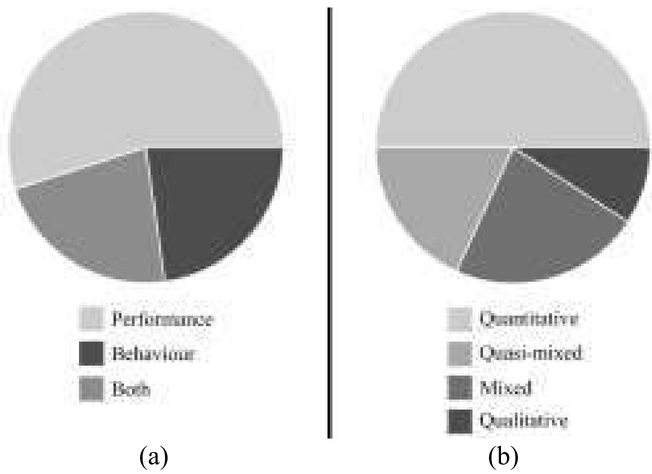

Figure 2: Methods and parameters included in selected studies. (a) Academic performance versus behavior and mood parameters induced by light conditions were tested; and (b) Approaches used in methods included Quantitative, Quasi-Mixed, Mixed and Qualitative.

In the Hansen et al. review of 21 articles in the literature between 1974 and 2016, they found 75% of them included academic parameters, with half focusing solely on performance; while about 33–34% focused on the effects of light on student behavior, mood, and use of light. In fact, 50% of the studies, therefore, used exclusively Quantitative methods, while less than 10% applied Qualitative; and 22% used Mixed and 18%, Quasi Mixed.

3.1 Impact of lighting on the learning environment: Using academic performance as a test parameter

One of the most common ways used to test the impact of lighting on the learning environment is the Academic Parameter, through the use of standardized tests of reading performance for accuracy, speed, and expression. Analysis by Mott et al. showed there is more improvement in reading under a "focus" setting (6000K, 1000lx) in comparison to the "normal" (3500K, 500lx), during their study [3]. However, further review showed a contradiction between the impacts of lighting under controlled and field experiments, indicating that lighting infield experiments, which test in conditions much closer to everyday life, could be more precise in predicting the effect of lighting on the learning potentials of students in real-life situations [3]. Hartstein et al., however, examined the light exposure influences on cognitive task performance in 38 preschool children aged 4.5–5.5 by dividing them into two groups, the control (n = 18) and experimental group (n = 20), and exposing them to two different tasks aimed at measuring their sustained attention and task switching abilities, under varying light-emitting diode (LED) lighting condition of 3500K or 5000K [2]. The control group engaged the two-study task twice under the 3500K lighting conditions, while the experimental group had the two-study task under the 3500K lighting conditions as a baseline assessment, and after that, the 5000K lighting conditions. They found that exposure to higher correlated color temperature (CCT) light led to greater improvement in preschool-age children's task-switching performance, while no impact was seen in their sustained attention.

Likewise, Mott et al. [1] added further to their research in 2011 that found the usage of focus lighting (glare free, high-intensity light) to increase the ORF scores (a key index of reading comprehension) of grade 3 students. They explored the usage of focus lighting on literacy instruction on high-risk grade 3 students, using a sample size of 172 students, by establishing three lighting settings: A focus setting of 6500K and 1000lx for concentration, a normal setting of 3000K and 500lx for regular classroom activities, and a calm setting of 2900K and 300lx for independent and collaborative learning. With the three tests conducted, they found that all students performed better on the ORF-test over time, indicating the learning effects expected of Grade 3 children; however, the differences in time within each different lighting condition suggested that the usage of a focus setting during literacy instruction has a positive influence on a gain in oral reading (Fig. 3).

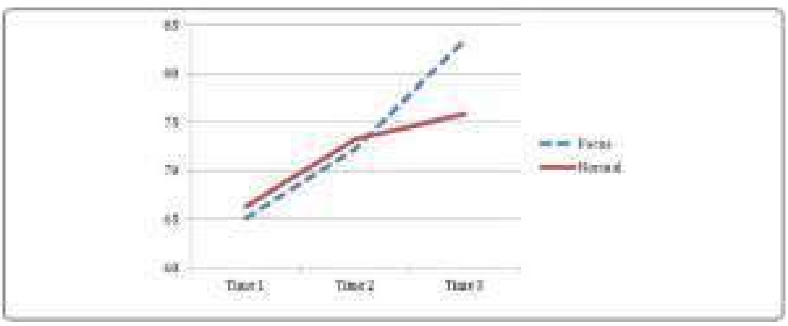

Figure 3: Means for student oral reading fluency (ORF) scores under different lighting conditions, through time [1].

Notably, over the course of a year, the focus lighting students increased their ORF scores at a greater rate, compared to the normal lighting students, as they demonstrated better words read correctly per minute (WCPM), showing that artificial lighting actually helps create an effective learning environment that is crucial to ensuring that at-risk children reach their full potential.

3.2 Impact of lighting on the learning environment: Using behavior and mood as a test parameter

Some research by Hansen et al. [3] was identified as having produced contradictory results, while others provided similar findings as related to the impact of "Normal" Color Temperature (3000k, 4000K) and blue-enriched light to increase concentration and cognitive performance (processing, speed, concentration and memory) of students; however, Morrow and Kanakri [7] provided sound findings on the impact on learning as highly correlated to color LEDs and fluorescent lighting on students in the classroom, while recognizing LED as a more recent and preferable option for optimal energy efficiency than fluorescent (Fig. 4, additional background Fig. 5).

Figure 4: Year(s) of teacher experience in classroom using different light fixture lenses [7].

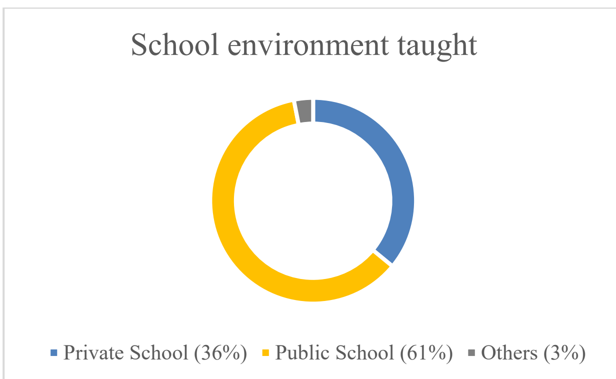

Figure 5: Percentage of teachers and type of school monitored in the Morrow and Kanakri study [7].

The findings from the data in Figures 6 and 7, obtained from 75 teachers in three Pre-K through 12 schools and other independent personal contacts, illustrated that bluer/higher kelvin (K) temperatures emote alertness, focus, and arousal, while lower kelvin can be used for calmness; therefore, teachers preferred a 6500K classroom for focusing the students' attention and on-task behaviors by 54.79%, compared to 38.36% preferring a 5000K lit classroom. Likewise, 81.08% of teachers indicated that adjusting lighting levels in the classroom does impact mood, attention, and engagement regarding specific activities and times of the day.

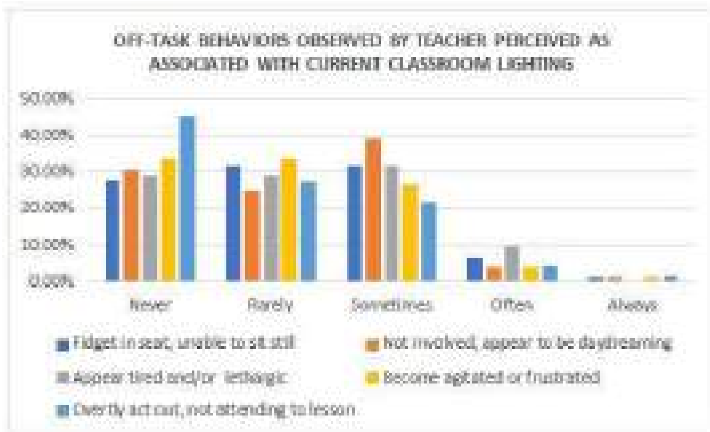

Figure 6: Teacher perception of off-task behaviors [7].

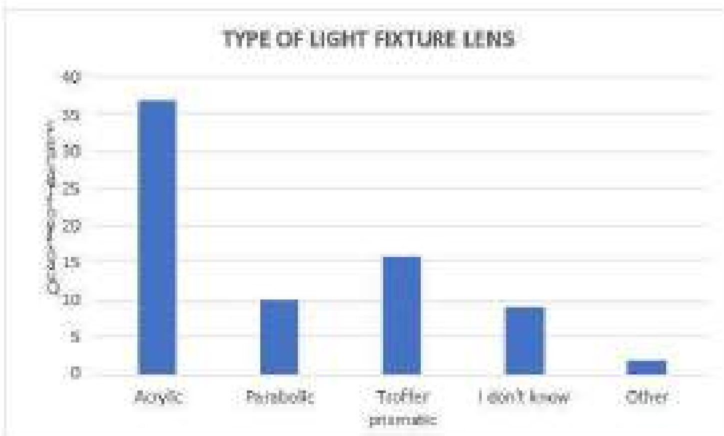

Figure 7: Percentage of teacher adjustment [7].

Taking the Morrow and Kanakri research [7] beyond the quantitative opinion of teachers Schledermann et al. [8], the former conducted a mixed field study to understand the impact of lighting on teaching and learning activities, by providing classrooms with lighting technology with four different lighting scenarios, while studying their use through a lighting control system; and combining this with observations, interviews and recording data over a three-and-a-half-month period. They focused on three classrooms for the field study: each consisted of 22 to 24 students between the ages of 11 to 12 years, with a window on one side of the room.

Four lighting scenarios included (Fig. 8): Standard, Smart Board, Fresh, and Relax. For Standard: Ceiling luminaries were at 300lx, 3500k, Board Luminaries at 500lx, 3000k, and Wall Washer was off; for Smart Board, ceiling luminaries were at 300lx, 3500k, Board Luminaries at 300lx, 3000k and Wall Washer at 300lx, 4000k; for the Fresh scenario, ceiling

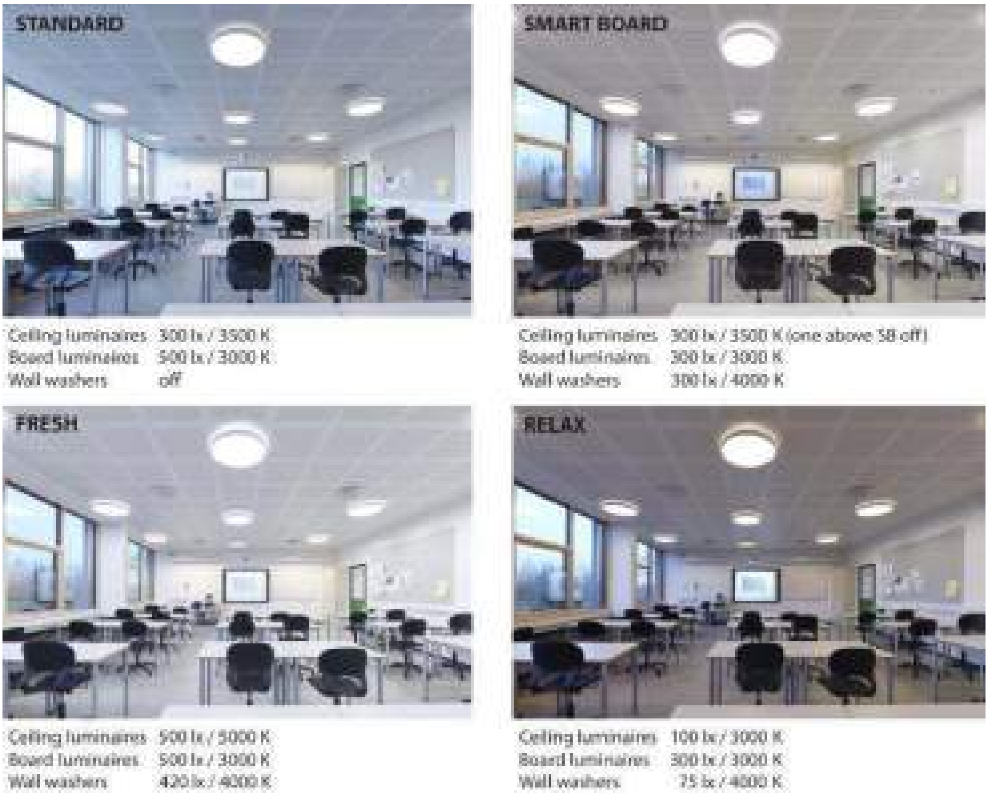

Figure 8: The illumination level and correlated color temperatures of different luminary groups used in the four lighting scenarios [8].

luminaries were at 500lx, 5000K, board luminaries at 500lx, 3000K, and the wall washer at 420lx, 4000K; while for the Relax scenario, ceiling luminaries were at 100lx, 3000K, board luminaries at 300lx, 3000K and the wall washer at 75lx, 4000K.

The researchers were able to ascertain (based on the weekly averages of daily use of lighting scenarios in classrooms (Fig. 9) and the lighting scenario used by teachers during selected activities (Fig. 10)) that: (i) Changes in the lighting scenario often happened with a change in activity, during the lesson. Teachers therefore identified the use of lighting as support for different activities, with the use of an adequate lighting scenario used to structure the childrens' learning activities; (ii) Lighting could be used as a tool for communication with students, and as students became accustomed to a different light scenario, they made reminder requests for a change in lighting scenario, if the teacher forgot; (iii) Teachers used different lighting scenarios to reduce or increase the activity level of the study or change their students' behavior. Fresh was used to encourage focus; relax was used to reduce the energy level of students (Fig. 10), but also made a hypothesis that the maturity of a student in a year could have been an added reason; (iv) The varying lighting scenarios provided a varying atmosphere. An example is the use of warm-toned light, which proved effective in creating a cozy environment, making a more comfortable environment for those lagging behind. Warmer tones with decreased illuminance levels due to reduced natural light from outdoors

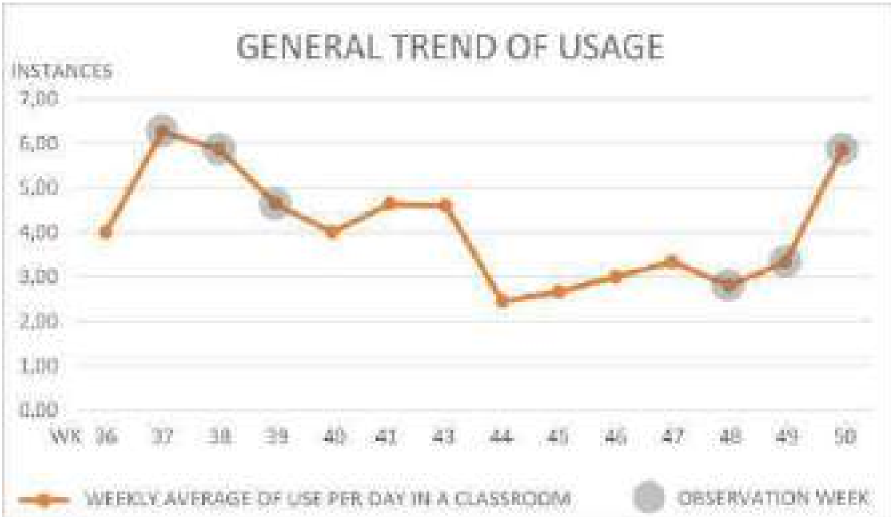

Figure 9: Weekly averages of daily use of lighting scenarios in a classroom [8].

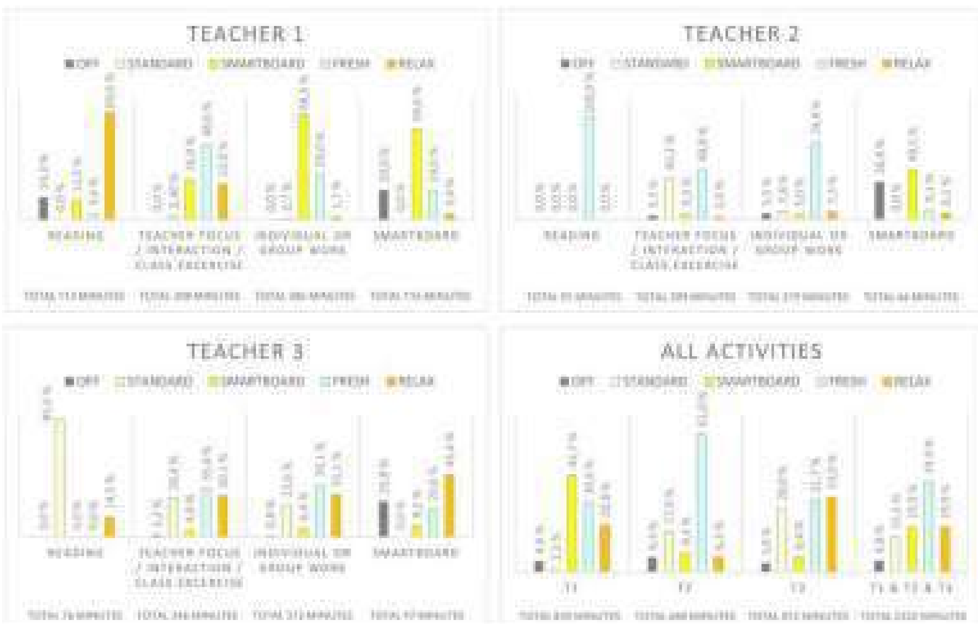

Figure 10: Relative amounts of lighting scenarios used by teachers during selected activities and all activities [8].

was used during winter; (v) The varying lighting scenarios also helped ensure suitable lighting conditions to support visual tasks and maintain visual comfort. Reduction of glare from natural sunlight by drawing the curtains, or to increase visibility of the smartboard.

3.3 Impact of lighting on the learning environment: Using academic performance, behavior and mood as a test parameter.

The impact of lighting through both academic and the “behaviors and mood” parameters, was done by Choi and Suk [9], by investigating the effects of lighting color temperature on student performance. Three studies were carried out: A preliminary study to measure the physiological response to be able to lay a potential expectation of performance, a laboratory study, and lastly, a field study. The preliminary study measured the level of arousal of 17 healthy adults, versus adults used to provide accurate data measurement, as electrocardiogram (ECG) signals are impacted by motion artifacts. The laboratory study involved 31 visual healthy fourth-grade students whom were recruited to engage in both academic and recess activity, under three lighting conditions (3500K for easy activity, 5000K for standard activity and 6500K for intensive activity with an illuminance level of approximately 500 to 600 lux); but results showed no significant difference during academic activity. Therefore, no meaningful interpretations were derived relating to lighting CCTs and human behavior.

Finally, the field experiment was conducted in two fourth-grade classrooms of 27 students each, as a control and experimental group. The average age of the class was 10 years and each classroom had natural lighting coming from one side of the room. The two groups conducted arithmetic problems during different lighting exposures, as the experimental group had their fluorescent lighting replaced in the second week of the study by solid-state lighting (LED) with three lighting conditions (Easy, Standard and Intensive), as described in the laboratory study; but the control group utilized the existing fluorescent lamps throughout the experiment.

Results showed that there is a significant effect of lighting CCTs on both the academic and recess activities. Here, 6500K was subjectively perceived as the most appropriate lighting for learning, while 3500K received the highest average score for recess activity. Also, the results of the arithmetic activity indicated that a larger percentage of correct answers occurred with 6500K; and therefore, provided meaningful results to support that lighting CCT does have effects on both cognitive and behavioral performances. The Standard lighting present was advised for activities such as reading, while the Intensive lighting was pressed for problem-solving academic activities. This provided an inference that the laboratory experiment had inconsistent results due to the artificial setting, a short-time exposure to lighting, and a varying of illuminance from 445 to 572lx.

4 CONCLUSIONS

The various research studies reviewed provided insight into the impacts of lighting as assessed through various methodologies; namely, the qualitative, quantitative, mixed, and quasi-mixed methods; where each provided contributions to the impact of daylight and lighting on learning environments. Major findings and understanding were established through the mixed and quasi-mixed methods, as they enabled more variables to be removed, linked and established, by reviewing the impacts of light on learning through major parameters like the moods, behavior, and academic performance of students, including high risk students, at various learning cadres. Therefore, our review further establishes the importance of lighting in learning, to ensure: (a) Comfort (mental and visual comfort) through varying lighting scenarios; (b) Provision of a suitable atmosphere that can help teachers and students switch to varying or desired tasks, either for reading, arithmetic, or recess; (c) Manage communication, as the lighting could be used to arouse concentration and discussion, encourage movement and group activity; (d) Enable the desired improvement in academic performance, especially for those children lagging behind and at-risk students; (e) Improve student behavior, learning capabilities, and cognitive performance, encouraging student growth.

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SECTION 7
ARCHITECTURAL ISSUES

FUTURE OF DWELLING: THE ADVANTAGES OF PREFABRICATION IN ALLEVIATING THE RESIDENTIAL CRISIS

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ABSTRACT
The United States is facing an affordable housing crisis which is affecting people across the whole income spectrum. In 2018, the National Income Housing Coalition found that there is no state where a renter, working full-time at minimum wage can afford a two-bedroom apartment. Nationally, there is a shortage of more than four million affordable homes which in turn increases the price of all existing dwellings. This results in nearly 60% of renters nationwide unable to buy a home, with 70% of low-income families severely cost-burdened, paying more than half their income on rent. Even as the economy continues to grow and the housing market rebounds from the 2008 recession, the population faces widening inequality. For many, an inability to comfortably pay for housing, stagnation of wages and increasing housing cost is making housing insecurity one of the hidden truths of the present real estate market. COVID-19 has made the situation more complicated by raising the cost of labor and materials, due to a scarcity of both, which makes affordable housing expensive to build and the attempt to follow a sustainable construction system of circular economy very complicated. Since accessible housing is the key to reducing intergenerational poverty and increasing economic mobility, a solution needs to be found. This article will present an overview of the prefabrication industry resulting in a design to be used as a case study to test the feasibility of this construction manufacturing process, to test why the future of dwelling resides in prefabrication.
Keywords: affordable housing, prefabrication, interdependence, COVID-19, housing insecurity, inequality, economic mobility.

1 INTRODUCTION

Long waiting lists, high rents, thousands homeless, millions living in insecure or unsuitable dwellings and a generation of young people priced out of the housing market are the main characteristics of the US's broken housing system. As supply fails to keep up with demand, home prices nationwide are rising at twice the rate of incomes and three times the rate of inflation [1]. The affordable housing crisis continues to be a major problem in the United States, and it is getting worst every year. For a sector that generates more than $640 billion in GDP, employing around 7 million people, and building $1.3 trillion worth of construction every year, the cost of doing nothing to fix the problem is not an option. Several interdependent elements are needed to deal with this crisis. The first is removing regulatory barriers at the local, state, and federal level to allow more homes and apartments to be built. This needs innovation on the construction industry side to build faster, increase productivity, and lower costs. Followed by creative finance allowing more people to qualify for a mortgage to buy a home, and to provide more affordable housing for renters. And finally, getting more access to land to provide greater housing opportunities. This article will discuss issues directly related to the construction process and the advantages of using prefabricated construction systems to help alleviate the residential crisis. Prefabrication or industrialized building systems (IBS) is a mass production industrialized construction process that uses emerging technologies and a manufacturing factory model to produce modular architecture in a controlled environment (off-site) through an efficient logistical construction schedule, planning and management.

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2 THE PROBLEM

The US economy has recovered and expanded since the great recession of 2008, except in the housing market. For the last 12 years, housing shortage and costs have been the most significant factor in preventing the younger generations from attaining their own households (Fig. 1). But why do we have a housing shortage? A few of the most cited reasons feeding this problem are, the lack of available skilled construction labor, land use regulations, zoning restrictions, lack of land developers and a lack of land to develop. After nearly a decade of low levels of residential construction, the US housing market is 3.8 million single-family homes short of what is needed to meet the country's present demand [2]. And according to Freddie Mac, these units are needed not only to meet the demand from the growing number of households but also to maintain a target vacancy rate of 13%. The combination of a low supply of entry-level units and high demand for the same, is causing entry-level prices to rise, triggering affordability issues for buyers. If supply continues to fall short of demand, home prices and rents in the United States are likely to outpace family income.

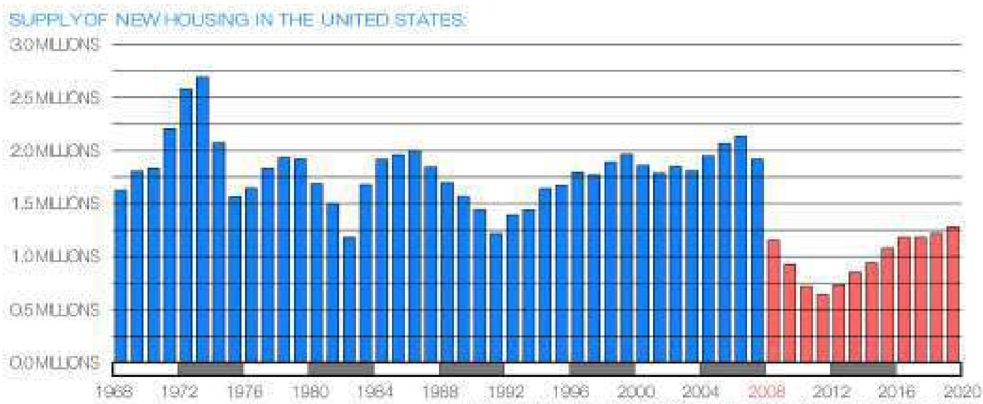

Figure 1: Supply of new housing in the United States after 2008 [3].

3 PREFAB MODULARITY: A BRIEF HISTORY

Known as *Mill-cut Houses, Pre-cut Houses, Mail Order Homes, Catalogue Homes or Kit Houses*, the predecessor to the modular homes became a part of North American life in the first half of the 20th century. Sold through catalogue, a home buyer would send a check to one of the multiple companies selling mail order homes, and a house kit including blueprints and construction materials would be shipped back via railroad or boat to a depot close to the customer's hometown. From there, the new owner was responsible for transporting the kit to the construction site. The first kit homes were sold through catalogue by the Aladdin Company from Bay City, Michigan in 1906 followed by Sears & Roebuck and Co. in 1908. The company had a long life, manufacturing modular houses that started in 1906 and ended in 1981. In this period of time, they sold more than 75,000 homes domestically and internationally to both families and corporations. Advertised as *Readicut* and *Built in a day*, Aladdin and other kit home manufacturers like Montgomery Ward, Lewis and Sears & Roebuck and Co. revolutionized the access to affordable housing for the middle class. Their best seller from 1890 to the 1930 s was the Foursquare kit home named *the Rochester* [4], which sold for $1,387.00 dollars (Fig. 2). The average *Home-kit* had 25 tons of materials, with over 30,000 parts. The key to the kit revolved around the pre-cut lumber which arrived cut to the right length, width, and thickness.

Figure 2: Four square kit-homes samples including the Rochester by Aladdin Company.

The use of balloon framing and pre-cut and fitted materials, cut construction time by up to 40%. The ability to mass-produce the materials used lessened manufacturing costs, which lowered purchase costs for customers. Each piece had a stamp with a unique code designed for easy assembly. The kit also included an instruction manual (averaging around 70 pages) designed to guide the new owner in the construction process which was advertised to take even the most rudimentary builder around 90 days to assemble (a precursor to IKEA). Electricity, plumbing, and heating were not included in the basic kit but could be added as at an extra cost. Also, for an extra fee, the house could be customized. While some built their own homes, most buyers hired local construction companies to assemble the kits, paying only for labor cost. The kit home served as a good predecessor for residential modularity. Richard Sears in 1913, following Henry Ford's use of the assembly line, had the idea of building family homes in a factory using a similar system. This idea would have as an advantage keeping all the skilled labor in one place resulting in lower production costs. Ready to assemble homes remained popular until the stock market crash of 1929. After that, the middle class could not afford to buy homes anymore and some of the companies making kit homes went out of business. It wasn't until the post war era (1950s) that the modular home became popular again. The returning troops wanting to start families needed homes. The modular home, now easier and cheaper to transport, thanks to the new highway system surged in popularity again. In 1943, Skidmore, Owings & Merrill (SOM) built secretly 3000 prefabricated houses to house members of the Manhattan Project in a location now known as Oak Ridge, Tennessee. In 1958 the first double wide home was built. A double-wide is a prefabricated modular home measuring around 90 feet (27 m) in length and 20 feet (6.1 m) in width, which is towed as two separate units to the site where they are joined together. Many home building companies saw the benefits of building sections of a house in a factory setting. The popularity of this type of home led the federal government to regulate the construction process. And in 1976 the US Department of Housing and Urban Development created the building code (HUD code) setting standards for both modular and traditional homes. Modular home construction had to adapt to new codes pertaining to fire safety, structural design, heating, plumbing and electrical systems. In the second part of the 20th century some failed attempts at designing modular homes were made by very famous designers: Le Corbusier proposed his *Dom-Ino* post war typology, Jean Prouve his *Maison Demontable*, Frank Lloyd Wright his American *System-Built Home,* Buckmister Fuller his *Dymaxion House,* Richard Rogers his *Zip-up house* and Philippe Starck his *Prefabricated Accessible Technological Home (PATH*). Today, the modern modular home is built in an eco-friendly way, using Structurally Insulated Panels (SIP) panels, at a factory. The pieces are transported by truck to the site and assembled. And they are no longer purchased through catalog, or maybe they are, if we consider the internet to be one.

4 MODULAR ARCHITECTURE: THE FUTURE OF AFFORDABLE HOUSING

Even though historically, some of the first ideas about prefabrication started in the United States, when we look at modern prefab modular architecture, we must look at places like Sweden, Japan, and the Netherlands. And that is because while in the US, Australia, or the UK no more than 5% of permanent housing has prefabricated elements, 84% of all detached houses use them in Sweden, 15% in Japan and 20% in the Netherlands [5]. The United States has fallen behind because of a lack of the demand drivers of these leading countries, including in some cases: extreme weather, earthquakes, or environmental activism. In January 2003, Dwell Magazine issued a design challenge to 16 architecture firms to design a prefab home for $200,000.00 to start a conversation about prefab modularity and to change this trend. The competition was won by Resolution:4 Architecture, who developed a building system based on prefabricated modules produced in a factory environment, transported by truck to the site, and then craned onto a concrete foundation designed to house all the dwelling's mechanical systems [6]. The house was composed of two intersecting bars overlapping each other. The top module housed the private areas of the house while the bottom one did the same for the communal spaces. And while it is true that much of the public appeal of prefab has been tied to cost savings, for the owners of the winning house, those savings were proven to be not as significant as they might have hoped for. But the competition did show the public in general not to underestimate the efficiency, precision and the time savings in the prefab construction process, something not often seen in today's building practices. Because architecture has always been tied to the construction industry, prefabrication has the potential to help fix an industry that suffers from inefficiencies that are harmful to the client's time and money [7], and the environment as a whole [8]. Material waste, the high cost of labor, the length of construction times and troublesome levels of maintenance are a few of the many consequences of today's outdated building construction practices. Contributing to the inefficiencies there is a lack of standardized workflow between the different construction trades. And on top of that, there is also a skilled labor shortage, due to a combination of; Millennials not going into the construction industry, nationalist immigration policies, the Boomer generation starting to retire and the COVID-19 pandemic. The entire building community needs to reform itself, but this is going to be very hard due to all the special interest groups at play.

As this industry starts to become more dependent on technology, we start to see less waste, better scheduling, and a faster construction process. The construction process needs to resemble more that of car manufacturing, because factory construction is a big part of cutting construction costs. The benefits extend also to the workers [9], who get better paid, get training, the controlled setup makes a hard job easier, there is no more commuting to different job sites, and they have a job every day, regardless of what the weather is like. And it also benefits the neighbors by creating less construction disruption in the neighborhoods thanks to the short time of onsite work that the prefab system requires.

While traditional construction cost has been rising between 5–10% annually for the past three years [10], modern prefab modular construction can reduce the cost of construction by 20–40% and the construction time by 30–40%. And although modular construction represents only 3% of homes in the market [11], this number is growing, presenting a concrete and promising alternative to help alleviate the affordable housing crisis. A proof of this is that the tech industry is noticing. In 2017, Google spent $30 million to build 300 modular housing units for its employees in San Francisco [12]. The project was built by Factory OS. Microsoft is investing half a billion dollars in a similar project in Seattle [13]. And if the tech industry has noticed, the government will follow. As seen in Brooklyn, where the New York City Affordable Housing Agency is explicitly requiring modular housing construction as part of their Housing New York 2.0 Plan [14]. Other cities are seeing the benefits, having plans to use modular construction in the creation of homeless shelters. So, if the projects keep flowing and the factories are kept busy, modular construction seems to be creating a space for itself in the building industry.

5 UNDERSTANDING THE MODULAR PREFAB CONSTRUCTION PROCESS

In the United States, companies like: RAD Urban, Factory OS, Plant Prefab, Roombus, Dvele, Entekra, Katerra, Fullstack Modular, Blokable, Blu Homes, Connect Homes and Method Homes, are layering smart and prefab technologies, promising a more holistic approach to homebuilding that considers the entire life cycle of the home. These companies are inclined to be more progressive and advanced in the way they are building homes, investing in technologies that are yielding zero utility bills, require less maintenance, and are more durable and resilient. Each company seems to have their own take on modular construction and their own strategy for reshaping the building industry. While each company has their own specialties, the construction building process (Fig. 3) follows more or less the same parameters for all of them. Projects are digitally designed and streamlined with exacting precision before assembly begins. Once in the factory, the first stage on building a prefabricated house starts with welding a steel frame the size of the module (14’ × 76’ max. due to shipping restrictions). This, followed by joists, decking and the floor being installed onto the frame. Which in the factory is set to about 6 feet (1.8 m) above grade allowing for workers to work simultaneously above and below it. The second stage attaches the walls, which have been built separately and are brought assembled to be positioned vertically, over the flooring and frame. At this point the designed interior wall finishes are added, followed by windows, insulation, electrical wiring, plumbing, and any custom components. While this is taking place, the roof is being put together at another station. As the module moves down the assembly line, an overhead crane hoists the roof onto the walls as part of the third stage. And finally, on the last stage, the interior is finished, built-ins and fixtures are added. While inside the roof, ductwork is run, as well as additional electrical wiring and other components. Exterior finishes and weather proofing are attached while doors, interior trim and cabinets are completed. In a typical modular construction project, up to 90% of the construction is completed in the factory. This system cuts down time. Once fabrication starts, all the time-space management has already been done to understand the labor required at each stage, defining the number of staff needed for each task. It takes about 14 days for a module to be constructed from beginning to end in the factory, after which is taken to the site where it is assembled to other modules like *Legos*, capable of rising to 5 story tall if designed to do so. The biggest bottleneck is the process of getting planning approval. Whether building off-site or traditionally, you cannot start building unless you have planning permission. In the end, a fully integrated prefabricated project offers a lot of benefits and can be cost-effective by allowing for minimum material wastage, decreased amount of equipment used on-site, fewer resource requirements, increased control due to factory production, and decreased operational and labor cost due to short project timeline. All of which benefits the client and the environment.

Figure 3: Pre-designed prefab vs. custom prefab vs. custom build construction process comparison.

6 WHAT IT MEANS FOR SUSTAINABILITY

Around 40% of landfill waste in the United States, comes from the construction industry. The US Environmental Protection Agency estimates that 600 million tons of construction and demolition waste were added to landfills in 2018 [12]. And while moving construction off-site into factories holds a lot of promise for efficiency and innovation, it can also have a positive impact on construction waste management, reducing environmental impact and conserving resources. The possibility of applying circular economy principles to prefabrication [15] to achieve these goals is not only possible but is already in use as part of prefabrication building systems models [16]. The construction process when held in a controlled environment gives the builder more oversight over inventories, allowing for any leftover material to be recycled and reused in future projects, reducing the construction waste that ends up in the landfill. The controlled environment created in the factory also uses less energy than a traditional construction project and allows for large portion of works to be completed simultaneously, reducing the construction time. Soft costs like: Real estate fees, inspection fees, project management, and taxes, are minimized thanks to the fast pace of the construction process. Buildings are designed and built to the same or to have higher sustainability standards as those of traditional construction. Europe is a good example in that they require that all new homes are Net Zero and fabricators are building to Passive House standards which is the most rigorous building performance system in the world at this moment. Modular prefabricated houses following Passive House requirements have reduced energy consumption by up to 90% when compared with traditional construction [17]. Another sustainable advantage is that since most of the construction process takes place off-site there is less impact to the building site and surrounding community, since site construction time is shorten, covering only foundation work, landscaping, and the setup of the modules. Through innovation and control, factory prefabrication is playing a major role in making the building sector more sustainable in ways not seen in traditional construction.

7 METHODOLOGY

7.1 Research methodology

The research methodology was divided into three stages. *Stage 1* produced historical, material, and practical research through interviews, site visits, project analysis and research-based reading. This information was implemented on *stage 2* to create a university course where to implement the work done on *stage 1*. Multiple projects were designed with student participation, that tested modularity and prefabrication. And the outcomes of this process were then used professionally, to create a prototype which was presented to an architectural competition in the subject. *Stage 3* will get the project build (unfulfilled at the moment the article was written). A couple of possible clients were approached, and prefab companies in the locality of the sites have been consulted, but the construction process has been put on hold due to the shortage of labor and materials as a result of the pandemic. Following is the research methodology behind our work.

7.1.1 Stage One

Reviewed a selection of literature on the subject of prefabrication between the years of 2000 and 2021, pertinent to the goals of the process precented on this article.

Looked at historical precedent in multiple countries (Canada, Denmark, Japan, Spain, Norway, Sweden, United States, etc.) to understand the evolution of the prefabricated conceptual process and building systems. Documented past and existing prefabricated construction methodologies and applications.

There is presently no reliable assessment tool for assessing the efficiency of the prefabrication process. Based on our literature review and the opinions of prefab construction companies, the industrialization efficiency of prefabricated residential building could be checked based on the following criteria: The level of the standardization of the design, the amount of off-site manufacturing, the amount of on-site construction, the cost of the transportation of components, the efficiency of the Building Information Modeling (BIM) in simplifying the management of the project, and the sustainability of the process in terms of reduction of waste. But because every company has different production methods, comparing them becomes problematic. A lot more work needs to be done, to develop quantitative systems for this type of assessment [18].

Analyzed material options for the construction process to understand if there was a benefit in using local materials.

Discussed with prefab companies, their construction process, approach to regulations, costs, and sustainable approach. And observed the construction process in field trips to manufacturing facilities.

Discussed with participating workers the benefits to labor when compared to standard construction methodologies.

Discussed with architecture companies with prefabricated experience about their process.

Discussed with banks to better understand the loan mechanisms at the client's disposal to finance a prefabricated residential project.

7.1.2 Stage Two

Set up a studio course (400 level) in the Fall of 2020 at the College of architecture, Art, and Design (CAAD) to start to explore modularity. The work produced was exhibited in the Studio Gallery at City Center in Sharjah, UAE.

Participated on the Modularity Home Design Challenge 2021 (set up by Bee Breeders Architectural Competition Organizer) to put our research and ideas into practice.

7.1.3 Stage Three

Implementation of a prefabricated design by finding a client interested in prefabrication.

Implementation of a design and construction process assessing the potential for implementing a creating a circular economy. This last point being a very complicated one, because presently the construction industry is set up as a linear economy rather than a circular one [19]. Making these changes hard when working at a project per project basis. COVID-19 has added to this issue by making sustainable materials scarce and hard to find. So, our approach has turned to one that focus on the use of local materials and working with construction companies that offer some level of circular economy management. The real implementation of this will be apparent once construction starts and sustainability within COVID-19 is explored within the construction process. Our research found that the implementation of a circular economy on the prefabrication process is still new but has potential of growth in the prefabrication industry. The reasons for its lack of implementation are mainly a lack of political awareness, resulting in no consequential government incentives.

7.2 Design methodology

- *Drawing Preparation:* In this stage, a design is produced focusing on how the modularity of the different elements will work together (Schematic Design & Design Development). This stage uses all the research explained in the Research Methodology.
- *Material estimation:* In this stage, the design produced previously is developed to the detail level and used to estimate the material requirements of the project (Construction Documentation).
- *Project duration:* In this stage, the construction schedule is created based on the work needed to fulfill the proposed design accomplished in the last two stages. The construction schedule is done with the prefabrication company to adapt the design needs to their industrialized prefabrication process. Normally this process uses a critical path method.
- *Cost Analysis*: *From* the last three stages, the project cost is defined. These includes, design, labor, machinery cost and profit.
- *Data Collection:* By analyzing the schedule in action, we can assess elements that can be done more efficiently in the next build. This step is especially important when doing multiple dwellings. This process also helps defines the duration of the construction process.
- *Project Duration:* All the previous stages result in the information used to produce the construction schedule. Fig. 4 shows the implementation of this methodology compared to the traditional method for the project proposed on the following section.

8 DESIGNING A PREFABRICATED DWELLING

The project was designed to function in an urban lot as well as a sub-urban one. For this reason and with the idea to minimize on-site work, a foundation system was developed, named a spider-foundation. This system consisted of a structure lifted off the ground, designed to touch down only at specific points. Cement footings would be set only at the points of contact with the foundation system, no other site work would be needed except for

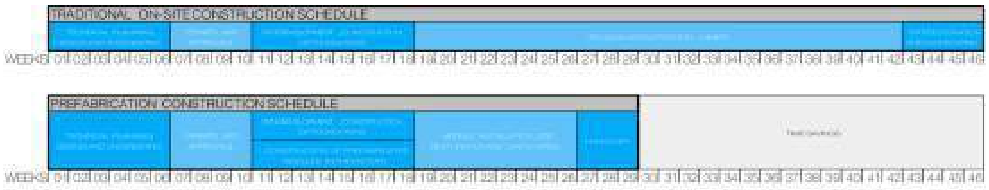

Figure 4: Typical construction process time comparison.

plumbing and electric work but only in cases were the house was not built to be self-sufficient. The result is a non-obstructive dwelling lifted from the ground. This system allows the house to be set in different topographies without having to flatten the land and it allows for flora and fauna to interact uninterrupted with the dwelling. Animals can even use the underside of the dwelling as shelter when needed. The foundation is then the first element to be set once the on-site construction process takes place. The competition brief called for a recommended maximum usable floor area of 90 m^2 (968 ft^2) and for the modules to be 3.6 m (11.8 ft) in height with a maximum module width of 4.2 m (13.7 ft) and a module length of 1.8 m (5.9 ft). Normally modular sizes are designed to fit the maximum size and load allowed in the area between the factory and the site. Because this size is dependent on the means of transport, this size is normally a lot larger than the competition requirements. To be able to work with the requested modularity in an efficient way, taking into consideration what we now understood of the prefabrication process, a house was designed based on an extruded volume that would allow us to break it into the number of modules needed to fulfil the program. The volume could not be any wider than 4.2 m, this constrain forced the program to adapt into a proposal that would fit on a space generated by that width and the 90 m^2 (968 ft^2) of possible enclosed area. In this space we designed an open plan which would allow for a more fluid relationship between the kitchen, living room and dining room, but also from a practical perspective, it would provide a mainly empty space that could be cut where needed, into modules. On-site, once the foundation system has been set on the concrete footings, the modules can start to be installed by crane, one after the other and linked to the spider foundation and each other. You can see the process on Fig. 5. This process can be done in two days.

Following the module requirements, a volume composed of five enclosed and one open (to the weather) modules were designed. This dwelling used its longitudinal sides to enclose elements like the kitchen, toilet room, and shower within long built-in fixtures. These fixtures served to conceal the cut lines between modules giving the interior a sense of continuity. A smaller built-in volume separates the main space of the house from the master bedroom and serves as the children bedroom. By making all the modules the same size we ended up with a common shape that is repeated, making it a lot easier to build in the first phase of the factory process to be individualize only internally down the line. All the modules are basically the same element to which different aspects of the design get incorporated (Fig. 6). All exterior and interior work would happen on the factory, leaving minimal work done on-site post assembly. The construction process in factory of this design would take from 4 to 6 weeks. You can see the final product in Fig. 7. The house is designed to be self-sufficient, incorporating an atmospheric water generator to produce water, solar panels for energy, an interior hydroponic farm, a produce garden on the terrace, and a series of other technologies that make the house a net positive dwelling. The

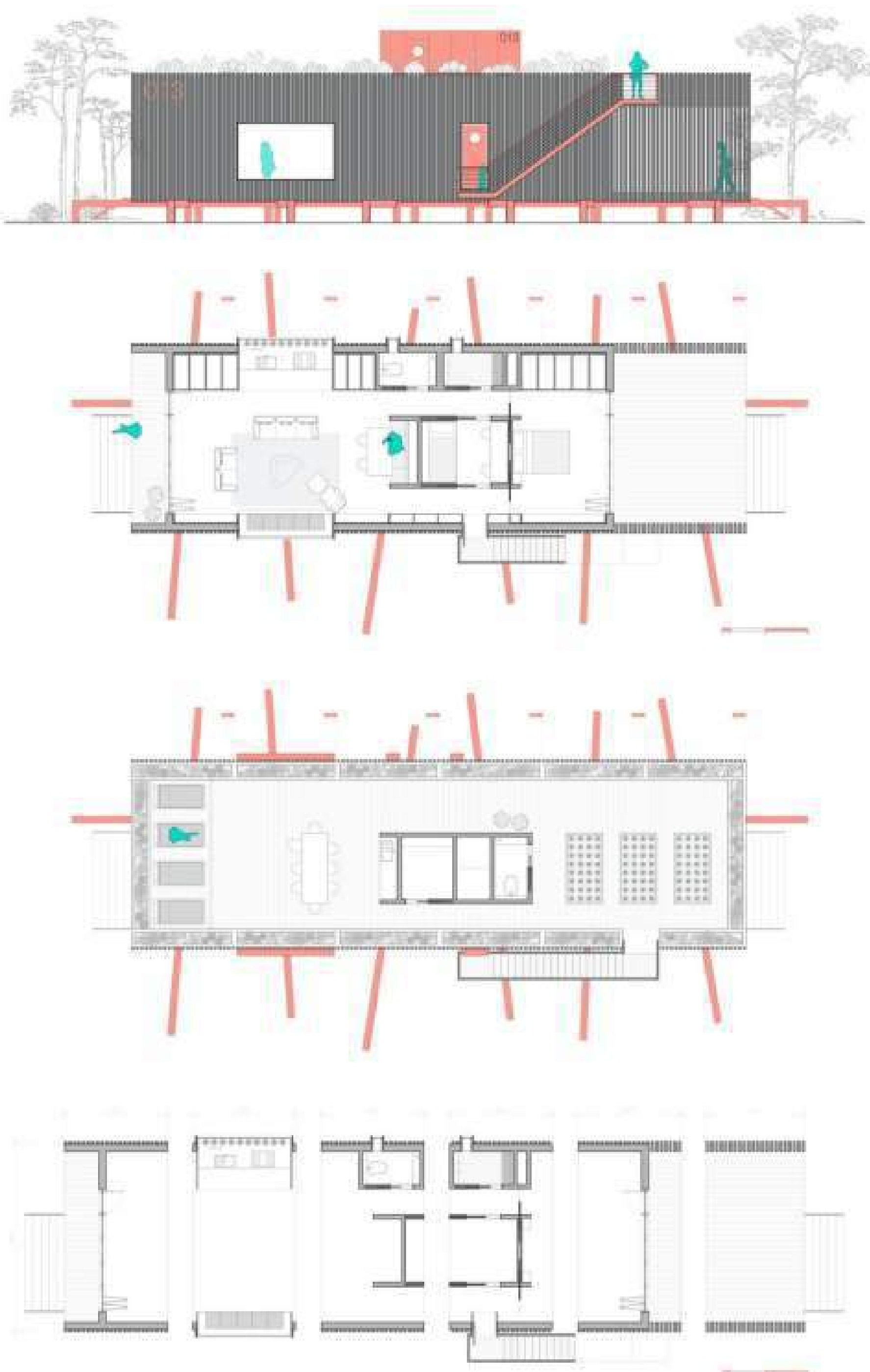

Figure 5: Side elevation, ground floor plan, terrace plan and separated prefabricated modules.

Figure 6: Modular assembly on site.

proposal, we estimate will cost 18% less than if it would have been built conventionally. By incorporating all the research into the design process and talking extensively to the people building factory manufactured houses, this project was designed for prefabrication and can be set up for Building Information Modeling (BIM). No one in the design team had any previous experience with Design for Manufacture and Assembly (DFMA) which forced us to adopt a strategy of overplanning. This forced the design team to consider, coordinate and finalize decisions much earlier than in the traditional design process. And even though the project has not been built yet, the design development and construction documentation process are finished since they would be needed immediately once a factory starts construction. A post construction analysis will be needed once the project is built which leaves for now, *Stage 3* from the research methodology unfulfilled.

Figure 7: Modular single-family house with 1,012 ft^2 (94 m^2) of interior space 380 ft^2 (35 m^2) of exterior covered space and 1,180 ft^2 (110 m^2) of terrace space.

9 EXPECTED COST SAVING OBSERVATIONS

Following we will discuss some observations that will help better understand the cost savings potential, for both client and owner, of the prefabrication process:

- *Design Cost:* Architects and designers will need to adapt to new ways of thinking about the design process keeping the prefabrication requirements in mind. Components will have to fit the maximum size and load allowed for transportation and as these elements are added to each other, the way they join together will also require a level of design adaptability. BIM will be an essential tool to achieve this. Once this process of adaptation ends, the results will manifest in a decrease in design costs.

- *Site Overhead:* When compared to traditional construction, off-site manufacturing has already proven to reduce project schedules. The result is less management cost and site overhead because there is less work taking place on site.
- *Material Cost:* By buying materials in bulk, not using intermediaries, storing the materials in or near the factory and recycling or reusing materials from one project to the next material cost can be reduced.
- *Labor Cost:* Because 80% of traditional labor can be moved off-site and into the manufacturing facility, the more standardized and controlled construction environment will increase productivity. This move will also eliminate traditional on-site down time thanks to controlled scheduling, resulting in lower labor costs [9]. This process will also benefit the workers by giving them a safer workplace, always on the same location and not dependent on the weather.
- *Logistics Cost:* For the prefabrication system to work, the productivity gains need to outweigh the extra cost of transporting the finished units to the site.
- *Financing Cost:* For this system to function for the client, financial institutions need to adapt to the times. Lending rates for prefab manufacturing tend to be higher due to the novelty of the concept which is not yet fully understood by financial institutions. Because the prefabrication construction process functions differently than traditional construction, full payment is normally required upfront. Which also scares lenders.
- *Factory cost:* Setting up the manufacturing process for the owner of the company is a cost that needs to be taken into consideration against potential cost savings.
- *Lifecycle cost:* The increased in construction precision that results of the factory-controlled environment has a significant impact on the quality, performance, and longevity of the building. The enclosed environment allows for closer scrutiny being placed on all the work being produced.
- *Reuse cost:* The reuse of buildings constructed with prefabricated techniques will be facilitated by easy dismantling.

10 CONCLUSION

Current traditional construction techniques do not reflect innovation trends and technology in the use of manufacturing for construction. We are building now in largely the same way we have for the last 70 years. Transitioning some types of construction to an offsite manufacturing model can produce the kind of dramatic productivity and environmental improvements that have long eluded the construction industry. Improving the productivity of such a large lagging sector of industry would result in economic growth. In an era of shrinking margins and growing costs in the construction industry, prefab housing is proving to be a necessity. In 2021, things can be done much more affordably, of better quality and more efficiently inside a factory. Where the use of new technologies provides a higher level of precision in the design and construction process. Using prefab technologies, like virtual design and construction (VDC) and building information modeling (BIM) are helping designers, engineers, builders, and fabricators communicate better, solving the construction's industry translation problem. The process has also allowed for a better system of controls and reviews, because most of the construction is done in a controlled environment where the production lines optimize the workflow. This level of productivity also reduces the risk of accidents since all the construction stages are not overlapped onto the same site as it is in traditional construction allowing for a cleaner environment. And one of the most significant prefab drivers is not just the cost savings in on-site building labor. It's the ability to build quickly in an industry lacking enough skilled workers.

Prefabrication has also proven to be environmentally sustainable, due to upfront planning resulting in less material waste, less re-work, better scheduling, and less use of material in the finished product. Making it an industry perfectly set up for adopting circular economy systems as part of its process. While prefabrication alone is not going to solve the housing crisis, it is a first step toward a more equitable residential solution that together with other mechanisms can reshape the future of dwelling.

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RESPONSIVE FAÇADES DESIGN USING NANOMATERIALS FOR OPTIMIZING BUILDINGS' ENERGY PERFORMANCE

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ABSTRACT

According to the International Energy Agency (IEA) buildings and construction sector globally is showing an increase in both emissions and energy use, limited progress on new and existing policies, and a further slowdown in energy-efficiency investment growth. In the meantime, 40–60% of all energy used in buildings is affected by the design and construction of building façades therefore, considering sustainable strategies for energy efficiency of building façades are very important. Responsive façades can improve buildings' energy performance as they create an adaptive environmental filter around the buildings with the ability to interact with the outdoor conditions. New building façades materials and technologies are needed to encourage construction towards nearly zero-energy buildings. For this reason, the construction industry recently started combined the use of nanomaterial with conventional building material. These adaptive nanomaterials can be integrated into buildings' responsive façades, based on the specific material properties that can be modulated. To vary their solar properties (transmission, absorption and reflection coefficients) as well as their heat transfer (thermal conductivity). This research presents a comprehensive overview of responsive façades detention and classification through novel information focused on the systems which use active nanomaterials to enhance buildings' energy efficiency.

Keywords: adaptive nanomaterials, energy efficiency, energy performance, nanomaterials, phase change materials, responsive façades, shape memory materials.

1 INTRODUCTION

During the last decade the construction of energy efficient buildings centred around two strategies: firstly, the installation of highly efficient energy recovery systems and secondly, the use of passive design solutions to improve the efficiency of building façades. For example, optimizing buildings shape or improving insulation materials for façades and windows, however, this static design concept cannot be sufficient to achieve environmental sustainability targets [1].

This is based on the fact that the limitation of static façades to how much energy savings can be achieved as they are incapable of interacting with the outdoor conditions which would benefit the indoor environment consistently, as well as give building users the ability to modify the building façades to meet their needs. With seasonal variability, and changing of weather patterns, static façades cannot provide consistent climate control [1].

Like the skin is to the human body, building façades have the responsibility to regulate internal physical conditions. Thus, "responsive building façades" could solve problems faced by static façades by supplying the ability to play more than one role at a time according to outdoor climate conditions. Such as, allowing solar heat during certain times but restricting it at other times. Ultimately, shifting between functions in adaptation to different conditions allows façades to decrease energy consumption and improve the efficiency of building energy [2].

A noticeable change on architectural skins appeared during the second half of the last century the building envelopes role has evolved from protection only to energy storage, and

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generation according to need through many improvements in terms of materials, system designs, and energy efficiency simulations [2].

2 RESPONSIVE FAÇADES

Responsive façades can effectively respond to the changes in the interior and exterior environment to achieve or improve the envelopes' functional requirements in terms of thermal comfort, air and water vapour movement, solar radiation, strength and stability. Therefore, multi-functional responsive façades should be able to respond repeatedly and reversibly over time to changes in performance requirements and changing boundary conditions. In other words, responsive façades would be able to provide controllable insulation and thermal mass, radiant heat exchange, ventilation, energy harvesting, daylighting, solar shading or humidity control [3].

2.1 Classification of responsive building façades systems

Responsive systems are primarily classified into three different categories shown in Fig. 1, according to responsivity type [4], [5].

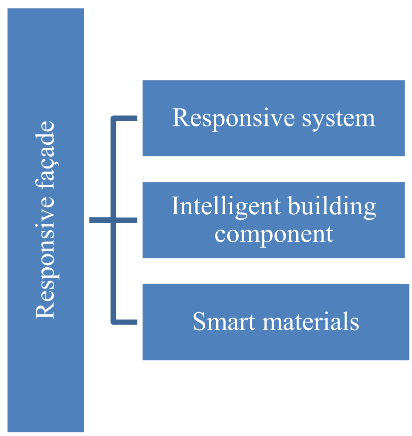

Figure 1: Responsive façade classification. *(Source: [4], [5] edited by author.)*

2.1.1 Responsive system

The term "responsive" in building façades describe "the interact, and response between natural, and artificial system using computational algorithms to ensure the building system's ability to self-adapt and learn over time (Table 1). Systems equipped with sensors, processing units, and actuators that can be programmed and could answer to real-time weather conditions were incorporated into the envelope [6]. They are based on data acquisition systems (DAS) of a closed loop protocol, based on an integrated system where the stimuli are sensed, and their processing is used as a control device [7].

As a result, responsive building skins not only incorporate methods for user sensing and response, but are also devoted to informing the building and its occupants. Data is presented to the building's users through an interface system, called ALIS (adaptive living interface system). It provided real-time energy and resource use feedback in both numerical

Table 1: Responsive façade system and mechanisms. *(Source: [6] edited by author.)*

Response input	Mechanical elements	Smart Material
Exterior climate Sun–wind–moisture pollution	Movable sunshades – louvers – panels	State change – energy change
Interior climate Temperature – humidity – CO2 – VOCs	Operable vents – air velocity control	State change – biochemical reaction
Users	Direct control	
Preference settings -manual control	Control panel-web application -mobile applications	

and ambient formats, alerting users when occupant actions would compromise energy optimization. For example, opening the louvres on a sunny day. So that, the building's users can gain awareness by time, and regulate their actions according to climate and energy load. Finally, both the building and the residents are in an ongoing, evolving conversation [6].

2.1.2 Intelligent component

The aim of an intelligent building component is to improve the buildings' system according to the outdoor climatic conditions, energy consumption, and users' comfort. Using building automation, and physically responsive features (Fig. 2) such as louvers, sunshades, operable windows and smart material assemblies.

Figure 2: Intelligent double-skin façade system for the Terrence Donnelley Centre for Cellular and Bimolecular Science at the University of Toronto with integral automatic shading [6].

2.1.3 Smart material

"Smart materials" are described by Addington and Schodek as systems with "embedded technical functions" which provides specialized environmental responses, operating either through internal change in physical possessions or through external exchange of energy Smart materials have a number of characteristics that distinguish them from the known traditional materials as shown in Fig. 3 [8].

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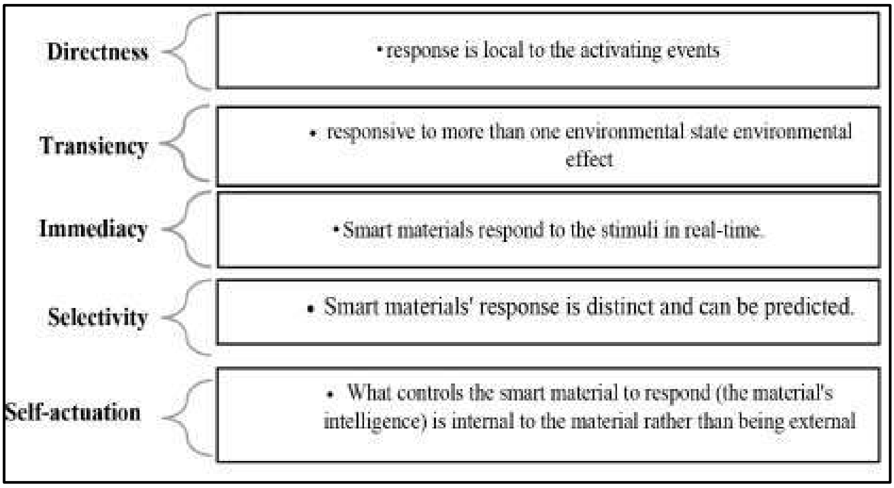

Figure 3: Characteristics of smart materials. *(Source: [8] edited by author.)*

Due to their integral characteristics, smart materials can play an important role in responsive envelopes. One of the most crucial features of smart materials is that they form responsive systems by themself. Through, there capability of transforming their materialistic features, and/or shape or exchanging energy without the need for complex electromechanical systems or additional energy supply [9].

A recent example of a responsive smart material installed in a completed building is media-TIC building, (Fig. 4) in Barcelona in 2011 designed by Cloud 9 architects and envelope specialists Vector Foiltec Ltd.

Figure 4: Smart envelope comprised of ETFE encased solar-activated lamella shades developed for the Media-TIC building in Barcelona [4].

The envelope is composed of a pillow cladding system made of ETFE (ethylene tetrafluoro ethylene), a transparent polymer sheeting that is ultralight and elastic while being extremely robust. EFTE is used as an alternative to glass and hard plastic in some new structures [4].

There are 106 EFTE membranes or pillows in total, which will gradually inflate or deflate based on the environmental condition (Fig. 5). Each "pillow" is regulated individually, with separate sensors detecting heat, temperature, and sun angle.

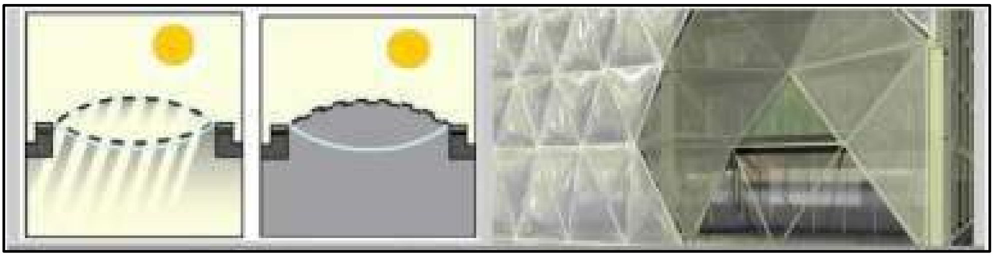

Figure 5: Diagrams of the way the ETFE diaphragm move in response to climatic conditions [4].

When compared to glass the use of ETFE material reduces energy consumption by 40%, lowering the solar factor (SF) by four times, from 0.45, as required by the Building Code, to 0.10, and costs between 24 and 70% less to construct [4].

3 NANOMATERIALS AND SMART MATERIALS

An important aspect of sustainability in buildings is the efficient use of energy. Nanomaterials and nanotechnologies have a great potential for achieving high-performance energy-efficient buildings for a sustainable future. It is a revolutionary technique that deals with manipulating materials at the nanoscale, affecting their characterization, improving, or creating new properties of the product [10]. Nanotechnology can be employed in construction applications to provide one or more functions like air purification, self-cleaning, anti-soiling, energy generation, temperature regulation, solar radiation control, and fire prevention. The use of nanotechnology in architecture has not only been determined by energy efficiency and sustainability but also been involved in the architectural design process [11].

The availability of nanomaterials and nano-devices offer the possibility to produce smart materials. Nanomaterials add smartness to the materials using coating, like self-healing, antimicrobial, anti-fouling, self-thermos regulating, etc. [7].

4 ADAPTIVE NANO MATERIALS FOR ENERGY EFFICIENCY RESPONSIVE FAÇADES

Nanotechnology has enormous potential in spatial deformation due to adjustable variance in material properties. The availability of nano microprocessors incorporated in smart materials allows them to transform shape in real-time in reaction to environmental changes. Consequently, respect the environmental concerns about sustainability. As a result, it will be an addition for architects to apply these materials to the building's façades to guarantee the optimum energy saving [7].

4.1 Adaptive nano material families and classification according to their input and output reactions

Adaptive materials have a range of values based on the switching parameter, or they have a "memory" for stored energy fluxes, such as phase transition materials. Because of the variety of these features, not all materials can be classified by the same set of properties. In Table 2 representative adaptive material families are categorized based on the dynamic behaviors or performance that can deliver in response to a specific trigger. This thorough material family classification is based on the input and output of the response, allowing for significant scoping in respective changes of application in facade systems. Although, this research will focus on phase change material and shape memory nanomaterial application for responsive façades [5].

Table 2: Material families and classification according to their input and output reactions. *(Source: [5] edited by author.)*

Reversible colour opacity change	Shape changing	Humidity absorption	Reversible heat flow direction
Electrochromic	Composites	Hydro gel	Phase change material (PCM)
Thermochromic	Shape memory material		
Photochromic	Piezo electronic memory		
	Thermo bimetal		

5 PHASE CHANGE MATERIAL AND SHAPE MEMORY NANO MATERIALS

Nanotechnology provides a novel concept for creating what could be termed as a "living facade." Using Stimulus responsive material (SRM) (Fig. 6). Such as, phase change material (PCM) which changed as a response to the rise of the temperature from the crystalline to the liquid state [12]. Or Smart materials supplied with (shape memory metal strips) that can remember their shape at the designed degree of temperature to be self-responsive and adaptable according to the outdoor environmental changes. They can be used to cover the façades to detect heat and then change shape as the temperature changes. As a result, the change in these strips will cause the façades material to adapt to the change as well. Shape memory materials, like metal (SMA), polymers (SMP) or ceramics (SMC), can return to their original shape after removing the stimuli like the change of temperature, pH-value, UV-light, electric or magnetic fields [7].

5.1 Nano PCM (phase change material)

PCM (phase change material) can be used to effectively regulate indoor room temperatures. It's also referred to as latent heat storage materials. The concept is like that of an ice cube in that it has a large thermal capacity and begins to change state to liquid at 0°C, but the energy required for this transition is equivalent to that required to heat liquid water from 0°C to 80°C. The same idea is used here with PCM.

Building temperature regulation require massive amounts of energy, both for heating and cooling. With the help of nanotechnology PCM is made up of microcapsules on a nanoscale, and its contents operate on absorbing heat; hence, energy consumption can be greatly reduced. Since PCM thermal storage is so large, it can absorb temperature fluctuations, allowing indoor spaces to stay colder for longer periods of time [14].

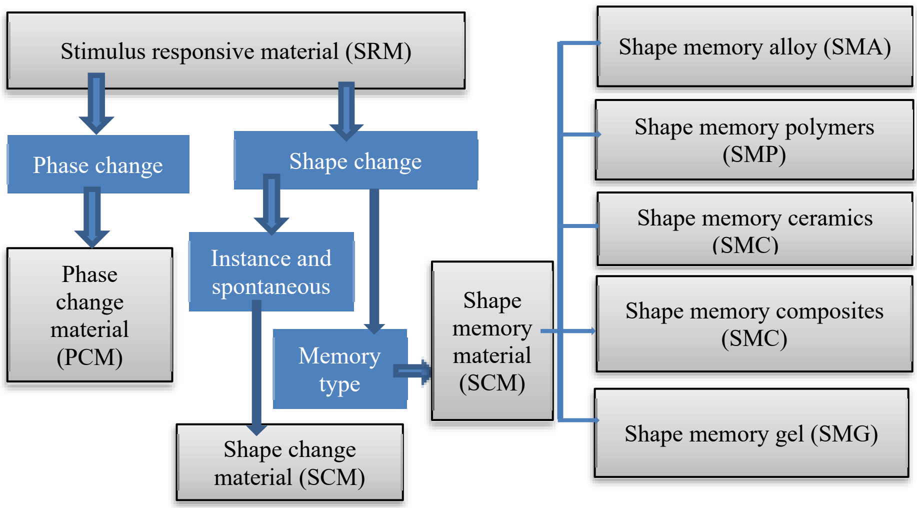

Figure 6: Phase change material and shape memory nano materials [13].

The inclusion of PCM on building elements has been assessed in façades as follow Fig. 7: window panels, dynamic shading systems, Trombe walls, concrete blocks, and cellulose insulation [14].

Figure 7: PCM current applications.

5.1.1 PCM-incorporated transparent glazing

Among building façades, approximately 50% of the energy is lost through windows, so more attention has been focused on energy efficient windows. The outer and inner insulating glazing units provide the passive solar mechanism of PCM glazing systems. The outer insulated glazing unit with suspended prismatic filter between the panes of glass reflects the higher angle sunlight back out while transmitting the low-angle sunlight into the inner unit (Fig. 8) [15].

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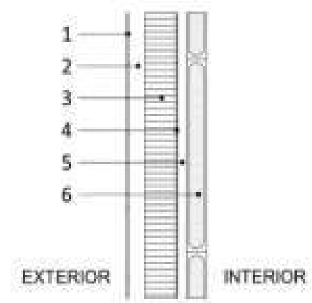

Layer Id	Description	Thickness [mm]
1	Glass pane	-
2	Air gap	-
3	Transparent insulation material	-
4	Glass pane	-
5	Air gap	-
6	PCM in a glass container	-

Figure 8: Layout of external PCM glazing system [15].

As a result, the summer sun is kept out of the building, while the lower angle winter sunlight is allowed to be captured by the PCM, as illustrated in Fig. 9. This potential is allowed by the phase transition between the liquid and solid states, allowing the glazing system's thermal inertia to be increased. The overall result of this process is a reduction in heat flow from outdoor to inside space during the daytime, which saves a significant amount of energy [15], [16].

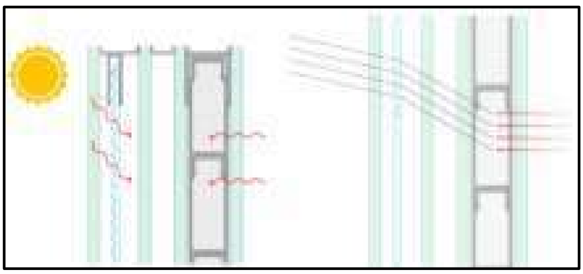

Figure 9: Fundamentals of operation of transparent PCM [15].

5.2 Example of PCM application in a dynamic façade of University of Washington building

5.2.1 Project overview

This project was designed to take full use of the naturally occurring natural climate variations that occur in the Pacific Northwest on a daily basis. Thus, the project designer used a phase change material to take advantage of temperature variations, allowing the material to disperse heat gathered during the day and avoid the need for traditional mechanical cooling [17].

5.2.2 PCM integration with dynamic envelope system

The design team worked with Phase Change Energy Solutions to identify the proper temperature and volume of phase change material. The Phase Change Energy Solutions material was installed in cavities above each level and the exterior solid walls to absorb heat from solar gain, electronics, and people. The damper system turns on mechanical

Figure 10: University of Washington building [17].

louvres that combine with ventilation fans at night. This mechanism sweeps cool outside air over the PCM, allowing it to release and exhaust heat collected during the day. This process allowed the PCM to recharge, allowing it to absorb the day's excess heat [17].

5.2.3 Energy saving results

This unique design concept is quite effective. HCAV energy consumption was reduced by 31%. The building's occupants are satisfied, and the energy savings are projected to be $70,000 per year [17].

5.3 Shape memory alloys (SMA)

Shape-memory alloys have several unique properties, including shape memory and super elasticity compared with standard metallic material's dissipation capacity. The usage of SMA in architecture, whether as a standalone dynamic system or as part of a larger system, has shown a significant increase in performance and energy savings [13].

For adaptive façades, SMA is used to manage solar gain, which provides a kinetic system that can move without the use of motors, electricity, or mechanical parts. So, enhancing the energy efficiency of buildings through changes in light, temperature, and air quality. The uses of SMA in architecture either as a dynamic system by itself or as a part of a bigger one has shown an important improvement in performance and energy consumption [18].

5.3.1 Nickel-Titanium alloy (NITI)

NITI because of its consistent mechanical performance, is the most reported SMA in responsive envelope systems using the non-diffusional phase transition protocol as an actuator (Fig. 11). NITI matrix was employed as an actuator by several dynamic surfaces focusing on the management of heat and light in buildings. The operation of these systems is based on prestressed springs or wires that attempt to restore their normal shape because of heat changes, which generate mechanical force in the operation [18].

As a resault of the mechanical force acquired by NITI phase transition, the use of NITI as wires and springs was reported and was used to panels skins illustrated in Fig. 12, dynamic indirect illumination and heat-gain control by shadowing were obtained [19].

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Figure 11: Nickel-titanium alloy (NITI) [5].

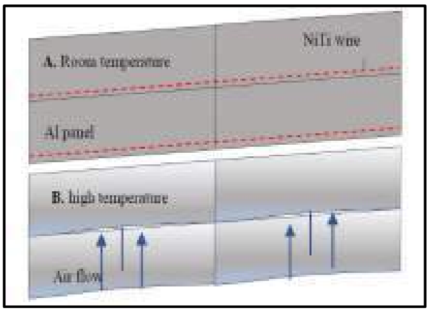

Figure 12: Kinetic facade actuated by NITI wires. A. Close module wire stressed. B. Open module wire contraction [13].

5.4 Example of Shape Memory Alloy – THERMAL BIMETAL, "BLOOM", Los Angeles, California (USA), 2011 DO|SU Studio Architecture, Doris Kim Sung

A research installation titled "Bloom", designed by DO|SU studio architecture, was on exhibit at the materials and application gallery in Los Angeles without the need of an energy source or other mechanical parts, using a material having responsive potential (Fig. 13). The project functions as a solar tracking detector that detects time and temperature [5]. When the metal is cool, the surface appears as a solid object, but when the afternoon heat penetrates the metal, the panels of custom woven bimetal adjust and fan out to enable air movement and improve shadow potential.

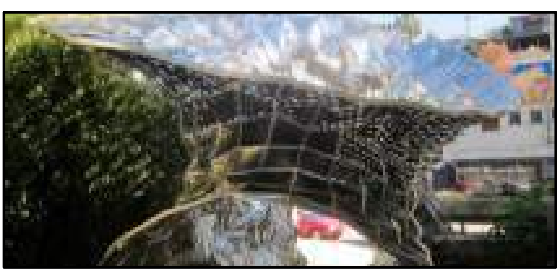

Figure 13: Thermal bimetal, "BLOOM" [20].

The towering shade structure is supported by a self-organizing cellular panel system made of laser cut custom fabricated thermo-bimetal alloys sheet metal, which tests the materials' ability to work as a responsive shell.

The design of the project explores the possibilities of a thermally responsive metal surface which reacts to both the change in temperature and direct solar radiation for energy saving [20].

6 CONCLUSIONS

Responsive building façades will play a crucial role in converting the world's energy usage into a more decentralized, sustainable, integrated and flexible system that guarantees sustainability and allows optimum use of all resources while at the same time enabling a healthy living and working atmosphere for inhabitants.

Additionally, nanotechnology provides new set of smart material and devices with responsive properties. So, designers and architects get a new material to deal with. Providing the optimum design solutions for sustainable energy efficiency responsive architectural façades.

As a result, architects will need to be knowledgeable about the properties of smart materials. Then, to use them as a preliminary step for an integrative design process and to push the boundaries of creativity in multi-functional sustainable complex patterns in architectural design.

All the materials that are mentioned above could provide energy efficiency, sustainability, high performance features and also aesthetic dynamics.

Furthermore, active materials for responsive building façades represent a highly promising sector of research and innovation that has the potential to transform the way we construct buildings in areas such as sustainable society and smart cities. However, large-scale solutions, lower costs, and improved durability, notably with shape memory/responsive polymers SMP, must be developed further.

Finally, to provide optimal solutions, areas such as artificial intelligence, big data, and the internet of things are crucial to be integrated into responsive buildings envelops for the optimization of those materials, and systems within the cities.

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RESIDENTIAL ARCHITECTURE: EVALUATION OF TENANTS' SATISFACTION IN PRIVATE CULTURE

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ABSTRACT
This paper focuses on the significance of privacy in housing design for private cultures and analyses residential satisfaction of design. Furthermore, the paper presents the unique features of a traditional house in Islamic cultures, and the role it plays providing residents of these houses with the desired privacy along with the importance and the meaning of residential privacy in private cultures, and how the contemporary architecture respects the privacy achieved in the traditional Islamic housing. Mirbat town in the Sultanate of Oman is used as a case study for this research and builds on the authors' previous study of Mirbat's old and new residential quarters where the detailed study of the architecture of 102 traditional residences were conducted and assessed. Furthermore, two additional surveys of young and older residents (as focus groups) of traditional and contemporary housing in Mirbat were conducted to expand and strengthen the findings of the current research, which aimed to study residential satisfaction as it relates to different aspects of privacy and as a measure of evaluating residential quality. Through a comparison of old and new quarters of Mirbat, and traditional and contemporary residences, the authors expose the differences in design between the old and the new. Finally, the authors conclude that those unique features that were employed in traditional housing design are no longer employed in contemporary residences' design (or employed only as decorative elements) compromising the privacy of the residents.
Keywords: private cultures, privacy, residential architectural features, residential satisfaction.

1 INTRODUCTION

In private cultures such as in Arab Gulf countries and other Islamic cultures, the concept of privacy has always been of a primary consideration and traditional houses were built to adapt to the local natural habitat to satisfy societal and cultural values. Islamic architecture designates certain cultural norms [1], particularly its strong accent on the highly societally valued attribute of family privacy. As the home is considered a social unit whose structure cannot be disassociated from the family living inside it, Islamic architecture particularly prioritizes the human needs of safety and privacy. By designing from inside out and implementing a strong spatial hierarchy, traditional Islamic architecture satisfies inhabitants' desires for both privacy and social contact [2], [3].

This research presents the unique features of a traditional house in Islamic cultures and the role it plays in providing its residents with the desired privacy. It also explores the meaning residential privacy in private cultures has, and evaluates how much contemporary housing architecture respects the privacy achieved in the traditional Islamic housing using Mirbat as a case study. The research builds on the authors' previous study [4] of Mirbat's old and new residential quarters, and detailed study of 102 traditional residences. Mirbat, a defensive city of Dhofar region in the Sultanate of Oman, which is situated along the coast of the Indian Ocean, dates back to the fourth millennium BC. Formerly well known for exporting frankincense and Arabian horses, Mirbat currently exhibits a blend of old inhabited and/or abandoned stone houses designed in local Islamic style, and newly evolved modern structures. Through a comparison of old and new quarters of Mirbat and traditional and contemporary residences, the authors expose the differences in design

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between the old and the new, and how those unique features that were employed in traditional housing design are no longer employed in contemporary residences' design (or employed only as decorative elements) [5] compromising the privacy of the residents. Furthermore, two surveys were conducted using young and older residents (as focus groups) of traditional and contemporary housing in Mirbat. The surveys were conducted to expand and strengthen the study which aimed to study residential satisfaction as it relates to different aspects of privacy and as a measure of evaluating residential quality [6] and was executed through the self-assessment questionnaires.

The findings of this research show that the design of contemporary residences, in comparison to the traditional ones, do not contemplate privacy as first consideration and do not employ architectural design features that were culturally considered important for residents' safety and privacy provision. Additionally, the analysis of the surveys conducted among residents show that most of them, despite the age group, are dissatisfied with the design of their contemporary housing. As residential satisfaction is defined as indicator of inhabitants' perception of their quality of life [7], [8] this study concludes that the design of the contemporary housing in Mirbat does not meet the cultural expectations of the residents.

2 THEORETICAL BACKGROUND

A residence, a house is a place to settle and calm down, relax, and/or reside [9], a place, where residents spend most of their time [3]. Its primary purpose is to provide residents with a safe, comfortable, healthy and secure indoor environment in which they conduct their daily activities as well as social interactions [10]. Beyond the satisfaction of residents' basic needs, a house acts as a social control mechanism, which is strong in traditional cultures [11] and, therefore, should also satisfy residents' spiritual desires, as well as their lifestyles' cultural and religious aspects [3]. In other words, the image of an ideal home is constructed by peoples' goals for their residence, which must satisfy inhabitants' personal and cultural needs as dictated by their social backgrounds and lifestyles [12]. These aims were perfectly achieved by vernacular architecture, which is the art of constructing communities reflecting a society's inherent culture [13].

When examining housing design examples in various Islamic countries, certain spatial and layout similarities and features are evident [14]. For example, Nafeesi [2] and Poirier et al. [15] describe the traditional Gulf house as a unit with a high level of privacy, where bedrooms and family quarters are farthest away from the point of entry. An L-shaped entrance hall leading to the public portion of the house prevents the inhabitants from being viewed from outside. The inner courtyard, which is surrounded by rooms, forms a visually and physically protected outdoor space in which the residents can enjoy full freedom. Most of the windows face the inner courtyard; those that face the street, along with any terraces or balconies, are latticed or protected with mashrabiya screens (the Arabic term for a wood lattice screen used in the Middle East on windows, balconies, room dividers, etc. for privacy provision).

Similarly, in Malaysia, internal design, layout and features are also influenced by culture, particularly with regard to respect for the elderly and the elevated household position of women. As such, the house's public space – the reception hall – is used only by male visitors [16].

The configuration of Iranian houses [3] anticipates balance between hospitality, social contacts and the inhabitants' privacy. This balance is facilitated by the division of spaces into exterior (guests') and interior private rooms. The interior rooms are located to prevent outside observation and access, while the exterior rooms (vestibule and reception area) located at the entrance are used for male visitors only, and the inner courtyard formed by surrounding rooms provides a private area for the house's inhabitants.

In Yemen, the typical Shibam house [9] encompasses spaces such as the diwan (reception area and guests' rooms are used only on special occasions and by male visitors only), dining area, bedrooms, courtyard, balcony and rooftop terrace surrounded by high walls. The ground and first floors are dedicated to business and storage, the second is for women's activities and the third floor is for men's activities.

In Oman, the typical Dhofari dwelling, which houses the head of family with his wife or wives and their children, is distinguished by a reception room for male visitors (majlees) with a segregated entrance and adjacent bathroom. A separate entrance allows family members to access the house's private spaces, including the sallah (living room), kitchen, bedrooms and/or multipurpose rooms. The house's exterior design, which is influenced by military style, is distinguished by the contrasting features of massive walls with decorative roof stepped parapets and carved wooden doors/windows with mashrabiya screens [1], [4], [17].

Irrespective of cultural and national differences, a home is commonly defined as a physically bounded area where private and family lives develop [18], it refers to the desire to maintain solitude, isolation, anonymity, reserve and intimacy with friends and family. Furthermore, Article 8 of the European Convention on Human Rights [19] states that everyone has the right to respect for his private and family life, his home and correspondence. To assess the quality of housing design, residential satisfaction surveys are usually conducted. Residential satisfaction is an indicator of how the quality of residents' life is perceived by them and depends on expectations dictated by cultural norms [7], [20], [21]. Multiple variables such as functional suitability of the building (space utilization, physical condition, safety and statutory requirements), design and construction quality (services within the building), building serviceability (with respect to occupants' needs and provided facilities), environmental performance (indoor air quality, appearance and lighting, energy consumption, intrusion prevention and control), and post-occupancy evaluation (the building's technical, functional and behavioural aspects) [10], [22], [23] are used for determining residents satisfaction or dissatisfaction. Variables depend on the subject of study and the purpose of residential satisfaction evaluation. As for private cultures, privacy of residents is a main variable that assess the quality of the residential environment and how it impacts residents' comfort, security and mobility [7].

3 METHODOLOGY

The study is divided into four stages as shown in the research conceptual diagram given below (Fig. 1).

Figure 1: Research conceptual diagram.

As previously mentioned, it builds on study of Mirbat traditional housing conducted by the authors in 2014 and theoretical study on privacy considerations in housing design for private cultures, followed by traditional and contemporary housing design comparison, survey and analyses of residents' satisfaction after which a conclusion is drawn.

To evaluate the effectiveness of Mirbati housing design as it relates to residents' privacy, two group administered surveys were conducted, for which, close ended, paper-and-pencil based questionnaires were prepared. The surveys evaluated residents' satisfaction with the level of privacy of modern and traditional residences.

The first survey was conducted in Dhofar University's Department of Graphic Design and Interior Architecture (Oman) in November 17–22, 2017. The participants, who were volunteers, were restricted to female students pursuing bachelor's degrees (age group: 19–25). In private cultures such as Dhofari (Muslim), privacy is an issue for a woman, and not for a man, the woman is requested to cover herself, thus no part of her body is exposed for men's observation, but only for women and family members. The questionnaires were distributed among students during break times and the participants were briefed regarding its purpose. Of 110 qualifying students in the department, 100 participated in the questionnaire survey, representing 47.6% of the total possible participant pool.

The second survey was conducted in the central area of Mirbat town, where the old (traditional) and new residences are mixed together. The survey started on 3rd March and ended 24th April 2018. The questionnaire was distributed to one hundred households where the recipients were 211 female inhabitants from the age of 35 and above. The data was systematized into column charts using Microsoft Office Excel 2013.

The first survey, conducted among young female at Dhofar University, is a nine-item questionnaire and considers the following dimensions: (1) usage of the courtyard; (2) reasons of not using the courtyard; (3) frequency of curtain usage; (4) reasons of windows curtaining; (5) usage of the roof terrace; (6) reasons of not using the roof terrace; (7) usage of balconies/terraces; (8) reasons of not using balconies/terraces and (9) satisfaction with the privacy of the residence. The second survey, conducted among elderly female generation in Mirbat town, is similar to the first one, but contains additional questions concerning age and type of the residence (modern/traditional).

4 RESEARCH BACKGROUND: MIRBAT OLD TOWN

Authors' findings from previous study [4] along with theoretical work on homes, private cultures and residents' satisfaction, motivated the examination and comparison of old and modern Mirbat residences, specifically the analysis of those features that contribute to the facilitation of residents' privacy (Fig. 2).

4.1 Old town area houses' design examination

Traditional Arab cities are characterized by their organic spatial patterns with minimal open spaces and highly dense housing arrangements [24]. Subsequently, Mirbat's old town exhibits an organic, non-geometric and spontaneous scheme, with unordered arrangements of districts around the city centre comprising the castle, mosque and marketplace. The urban pattern, which follows the topography, is also organic, with irregular curved streets of varying lengths and widths. The area's traditional residences, built around one hundred years ago, are grouped together to form family residential quarters. The family quarter comprises several attached houses of different size and height built along the irregular, narrow dirt streets. Despite their different size, height and ownership, all residences bear common distinctive characteristics dictated by defensive city requirements, climate and inhabitants' lifestyles (Figs. 2 and 3) [4].

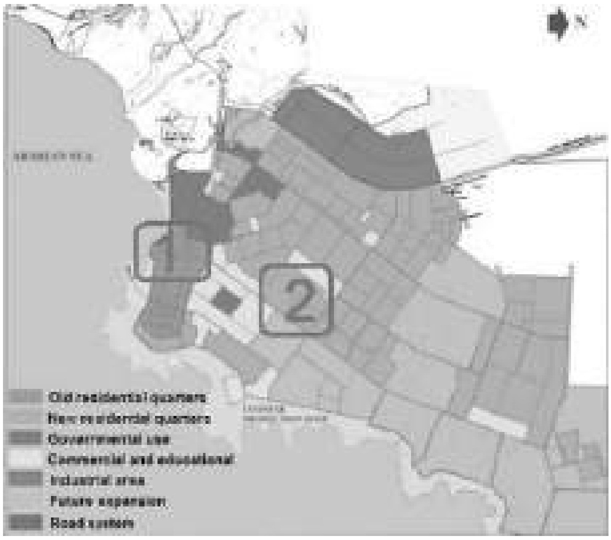

Figure 2: The two areas of Mirbat, featuring old (1) and new quarters (2), wherein the old area accommodates the old quarters with typical traditional and modern houses, while the new quarter accommodate newly designed residences.

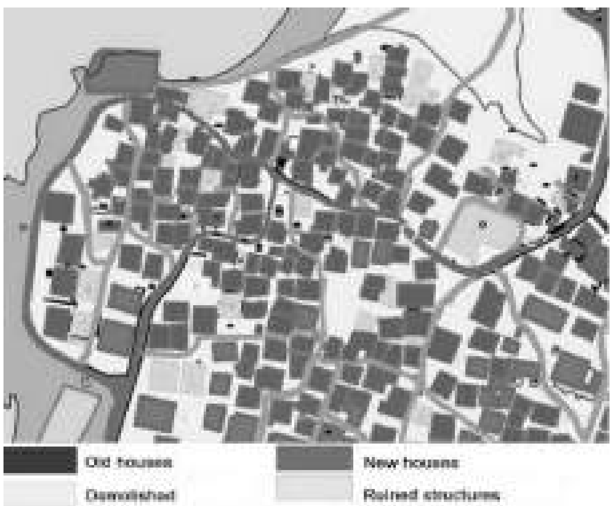

Figure 3: Mirbat old town's map.

The typical traditional Mirbati house is a medium-sized, two-storey building with a ground floor (bakhkhar), first floor (gharfat) and roof terrace (rawshan). The houses' sandy-coloured façades (finished with limestone plaster (norah)) are characterized by asymmetry, absence of projections, minimal decorative elements, flat roofs, high parapets crowned with stepped merlons (mijmara), protruding roof drains made of palm tree trunks, and roof spouts. Stone benches line the perimeter. The beautifully carved wooden windows, which are mainly located on the upper level, are composed of two units: the outer fixed screen, and a segmented inner shutter. Each house contains a minimum of two types of doors (all wooden and richly carved): a large outer double door, and a smaller inner one. The doors are equipped with massive locks inside locks and one outside lock (Fig. 4) [4].

Figure 4: Typical traditional house located in the old town of Mirbat.

The houses' interior spaces are screened by a gallery that lines the inner courtyard, which maintains the privacy within the house. Both ground- and first-floor layouts observe a strict division of public, semi-private and private spaces. The ground floor encompasses a large room used as reception hall for male visitors only (majlees), and includes a segregated entrance, entrance hall with living room (sallah), multipurpose rooms (dahrizes), kitchen and storage. Sallah is usually used for family gathering, dinning and celebrations, while Dahriz is used for sleeping and as private living area for family members, though could be used by house visitors as well. On the upper level, there are more dahrizes, a roof terrace and a walled open-air toilet situated above the storage room. The interior spaces are lit and ventilated via courtyard-facing openings [4].

4.2 New town area houses' design examination

Mirbat's newest districts are arranged in a grid, with blocks of houses located along streets of regular length. Because the government allocates plots of land (usually 600 m^2, except of those at the edge of the quarter – 700 m^2) to inhabitants for house construction, residential blocks are of identical size, though might differ by shape (Fig. 5(a)) [25].

The modern Mirbati house is a generally medium-to-large, generally two-to-three-storey residence with an adjacent (or no) courtyard. The inner spaces are situated around a large interior sallah accessed through the adjacent entrance hall. The majlees, which is usually situated on the ground floor next to the main entrance, might have either a segregated or a shared access with the entrance hall. Beside the majlees and sallah, the ground floor also contains dahrizes, the kitchen and bathrooms. Family bedrooms are mainly located on upper floors, and the flat roof is used as terrace. Interior spaces are mainly lit through single-glazed windows located on the house's exterior walls (Fig. 5(b)).

(a) (b)

Figure 5: (a) Mirbat new town's quarters; and (b) Modern house situated in a new district of Mirbat town.

4.3 Privacy comparison between traditional and modern residences' design

This section evaluates Mirbat's traditional and modern houses in terms of privacy, particularly with regard to those features initially designed for safety provision, such as block type and layout, façade height and type, spatial and courtyard layout, window/door types and locations, and roof parapets, etc.

A comparison of the two Mirbati housing types indicates that both traditional and modern houses evince a strict spatial hierarchy (public, semiprivate and private) dictated by cultural concerns. However, most traditional house features generally facilitate privacy, while only some of modern house features accomplish the same.

In the old quarters, residential blocks are located randomly, and houses share walls or are positioned very close together. However, building heights are regular, which restricts the view from neighbouring houses to the inner courtyard and roof terrace, the latter of which is safeguarded by a high parapet. Each house's main street-facing façade accommodates rare upper-level windows; other walls are either shared or left blank. All windows (even those facing the courtyard) are screened from the out-side and shuttered from the inside. Multiple doors provide direct access to public spaces, and the entrance hall door, with its small opening, limits the view to the house's interior. Spaces located along the perimeter are accessed from the courtyard, which is protected by the house's walls. Such a layout permits multiple windows without compromising privacy requirements (Table 1).

In the new quarters, the residences are located at approximately similar distance to each other. While building heights are uniform, windows located on façades facing neigh-boring buildings allow observation of interior spaces. The windows (despite featuring reflective glass) are not screened and require thick curtains. The adjacent courtyard and balconies, when available, can be viewed from the upper floors of neighbouring residences. All of the modern house features listed above potentially compromise inhabitants' comfort and privacy (Table 1) and contradict local regulations (the architectural design of the building shall conform with the social norms of the Arab Muslim families in terms of the location of various parts of the residential unit such as windows, doors, screens, etc. for privacy provision) [25].

Table 1: Old and new houses' features relevance to the privacy provision.

Housing features	Old quarters		New quarters	
	Description	Privacy provision	Description	Privacy provision
Block types	Irregular, shared walls	Yes	Regular, closely located	No
Heights	1, 1.5, 2, 2.5	Yes	2, 3	Yes
Façades	Rare windows	Yes	Multiple windows	No
	High roof parapet	Yes	High roof parapet	Yes
	Roof spots	Yes	Unscreened balconies	No
Window types	Double: fixed outer screen; inner shutters	Yes	Unscreened	No
Window location	Street façade-upper level	Yes	Street façade-each floor	No
	Other façades-no, any	Yes	Other façades-each	
	Facing inner courtyard	Yes	floor	No
Door types	Main-with small opening	Yes	Without any opening	Yes
Door location	Multiple	Yes	Maximum two	No
Space types	Majlees, Entrance Hall, Sallah, Dahrizes, Kitchen, Store, Bath	Yes	Majlees, Entrance Hall, Sallah, Dahrizes, Kitchen, Store, Bath	Yes
Spaces layout	Around the courtyard	Yes	Around inner Sallah	No
Courtyard	Inner	Yes	Adjacent	No
Note: Yes – indicates that house feature facilitates inhabitants' privacy provision				

5 RESULTS

First survey conducted among the young generation of female residents asked the following questions: (1) Would you like to improve the privacy in your residence, (2) Are you using your courtyard, (3) If yes, are you afraid of, (4) Are you curtaining your windows, (5) If yes, are you afraid of, (6) Are you using your roof terrace, (7) if yes, are you afraid of, (8) are you using your house terraces, balconies and (9) If yes, are you afraid of (Fig. 6).

The results of the survey demonstrate that the modern residence does not fully satisfy the privacy desires of the inhabitants: 93% of respondents are not satisfied (1% – satisfied, 6% – are not sure about it) would like to have their residences improved (Chart 1). As shown by further results residences' privacy is largely maintained by the use of enclosed spaces and window curtains. The results of the second item show that only 27% (61% – no, 12 – sometimes) of respondents use the courtyard (Chart 2). The courtyard is exposed to the visitors (28%), neighbours (41%) and by-passers (41%) and the residents are afraid of being overlooked (Chart 3). Most respondents (79%) keep the windows curtained (13% – no, 8% – sometimes) because they are afraid of being observed by neighbours (64%) and passers-by (36%) (Charts 4 and 5). Additionally, the residents (66%) consider that the

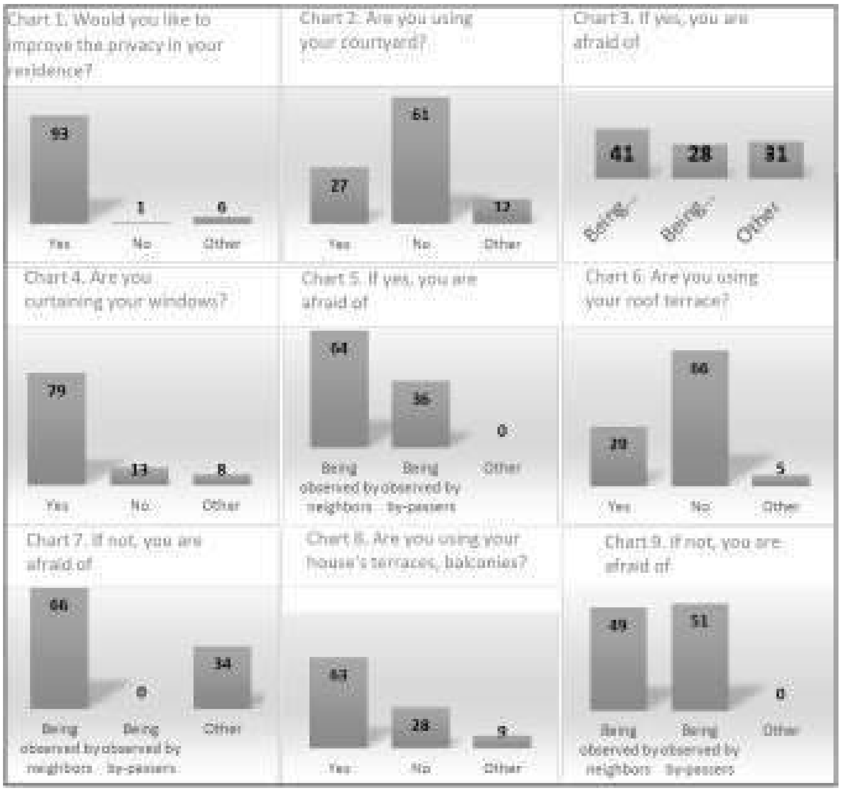

Figure 6: First survey, charts 1–9 demonstrate young female residents' satisfaction with residences' privacy.

neighbours overlook the roof terrace and, therefore, they are being observed (Charts 6 and 7). The balconies of the residences are used by 63% of the respondents (28% – no, 9% – sometimes), though 49% of them consider that they are overlooked by the neighbours and 51% by-passers (Charts 8 and 9) (Fig. 6).

The second survey considers the opinion of the elderly female residents. The results show that 100 households participated in this survey house 211 female residents of age group from 35 and above (35–45: 43 residents; 45–55: 92; 55 and above: 76) (Chart 1) and 184 of them are living in modern residences, while 27 in traditional houses (Chart 2). The third item is composed of four questions and studies the level of privacy of the modern residences and inhabitants' satisfaction (Charts 3a, 3b, 3c and 3d). These results show that 19 residents cannot use the courtyard without being overlooked,134 of them are using the courtyard, but wearing an abaya (a loose over-garment, a long black dress, wore by Muslim women, which covers her head and veils her face), 31 of them are not using the courtyard at all (Chart 3a). Chart 3b shows that 176 of the participants achieve privacy from being observed by the neighbours and by-passers via curtaining the windows and only eight feel secure without curtaining the windows. Chart 3c demonstrates that none of the residents can use the roof terrace without being over-looked, 66 of them are using the roof terrace wearing an abaya and 118 are not using the terrace at all. Most of the respondents (82) are not satisfied with the privacy level, 67 are partially satisfied and 35 considers that the house's spaces are private (Chart 3d). The forth item examines the privacy offered by the old residences and inhabitants' satisfaction with it. Similarly, to the third item, is composed of four questions: usage of the courtyard, windows curtaining, usage of the roof terrace and satisfaction with the residence's privacy.

The results show that all 27 female inhabitants of the old residences are using the courtyard without being afraid of being seen by the neighbours or/and by-passers (Chart 4a). Chart 4b shows that 20 (the majority) of the residents are not curtaining their windows (the windows face the courtyard and are not over-looked), four of them keep their windows closed and three of them have a different opinion. Chart 4c demonstrates that 18 of the residents consider the roof terrace private, five of them cannot use it without abaya and four residents are not using the terrace at all. Most of the residents (23) are satisfied with the privacy, only one is not satisfied and three consider that their residence partially satisfies their cultural demands for privacy (Chart 4d) (Fig. 7).

Both first and the second survey show that both young and elder generation of respondents are not satisfied with the privacy suggested by the modern house, therefore they cannot utilize the outdoor spaces and the indoor spaces' privacy is achieved through windows curtaining. On the other hand, a traditional house, as seen from the results, suggests higher degree of privacy to its inhabitants.

6 DISCUSSIONS AND CONCLUSIONS

In traditional Arab cities that are distinguished by their organic pattern, lack of open spaces and densely arranged housing units, the notion of privacy and hospitality has a significant influence on home culture and housing formation. This close relationship between culture, lifestyle and housing differentiates Islamic architecture from that of other cultures. Another distinguishing feature of Islamic architecture is the traditional courtyard community that is the customary residential form. Enclosed within the house's exterior walls and safeguarding the interior spaces, the courtyard extends the interior space, provides shade and protection against wind and sand and privacy to its inhabitants.

However, privacy concerns can limit designers' freedom and, therefore, contemporary architects often compromise it in favour of other principles such as aesthetics, modernism and construction cost. Furthermore, in private cultures such as in Arab Gulf countries, traditional houses built to adapt to the local natural habitat and to satisfy societal and cultural values are, for many (especially younger generations), are associated with limitations, hardship and a regressive past. The Arab city trying to catch up with the modernity, started losing that tight relationship between culture, lifestyle and housing and, subsequently, its uniqueness and the ability to meet its residents' cultural needs. As income and population continue to climb steadily in the Gulf countries, modern styled housing design, which values aesthetics, construction cost and modern technologies over cultural values, has become increasingly preferred over traditional architecture. As shown in Mirbat's case, the traditional courtyard house has been displaced by more modern structures. These structures are less able to offer subjective safety, which refers to the feeling of security (or, conversely, the absence of fear that cultural values are threatened). This research indicates that most modern houses in Mirbat use blinds or thick curtains to protect their privacy. Furthermore, the results of the surveys demonstrate that outdoor spaces are not used effectively because the inhabitants are afraid of being observed by neighbours or visitors, indoor and outdoor spaces cannot provide the inhabitants with their desired level of privacy, making them feeling insecure in their own homes.

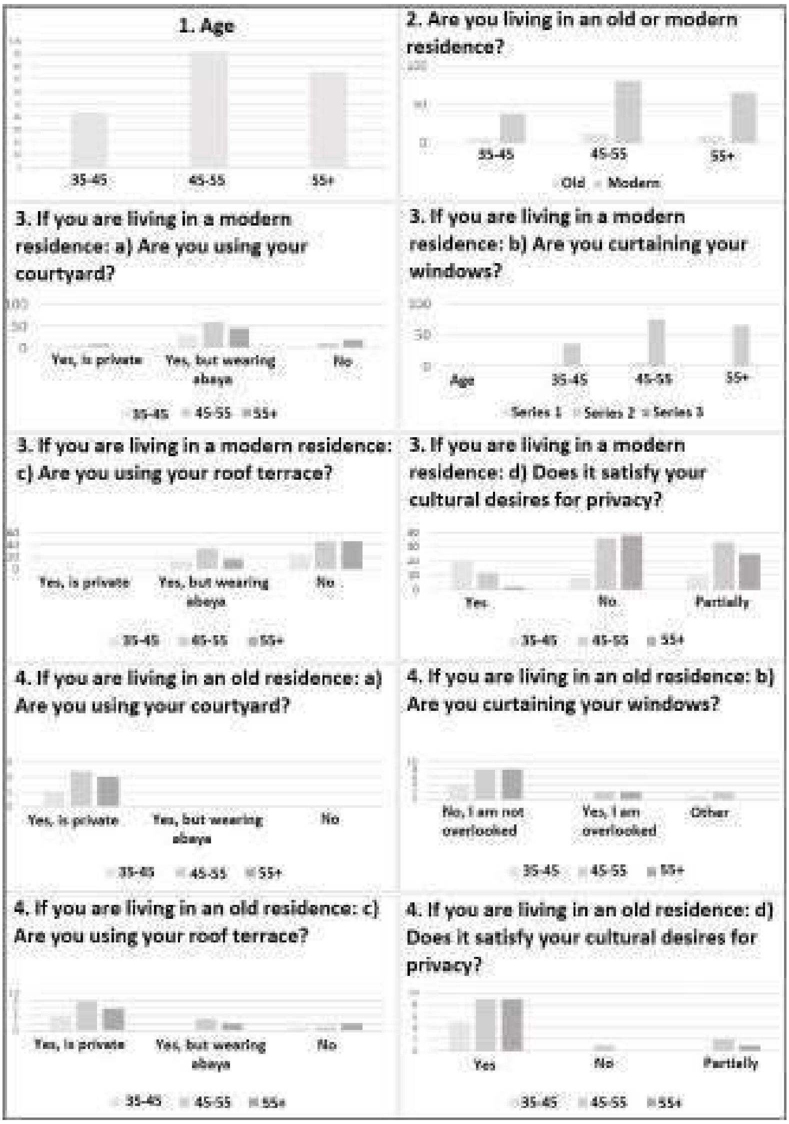

Figure 7: Second survey, charts 1–9 demonstrate elder generation female residents' satisfaction with residences' privacy.

This study's findings also support existing literature [26]–[30] in terms that for 'traditional house original cultural meaning preservation' a new design approach is required, which also incorporates innovations for comfort improvement while not compromising the privacy of the residents. Lessons learnt from traditional housing and residential satisfaction survey should be used for improving the performance of contemporary residences to maintain traditional housing private features but satisfies current needs of the residents. The results of this study show that by the employment of new construction materials and technologies, modern housing has eradicated limitations such as space and size, number of floors that existed in old traditional design and suggests comfortable conditions associated with a new style and a better life. However, while housing must certainly adapt to the rapidly changing society, contemporary designs, as seen from Mirbat's case, fails to capture private cultural traditions. Therefore, the survey conducted on modern residences' spatial use and residential satisfaction should be considered in housing design for private cultures and sets the base for further research that will take the next step of proposing a new experimental residential design.

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INFLUENCING FACTORS ON COOLING DEMAND OF HIGH-RISE BUILDINGS IN HOT/HUMID CLIMATES: A REVIEW

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ABSTRACT

A significant amount of energy is consumed on cooling buildings in countries that experience hot/humid climates. The increasing demand for high-rise buildings, with their inherent air conditioning systems, adds extra requirements to electricity grids or local district cooling systems. Thus, this work is structured to identify the influencing factors of cooling energy demand in high-rise buildings that are geographically restricted to countries of these climates. The influence of the factor is quantified as its contribution to cooling energy savings when manipulated or optimized. It is found that the average annual cooling reductions are 12%, 24.7%, 18.3%, and 20% with ranges of 3%–27%, 2.6%–60%, 5.6%–30%, and 11%–29% for building typology, envelope, system, and operation factors, respectively. Environmental factors lack quantification in the literature, although they are considered, however their effect is not quantified. In general, most studies considered building typology and building envelope factors which are related to building design, while few studies considered building operation and building system factors. The aforementioned factors and their importance lead to suggestions of conducting more studies on building operational and building system factors as they significantly contribute in cooling energy savings. Since Urban Heat Island (UHI) can cause a change of a city's microclimate which may double the cooling demand, it is listed as one of the essential environmental factors. This review has shown various aspects that are vital in studying building cooling load demand and its related energy performance.

Keywords: cooling load, building energy, high-rise building, humid climate, hot climate, building cooling, high-rise building energy, cooling demand, cooling influencing factors, energy demand.

1 INTRODUCTION

In areas of hot climates, up to 80% of the building electricity is consumed to run cooling systems [1]. For example, in 2016 in Qatar, the electricity consumption reached 85% of the country's capacity [2] and this increase is correlated to the high ambient temperature [3]. In 2015, Kahramaa [4] reported that air-conditioning and residential electrical appliances are the main two sources (representing 60%) of Qatar's high electricity consumption. This is frequently observed in other countries with extremely hot climates, with the highest annual per capita electricity consumption led by Qatar, followed by UAE, Kuwait, Bahrain, the KSA, Oman, and then the middle east, followed by the rest of the world [5]. The high energy consumption on space cooling also includes countries with humid climates, with an estimated 60% of electrical energy used for air-conditioning in Hong Kong, China, during the summer months [6] and up to 48% of the energy used for space cooling in Malaysia [7]. Another energy extensive factor that adds-up to cooling is building altitude. High-rise buildings contribute significantly to energy consumption in buildings which accounts for 40% of the total world energy use [8]. Radhi [9] found that the cooling requirements of a high-rise building is 22% more than a low-rise building at the same occupancy rates. Thus, high-rise buildings that are in hot/humid countries are energy extensive due to their cooling demand. The Council on Tall Buildings and Urban Habitat [10] showed the rapid increase in high-rise building construction through a timeline, considering the Middle East of which up to 98%

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are being constructed in countries classified under hot climates. Also, it reports the rapid urbanization of high-rise building in Shenzhen, China, which has a humid climate. This gives an idea about the severity of the problem when hot climatological areas worldwide acquire high-rise buildings urbanization.

Understanding the factors that influence the cooling energy consumption in high-rise buildings in countries with hot/humid climates is necessary to analyze how to reduce energy consumption. This literature review explores the studies that have addressed the cooling and energy performance of high-rise buildings in the hot/humid climate. It is structured as follows. In Section 2, the selection criterion of articles available in the literature is presented. In Section 3, the categories of influencing factors are presented and analyzed in detail. Then, conclusions are drawn in Section 4.

2 SELECTION CRITERIA OF LITERATURE

In this section, the criteria and basis of selecting the case studies are presented. While in the literature, many studies are assessed for cooling and energy requirements, not all are necessarily relevant due to the variation in the altitude (height) of the building, as well as the climatological conditions of where the building is located. This section describes the selection criteria of the literature used for this review and how they are determined. The first criterion is about climate. In this paper, only the literature focus on a study in a hot/humid climate is analyzed. Owing to the high possession and on-going requirement of high-rise buildings and their unique cooling load/energy performance, the second criterion is about building altitude. This paper will focus on high-rise buildings.

2.1 Hot/humid climates

To determine the areas of hot/humid climates around the world, the Köppen–Geiger climate classification is used [11]. A world map screening is conducted over the different climates according to universal standards, identifying seven climate descriptions according to the Köppen–Geiger world map classification code: Arid/desert Hot climate (BWh), Tropical Rainforest climate (Af), Tropical Monsoon climate (Am), Mediterranean Hot Summer climate (Csa), Humid Subtropical climate (Cfa), Dry-winter Humid Subtropical climate (Cwa), and Hot-summer Continental Climate (Dwa)

2.2 High-rise buildings distribution

The selection of the countries based on climate consideration only is not sufficient since all land is not urbanized. For example, Australia exhibits a wide geographical area that experiences BWh climate. However, this area is a desert that is not subjected to urbanization. Besides the climatic classification, urbanization with high-rise buildings is taken as another criterion. Hereby, a definition of a high-rise building is set according to Knoke [12] which gives a range of 23–30 m of the available fire-fighting equipment altitude as a measure to define a high-rise building. Cities with high-rise buildings in countries that experience BWh climate are identified to be those with up to 970 of 150+ m buildings, along with considering cities that are extremely humid such as Hong Kong (Cfa climate with up to 364 of 150+ m buildings), Shenzhen (Cfa climate with up to 394 of 150+ m buildings) and Kuala Lumpur (Af climate with up to 122 of 150+ m buildings) [13].

3 CASE STUDIES OF HIGH-RISE BUILDINGS AT HOT/HUMID CLIMATE

This section is structured to focus on analyzing and identifying the influencing factors on cooling loads and energy consumption of studies identified to meet the criteria of considering high-rise buildings in hot/humid climates. As shown in Fig. 1, the main categories of factors can be summarized as building typology, building envelopes, building systems, building operation factors, and climatological factors. The significance of each factor influencing the cooling loads in each study is reflected in the factor order. The influence of the factor is quantified as its contribution to cooling energy savings when manipulated.

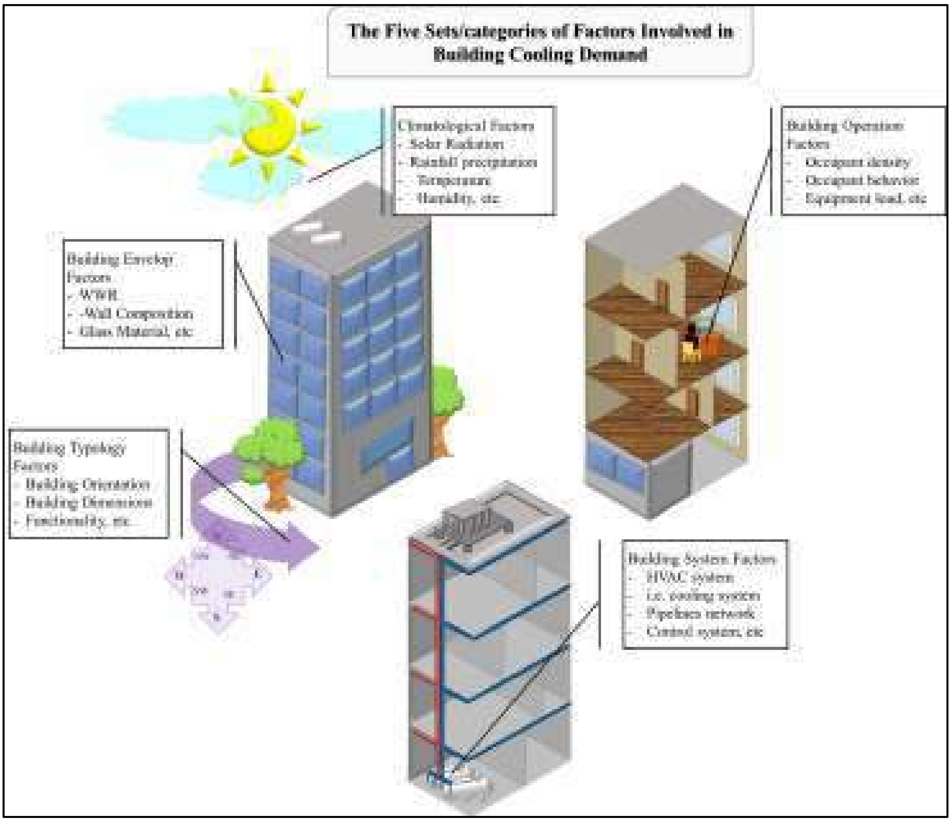

Figure 1: The five categories of factors involved in high-rise buildings cooling demand used in this review.

3.1 Building typology factors

Examples of building typology factors are the total floor area, floor height, shape, orientation, aspect ratio, shading (can be a building envelope factor upon relevance), building function, etc. Building shape is one factor that is analyzed by AlAnzi et al. [13] who found that window to wall ratio (WWR), which is the ratio of the surface areas of the windows to the wall of a given building, is independent of building shape at 0% and 50%. Also, the relative compactness (RC) of the building, which is defined as the ratio of the building volume to its surface area, is found to be inversely proportional to its cooling load for all buildings' shapes where a decrease in RC from 0.99 to 0.17 increases cooling energy to 115% and 90% building energy. Also, Ourghi et al. [14] found that cooling loads and total energy decrease with the increase in building RC, WWR, SHGC. Friess and Rakhshanb [15] concluded that better performances are recorded by the square compact buildings relative to elongated ones. Window to Floor area ratio (WFR) is another shape-related factor that is addressed in several studies which can be defined as the ratio of the surface areas of windows to floor of a given building. Cheung et al. [16] verified the effect of increasing WFR from 10% to 40%, showing 12.8% and 10.4% reductions in annual and peak cooling loads, respectively. Also, both loads showed a linear increase with WFR, i.e., a 1.3% increase in annual cooling load is found for every 10% increment increase in WFR. Raji et al. [17] showed that when using Y plan shape instead of ellipse plan shape, the total energy consumption can increase by 15.7% and 12.8 in Cfa and Af, respectively. For the plan depth, its impact is less significant in Cfa (around 6% increase in total energy consumption), while for Af, its impact can increase to 8.8%, and the suggested depth is from 1:1 to 3:1. It is also concluded that, for the factor of building orientation, its impact on energy consumption has no particular significance among the different climates. Krem et al. [18] found that the position of the vertical structural core/wall, the aspect ratio, and shape of the floor plan (central, edge, half sides, and sides) represent significant impacts. The factors presented in the previous two studies belong to building typology and envelope parameters, showing that these two categories are dependents in influencing the cooling loads.

Shading and orientation are two other factors that affect the cooling loads in building, as they help in controlling the amount of solar irradiation received by the buildings. Cheung et al. [16] found that the wing wall can reduce up to 4.6% and 4.9% of the annual and peak cooling loads, respectively, and the overhang can reduce up to 2.9% and 3.2% of the annual and peak cooling loads, respectively. Friess and Rakhshanb [15] indicated that delicate attention should be given to the length to width ratio, orientation, and shadings of the buildings in verifying energy requirements for buildings. A peak reduction of up to 9% can be accomplished if overhangs are applied at 1 m depth. Sozer et al. [19] showed how the design parameters, orientation, elements might significantly impact the cooling loads. It is shown that a 38% reduction of cooling loads can be achieved by reducing the WWR, with the reduction reaching up to 57% if made in conjunction with caving and backyards and applying shadings by cables.

Lau et al. [20] found the best performance is by applying the egg-crate type with savings up to 3.4%, followed by vertical and then horizontal shadings. Savings up to 10% are achieved when shadings are applied on all orientations. However, they recommended to apply shading specifically at west and east façades. Building orientation is also addressed by Naamandadin et al. [21] who found that the east and west orientations receive the highest sun intensity that cause high cooling energy consumption using office building located in Malaysia as a case study. Also, Aflaki et al. [22] confirmed that indoor air temperature and relative humidity were influenced by orientation and height through a field study. Chan and Chow [23] investigated the effect of balcony addition at several orientations, finding that a balcony can reduce the annual cooling load by 12% when it faces the southwest, while only 3.4% reduction when it faces the north. The significant effect of building orientation on cooling energy is further confirmed by the study of Du and Pan [24] who verified the building orientation impact on cooling loads at same floor (building height/level), finding a difference of 10% of cooling loads among the two flats of different orientations. Other studies reported savings in cooling loads by considering the building orientation as a stand-alone factor, finding that up to 6.7% can be reduced from the annual cost when the building is reoriented [25]–[27]. Also, building orientation is highlighted in building envelope-based studies. Tibi and Mokhtar [28] highlighted the importance of considering the building orientation while selecting the building glass characteristics. Although building orientation is widely addressed in building energy studies, it shows limited contribution to cooling energy reduction which was the conclusion reported by other studies [29], [30]. As for building functionality factor, Tibi and Mokhtar [31] showed that commercial building requires a higher cooling load when compared on equal bases.

As for building altitude, this is also addressed. Radhi [9] found that the high-rise building requires almost 22% more cooling than the low-rise building when compared at the same occupancy levels. Bruelisauer et al. [32] noticed a significant impact of building altitude on the stack effect, which could increase the temperature by up to 13 with increasing building altitude. Weerasuriya et al. [33] found that the apartments that are located near the windward side of higher floors have higher energy saving up to 23% relative to the apartments in the middle and lower floors. This conclusion is also confirmed by Du and Pan [24], who considered a number of flats at floors 3 and 39, finding that at higher floors, cooling loads reduce up to 12% due to climatic factors, i.e., wind speed. Also, Du et al. [34] found that electricity bills of apartments on 20th floor and higher are up to 26% lower than those of lower floors due to the different usage of air-conditioning and natural ventilation, i.e., opening windows.

3.2 Building system factors

The building system involves parameters that directly impact the cooling requirements in the building since they involve the cooling system. Parameters of building systems include Heating, Ventilation, and Air Conditioning (HVAC) system, component efficiency, control settings, lighting fixtures, daylight control, etc.

Radhi [9] found that the HVAC system is the most significant energy consumer in the building. Afshari et al. [40] found that the elements that are responsible for satisfying cooling requirements are chillers, pumps, and fans which acquire 47%, 7%, and 7% of total electricity consumption, respectively, leaving cooling requirements with a total of 61% among energy consumption in the building. Deng et al. [41] showed that chilled water system can achieve up to 35% savings with 29% better energy performance by applying systematic optimization of operational and control factors of cooling system and device design selection factors. Sun et al. [42] found that up to 6.6% can be reduced of chiller energy consumption. By altering operational strategies, a difference in the peak cooling loads can reach up to 21%, showing the significant effect of operational factors on cooling loads in high-rise buildings. Attia et al. [43] concluded that the air-conditioning is the main energy consumer for the cooling demand in buildings. The significant contribution of the HVAC system has motivated some studies to develop solutions. Assem and AI-Mumin [44] noted that the heat recovery of the HVAC system during the hot seasons can reduce the cooling requirements by 15% and 18% for water- and air-cooled systems respectively. Shaikh and Chaudhry [45] conducted a numerical investigation of the cooling system performance of a high-rise building in the UAE. The involved cooling system is based on the vapor-compression cycle with the refrigeration system. By the use of a variable speed drive (VSD) fan, which is a type of fans that is designed to slow down or speed up upon necessary, a reduction of 20% in cooling loads is achieved, and an 8% reduction in the overall building energy requirements. The variable refrigerant flow principle is applied to result in a roughly 30% reduction in cooling requirements. The study recommends that a high-rise building that is present in a BWh climate should use a hybrid cooling system to promote energy savings.

3.3 Building envelope factors

In this section, the studies that considered energy performance measures concerning building envelope parameters and building physical characteristics are reviewed. Cleveland and Morris [51] defined building envelope as the layer that physically separates the indoor and outdoor environmental conditions such as air, moisture, heat, light, etc.

Glass-related characteristics such as type, SHGC, WWR, U-Value, spacing manner, etc., contribute greatly in building energy consumption on cooling due to high solar gains [35], [36]. Hassan and Al-Ashwal [37] showed that the lower the shading coefficient value, the lower the cooling energy consumption and peak load. Double Low-E glass can perform best with the cooling energy reduction of 19% and peak cooling reduction of 30%. While using single tinted glass can decrease the cooling energy and peak cooling by 9.5% and 10.0%. On the other hand, it is worth mentioning that reducing this value also reduces the saving related to lighting energy [38]. As shown in savings, up to 30% can be achieved in peak cooling in a tropical climate (Malaysia, Af climate). Cheung et al. [16] identified several glazing systems of which up to 4.6% and 4.9% of annual and peak cooling loads can be reduced, respectively. For the same climate, Bojic et al. [25], [26], and Bojic and Yik [27] studied several aspects of glazing types under the influence of solar absorptance and orientation, finding that up to 10% and 11% can be reduced from annual and peak cooling loads, respectively. Chan and Chow [23] varied the glazing type in their study, namely, clear glass, absorptance glass, and reflective glass. The results show that the clear glass shows the best performance in terms of reducing annual cooling load with 12% followed by the reflective glass of 8% with a southwest facing balcony. Since the performance of the same glass type would be different when coupled with different orientation balcony, this study further confirms various influencing factors should be considered together to attain the best energy saving performance. Cheung et al. [16] showed that as solar absorptance increase the cooling loads decrease after a value of 0.5. Wall insulation has a direct effect on building temperature as the insulation layer can be used to control the building heat transferee via building envelope [39]. Al-Tamimi [29] and Al-Tamimi and Fadzil [30] presented the effect of using Extruded Polystyrene (EPS) in thermal insulated wall on annual and peak cooling loads. They studied the effect of increasing the thickness of the EPS thermal insulation on annual and peak cooling loads reductions, showing reduction at ranges of 8.4% to 10.0% and 20.2% to 26.3%, respectively. Hassan and Al-Ashwal [37] reported that as the insulation thickness increases, the annual cooling reduces. Up to 18% in annual cooling reduction is achieved by increasing the thickness of the 25 mm thermal insulation of the external wall by the double. Also, a reduction in peak cooling of 22% is encountered at 25 mm that can reach up to 29% when increased to 100 mm. Cheung et al. [16] tested insulation at several thicknesses ranging from 0 mm to 100 mm and found that the maximum reductions achieved are 19.4% and 29.2% for annual and peak cooling loads, respectively, when 100 mm insulation is applied. Bojic et al. [25], [26] and Bojic and Yik [27] studied the effect of the several positions which showed reductions in annual and peak cooling load of 38% and 16% respectively. On the other hand, it showed increase in peak cooling load of 19% of other case, depending on the layers and position of insulation layers on the walls. WWR is another building envelope factor that is widely addressed in literature due to its overwhelming influence on cooling loads. Sozer et al. [19] indicated that reducing WWR resulted in a 38% reduction in cooling loads. Afshari et al. [40] showed a minor difference in peak load percentage reduction of 4.2% and 3.6%, respectively. By comparing these results to the conclusion of the data presented by Tibi and Mokhtar [28], it can be concluded that the lower the SHGC and U-values, the more cooling reduction is obtained.

3.4 Building operation factors

One of the key parts for improving building performance and for reducing energy consumption is building operations [46]. It includes parameters that directly impact building energy consumption. Parameters of building operation involve schedules, plug and process loads, lighting densities, ventilation needs, occupancy details such as number, ages, etc. Among building operation parameters, the occupant's behavior aspect is presented by Friess and Rakhshanb [15] for a high-rise building, reporting a reduction in cooling loads up to 29% when the temperature set point is increased by occupants from 22°C to 26°C. This shows the significant role that the temperature setpoint plays.

Natural ventilation is a factor that is controlled by the occupant behavior which affects the cooling loads and consequently total energy consumption. The use of balcony, opening windows in a high-rise residential building as presented by Weerasuriya et al. [33] in Hong Kong (Cfa climate) reveals that up to 27% energy savings can be achieved when wind-driven natural ventilation is used. The authors also reported higher savings that can reach 45% if the wind and buoyancy-driven natural ventilation are facilitated. Unlike the wind-driven ventilation that is recommended for apartments at higher floors, the wind and buoyancy-driven natural ventilation is recommended to occupants who occupy the middle and lower floors. Du and Pan [24] studied the effect of windows' operation on cooling load and found that ventilation that is controlled by occupant behavior is found to have a large impact on cooling loads, with reductions in energy consumption reaching around 11%. This aspect is addressed in humid climates more than in hot climates which is reasonable since one or two seasons of the year are of acceptable weather that allows natural ventilation such as region of BWh climates.

3.5 Environmental factors

The climatological and weather data are vital in determining the building energy efficiency [40], and the cooling energy requirements [47]. They represent the main inputs for simulation, especially for high-rise buildings in BWh climate [19]. Examples of climatological elements are temperature (including dry- and wet-bulb temperatures), humidity and relative humidity, wind speed, wind direction, pressure, rainfall, etc. Afshari et al. [40] found that temperature and relative humidity together are sufficient to represent the BWh climate.

Urban Heat Island (UHI) is a terminology refers to the urban/metropolitan area that is significantly warmer than its surrounding rural areas that is mainly caused due to human activities such as urbanization, affecting back the building's thermal performance. Radhi [9] reported up to 5°C increase in ambient temperature due to UHI effect when examined at arid/desert hot conditions. Palme et al. [48] found that high-rise buildings, for all urban cases, acquire more than double amount of cooling demand, showing that the effect of the building height is dominant over the rural area or different urban layout. Lima et al. [49] concluded that, in a hot climate region, a decrease of direct solar radiation reduces the energy consumption, while the UHI (increase in temperature) increases it. They found that up to 18% in cooling energy reduction is detected mainly due to shading induced by the geometry of the surrounding buildings. Radhi and Sharples [50] reported an increase in consumption of air-conditioning electricity up to 10%, particularly from April to October (summer season).

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Giridharan et al. [6] showed that reduction of UHI intensity during daytime can be achieved by increasing the tree cover from the range of 25% to 40%.

4 CONCLUSION

This literature review identified the factors that influence cooling loads of high-rise buildings in the hot/humid climates around the world. The influence of the factor is quantified as its contribution to cooling energy savings when manipulated or optimized. These identified factors can comprehensively assist researchers and engineers to slow down the increase of extensive energy consumption records on the cooling of this specific type of buildings. A selection criterion for both climate and building altitude were defined according to Köppen–Geiger climate classification and buildings above 23 m. Then, the categories of factors were defined and classified under five categories: environmental related data, building typology, building envelope, building system, and building operation data sets.

In this review up to 90 articles are reviewed. All of them focus on studying parameters that influence cooling demand of high-rise buildings at hot/humid climates. Only 30% of these studies quantified the effect of the studied parameter. It is found that the average annual cooling reductions are 12%, 24.7%, 18.3%, and 20% with ranges of 3–27, 2.6–60, 5.6–30, and 11–29 for building typology, envelope, system, and operation factors. However, most studies considered building typology and building envelope factors which are related to building design. while few studies considered building operation and building system factors.

Based on the literature review, the conclusion is drawn that there is a serious requirement in conducting more studies that investigate the effect of building operation and system factors. The building operation and system building factors are found to contribute greatly to cooling energy savings, however, they are found to be understudied; only a few studies consider them. Building operation factors maybe further investigated by conducting on-site surveys and questionnaires since occupant behavior is found to have a dominating effect. Building system factors can be investigated by developing optimization analysis for the cooling systems used or investigate new systems.

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RE-ENVISIONING INFRASTRUCTURES, RE-ARMING SUSTAINABLE (UNCONVENTIONAL) PUBLIC SPACES: FREE DESIGN EXERCISES FOR FURTHER IMPROVEMENT OF THE URBAN REGENERATION PROJECT FOR THE FERROCARRIL DE CUERNAVACA DISTRICT OF MEXICO CITY, MEXICO

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ABSTRACT

This study focuses on those new (unconventional) public spaces generated through the existing urban infrastructures transforming interventions. The case study is the regeneration of the urban district of Mexico City crossed by a local railway line, the Ferrocarril de Cuernavaca, still partially in use. After an international competition, the entire area has been recently transformed, basing on the urban regeneration "Bosque Urban Ferrocarril del Cuernavaca" project made up by the Gaeta Springall Arquitectos Office. This project can be shown as a "model", as a good design practice to develop new "third places of density", capable of managing the existing urban conditions complexity and generating new urban qualities, new liveable spaces: innovative public spaces are generated along a linear park of 4.5 km which crosses 22 different neighbourhoods with different social, economic and spatial conditions; new urban functions, formal/informal hybrid forms of living/using the city (or its parts) are settled or simply suggested. It follows "common" design topics of various interventions able to increase social, economic and spatial values and to completely change the existing urban condition by adding space, in-filling life. Following a case study approach, this study reports the results of a joint workshop, conducted by the "Laboratori Metropolitani" research group of the IUAV University of Venice and by professors and students of the Ibero-Americana University. Three projects, set up during the workshop and completed in three Master's degree theses in architecture, will be shown and described; necessary multidisciplinary approaches, core issues and design topics will be highlighted to characterize and to increase dialogues between academia and professional practice; to show different possible ways to use free design exercises (especially those developed through workshops and seminars) as useful tools to address shared reflections for further urban projects developments and to imagine other possible interventions to improve urban quality life.
Keywords: infrastructure, public space, collective realm, regeneration projects, liveable places.

1 INTRODUCTION

This study focuses on those public spaces, often unconventional, which are generated as a result of the transformation of existing urban infrastructures.

Their transformation results from simply necessary technical and technological adaptations or more comprehensive changes in their spatial settings or characteristics. It becomes more often an opportunity to trigger regeneration actions of whole (more or less extended) urban districts. The results, in terms of quality liveable spaces, are completely comparable in several cases, attested in different urban contexts and in equally different parts of the world. Regenerating urban infrastructures becomes an opportunity to widen the provision of public spaces and to make neglected or dismissed or traffic dominated areas more accessible.

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Several architectural and urban design projects, descending from common general principles and recurring guidelines, can be considered as “models”: they report different ways for managing the existing urban condition due to generate new urban qualities. Generating innovative (more often unconventional) public spaces, in-filling new urban functions and mixed uses, overpassing zoning, introducing or simply suggesting formal/informal hybrid forms of living/using the city (or its parts), transforming the existing urban infrastructures by reacquiring them to the public realm can be indicated as “common” design topics. Resetting urban fabrics, redesigning places, recharging their characters and values can be considered as starting points, shared tools of different regeneration projects, with strong strategical values and figurative features: a “Common ground”, by which, several contemporary metropolises are undertaking innovative policies and design features to rethink their existing conditions. In several cases – even if with situational differences – re-envisioning urban infrastructures and, contemporarily, generating or rearming the system of public spaces become opportunities, primary occasions to improve liveability.

Cities are expanding their dimensions or, at the same time and more frequently, are transforming entire internal parts (e.g. Jacobs [1]). High-impact interventions are rethinking and redesigning the built city “per parts”, placing themselves in between the existing urban fabric: new policies and new design processes are being developed, activated and implemented to transform places, change their characters, increase their values; highly relevant projects are directly linked to the system of public spaces and to the transformation of urban infrastructures; equally directly, the projects themselves are aimed at establishing significantly different conditions of integration between their specific domains (both infrastructural and public spaces).

In particular conditions of urban complexity – as can easily be imagined in the largest contemporary metropolises – several plans and programs are under activation. From these, equally various interventions are descending with recurring characteristics and common topics. Common design topics can be identified under the public spaces systems formations, renovations and developments issues; contemporarily, recurring design topics can be found under the infrastructural formations and transformations. In the same urban contexts, interventions on public spaces are concentrated and, in successfully cases, the same interventions are able to trigger positive dynamics of transformation affecting larger portions (compared to the real perimeters of the project areas) of the urban fabric.

Managing the system of existing public spaces and increasing themselves, with their different levels of variations and integrations with the rest of the built city, seem to be a common denominator and, likewise, the main vehicle for transforming and implementing urban qualities, living qualities. Similar conditions can be found in a series of interventions, more directly related to the urban infrastructures, aimed at minimizing their impacts and their roles as barriers, interruptions, etc. It seems, in other terms, that successfully interventions directly descend from more balanced and integrated approaches which simultaneously address characteristics, needs and claims of both public spaces and infrastructural systems (e.g. Aymonino et al. [2], Gehl [3], [4]).

2 COMMON DESIGN TOPICS, GESTURES AND OBJECTIVES IN TRANSFORMING CITIES, MANAGING COMPLEXITY

In several metropolitan cases, recurring interventions emerge, mostly supported by public initiatives. They mainly concern old and new expansion areas, the construction of new urban infrastructures and the regeneration of existing ones, and the provision of services. These interventions allow metropolitan areas, already overcrowded with population, to achieve new modulated densities and to establish new metrics for fluxes of people and goods (e.g. Berghauser Pont and Haupt [5]).

Urban regeneration policies become more complex: several programmes and projects derive from public policies following top-down approaches; various projects derive from more or less spontaneous place-use practices based on bottom-up approaches to urban regeneration issues. Following general principles and shared outputs, several projects are orienteered to qualify the public realm in its various forms. Liveable places are generated, lasting conditions of urban sustainability and inclusiveness are achieved through integrated interventions that restore balanced (and more or less direct or mediated) relationship between urban infrastructures and public space systems. In successfully cases, the identity matrices of places are restored, consolidated and valorised; positive spill-over effects are achieved on the same placed or on the surroundings areas.

Although the geographical contexts are different and the numerical and dimensional data of each metropolitan context are equally different, a sort of "common ground" can also be traced by observation recent regeneration processes. These are aimed at the transformation of the inner areas. The calibres of the interventions are comparable in terms of scalar dimensions, types of generated spaces and functions that can be settled. These are triggered and supported by the growth in the numbers of inhabitants, by changes in their composition, by the needs to improve the spatial qualities and to increase the provision of services and infrastructures (e.g. Sim [6]).

Possible alternative ways to promote, manage and control urban transformations are being defined; places of concentration of regeneration projects, types of projects to be developed, actions to be undertaken, scenarios of new urbanity to be pursued are already emerging. These new trends are the results of a sort of surrender and new life cycle of public actions in controlling urban transformations. In other words, public policies are coming to be more precise through the promotion of innovative urban design and planning projects, often modifying the contents and previsions of the more general instruments of control and management of urban transformations. (e.g. Caldarola [7]).

In the last decade, the "Laboratori Metropolitani" programme of the Iuav University of Venice has investigated several contemporary metropolises; various case studies have been defined; recurring topics have been recognised and evaluated through actions of research by design. Different cities – as i.e., Sao Paulo, Dar es Salaam, Seoul, New York, Santiago de Chile, Hong Kong, Mexico City, Moscow, Nanjing – have undertaken recent urban regeneration actions, directly related to the two main topics of re-envisioning urban infrastructure and rearming the existing public space systems. In all these metropolitan cases, possible new urban condition scenarios and new life cycles assessments are tested: cities become an experimental laboratory of primary importance (e.g. Caldarola [8]).

The comparison of the results of the analyses carried out on the case studies has made it possible to understand that the future urban structures must derive from the construction of new visions for their internal parts; the construction of new urbanity scenarios must start from those "central" peripheries that represent the most problematic (and, for this condition, most lively) parts of the urban fabric. Intervening on new possible balances of existing urban densities is not only related to numerical evaluations: their data (in terms of volumes, proportional ratios between built and unbuilt areas, presence of open spaces and endowment of services compared to the number of inhabitants, etc.) can become triggers to explicate unexpressed quantitative and qualitative potentials: this, if used as opportunities to reverse trends of misuse, lack of uses and users (e.g. Uytenhaak [9]). Unresolved or malfunctioning inner urban areas – due to their positional characteristics, their visibility and visitability, the amounts of transits and connective potentials – have the capacity to trigger virtuous processes, to generate models, to extend the perimeters beyond the real size of the project areas, to produce conditions that can be exported and applied to larger parts of the metropolitan areas.

Urban regeneration actions in some of the major contemporary metropolises are supported or triggered by innovative public policies and/or more spontaneous practices. Several projects are activated dealing with spaces of different nature, conditions and configurations. Urban regeneration projects that follow the more general principle/objective of qualification-implementation of public space go through gradual processes of densification and requalification of more or less central areas, characterised by conditions of abandonment or degradation and affected by phenomena of physical and social marginality (e.g. Koolhaas [10]).

Some of the world's metropolises show conditions that are not (at least not directly) comparable with the largest part of the European cities. Their size, the variety of transformations, the high-levels of physical-spatial and social inequalities, and the conditions of internal complexity make it almost impossible to imagine the formation of general plans or instruments for controlling and managing transformations. Forming complex urban design projects is more often preferred to the general plans assessment. Cities are more often transformed "per parts" (e.g. Caldarola [8]). Through urban projects, new life cycles are imagined for larger or smaller parts of cities. With this new central dimension, the urban project becomes an opportunity to define new cycles of public actions and allows cities to become a laboratory where "unconventional" interferences between different and evolving disciplinary areas can be addressed.

In the same contexts, urban projects are proposed following different plans and programmes, even conveying design competitions (as in the case study of Mexico City); the new urban projects concern spaces of different nature and configuration; although with different contextual variations, they descend from the more general principle/objective of qualification-implementation of public space; The new urban projects involve spaces of different kinds and configurations; although with different contextual variations, they derive from the more general principle/objective of qualification-implementation of public space. (e.g. Koolhaas [10]). Recurring topic of several projects is the implementation of urban public spaces. Addressing temporary or highly experimental and communicative interventions, possible solutions to local problems are explored. New public spaces are also generated with the direct involvement of citizens groups during the whole design process. Small-scale interventions are preferred as they allow to trigger virtuous regeneration dynamics on areas larger than those directly under transformation and to sustain effective long-term results (e.g. Lyndon and Garcia [11], Paans and Pasel [12]).

Through the actions of institutional research and of research by design promoted by the programme "Laboratori Metropolitani" of the IUAV University of Venice and conducted on case studies of contemporary metropolises, the aforementioned recurring dynamics have been verified and compared. Complex systems of mostly public and spontaneous actions with virtuous processes of urban regeneration have been inventoried and described. The research was also structured through educational programmes, in particular, through seminars and on-site workshops. These were activated to accompany the institutional actions with free design exercises that allowed to experiment integrated, multidisciplinary and multi-sectoral approaches and to generate multi-scalar scenarios. Recurring project topics concern the regeneration of abandoned or partially dismissed areas, characterised by low levels of use or spontaneous practices of inhabiting places, delimited by infrastructures that generate barrier-effects or by incongruous elements if compared to the pre-existing urban fabric and road networks. The interventions mainly focus on those spaces commonly defined as "Neglected spaces", "Lost spaces", "24 hours spaces", "Invaded spaces", "Exclusionary spaces", "Consumption spaces", "Privatized spaces", "Specialized or Technical spaces" (e.g. Koolhass [10]). Projects for their recycling and reuse become opportunities to imagine new uses and chapters of life (e.g. Marini and Corbellini [13]).New public policies of urban regeneration are under activation with top-down approaches; new spontaneous practices of appropriation (or reappropriation) and reuse of different places are emerging by bottom-up approaches and initiatives. Various renovation areas have been already transformed or have been identified as "resources", "starting point" for more complex developments; this, especially for achieving the more general objective of making the cities in themselves more liveable and sustainable

Ways of living and using places are becoming central design themes as well as the direct involvement of citizens in the conception and design processes. Alternative urban scenarios are being produced to explore alternative possibilities and to establish different conditions (e.g. Schenk [14]). Specific policies and projects are under development to identify and avoid (or, at least, minimise) the impacts of all those elements that can act as barriers, limits, preclusions due to generate new urban conditions of continuity and connection in those places, currently characterised by discontinuity, physical and social marginality, misuse, etc (e.g. Berghauser Pont and Haupt [5]). New squares, boulevards and green areas are being generated to increase the number of places for staying and gathering (e.g. Gehl and Svarre [15]). These interventions change the character of those places which can only be considered as transitional ones. New revitalised networks of covered and open-air streets and passageways are being created to make those places more recognisable as suitable for outdoor living (e.g. Colville-Andersen [16], Sadik-Kahn and Solomonow [17]). Public transport is being managed and cycling and pedestrian accessibility is being improved. New integrated programmes of materials and street furniture are improving the recognisability of places. Urban spaces are becoming greener. Liveable places are being generated and their liveability in itself becomes more often the principal indicator of the quality of design (e.g. Stipa [18]).

3 AN INTRODUCTORY LECTURE OF THE STUDY CASE OF THE FERROCARRIL DE CUERNAVACA DISTRICT REGENERATION PROJECT IN CDMX: FROM A RAILWAY LINE TO A LINEAR PARK

Mexico City is remarkable as a highly relevant case study, compared to the other cities investigated by the "Laboratori Metropolitani" program.

The entire metropolitan area presents complex and alternative urban conditions, comparable to the other metropolitan cases in terms of quantities and qualities of the numbers of inhabitants, population, areas undergoing transformation, public policies and private initiatives with more or less significant effects on the urban fabrics. Because of these specific conditions, some of the transformations attested in Mexico City can be indicated not only as case studies. They can also be identified as good practices of design and implementation.

Particularly significant in the ongoing debate on the transformability of the city, on the urban regeneration issues, on new buildings and construction and on urban transformations is what is being built along the extension of the Ferrocarril de Cuernavaca.

The regeneration interventions of the urban district of Mexico City, crossed by a local railway line, are central in terms of location. They are highly significant for the positive impacts both in physical transformation of the involved urban spaces and in practices of use of the places: This is the urban district, composed of 22 different neighbourhoods, characterised by the presence of the Ferrocarril de Cuernavaca railway line. The reactivation and regeneration of residual urban spaces, including those corresponding to partially or totally dismissed railway tracks, is a widespread strategic effort. It is recurrent in various actions aimed at reopen to the public use dismissed parts of cities or those suffering from spatial and social marginalisation. The Ferrocarril de Cuernavaca area was transformed into a linear park on the basis of the transformation previsions of an international competition by invitation, open to groups of urban designers, architects and landscape architects. The overall objective of the competition was to transform the infrastructure site and its surroundings into a dynamic public space. The participants in the competition were asked to develop projects that would enhance the historical features of the site, meet the demand for green spaces, recreational and relational places, by identifying innovative proposals for the renovation of the railway infrastructure. A linear public space had to be the result, where the landscape intervention had to become an opportunity to improve the soil permeability and to provide the area with a technical infrastructure for a sustainable water management. In the competition announcement, the main targets were oriented towards the sustainability of the interventions, the adoption of multi-scalar design solutions, the introduction of mixed uses, the integration with urban stakeholders and social inclusiveness.

Based on the objectives of the international competition (2016), the entire area was transformed, following the urban regeneration project "Bosque urban Ferrocarril de Cuernavaca" which was established, under public promotion, by the Gaeta-Springall Arquitectos Office (Fig. 1). The project pursues approaches that can be adapted as "common" to various interventions, capable of increasing social, economic and spatial values and completely changing existing urban conditions by adding spaces, bringing life to places.

Figure 1: First section of the "Bosque Urban Ferrocarril de Cuernavaca" project.

The partially dismissed local railway track is the real marker of the whole district. It is a linear infrastructure, characterised by low levels of use, which crosses several neighbourhoods, significantly different in terms of social composition and urban conditions. Along the railroad, a linear park – the "Bosque Urbano Ferrocarril de Cuernavaca" project – is progressively giving back to the city an infrastructural space that, until the beginning of the regeneration interventions, was privatised and affected by different, spontaneous and uncontrolled uses by the citizens. By mixing design processes with direct participative programs for the population, the formation of the linear public space Bosque Urbano FLCC, alongside the infrastructure, became the main opportunity to develop an urban quality project in Mexico city. The project proposal aimed to generate a linear park as a 4.5 km long urban forest; to cross over 22 different neighbourhoods (different in terms of social, economic and spatial conditions and values); to build a civic, democratic, active, programmatic, inclusive, sustainable, connecting space; to create a continuous space, easily readable and recognisable space, which is identity-based and capable of contributing to contribute to the community spirit; and to enhance the senses and practices of appropriation of public space by inhabitants and external users.

Starting from the closing of the competition (2016) and within the first year, the first 1.4 km section of the whole intervention extension (4.5 km) was completely realised and opened to the public. The executive project was developed interacting with different governmental stakeholders and by socialising and evaluating the overall strategy and specific design issues with the inhabitants and with the neighbourhood groups, each of whom operate in the same places and have a strong sense of ownership and belonging. In its totality and within the construction made by three different and subsequent phases, the project has generated a linear urban forest of 4.5 km in length. It has generated significantly different urban conditions; it has generated a new system of interconnected public spaces, each one directly located along the linear element of the railway line; it has added values to strengthen the sense of community, the sense of belonging. The project has more over contributed to the growth and transformation of the extended urban district; it has generated a new and necessarily balanced relationship between housing schemes and mixed uses; it has brought about new balances between developments and economic and social values, preserving those elements considered as belonging to the heritage and maintaining transformational conditions for their surroundings.

The project established not only a linear and continuous public space (with the same extension of the infrastructural line) with public facilities, but also a green area, achieving several social, economic and environmental benefits. The establishment of an urban forest addressed a unique and qualified condition with environmental and social benefits, from air quality issues, noise reduction to educational issues and community ownership and empowerment. The whole project consists of simple elements: a Red Line, which marks the entire linear development of the project area, avoiding walls and barriers, acting properly as an anti-wall and anti-boundary, as a programmatic gesture to suggest and indicate a system of permeable boundaries; Folies of water, to mark the presence of the water element, built along the entire extension of the linear park, and to mark and give importance and centrality to the self-sufficiency of the intervention and of the maintenance cycles; a continuous playground area, in order to achieve the objective of generating a friendly public space, especially modelled on the necessities of younger users, which can be deduced through labs and activities carried out with the direct participations of the inhabitants. All constituent elements were derived from direct involvement of the inhabitants in the decision-making processes.

All the actions of the project have been developed and framed within five clear objectives, such as: increasing social values, obtained by imagining a design process, in each phase of its development, directly established by and for the inhabitants and the neighbourhoods groups; maintaining identity and memory, through the generation of easily recognisable places, with a new general layout directly integrated with pre-existing elements; generating sustainable, liveable and quality places by addressing social, economic and spatial benefits; managing multi-scalarity, adding the possibility of further developments within the same areas of interventions or at its margins and boundaries or outside its perimeter; calming all costs of interventions, both on the initial implementation of the project and on maintenance cycles.

4 FREE DESIGN EXERCISES, ENVISIONING NEW URBANITIES CONDITIONS, ADDRESSING QUALITY LIFE

The "Bosque Urban Ferrocarril de Cuernavaca" project can be indicated as a "model", as a good design practice. The entire area of the Ferrocarril de Cuernavaca can be considered as "third place of density". It was affected by spontaneous practices and uses that had already transformed the specialized space of the railway line in a transitional and relational space with high social values for the inhabitants of the different neighbourhoods. The project idea was able to manage the complexity of the existing urban conditions and to generate new urban qualities, new liveable spaces. Innovative (unconventional) public spaces have been generated from the interventions on the existing railway infrastructure. The railway line was kept in operation and integrated into the project: the choice to use the red line as a marker in plan, instead of placing walls and other barriers in elevation was guided by the technical and technological requirements of the infrastructure. The new linear park – extended for 4.5 km between different various neighbourhoods with equally diverse social, physical-spatial and economic conditions – in its linear development, intercepts the civic cultural district, formal and informal settlements mainly characterized by residential or commercial uses, green areas, market areas, some of the main roads corridors and other infrastructural lines.

Throughout this series of different conditions, the project has established, incorporated (or simply suggested) new urban functions, hybrid formal/informal forms of living/using the city (or parts of it).

As clearly appreciable from the description contained in the previous section, the "Bosque Urban Ferrocarril de Cuernavaca" project can certainly be indicated as a good practice of design, management of the ideational process and consensus formation by the resident population as well as their direct involvement in the whole process. It can certainly be indicated as a complete project in itself, and capable of generating significant economic, social and spatial benefits.

In the same way, it can be said – as in the declared intentions of the design team – that the project has a variable perimeter: by breaking its physical limits – those foreseen and established by specific requirements of the international competition – it opens up to subsequent developments, to further transformations that may be take place within the same area affected by the interventions, as well as, along their perimeter, admitting the possibility of supporting them with further urban regeneration projects.

Following a case study analysis approach, this study collects some of the most significant results of a joint workshop, conducted by the research group "Laboratori Metropolitani" of the IUAV University of Venice and by professors and students of the Ibero-Americana University in 2018. Three projects, set up during the workshop and completed through three master's degree theses in architecture, are shown and described; the necessary multidisciplinary approaches, central themes and design actions to characterize and to implement the dialogue between the academic and professional practices fields are highlighted. Possible alternative ways of using free design exercises (especially those developed in on-site workshops and seminars) are suggested as useful tools to initiate, introduce and complete shared reflections. Through actions of research by design, possible extensions of the project areas are identified, further themes are developed, adding other design topics and multi-disciplinary approaches, and to imagine others possible interventions aimed at improving the quality of life in cities.

The project (Fig. 2) "The Origins. A Golden Stream in CDMX" (Author: Francesca Pasquali; Supervision: Professor Aldo Aymonino; Co-supervision: Architect Giuseppe Caldarola) suggests the possibility of transforming the linear system, defined by the linear park project along the Ferrocarril route, into a circuit, into a continuous circular public pedestrian area. To achieve this result, the project starts by rediscovering the ancient traces that characterised that part of the city, those that existed before its urbanization and that have been covered or erased over the last centuries. It achieves this result by suggesting or indicating a series of interventions on the street sections to characterise the use of the streets not only as transitional spaces but, also and above all, as a relational space.

Figure 2: Masterplan of the "The Origins. A golden stream in CDMX" project.

The project suggests the possibility to further implement the network of cycle and pedestrian pathways, characterised by "slow" walkability and usability; to enlarge the network of public spaces, forming new ones; to add functions and different possibilities of use and fruition of the same spaces, improving their readability, recognisability and interconnections. These objectives are achieved by using the "water" element and its presence (currently denied or covered) within the city as an opportunity for urban regeneration, for increasing the quality of living and experiencing places, for forming new public spaces, socially addicted.

It is well known that the urban fabric of Mexico City (at least, its more central areas) insists on the sediment of an ancient lake and on a series of canals. Through the reading of historical maps and through mapping actions, the author of the project has been able to identify the presence of an ancient Rio – the so called, Rio Consulado – which was covered in past time. The ancient Rio (still covered) intercepts the Ferrocarril route in two points, closely positioned to the initial and final sections of the area affected by the transformation of the railway infrastructure into a linear park. Through the actions of de-layering and re-layering, the author has been able to identify pre-existing functions, to highlight functional deficiencies, to identify critical issues, to evaluate and assess which areas could be integrated into the project to act as resources, to weigh alternatives, to suggest opportunities, to refine the project strategy and give it a specific character that would increase the overall imaginative values of the places. Starting from the road intersections near the entrance points of the Linear Park and following the path of the covered canal, the project proposes its partial reopening; it forms a further linear system, composed as an annular sequence of relational public spaces.

Along the rediscovered route, these spaces are formed as places for staying, places for gathering, places for cultural events and markets. These new relational spaces are formed and connected by a continuous pedestrian pathway, located at a lower level than the road one but directly accessible from it at several points, suitable for improving connections with the neighbouring urban fabric.

The project focuses on three key points; it assigns a general image and deeply characterises the places; it assigns them a specific architectural layout. The first focus is near the cultural district, just in front of the public area marked by the presence of several museums. Staircases and ramps mark the entrance to the new linear public space along the rediscovered canal; a small plaza introduces the sequence of small open-air pavilions, adaptable to different uses (spaces for temporary exhibitions, market places, etc…) and new pedestrian routes. The second focus is directly connected to the entrance of the Modelo brewery: here the project suggests to place a multi-level, mixed-uses building that can serve as a landmark, a new green area and sports facilities. The third focus area is directly close to the end of the second section of the Linear Park (actually, the project made by the Gaeta-Springall Office is carried up to that section). Here the project suggests the construction of a small plaza, connected to the existing street level by staircases and ramps, with a multifunctional pavilion, covered by a high tech roof capable of regulating the alternation of lights and shadows and microclimatic conditions. The technical artefacts are arranged along the entire extension of the new linear public space along the stream.

The second project "Mexico 18. Mixing den-city" (Author: Alberto Bressan; Supervision: Professor Aldo Aymonino; Co-supervision: Architect Giuseppe Caldarola) insists on the second focus area of the previous project. It follows the prevised general layout for the area; it explores the possibilities of increasing the roles of the new green areas settled and the sports facilities located; it works deeper at the architectural scale to address a more complete reflection on the opportunity to increase densities (volumetric and functional ones). These objectives are achieved by designing a new high-density, mixed uses tower that overlaps a public podium directly accessible from an aerial pedestrian pathway: a sort of "pedestrian highway", with its sprawling tentacular unvolumetric structure, bypasses one of the most traffic dominated roads of Mexico City (the Avenida Cervantes); it establishes direct connections with the residential neighbourhoods that are located on the opposite side of the street; it marks the entrance point to the new public spaces, to the recreational spaces and to the sport facilities; it generates new direct connections with the Modelo Brewery, overpassing its fences and reaching the Ferrocarril Linear Park. This project suggests alternative possibilities to enhance the qualities and quantities of the existing public spaces and to set new multi-levels ones, following general recurring design principles derived from different experiences of formation/implementation of public spaces in high-density contexts.

The third project (Fig. 3) "The Big Bundle" (Authors: Davide Castegnaro, Luca Rizzo, Gianluca Trovò; Supervision: Professor Aldo Aymonino; Co-supervision: Architect Giuseppe Caldarola) is located in the ending point the third focus area of the first project. It is placed along one of Mexico City's main traffic corridor, where is located the north-eastern entrance point to the Linea Park. The entrance is marked with a multifunctional mega-structure. The project suggests and explores the possibilities of adding architectural objects, of different scalar presences (if compared with the existing urban fabric all around), that can act as landmarks, as indicators that something new can happen in that point. The new mega-structure, almost completely unvolumetric, consists of a continuous sequence of multilevel pedestrian pathways serving versatile spaces, suitable for installing different temporary functions.

Figure 3: Render of "The Big Bundle" project.

Within the same unvolumetric building, the basement and the ground levels collect the connections with the underground station and the bus stops and with the system of neighbouring public spaces; the parking areas are disposed on one of the two underground levels. By applying traffic calming techniques, the existing roads network is transformed into a woonerf (fast vehicular traffic is moved to the first underground level). This type of intervention has a strong strategical value because it allow the possibility to reduce the actual role of the street that acts as a barrier disposed between two residential areas which aim to be more interconnected. At the ground level, a new roads system is generated in forms of traffic calmed, more pedestrian friendly, roads network directly connected to the upper multilevel public space. Among the suggested public functions is the possibility of using the megastructure as a kind of vertical market. The spaces for temporary markets allow in fact to maintain and amplify the existing ways of using and living the places: in the same site in fact, through the mapping actions, the design team has recorded the presence of a daily market that, when set up, completely changes the current way of using the street space. in fact, it is well known the role of market places in adding social and liveable values to the places).

The "free" character of these design exercises is simply appreciable as a possible way to equally "free" admittance, within the ongoing public debate on urban regeneration projects, of alternative visions and indications. These free design exercises, included in this study, are meant to be indicated as exempla of possible alternative strategies for further improvements of the ongoing urban regeneration processes. However with a certain level of approximation, they admit the possibilities of constructing visions, scenarios not directly set up to respond to the claims, rules and prescriptions required by the public commitment. They make it possible to widen the perimeters of the areas of intervention, to suggest alternative or complementary strategic directions with respect to the current transformations. They allow some professional practices to be reopened to different multidisciplinary suggestions and approaches and to indications coming from academic efforts and, vice versa, they allow academic approaches to be brought closer to professional practice.

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relating to the implementation of sustainable development models for selected contemporary metropolises cases, characterized by strong expansion and/or transformation dynamics. The scientific committee is composed by professors A. Aymonino, E. Fontanari, P. Bonvini, G. Mondaini, R. Simone and other professors of the foreign universities to whom special thanks by the author of this paper have to be addressed for their contribution of ideas. Editions/cities: São Paulo, Brazil, with the Universidade de São Paulo (USP) – Faculdade de Arquitetura e Urbanismo (2011); Dar es Salaam, Tanzania, with the Ardhi University of Dar es Salaam (2012); Seoul, Korea, with the SKKU University of Seoul (2013); New York with the Parsons New School of Design (2014); Santiago, Chile, with the Universidad Diego Portales (2015); Hong Kong with the Polytechnic University of Hong Kong (2016); Mexico City with the Ibero-American University (2017); Moscow with the Moscow Institute for Architecture (2018); Nanjing with the Southeast University of Nanjing (2019). The laboratory, with annual programming, is structured in a cycle of introductory lessons, a study trip with on-site surveys and 2-week workshops plus an 8-week intensive workshop in Venice during which the first analyses and design ideas, as emerged during the workshop abroad, are deepened, completed and reassessed in a final exhibition and in a seminar.

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SECTION 8
THE S3 CITY: SMART, SUSTAINABLE AND SAFE

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MUNICIPAL IOT IMPLEMENTATION STRATEGY FOR BRASÍLIA, BRAZIL: SMART CITY GUIDELINES AT THE LOCAL LEVEL

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ABSTRACT

While cities face multiple challenges, population growth must be combined with resource efficiency and sustainability. In this context, many municipalities intend to become smart cities, where good urban management practices are combined with various technologies to generate highly connected and monitored cities, aiming to improve the quality of life of their inhabitants. In Brasília, the capital of Brazil, while several individual initiatives have emerged in this direction, a comprehensive plan for the implementation of a smart city has not yet been consolidated. This research proposes an action plan for making Brasília a smart city, with a focus on enabling Internet of Things (IoT) at the municipal level. The strategy is based on a local diagnosis of socio-economic aspects, technological landscape and regulatory constraints, and brings together a series of recommendations and references of projects that could be implemented in the city to make urban public services more efficient.

Keywords: Internet of Things (IoT), smart cities, public policy, urban management, urban infrastructure, Brazil, Sustainable Development Goals (SDGs).

1 INTRODUCTION

Global negotiations reached targets to guide the efforts of nations to build a more just and responsible world, such as the Sustainable Development Goals (SDG). In order to achieve them, the strategic management plans that nations generate in these matters are relevant. Along with them, new technologies play a fundamental role in making it possible for intentions to come to life, optimizing the scarce resources available, especially in less developed countries. Within these plans with good intentions, cities play a fundamental role [1]. Smart cities today represent an urban management model, where the strategic management of municipalities, together with a wide deployment of technology, seek to improve the well-being of the inhabitants in matters of transportation, environment, quality of infrastructure and urban services in general [2]. In this context, the Internet of Things (IoT) is a key technology, since it provides an opportunity for cities to have more efficient public services while still encompassing the matter of social disparities, improving the quality of life by making cities capable of implementing these technological advances while also minding social concerns [3].

Various cities in the world are turning into the smart city paradigm. In addition to urban renovations and strategic management plans, the implementation of 5G and IoT are elements that stand out in most successful implementation cases [4]. The most digitized cities in the world, in Asia, Europe or North America, today have extensive IoT networks, and seek to expand these systems to improve and increase the amount of interconnected services. For example, in the case of New York, the guidelines for smart cities propose and regulate the use of the IoT in a coordinated manner between public and private entities, promoting the privacy, transparency and security of the city's infrastructures and data [5]. On the other

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hand, Barcelona has implemented a network of sensors throughout the city, which in real time thanks to the IoT allow monitoring a series of environmental factors and the quality of interconnected services. In Latin America, although there are smart city plans, mainly for capital cities, implementation is slower. Smart city plans seek to promote these trends, however, specific guidelines are not yet completed, and mainly specific initiatives are implemented, in many cases, not integrated. In the case of Brazil, the main initiatives are in Rio de Janeiro, where smart lighting plans and public Wi-Fi networks stand out as pioneers; and in Brasília, where technological development initiatives for the efficiency and monitoring of sanitation, energy and communications services have begun to be promoted in the last decade [6].

In this context, this paper identifies the contribution of IoT and smart city planning for Brasília, in response to the needs of the city and the particular initiatives that are under development. Thus, strategic actions are proposed for the successful deployment of these new technologies on a massive scale in the city, with a view to its transformation into a smart city. The research methodology is divided into three stages: (1) Smart city elements and models; (2) Diagnosis; and (3) Action plan. In the first stage, the elements of technological infrastructure, strategies, methods and case studies for the implementation of smart cities are identified. In the second stage, a diagnosis of the city of Brasília is developed, focused on understanding its socio-economic, technological and regulatory context. Finally, based on the previous stages, an action plan to implement IoT for smart city applications in Brasília is developed. Fig. 1 shows a diagram of the research methodology, with the stages, activities, research tools and deliverables.

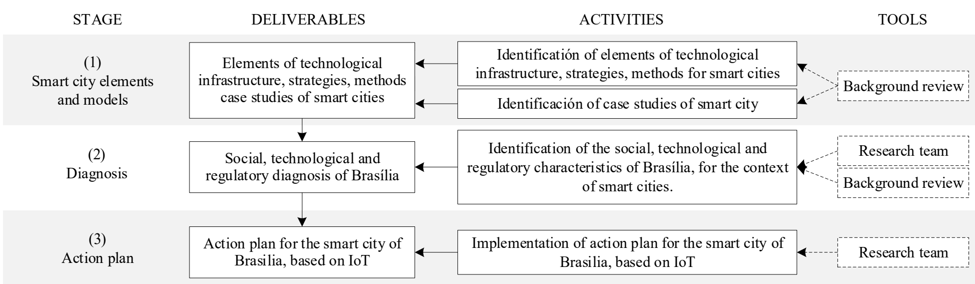

Figure 1: Research methodology.

2 BACKGROUND

2.1 IoT urban infrastructure elements

The urban infrastructure of information and communication technologies (ICT) is based on providing conditions for data traffic between data consumers in the city and data centers located in other cities, countries or continents [7]. With the popularization of the Internet, a global network of data traffic was consolidated. ICT infrastructures in urban spaces are made up of three main components: access network, transport network and data storage [2]. The access network, also called the last mile network, corresponds to the most peripheral ICT infrastructure, where information is collected and distributed to each of the homes, offices or users in general. The transport network, also called the backbone, is the central component of the telecommunications networks that connects the different access networks and other parts of the IT system. The third component is data storage, which must keep the data over time for use when required by a user from a computer or other type of device.

Understanding an IoT architecture for urban utility devices can be simplified for public policy purposes in a system with three layers: device layer, network layer, and service layer [8]. Fig. 2 shows this simplified architecture on a municipal scale, identifying its main elements and relating the layers to the broader structures of the telecommunications system. It can be noted that a typical IoT municipal infrastructure implementation includes the deployment of multiple technologies and requires a broad diversity of expertise [9].

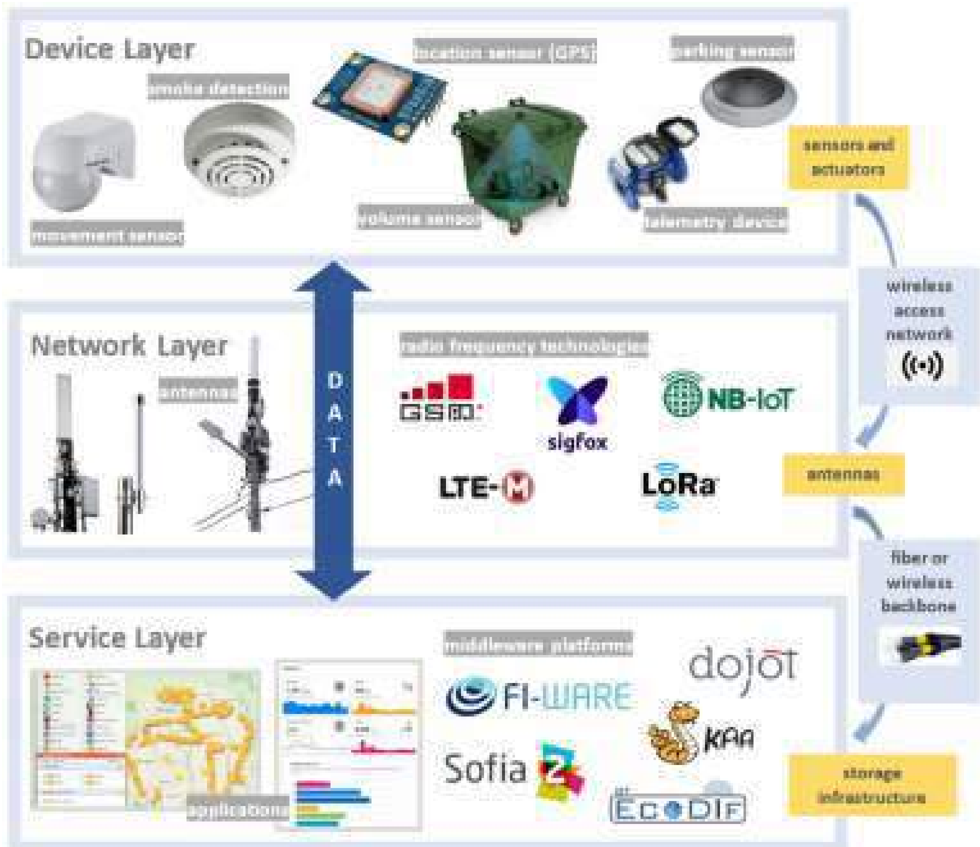

Figure 2: IoT urban infrastructure diagram for public services.

2.2 Case studies of IoT implementation for smart cities

The planning, development and consolidation of a smart city strategy is a complex process that requires the incorporation of different elements that provide answers to multiple variables to be studied in a specific environment [10]. It is evident that the particularities of each territory must be resolved according to its needs, legal aspects, cultural elements and idiosyncrasies, but international references can also be very useful as a guide. In this context, Table 1 shows six case studies of initiatives that could be interesting to guide potential guidelines to be followed in the context of the city of Brasília. These have been selected based on the characteristics of the IoT to be implemented, focused on implementation aspects, regulations, forms of contracting, among others.

Table 1: IoT implementation case studies for smart cities.

City	Description of initiative
New York (U.S.A.)	Common framework for government entities, seeking to maximize transparency and openness regarding design, installation and operation, provide clarity on minimum requirements and expectations, and promote public dialogue on how government, industry Private and academic partners can maximize the public benefit of IoT solutions. They address aspects of Privacy and Transparency; Data management; Infrastructure; Security; and Operations and Sustainability [11].
Seoul (South Korea)	The city has undergone a series of transformations and policies to provide the city with state-of-the-art technology. Smart Seoul Network (S-Net) will give all citizens access to the Internet through the deployment of a new smart city infrastructure, based on the establishment of a municipal broadband network, the deployment of free Wi-Fi networks and further integration of IoT infrastructure based on LoRa devices [12].
Barcelona (Spain)	The open source Sentilo platform in Barcelona consolidates the applications that are developed to use and take advantage of the information "generated by the city" and the layer of sensors deployed by it, to collect and disseminate this information. Sentilo makes it possible to fit into the smart city architecture of any city that seeks openness and simple interoperability. It is designed as a cross platform, in order to share information with heterogeneous systems and integrate similar applications [13].
Jaipur (India)	The smart city plan is based on important high-tech and scientific strategies. The first phase is already in the process of turning Jaipur into a smart city with the use of ICT and Communication based interventions. On the other hand, the second phase seeks to implement initiatives for the digitization of citizen services and E-governance [14].
Las Vegas (U.S.A.)	The plan seeks to improve the interoperability of transportation, energy, public works, facilities and public safety, law enforcement through open source data sharing, real-time data analysis, and decision-making support. It pursues to keep people safe and connected, and provide them with the information they seek when they need it, based on a public–private partnership [15].
Rio de Janeiro (Brazil)	The plan integrates projects that support the strategic planning of the local government, strengthening the relationship of citizens with the city and the government. It considers the local monitoring service of the city's Operations Center, and a digital inclusion program, an important indicator that tracks the population's access to new technologies, especially in disadvantaged communities in the city [16].

2.3 Smart city implementation models

Like any public service, the implementation of a municipal IoT infrastructure for smart urban management, especially of connected devices, antennas and the backbone network, requires a solid and transparent structured model so that the local government can meet the objectives of their public policies [17]. Three implementation models were identified: (1) Construction and ownership; (2) Subscription; and (3) Public–Private Partnership (PPP). In the first, a government agency develops specific requirements for an IoT network, prepares a competitive bidding process, and establishes a contract with a company to implement the network with predetermined requirements. In the second type, private companies define the requirements according to market demands, build and operate the connectivity network. The government periodically pays network utilization fees to companies established to implement their IoT projects. On the other hand, in the PPP model, a tender is opened for the implementation and maintenance of the network, which is built and administered by the chosen company. The contract provides for its use by public devices at no cost or at a previously determined cost. At the end of the term, the implanted infrastructure remains owned by the government [18].

According to the guidelines of the National Bank for Economic and Social Development (BNDES) of Brazil, Fig. 3 shows the eight steps that must be considered for structuring a device connectivity strategy for an integrated smart city solution, in this case, for the city of Brasília. The process starts with a political decision and the creation of a multidisciplinary implementation team. As the project is minimally structured, citizens are able to provide input and assist in determining the guidelines and demands of the project. A complete local assessment covering social, technological and normative aspects is the base to the business model definition. An action plan must then be elaborated with steps to achieve the proposed goals, which can include a pilot project to validate the chosen strategy. As the plan is executed, it should be continuously monitored [19].

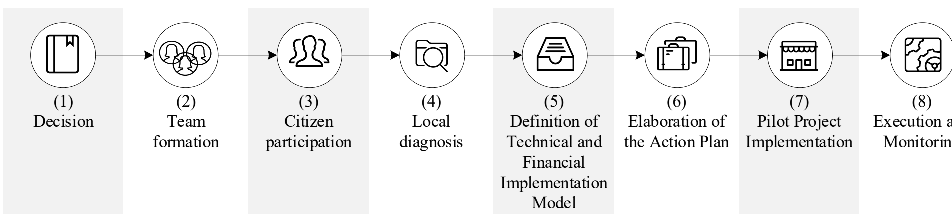

Figure 3: Step by step for the implementation of a smart city.

3 SOCIAL, TECHNOLOGICAL AND NORMATIVE ASSESSMENT

Before developing a public policy, it is always essential to make a complete assessment of the current situation. In the case of an IoT implementation strategy in the context of smart cities, the assessment is divided into the study of socio-economic, technological and regulatory factors. Understanding the social conditions of the population, the telecommunications infrastructure and the regulations applied to the project is essential for the making of a successful action plan.

Brasília currently has 3,055,149 inhabitants. The Brazilian capital still attracts many immigrants due to job opportunities, mainly in the public sector, where the majority of the economically active population of the city (71.8%) works in the service area, and 15% are civil servants, defense or social security. Brasília's GDP is around R$244,682,756,470 (€37,387,734,220), which corresponds to 3.8% of the national GDP. The median per capita income of Brazil is R$30,433.99 (€4,650), however Brasília has the highest per capita income in Brazil, with around R$80,502.47 (€12,300.84), according to the IBGE [20], [21].

When it comes to the technological context, Brasília has a series of public and private initiatives that can support various initiatives towards a smart city. The Federal District has good connectivity compared to other Brazilian states, where four large private operators offer internet services at the last mile. In addition, Brasília has coverage of three public fiber optic networks: Gigacandanga for universities, GDFnet for the local government, and Infovía Brasília for the federal government. The GigaCandanga network of REDECOMEP-DF is a community of education and research network that integrates research and higher education institutions in Brasília. On the other hand, in 2017, the local government inaugurated a new data center, which concentrates all the GDF data and systems, such as the Transparency Portal and those for the issuance of electronic tickets for the metro system. The usable physical area is 260 m^2 and the storage capacity reaches 2.5 petabytes. In addition, with a focus on innovation in biotechnology and information and communication technology, BioTIC will be the main pole of scientific, technological and innovation development in Brasília. The project will allow the installation of several companies, as well as research institutions and innovation centers [22].

Along with these initiatives, a series of installed ICT infrastructure with growth potential has been implemented in recent years in various fields [23]. The following information was collected by entities of the local government:

- 5,869 telemetry devices are installed. Data transmission technologies: radio frequency, LoRa and Caesb. Pressure and flow sensors in the water network.
- There are 6,400 establishments with telemetry devices in the Federal District. Real-time monitoring in substations with reading of energy measurements.
- Currently, 600 buildings of the local government are served by SUTIC's Internet network (GDFnet), which represents 33% of the total buildings of public entities.
- Public transportation benefits, such as complimentary travel for the elderly and students already work with facial biometrics, with a total of 860,080 people in the image registry with active cards.
- In the urban video monitoring project in development by the Secretariat of Public Safety, there are 779 cameras installed in different parts of the city. Facial recognition technology is not yet used.
- 14 hospitals and 37 health units are served with 1 GB/s fiber optics. Some big data analysis techniques, machine learning and artificial intelligence are being used.

In Brasília in recent years there has been an effort to regulate the issuance of permits for telecommunication infrastructure, with the intention of promoting the development and deployment of this technology. In the context of the implementation of a smart city, it is essential to understand the opportunities and conditions established by the regulatory context and their implications of an IoT Strategy for Brasília. Six different regulations have been identified, which regulate telecommunications facilities in technical terms and urban parameters, as well as aspects associated with IOT and development plans towards a smart city.

4 AN IOT ACTION PLAN FOR BRASÍLIA SMART CITY

Aligned with the provisions of the Federal District Plan for the Internet of Things, six fields of action for the action plan have been considered: (1) Science, Technology and Innovation;

(2) International outreach; (3) Education and professional training; (4) Connectivity and interoperability infrastructure; (5) Regulation, security and privacy; and (6) Economic feasibility. Activities have been defined for each action area, in accordance with initiatives based on the Internet of Things (IoT). The proposed activities are framed in the needs and dispositions obtained from the evaluation of the city of Brasília, based on its particular contexts. In addition, as a general framework, for each activity, its taxation towards the fulfillment of one or more sustainable development objectives (SDG) has been defined, as shown in Table 2, in order to frame any provision in this international development context. The actions for each item of the action plan are shown in Tables 3–7.

Table 2: Contribution of the action plan to the SDG.

SDG	Science, technology and innovation	International outreach	Education and professional training	Connectivity and interoperability infrastructure	Regulation, security and privacy
1. No poverty			x		
3. Good health and well-being		x			
4. Quality education			x		
5. Gender equality			x		
7. Affordable and clean energy		x			
8. Decent work and economic growth		x	x		
9. Industry, innovation and infrastructure	x			x	x
10. Reducing inequality			x		
11. Sustainable cities and communities	x	x	x	x	x
12. Responsible consumption and production	x				
13. Climate action		x		x	

Table 3: Action plan for science, technology and innovation.

Item	Description
General description	Program for the integration of local technological initiatives seeks to create an ecosystem of science, technology and innovation in the city of Brasília. It includes the following actions: R&D technical tables; scholarships for foreign human capital; conferences and local outreach fairs; and start-up incubation.
Impact	The impact on the city is related to the focuses defined within the program and is related to the following aspects: Consolidation of the SC-IoT ecosystem; creation of 20 technology-based companies; DF as the focus of SC-IoT; IoT infrastructure installed and operating in Brasília, for the benefit of citizens.
Model	Public–private partnership financing model, where public spending is focused on ecosystem development, and private investment on implementations.
Monitoring	Implementation: Phase 1: 1-year, technical tables and ecosystem, and selection of start-ups; Phase 2: 1-year, consolidates the ecosystem, local R&D policies, usable start-up prototypes, pilot tests; and Phase 3: one year, implementation of the initiatives. KPIs: No. of experts (minimum five in 2 years); Number of incubated start-ups (minimum 20 in 2 years); Number of members and typologies in technical tables; and Number of initiatives in pilot tests.

Table 4: Strategy for international outreach.

Item	Description
General description	The transformation of Brasília into a smart city requires a process that includes the participation and collaboration of its citizens, seeking a better quality of life, based on a more human-scale habitat that is sustainable in the long term. It includes Informative display; and International Promotion: Science and Technology International Fair.
Impact	The culture change that is expected to be achieved will be noted in the international event, while visitors, whether they are representatives of companies or enthusiasts, can experience throughout Brasília what it is like to live in a smart city. This aims to be an example for the entire region and strengthen the potential to turn the city into an important tourist destination.
Model	Public–private partnership financing model.
Monitoring	Implementation: Stage 1, year 1: Development of government communication plans, the axes of smart development and its promotion at the local level and preparation of the necessary event facilities. Stage 2, year 2: Fair promotion contracts and confirmation of participants. Stage 3, year 3: Hosting the international event. KPIs: Indicators of CO_2 emitted and others; Level of local, national and international knowledge about the Smart Brasília fair in social media and online visits; % of advance; number of participants; and number of closed deals.

Table 5: Strategy for education and professional training.

Item	Description
General description	In the last ten years, many problems in education have been gradually overcome, due to the economic development of Brazil and in particular Brasília, but another factor has emerged that is based on households and its lack of assistance to minors in terms of guiding adults to help facing the challenges of the future, which has influenced a discouragement in the perseverance of the students.
Impact	Reduction of social gaps, through the support of new ICTs. Better coverage and quality of school education, and technical skills. Increase the opportunities in informal settlements of accessing jobs in ICT companies. Reinforce the involvement of parents and guardians through ICT School for Parents.
Model	Mainly public investment.
Monitoring	Implementation: Long-term, analyzing the performance of students in school. For adults, results will depend on how many students are getting a job. KPIs: % of students who resume studies; % dropout of secondary students incorporated into the ICT learning model; % of teachers trained in digital; Number of older women, who resume their basic studies in technology; % growth of online training; employment index by gender and educational level.

Table 6: Strategy for the connectivity and interoperability infrastructure.

Item	Description
General description	Brasília must review in its computer systems their ability to interact between the different computer programs and in the data, they generate, where they are stored, the capacity to standardize formats, process and cross data between different public administration agencies in local and federal level and the private sector.
Impact	By having an interoperability system, the decisions made by the administration will be more holistic and robust, this will allow it to address challenges more efficiently, improve public services to citizens, savings in the municipality's budget and planning that can reinforce programs socially. On the other hand, if the databases are open by default, it will allow the development of a source of entrepreneurial projects that have citizens as clients.
Model	Public–private partnership financing model.
Monitoring	Implementation: Design stage lasts 1 year: Hiring companies for system and workforce assessment; Bidding Stage 1 year: Raising of Public–Private proposals, tender, adjudication, and allocation of resources; Implementation stage lasts 2 years. KPIs: Level of interoperability of computer systems at the community level; Online digital certificate numbers; Savings in expenses for process digitization; Income from new industrial and commercial patents in the city.

Table 7: Strategy for regulation, security and privacy.

Item	Description
General description	Brasília must ensure the security and privacy of its citizens' data, which are incorporated into the databases of public bodies through the digitization of processes on a voluntary basis, or by capturing them, due to IoT sensors, which are necessary for a better management and administration of the city.
Impact	The confidence of citizens in the Governance management systems must be complete, this implies that the information they develop in the data analysis is duly protected, allowing to strengthen the support for the management of the authorities, in technological investments each time more sophisticated, which help improve the well-being of citizens and the environment.
Model	Public funding
Monitoring	Implementation: Stage 1 is the uniformization, in public bodies, of the request procedure for collection and use of personal data; Stage 2 is the dissemination of the personal data protection law and informative talks to all public officials, school civic education classes and dissemination through open TV channels. KPIs: Number of media that participated in the disclosure of the personal data protection law and % of population coverage; Percentage of public officials attending talks on the data protection law.

The aspect of economic feasibility was done by analyzing the financial capacity to undertake the above mentioned strategies. Brasília has an approximate annual budget of €6,482,000,000. The proposed action plan considers an implementation cost of €50,000,000. The implementation of the action plan is mainly based on a cost of approximately 0.53% of the city annual budget. The plan allows to visualize and support the development of a human-centered smart city.

5 CONCLUSIONS

The social and technological preparation for the implementation of IoT devices in Brasília that this paper proposes depends on political coordination and budgetary forecasting. The city has a unique condition in Brazil, due to its high social development, which can serve as an example to the entire country and also Latin America. However, the city must overcome the management challenges, coordinating the actions of the different entities of the administration for the common objective of implementing a complete and efficient IoT strategy. The preparation for the IoT will be very beneficial because it will also prepare the city for the advent of 5G and all its potentialities. The implantation of antennas must be coordinated and accompanied by the modernization of the applicable regulations. Although the costs are significant, the socio-economic development and the financial return provided by the massive deployment of IoT can inaugurate a new phase of economic development in Brasília. It must be ensured that Brasília is not just another city that can buy technology, but one that can lead the development and deployment of the IoT on a massive scale at the municipal level. The training of youth and workers, and the attraction and retention of talents in the city is essential in order to fulfill this goal.

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EDUCATION FOR SUSTAINABLE DEVELOPMENT: A STAKEHOLDER ANALYSIS BETWEEN A CHINESE AND SINO-FOREIGN UNIVERSITY

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ABSTRACT

As the development of Sino-foreign universities in the current decade has grown significantly, the differences between Sino-foreign universities and standard universities in China has become a key topic of discussion. There is a lack of comparative studies on Sino-foreign universities and Chinese universities, and even more so on topics such as sustainable development. Currently, campuses within China have a huge impact on resource depletion, environmental pollution and social interactions and development. Also, universities are key players in knowledge creation and transformation, talent cultivation and technical innovation, and nationally it is recognized that the growth and development of campuses is critical to the overall sustainable development within China. Thus, this research aims to enhance the Education for Sustainable Development (ESD) in China through understanding the strengths and weaknesses of the ESD approach between a Sino-foreign universities and normative universities. This is executed through stakeholder analysis, which involves identifying, categorizing, and investigating the relationship within university stakeholders with regard to ESD. Further analysis is conducted with an interest and influence matrix chart that determines the priorities and influences of university stakeholders. Two universities (Chinese university – Ningbo University and Sino-foreign universities – University of Nottingham Ningbo China) will be used as case studies within China to draw out the synergies and differences of ESD.

Keywords: sustainability, education for sustainable development, stakeholders, stakeholder analysis.

1 INTRODUCTION

In recent years, sustainable development (SD) has become a focal topic, and the term Education for Sustainable Development (ESD) has attracted public attention. ESD aims to develop knowledge, skills, values, attitudes, and people's behaviours in caring for the environment through environmental education, and it is widely accepted as one of the most significant parts of achieving sustainable development [1]. Among a great range of fields involving ESD, this paper focus on the stakeholder analysis in the context of ESD in a typical Chinese university and Sino-foreign university. Universities are leaders in education, research, and innovation [2]. They have a crucial role in promoting students' perception of sustainable development to grow as a sustainable development leader and support the transformation of sustainable societies [3].

The Chinese government highly values sustainable development in universities, which started in the 1990s [4]. In 2008, 32 top Chinese universities, led by the MOE, announced the Declaration of Building Sustainable Campuses, aiming to promote sustainable development among campuses in China. However, SD in Chinese universities is still in the early stage, and there are still gaps and issues in effectively executing ESD in Chinese universities. One of the gaps is regional differences caused by the size of China [5]. Other issues could be the lack of research of Chinese institutions and gaps between updated research and teaching materials. Also, Tan et al. [6] summarised the progress of green campuses in China and found that energy and resource efficiency is the major focus. Additionally, Wang et al. [7] used the five-point Likert scale questionnaire to compare sustainable development

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in public and private universities from students' perception and found that students in private universities have a higher level of sustainability perception. However, the studies on ESD are still limited, especially those with the methodology of stakeholder analysis and from the perspective of Sino-foreign universities.

In this study, China HEIs is the core of the stakeholder analysis considering ESD and how this can be enhanced across various university setups. i.e., fully Chinese university and Sino-foreign university. The Sino-foreign University is a growing classification of higher education institutions in China, with different curriculum settings, management structures from regular Chinese universities. As it stands, there is a lack of comparative studies on Sino-foreign universities and Chinese universities, and even more so on topics such as sustainable development. Campuses within China have a huge impact on the environment, social interactions, and development.

Thus, this research aims to enhance the Education for Sustainable Development (ESD) in China through understanding the strengths and weaknesses of the ESD approach between Sino-foreign universities and normative universities. Further analysis was conducted with an interest and influence matrix chart determining university stakeholders' priorities and influences. This matrix allows for a better understanding of the university's sustainability strength, structure and approach, and sustainable development direction. Additionally, two universities (Chinese university – Tongji University and Sino-foreign universities – University of Nottingham Ningbo China) was used as case studies within China to draw out the synergies and differences of stakeholders in ESD. Ultimately, these results can help people to improve ESD in the future.

Hence, this paper aims at understanding the different stakeholders involved in ESD decision making in Sino-foreign and Chinese universities. In addition, the influences of the key stakeholders in achieving ESD goals. To achieve the aims of this study, several objectives were defined to ensure the completeness and reliability of the research process.

1. Identification of the different stakeholders in ESD decision making between Sino-foreign universities and Chinese universities and understand their current sustainability state.
2. Determine the stakeholders' influences and interests in achieving ESD goals and categories them into groups accordingly.

2 LITERATURE REVIEW

2.1 The argument for stakeholder analysis in ESD in Chinese universities

Many gaps and issues exist in effectively executing ESD in Chinese universities. The regional difference is one of the gaps. An important reason for this is that most undergraduate schools are located in the middle and eastern parts of China, and education in these regions has a long history, which means it is easier to promote ESD in the middle and eastern parts than in other parts of China [5]. Another reason could be provincial-level economic development. Current studies on the provincial ESD performance indicated that ESD in most regions of China is at a medium level. However, it is unbalanced across regions, and the level is synonymous with economic development at the provincial level. Research shows that while the coastal regions are more developed in terms of economic and social development, ESD also performs better in coastal regions of China than in the inner land.

A study conducted by Geng and Zhao [8] found that six out of 11 coastal regions in China are graded higher than "fair", while only five out of 20 non-coastal regions meet the "fair" standard. Other issues could be the lack of research of Chinese institutions and the gaps between updated research and old teaching materials. Progress has been made in the research of ESD. For example, Yuan and Zuo [9] used a visual assessment of sustainability in universities to investigate students' awareness of sustainability and their perceptions and found that students generally attached importance to sustainability issues. Tan et al. [10] summarised the progress of green campuses in China and found that green campus is developing at a rapid pace and the Chinese government strongly encourage developing green campus by giving policy and financial support. Li et al. [11] developed a methodology to analyse students' carbon footprint with a case study of Tongji University and found relations on students' energy consumption patterns, behavioural tendencies, and energy conservation willingness. Wang et al. [7] used a five-point Likert scale questionnaire to find out students' perceptions of sustainable development and compared the result of public and private universities. Except for the finding that students in private universities are of a higher level of sustainability perception, the result also shows that while students are most interested in sustainability commitment and the role university plays in sustainable development, they are least concerned about sustainability curricula and research. Even the mentioned studies had been done, the studies on ESD are still too few, especially those with the methodology of stakeholder analysis and from the perspective of Sino-foreign universities.

To achieve the goals of ESD, stakeholders need to share responsibilities and explore solutions. The influence of stakeholders needs to be considered since their actions influence the success or failure of achieving goals [12]. This includes any group or anyone affected. In the process, their impact and interests will be accessed. Regarding the impact of stakeholders, Leal Filho and Brandli [12] cited the following three points: First, higher education produces better results. In achieving ESD sustainable development, universities and stakeholders should collaborate, which can better understand market conditions and improve the social responsibility and reputation of universities. Second, it can increase the possibility of fair decision-making as the value collision of different stakeholders may generate more ideas and create common goals. Finally, it allows ideas to be refined before they are adopted [13]. Different stakeholders have different experiences in dealing with a matter, and they have different influences in society. The superposition of experience may allow the solution of the matter to be verified by the groups representing different interests.

3 METHODOLOGY

3.1 Stakeholder identification

Generally, the university stakeholders were classified into internal and external stakeholders [7], [14], as shown in Table 1. The identification of stakeholders in sustainable development commenced from the basic framework, with the people in the table as the focus group. The process started with the search on the targeted university's official website, where detailed information of the stakeholders was obtained. Snowballing was proceeded in some cases via the interviews of the focus group to collect suggestions on the unclear boundary of the stakeholder group. After the identification of the different stakeholder groups, all the necessary members in the various groups were considered, and sub-groups were established for clarification.

3.2 Stakeholder influence and interest ranking

Stakeholder groups have different interests and influences on sustainable campus development, contributing to different levels. In this part, stakeholder groups were scored

Table 1: Basic framework for stakeholder classification.

Internal stakeholders	External stakeholders
University management	Community
Faculty	Alumni
Staff	Funding agency
Students	Government
Internal stakeholders	

with 14 dimensions of sustainability (Table 2), summarised from the study for Chinese universities by Shuqin et al. [15] and literature review of several existed campus sustainability tools by Alghamdi et al. [16]. The different stakeholder groups were scored with "1" if they were proven to be interested in a particular dimension, representing that all dimensions, in this case, were equally weighted; else, this group was scored with "0" in this dimension. In the interest analysis, each group got a maximum of 14 points, and the points each group got meant the number of aspects they were interested in.

Table 2: Description of different stakeholders' categories.

Stakeholder influence (sustainability dimensions)	Stakeholder interest
Urban ecology and biodiversity	Organizational impact
Reducing energy	Education and training impact
Governance dimension – institutional governance maintenance and management	Knowledge and research impact
Sustainable site planning and construction	Environmental impact social impact
Water	Social impact
Waste	Economic impact
Transport	Organizational impact
Social operations and engagement (Engagement on campus)	
Financial operations	
Education dimension	
Research dimension	
Sustenance, security, and safety (resilience)	
Health and wellbeing	
Smart campus	

As to the influence, stakeholders were assessed in six dimensions (Table 2), adapted from the study by Kioupi and Voulvoulis [17], which considered the fundamental aspects of sustainability and function of the university. The different stakeholder groups were scored with "1" if they were proven to have influence in a particular dimension, representing that all dimensions, in this case, were equally weighted; else, this group was scored with "0" in this dimension. In influence analysis, each group got a maximum of six points, and the points each group got meant the number of aspects they had influence.

3.3 Stakeholder categorization

Based on the marked score, stakeholder groups were classified into four categories based on an existed interest–influence matrix [18] with corresponding characteristics shown in Fig. 1 (high influence, interested people; high influence, less interested people; low influence interested people; and low influence, less interested people (Table 3). In interest analysis, stakeholder groups scored 1 to 7 were placed in “low interest”, scored 8 to 14 were placed in “high interest”. As to the influence analysis, stakeholder groups scored 1 to 3 were placed in “low influence”, scored 4 to 6 were placed in “high influence”.

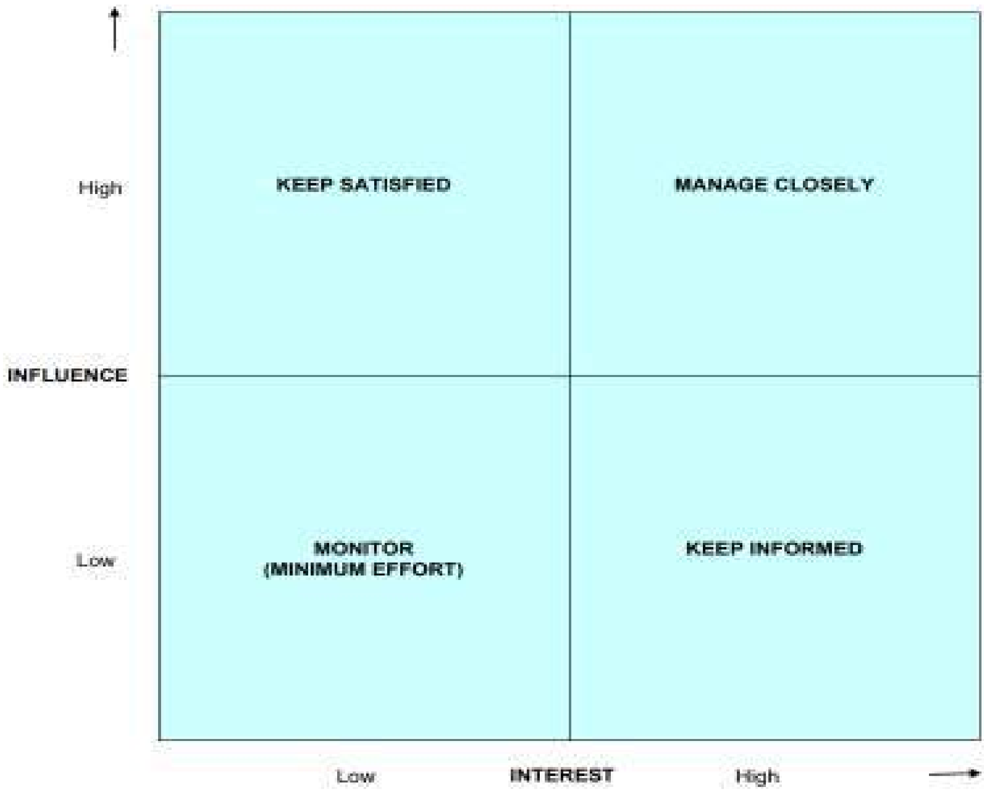


Figure 1: Influence and description of different stakeholders’ categories.

4 RESULT AND DISCUSSION

4.1 Overview of stakeholder identification

The comparison shows that the primary stakeholder groups of campus sustainability are similar in both Sino-foreign universities and Chinese universities (Table 4). Both types of universities own the same structure in the common HEIs, with an extra group “Expert” classified in campus sustainable development. The term Expert in this context refers to those faculty members or researchers whose research area, educational experience, or current

Table 3: Description of different stakeholders' categories.

	Low interest	High interest
High influence	High influence, less interested: Provide sufficient information to these people to ensure that they are up to date but not overwhelmed with data, e.g. the accountable body (management board or operations committee)	High influence, interested: These are the people who must fully engage and make the most excellent efforts with, e.g. the head of a department, who represents the users/customers
Low influence	Low influence, less interested: Provide these people with minimal communication to prevent boredom, e.g. other departmental members, teams unaffected by the change	Low influence, interested: Keep these people adequately informed, talk to them to ensure that no significant issues arise. These people can help with the detail of the project, e.g. end users, other project managers, business community

teaching module is related to sustainable development in either environment, society, or economy. Thus, the experts are considered different from regular teaching staff in the following analysis.

Table 4: Identified primary stakeholder groups in university campus sustainable development.

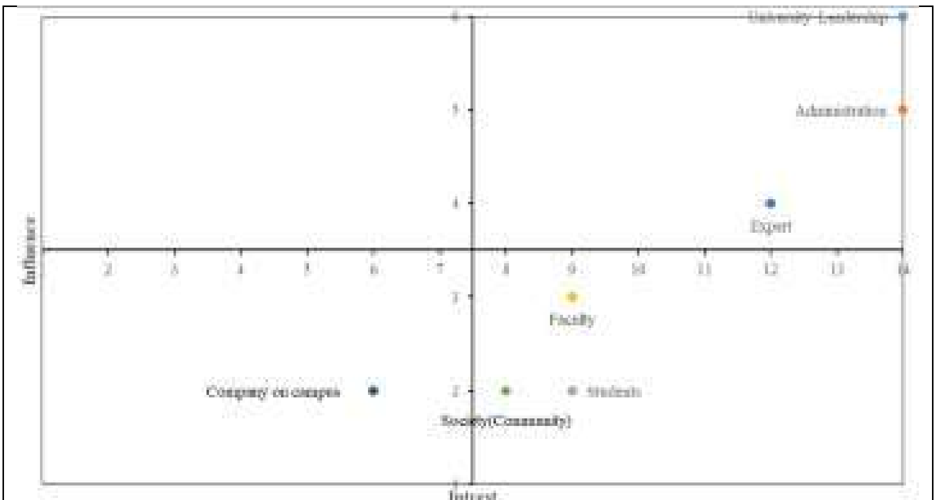
University of Nottingham Ningbo China (UNNC) (Sino-foreign university)	Ningbo University (NBU) (Chinese university)
University leadership	University leadership
Management • University administration • Governmental supervision	University administration Government
Faculty	Faculty
Expert (in sustainability)	Expert (in sustainability)
Students	Students
Society • Campus community • Surrounding residential community • Surrounding business	Society • Campus community • Surrounding residential community • Surrounding business
Company (university as the service provider)	Company (university as the shareholder)

Sino-foreign universities have a different leadership framework from that of typical Chinese universities. According to the *Higher Education Law of the People's Republic of China*, in higher education institutions run by the State, the system shall be applied under which the presidents take overall responsibility under the leadership of the primary committees of the Communist Party of China in higher education institutions. In Chinese universities, the positions for the university president and the Party Secretary are assumed by two individuals, with the powerful right held in the Party Secretary; seldom are the two positions filled by a single individual. In contrast, though Sino-foreign university sets the Party Secretary, the secretary's mission is mainly related to government affairs [19]. It is pointed that the governmental supervision is integrated within the university administration in UNNC, while this is set outside of NBU. In China, state-run universities are highly dependent on the local authorities, especially in finance and policy. Thus, the government would play as a more identified stakeholder in NBU than in UNNC. However, it should still be noted that it is unclear the supervision via the party secretary has in decision making and influencing the general sustainability directions at UNNC.

4.2 The influence and interest spectrum

By utilizing the influence spectrum, this study provides a better idea of the impact of the stakeholders within both institutions. The results from Table 4 show similarity of local and Sino-foreign university in terms of identified stakeholders. The influence spectrum from both UNNC (Table 5) and NBU (Table 6) categorize those groups identified according to their interest and influence. The results provide insight to the classification that is generally observed in area of planning and decision making within Chinese society, which is the top-down influence. The results also show that from Sino-foreign perspective, top-down influence remains relatively the same i.e., students, faculty and local community have little impact on the key sustainability decisions as compared to university leaders and administration, in spite them being affected the most by these decisions.

Table 5: Stakeholder group categorisation in UNNC.



High influence	N/A	1. University leadership 2. Administration 3. Expert
Low influence	1. Company on campus	1. Faculty 2. Students 3.Society (community)
	Low interest	High interest

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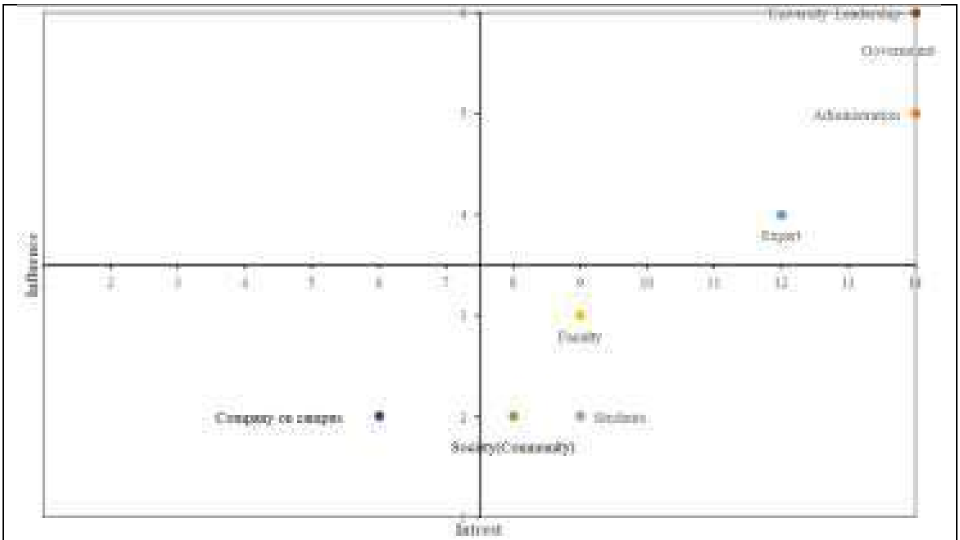
Table 6: Stakeholder group categorisation in Ningbo University.



High influence	N/A	1.Government 2.University leadership 3.Administration 4.Expert
Low influence	1.Company on campus	1.Faculty 2.Society (community) 3.Students
	Low interest	High interest

Relating results from Tables 4–6, the implication would be that the government in both systems have significant influence on the sustainability direction of the institution from top-down vantage points. This is also more impactful due to the current Chinese national plan that is focused on achieving carbon emissions peak by 2030 and carbon neutrality by 2060 thus the current agenda in terms of sustainability is focused on reducing emissions [20]. Within China, this has traditionally been done through the widespread implementation of renewable energy technologies and energy efficacy measures. In fact, reviewing the history of campus sustainability, China began its approach towards sustainability with its eco-technology demonstration and facility energy management with strong enforcement from the government. A series of regulations and guidelines, such as "The Construction and Management Guidelines of Energy and Resource Conservation Oriented Campus in Colleges and Universities [2008] No.89", "Technical Guidelines of Campus Energy Management System Construction in Colleges and Universities [2009]", etc. was created to provide technical guidance for the construction of an energy and resource conservation-oriented campus [15]. Thus, in both institutions, it is quite likely that their motivation and directions of sustainability will be influenced by the government's sustainability agenda. This could trickle down to the experts that are hired i.e., to say though they have influence in terms of sustainability, this would likely be from research output, consultancy, and advisory perspective. Also, though flexibility may exist in terms of the actual research direction and expertise of the institution, this still would still revolve round energy and environmental based activities. The problem with this approach to management is that sustainability, in particular ESD oriented goals needs to consider all dimensions of sustainability i.e., economy, society, environment and institutions, and while it is commendable to address issues of carbon reduction, this does not inherently signify sustainability [21]. Even more so, the very premise of sustainability is based on participatory decision making and inclusivity where the relevant stakeholders are given a meaningful voice. Yet, when UNNC is compared to Ningbo University, only 18 staff are focused on sustainability aspects, with 13 out of those 18 staff focused reducing carbon through energy and pollution-based research. Alternatively, UNNC has 66 staff focused on sustainability-based issues, a stark difference from Ningbo University. This is likely because UNNC is a private Sino-foreign university with larger tuition fees, thus UNNC can afford higher number of staff. A second reason also exists, which is that unlike Ningbo University, whose management is strongly driven by Chinese party objectives. UNNC policies are also driven university mandates and direction which is from the parent campus in the UK. For example, the sustainability strategy is adopted from the UNUK strategy which states that they aim *"make an outstanding contribution to supporting the United Nations Sustainable Development Goals (SDGs) through our research and education, our engagement with partners and our behaviour on campus and in our communities. We will place a special emphasis on environmental sustainability, supporting the City of Nottingham's desire to be a net zero carbon city by 2028 and working with partners in China and Malaysia to improve sustainability within their regions"* [22]. The key point is that UNUK's management is focused more on sustainable development goals, which is internationally recognised and more balanced in terms of sustainability agenda, while China generally develops a five-year national plan/strategy that is implemented all through the country.

Additionally, it is clearly stated in UNUK sustainability strategy that environmental sustainability would be the primary focus. This is further evident because out of the 66 staff members focused on sustainability at UNNC, 43 of them focus on energy and environmental sustainability research or activities. However, Ningbo University does not have a specific sustainability strategy that exists on universal level, aside the current national mandate of carbon neutrality and carbon peak. This does not infer that other Chinese Universities do not subscribe to international frameworks, as universities such Tongji university in Shanghai is known for the establishment of the UNEP-Tongji Institute of Environment for Sustainable Development (IESD), which was established jointly by the United Nations Environment Programme (UNEP) and Tongji University on May 9, 2002 [5]. Regardless, this does not change the narrative that local mandates and agenda take precedence in China. Coincidently, it so happens that China's carbon neutrality agenda and Nottingham UK zero carbon City agenda align thus allowing for more seamless congruence on goals and less conflicting aims. The question which this paper requires further investigation is, what happens if such interest does not align. Which agenda would supersede the other? Therein lies a world another difference that is beyond the scope of the paper but requires further investigation.

5 RESULT AND DISCUSSION

To conclude, the structures of Sino-foreign and Chinese universities are similar in terms of the identification of relevant stakeholders, however, the powers the stakeholder wields varies. Chinese universities have fewer conflicting agenda's but may possess fewer resources than private Sino-foreign universities. Another key point is that within China, the National policy or sustainability agenda largely governs the direction where universities would allocate manpower and financial resources in terms of sustainability, however Sino-foreign universities need to contend with national laws or even university policies from the parent university abroad that may create conflict of interest in terms of unified approach to sustainability-based issues on campus. Moreover, through stakeholder analysis, it was made evident that both institutions utilize a top-down approach in terms of ESD and while other less influential stakeholders have high interest, their level is generally limited. A key limitation to this study was that the justification behind the classification of stakeholders and their interest, which was based on online information and data, a follow up study directly interviewing key stakeholders on their influence and interest will be conducted to provide additional context to the stakeholder analysis and offer relevant strategies to optimize inclusivity in ESD within both local and Sino-foreign universities.

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SECTION 9
URBAN TRANSPORTATION AND PLANNING

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ESTIMATING AND UPDATING GAP ACCEPTANCE PARAMETERS FOR HCM6TH ROUNDABOUT CAPACITY MODEL APPLICATIONS

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ABSTRACT

This paper treats on-field observing data and then applying estimation procedures to estimate follow-up headway and critical headway at roundabouts. The theory of gap acceptance constitutes the attempt to faithfully represent the behavior of users at non-traffic light intersections. The follow-up headway and critical headway are two critical parameters of the roundabout capacity model illustrated in the 6th edition of Highway Capacity Manual (HCM6th). The capacity model was developed as an exponential regression model and is strongly influenced by driver behavior and local habits. This paper, therefore, aims at verifying whether the suggested general values are also suitable for Italy. The follow-up headway can be measured on-field, while the critical headway cannot be obtained directly, in fact numerous studies and techniques have been developed for its estimation. The most popular ones are the Maximum Likelihood method, the Raff method and the Median method. The latter has been chosen as the calculation method, since it is the one that is more frequently used and is considered both the simplest and characterized by an acceptable approximation threshold. This method requires information on the accepted headway and the major rejected headway for each driver, therefore, a sample of data was recorded on-field with a digital camera and then processed. Sample data of the critical headway and of the subsequent headway were collected for three carefully selected roundabouts in the province of Lucca, Tuscany (Italy). As a check, it was verified that the values of the critical headway and of the follow-up headway calculated were comparable to those obtained from the analysis carried out in Tuscany in 2012. Finally, a comparison has made between the default values of HCM6th and our firstly obtained results indicated that the average critical headway was significantly lower than the recommended values. Insights for further research developments are suggested in the conclusions.

Keywords: gap acceptance theory, critical headway, follow-up headway, HCM6th, roundabout capacity model, median method.

1 INTRODUCTION

The Highway Capacity Manual 2010 roundabout capacity model (HCM 2010) [1] was developed as an exponential regression model with parameter estimates based on gap acceptance theory. Later this model was updated and further illustrated in the 6th edition of the Highway Capacity Manual (HCM6th) [2].

Gap acceptance models are strongly affected by driver behavior and local habits. Therefore, the HCM6th capacity model should be calibrated to local conditions. Two parameters that may be changed to reflect local driving behavior are the critical headway and follow-up headway (referred to as critical gap and follow-up time in earlier studies [3]). The accuracy of capacity calculations at roundabouts is dependent largely on the accurate estimation of critical headway and follow up headway. The NCHRP Report 572 presents a set of critical headway and follow-up headway values based on a comprehensive evaluation of roundabouts throughout the United States [4].

Its recommended operational models were incorporated into the 6th edition of HCM. The purpose of this research project is to test the adaptability of the HCM6th capacity model in Tuscany (Italy). To achieve this goal, we collected local gap acceptance data.

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The first step of this research project was related to the local data collection. Therefore, the study was conducted at three selected roundabouts located in the province of Lucca in Tuscany (Italy), collecting and analysing a field data sample. The follow-up headway can be measured on-field, while the critical headway cannot be obtained directly, in fact, numerous studies and techniques have been developed for its estimation. The most popular ones are the Maximum Likelihood method, the Raff method and the Median method [5].

The latter has been chosen as the calculation method, since it is the one that is most frequently used and is considered both the simplest and characterized by an acceptable approximation threshold [6]. This paper shows the results of such study, which can be considered as the continuation of the previous research, in fact, we also verified that the values of the critical headway and of the follow-up headway calculated are comparable to those obtained from the analysis carried out in Tuscany in 2012 [7].

2 DATA COLLECTION AND EXTRACTION

Data collection was carried out on three existing roundabouts using digital video cameras SONY DCR-SX34 placed at specific points of the roundabout intersections during weekday peak periods (Fig. 1) Flows of vehicles circulating in the ring and entering in the roundabout were recorded when high traffic volumes were actually observed.

Figure 1: Measurement station with Sony DCR-SX34 video camera.

A continuous queue at the entrance of each branch was required in order to have a considerable number of follow-up headways, while intense heavy flow on the ring was needed to obtain a significant number of drivers who rejected at least one headway before entering the roundabout. Sites were selected on the basis of the position of the roundabouts respect to the city of Lucca in order to measure headways related to different areas. As can be seen in Fig. 2 the selected roundabouts are located at:

- Porta Santa Maria;
- Porta Elisa;
- Piazzale Boccherini.

Figure 2: The three selected roundabouts in Lucca. *(Source: http://www.pacinifazzi.it.)*

As we can find in other studies [3], [4], [7], we made the following assumption: the conflicting flow was assumed unique and was not considered separately for each lane in the ring; in fact, experimental observations at multi-lane roundabout have shown that drivers are conditioned by the conflicting flow of both lanes in the ring. Headway data were extracted later from the recorded videos. For each entry, we first defined the finish lines:

- "s" as conflict section;
- "i" as entrance section;
- "u" as exit section.

Then three times events were recorded: the time at which an entering vehicle stopped at the stop line, the passage times of circulating vehicles that going directly conflicted with the entering vehicle, and the time when the entering vehicle left the stop line [8]. The passage times of circulating vehicles define the start and end of major stream headways that were either accepted or rejected by the entering vehicles. The definition of headways, from NCHRP Report 572, has used in this paper [4].

The procedure for extracting video data required the following steps: display the movie using the VLC media player™ software in order to record the frame number in which happens the event of interest; record the frame number on Excel worksheet; review the movie once for each event of interest.

3 DATA ANALYSIS

Accepted headways, maximum rejected headways and follow-up headways were calculated in the worksheet. The headways were determined through VLC Media Player™ software, by counting frames between successive vehicles (25 frames per second, for EU standards). Next, the Median method has been used as the calculation method to estimate critical headways. Finally, the follow-up headways have computed directly from the observed values.

3.1 Follow-up headway

Follow-up headway is the minimum headway between two entering vehicles, which can be calculated by the average difference between the passage times of two entering vehicles accepting the same gap under a condition of the queue [3].

Follow-up headways were computed from the recorded time events. Once all the individual follow-up headways were obtained, the average and the standard deviation were calculated. Table 1 summarizes the follow-up headway averages for the seven entrance branches of the three roundabouts. Instead, Table 2 summarizes the follow-up headway standard deviations for the seven entrance branches of the three roundabouts.

Table 1: The follow-up headway averages.

Roundabout site	The follow-up headway averages (s)					
	Entrance 1		Entrance 2		Entrance 3	
	Left	Right	Left	Right	Left	Right
Porta Santa Maria	2.55	2.49	/	/	/	/
Porta Elisa	2.53	2.44	2.51	2.39	2.40	2.60
Piazzale Boccherini	2.47	2.60	2.52	2.61	2.54	2.47

Table 2: The follow-up headway standard deviations.

Roundabout site	The follow-up headway standard deviations (s)					
	Entrance 1		Entrance 2		Entrance 3	
	Left	Right	Left	Right	Left	Right
Porta Santa Maria	0.58	0.61	/	/	/	/
Porta Elisa	0.54	0.56	0.59	0.55	0.53	0.58
Piazzale Boccherini	0.58	0.61	0.53	0.63	0.52	0.61

As we can see from the tables, as regards Porta Santa Maria roundabout only one entrance was considered, while for those of Porta Elisa and Piazzale Boccherini three entrances were considered. Furthermore, since each entry, of all the seven branches under study, was a two-lane entry, the distinction was made between the right lane and the left lane.

3.2 Critical headway

Critical headway represents the minimum time interval in the circulating flow when an entering vehicle can safely enter a roundabout [3]. In general, the critical headway is a parameter that depends on local conditions such as geometric layout, driver behavior, vehicle characteristics, and traffic conditions [9]. However, the critical headway unlike follow-up headway cannot be measured directly in the field or from recorded events. Hence, numerous studies and techniques have been developed for estimating critical headway.

The most popular ones are the Maximum Likelihood method, the Raff method and the Median method [5]. The latter has been chosen as the calculation method, since it is the one that is most frequently used and is considered both the simplest and characterized by an acceptable approximation threshold [6].

This method, like the others, require information about the accepted headway and the largest rejected headway for each driver. The rejected and the accepted headways were being enumerated within the Excel worksheet.

The Median method is a statistical method, based on the median of the observed distribution, that was used to estimate critical headway. This method assumes that the best estimate of critical headway for each driver is the average between the largest rejected headway and the accepted headway. The value of critical headway thus obtained for each driver was recorded in size classes of 0.5 s. This way, a histogram has depicted, where the *x*-axis contains the classes of critical headways and the *y*-axis reports the frequencies (in percentage).

Therefore, the class containing the median of the distribution was determined and at the end, the critical headway of the sample was estimated within this class, assuming a linear trend. An amount of 979 drivers was analyzed to calculate the critical headway of left and right lanes of the seven entrance branches of the three roundabouts. The obtained results of the critical headway measurements of all the sampled sites are summarized in Table 3.

Table 3: Observed critical headway values.

Roundabout site	Critical headway (s)					
	Entrance 1		Entrance 2		Entrance 3	
	Left	Right	Left	Right	Left	Right
Porta Santa Maria	3.70	3.79	/	/	/	/
Porta Elisa	3.72	3.69	3.71	3.36	3.78	3.72
Piazzale Boccherini	3.77	3.60	3.76	3.58	3.82	3.63

As an example, the calculation of the critical headway of the left lane of branch n. 1 of Porta Elisa roundabout is shown. The following is reported: an extract of first 10 rows of the excel table containing 72 rows, one row for each one of the observed vehicles traversing the studied entrance, its largest rejected interval, its accepted interval and the average between them (Table 4); the histogram containing the classes of the critical headway and the frequencies in percentage (Fig. 3).

To estimate the critical headway, first of all the sum of the percentages of classes 2.5, 3.0 and 3.5 was calculated (34.72%) to find the remaining percentage to reach 50% (15.28%). Hence, we evenly distributed the 0.5 s in the 4.0 class by dividing 0.5 by the percentage frequency 34.72 and obtaining 0.0144. Finally, we have multiplied the percentage 15.28% by 0.0144 and we have obtained 0.22 s, which is the period to add to the previous class 3.5 s to obtain the critical headway in this specific case (3.72 s).

4 RESULTS OF THE EXPERIMENTS

The experimental results for follow-up headway are summarized as follows. Follow-up headways averages range between 2.39 s and 2.61 s with a mean of 2.50 s. If we made the

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Table 4: Extract (first 10 rows) of the 72 rows critical headway worksheet.

Vehicles	Largest rejected headway	Accepted headway	Average
1	2.9	6.2	4.55
2	2.4	6.4	4.40
3	3.0	6.0	4.50
4	3.9	3.2	3.55
5	2.2	3.5	2.85
6	1.5	3.6	2.55
7	1.3	6.7	4.00
8	2.4	5.4	3.90
9	1.6	3.0	2.30
10	1.8	3.9	2.85

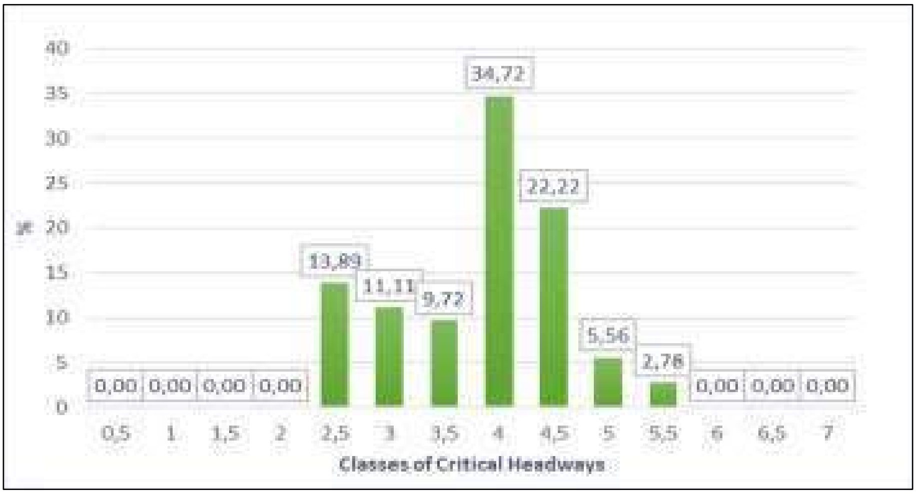

Figure 3: One of the experimental histograms.

distinction between the right lane and the left lane, the values are closer. In fact, for the left lane only, the follow-up headway averages vary between 2.40 s and 2.55 s with an average of 2.48 s; while for the right lane only, the follow-up headway varies between 2.39 s and 2.61 s with an average of 2.50 s.

The values of the average follow-up headway for each type of lane for the three roundabouts are summarized in Table 1. Regarding follow-up headways standard deviations ranges between 0.52 s and 0.63 s with a mean of 0.58 s. Also in this case, if we made the distinction between the right lane and the left lane, the values are closer. In fact, for the left lane only, the follow-up headway standard deviations varies between 0.52 s and 0.59 s with an average of 0.56 s; while for the right lane only, the follow-up headway varies between 0.55 s and 0.61 s with an average of 0.58 s.

The values of the standard deviation follow-up headway for each type of lane for the three roundabouts are summarized in Table 2. The experimental results obtained through the Median method for critical headway are summarized as follows. Critical headway ranges between 3.36 s and 3.82 s with a mean of 3.59 s. If we made the distinction between the right lane and the left lane, the values are closer. In fact, for the left lane only, the critical headway varies between 3.70 s and 3.82 s with an average of 3.76 s; while for the right lane only, the critical headway varies between 3.36 s and 3.79 s with an average of 3.58 s. The values of the average critical headway for each type of are summarized in Table 3.

4.1 Comparison with previous studies

In the following, the average critical headway and the average follow-up headway obtained in 2020 in Tuscany were compared with the values from previous studies. Initially, a direct comparison was carried out between this study and the similar work conducted in 2012, always for Tuscany, by Gazzarri et al. [7]. In that research it had already been done a comparison between their headway results and those from some international references, such as HCM2010 [1] default capacity model, NCHRP Report 572 [4] and Xu and Tian [3] (work conducted in 2008 for the State of California). Then, comparisons were made between the headway results from this research and the default data of HCM6th that is the international reference [2].

Table 5 shows the comparison between the critical headway of HCM6th, Tuscany 2012 and Lucca 2020. Table 6 shows the comparison between the follow-up headway of HCM6th, Tuscany 2012 and Lucca 2020. Finally, a comparison of the capacity model calibration by these different studies was carried out to evaluate the differences in capacity calculations at roundabouts.

Table 5: Critical headway comparison.

Average critical headway (s)	
HCM6th (2016)	4.29
Tuscany 2012	3.69
Lucca 2020	3.59

Table 6: Follow-up headway comparison.

Average follow-up headway (s)	
HCM6th (2016)	3.19
Tuscany 2012	2.59
Lucca 2020	2.50

4.2 HCM6th capacity model calibration

Local calibration of the capacity models is recommended to best reflect local driver behavior. [2] The HCM6th capacity model was calibrated by using specific data for critical headway and follow up headway. The estimates parameters *A* and *B* are shown in Table 7.

Table 7: Parameters *A* and *B* estimates.

	t_c (s)	t_f (s)	$A = 3{,}600/t_f$	$B = (t_c - 0.5\ t_f)/3{,}600$
HCM6th (2016)	4.29	3.19	1,128	0.00075
Tuscany 2012	3.69	2.59	1,390	0.00067
Lucca 2020	3.59	2.50	1,440	0.00065

The HCM6th capacity formula is a function of the parameters *A* and *B* and of the circulating flow *Qc*. A table was built with its relative graph (Fig. 4), where, as *Qc* varies, it is possible to obtain the capacity *Ce* of the entrance, using the parameters *A* and *B* of the HCM6th [2], of Tuscany 2012 [7] and of Lucca 2020. The circulating flow *Qc* was made to vary between 0 pc/h and 1,200 pc/h (Table 8).

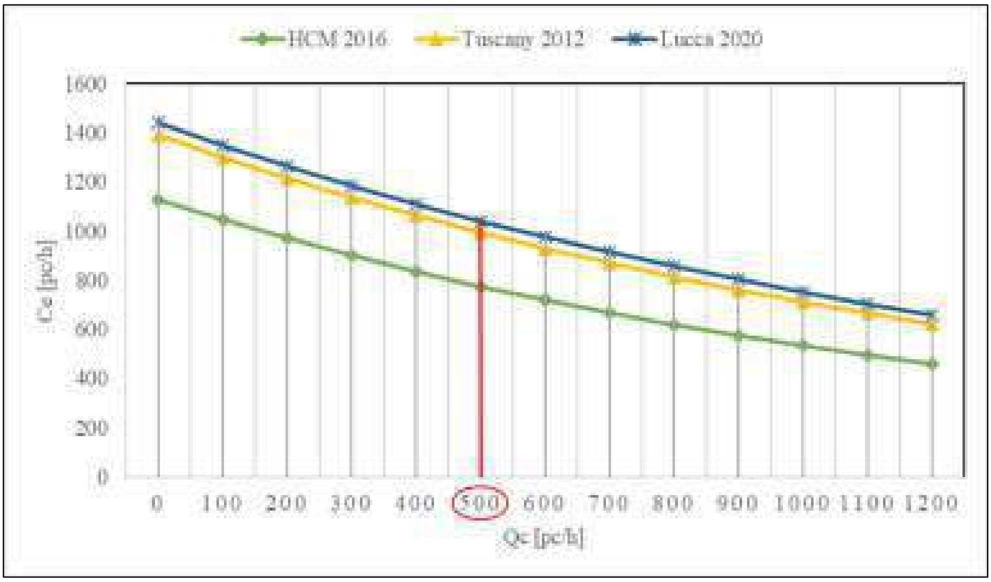

Figure 4: HCM6th roundabout capacity model calibration.

Table 8: Calculation *Ce* as *Qc* varies.

Ce = A^(-B·Qc)	HCM6th (2016)		Tuscany 2012		Lucca 2020	
Qc (pc/h)	*A*	1,128	*A*	1,390	*A*	1,440
	B	0.00075	*B*	0.00067	*B*	0.00065
0	1,128		1,390		1,440	
100	1,046		1,300		1,349	
200	971		1,216		1,264	
300	901		1,137		1,185	
400	836		1,063		1,110	
500	775		994		1,040	
600	719		930		975	
700	667		870		914	
800	619		813		856	
900	574		761		802	
1,000	533		711		752	
1,100	494		665		704	
1,200	459		622		660	

One can observe that models resulting from the use of Lucca specific data and Tuscany specific data for critical headway and follow-up headway have a higher intercept, and thus a higher capacity, over their whole range when compared with HCM6th model. Fig. 4 shows the trend of several capacity models. The "Lucca model" provides values of roundabout capacity significantly greater than those provides by HCM6th capacity model [2]: for example, considering a conflicting flow amounting to 500 pc/h, the capacity is +34.20% greater (Table 9).

Table 9: Percentage difference.

Capacity *Ce* (pc/h)	
Conflicting flow *Qc* = 500 pc/h	
HCM6th (2016)	775
Tuscany 2012	994 (+28.26%)
Lucca 2020	1,040 (+34.20%)

5 FURTHER RESEARCH

An observation that is easily understood is that the critical headway is not only variable from driver to driver, but the same individual may behave differently according of several factors. Furthermore, apparently irrational behavior by several drivers must be considered: some of their after refusing intervals of a given width, they accepted one of width inferior [10]. This attitude is called "inconsistency" and is probably realized when the user has been stationary at the intersection for a long time. This phenomenon is observable in the obtained data.

The continuous research and eventual updates of the critical headway and the follow-up headway are of fundamental importance, since the accuracy of capacity calculations for roundabout branches largely depends on the estimate of these two parameters that reflect the local driving behavior.

This research can be considered the natural continuation of the studies done in Tuscany in 2012 [7]. As with the previous study, these experimental results confirm that critical headway and follow-up headway are heavily influenced by driver behavior and local habits. The differences highlighted in the previous research between Tuscany (Italy) and the United States required further observations on the ground; then this research can be used as further confirmation of the results obtained. Anyway, the highlighted differences between Lucca and in general Tuscany (Italy) and the United States requires further field observations, to account for a wider range of local site conditions to improve the capacity model calibration. The median method is easier and faster than the other methods and it produces quite similar results, therefore it is the best to use also in future research.

Finally, as actual behavior of entering drivers may be influenced by the presence of heavy vehicles, this issue should be studied. Further next research steps will concern with both extensions of sample data, and application of simulation approach.

The experimental findings of this research work addressed to experimentally derive the roundabout model parameter values can be viewed as a practical design reference, which is useful both for the City of Lucca Technical Bureau, and for any other location in Tuscany.

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RETROFITTING PUBLIC TRANSPORT SYSTEMS TO REDUCE HEALTH HAZARDS FROM PANDEMICS

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ABSTRACT
The physical requirements of public transport systems are re-examined so that the influence of future virus pandemics can have minimal effects on public transport use. Rail, bus, tram and civil aviation are included. Previously suggested methods to increase usage of public urban transport are also included and reconsidered to help offset investment costs needed to provide security in future virus pandemics. It is also concluded that government controls to stimulate herd immunity should also include monitoring of the immune systems of populations in order to minimise adverse effects in future pandemics such as mutation of viruses.
Keywords: COVID-19, virus pandemic, public transport systems, human innate and adaptive immunity.

1 INTRODUCTION

The COVID-19 virus is at its most contagious within our big cities. It follows that it is mostly within the big city environment that we need to apply remedial measures. From the start the point must also be made that such virus pandemics are a natural control process of Nature. Predator/prey dynamics is the natural method of population control of any species where Nature perceives an imbalance in need of correction.

There are millions of different types of virus, based both on RNA and DNA genetics. Almost all viruses are benign in their effect on human life. Yet they all act as parasites on selected higher life-forms from the most humble of bacteria to ourselves. Having no reproduction systems like the higher forms of life which they invade, they reproduce by destroying cells in their host to use their chemicals in order to replicate themselves.

Despite the widespread belief that we should usually try to integrate ourselves with the forces of nature, the suggestion of changing our major cities to cope with disease is a very different matter of great concern to us. Our major cities are a vital part of our modern civilisation. Our cities host most of our high-level technologies on which we now depend. Also, cities need a very varied and highly skilled workforce to service these industries. In this respect it follows that we have no option but to find ways to accommodate high density human populations safely and adapt the raw forces of Nature and force them to meet our own specific needs.

2 VIRUS PANDEMICS

It is important to make good and long-lasting any investment in public transport systems. This raises the question of predicting the forms any future pandemics will take. This requires a good understanding of earlier pandemics and an understanding of the likely consequences of future mutations. At present our knowledge of COVID-19 is very limited and uncertain (see Appendices I and II). Fortunately, because cases of infection are now running into millions of victims we will, within a few months, be able, presumably, to analyse vast amount of statistical data (see Appendices I–III). This can be expected to answer many of our questions. This indicates that the present paper should only be considered as an interim report.

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It also seems logical that, when designing equipment to cope with pandemics, we should try to design "add on equipment" which can be removed easily and cheaply once the pandemic has run its course. The "add on equipment" can then be placed in store and hopefully be useful later when Nature inflicts the next pandemic on us. This is the policy adopted in the present interim paper. Future experience may well make this policy questionable.

3 ADEQUATE SCIENTIFIC PRELIMINARY INVESTIGATIONS

There are likely to be deficiencies in some of the statistical data mentioned above. In particular the state of a patient's immune system is seldom measured in medical practice in a detailed manner and an individual's immune systems can vary considerably even in persons of similar age [1].

4 EXTREME PROBLEM AREAS

Some of the areas of particular economic concern have factors which make it near impossible to come to conclusions at the present time. One such example is the heavily impacted cruise-ship tourist industry. This industry relies heavily on the social programmes of activity which are organised. The COVID-19 pandemic has to be recognised as a direct attack on any form of social activity. Such examples, which also include any form of public entertainment or education, are outside the scope of this paper.

5 A VENTILATED FACIAL SHIELD

Much has been written in the popular literature about the relative merits of the cloth face mask versus the transparent plastic facial shield used by many hospital workers. The mask gives only limited protection to the wearer, but its main value is to prevent larger droplets infecting other people nearby when the wearer coughs or sneezes. Larger droplets contain more virus than fine aerosol particles and consequently are likely to be far more dangerous. The fine aerosol particles obey Stokes law [2] where the aerodynamic restraining drag force on a fine aerosol particle makes them follow the surrounding air closely. These aerosol particles have much smaller cough/sneeze-projected trajectories than the 1arger droplets [2].

By contrast the hospital face shield also provides a shield against all droplets of any size and because the open base is quite wide, any upward air flow due to the wearer breathing is minimised allowing fewer fine aerosol particles to enter the wearer's lungs. We have all the technical information [3] we need to design this type of protective headgear. A final design for our purposes would be expected to look like that in Fig. 1. The approach illustrated in Fig. 1 seems likely to be used more frequently than other design concepts. This protective

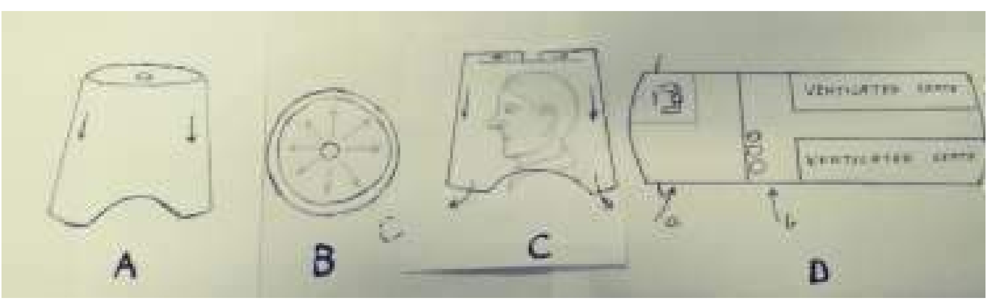

Figure 1: The most likely method of preventing virus infection in transport systems.

unit shown in Fig. 1 is likely to become commonplace in future equipment and is in the form of a truncated circular cone shown at A. Its flat enclosing top (B) has a short central inside-facing socket. This can be connected with a catch-clip to a hose feeding uncontaminated air for the wearer. The lower edge of the catch-clip socket ends in a circular disc ((B) and (C)) projecting the incoming air to the inner edges of the helmet (C). This is to minimise turbulence and attain a smooth downflow of air which exits at the lower edge of the helmet. Two indentations on the lower edge allow the helmet to sit correctly on the wearer's shoulders.

5.1 Application 1: Use in aircraft

Most civil aircraft are fitted with overhead air supply points for each seated passenger. They are called gaspers. Gaspers could be replaced with short pull-down hoses which turn the air supply on when pulled and the free end can then be clipped to the helmet. Clean outside air is readily available at high altitudes and can be heated and bled from the engines to supply passengers with uncontaminated air. This air is finally exhausted from the aircraft at floor level. The physical nature whereby passengers become infected in aircraft is not well studied at the present time. Even young and fit cabin staff sometimes test positive for COVID-19. How this happens may be unclear. Today's air terminals are often grossly overcrowded and not organised well enough to control infection. Like many other workplaces they need special attention (Appendix IV).

5.2 Application 2: Use in trains, trams and buses

Because of their truncated cone shape, these helmets can be easily stacked in circular containers. Fig. 1(D) shows the passenger entrances for a suggested retrofitted local bus. This bus has two entrance/exit points for passengers. The entrance "a" is for normal occasional passengers who pay the driver in the normal manner which is used today. These casual passengers are separated completely from those who enter at "b". These passengers entering at "b" can only pass the entrance harrier by inserting their own personal public transport card. This card, normally used with a mobile phone, carries all the information of a previously booked seat in the virus-free section of the bus. This bus has three identical vertical cylinders at the "b" entrance. Each cylinder contains a pile of these helmets. Each of the three containers has three lights (let us say red, green and yellow). These indicator lights are located on all three lids, one of which is on the top of each container. When a bus (or tram or train) stops, the lid of the container with a yellow light opens and departing passengers place their discarded helmets in this bin. When the first new passenger inserts their travel "ID" card in the check slot in the bus outer wall, the yellow-lit cylinder lid closes and its yellow light changes to red. The lid of another cylinder (which displays a red light) then opens and it displays a green light. Each embarking passenger then uses a finger to lift out a helmet and takes his/her registered seat and couples up the helmet to the clean air system. The bus then departs and when it comes to the next stop, the cylinder with the red light changes to green. Cylinders which display a red light always have a closed lid while an ultra-violet (C) lighting system (see Section 8) sterilises the helmets for re-use.

6 OFFSETTING RETROFITTING INVESTMENT COSTS IN PUBLIC TRANSPORT

It is normal for traffic congestion in most cities to act as a stimulus for using the public transport alternative. Because of personal fear of infection by COVID-19, public transport

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use has usually been found to dwindle to an uneconomic level. The simultaneous implementation of lockdowns also reduced traffic congestion, but this is not really a desirable feature and is just a consequence of the world economy taking a staggering blow.

By far the most important factor is that public transport systems are also usually underutilised, even in normal times. This is because most people live at an inconveniently long distance from the nearest bus stop or train station.

As the danger of further pandemics is placing public transport in the unenviable position of becoming unviable, it is appropriate to also reconsider an earlier study [4] which was aimed at developing a much-increased patronage of our existing public transport. The argument is that, if a time has now come to redesign public transport for health reasons, then it is reasonable to combine these measures with a program to make public transport much larger and with a stronger financial basis.

7 AN EARLIER RELEVANT STUDY

Fig. 2 shows a composite view of this earlier work [4]. View A shows a man leaving home to go to work. He is pulling a small case on 2 large wheels. The case is rather like the suitcases we normally use when traveling. He then unlatches the suitcase when he reaches the road to reveal a 20 kg folded motor scooter shown at B. This is easily unfolded in a few seconds and locking sliding-tube joints produce a lightweight motor scooter shown at C. He then travels at a maximum speed of 20 km/hr along bicycle tracks to a bus stop or railway station where the scooter is folded up and placed in its case. At D, he is stowing his scooter in a numbered locker in an express train. If he was catching a slow speed bus, his personal transport would be attached to a numbered hook system on the outer side of the bus. When he gets to his destination he unfolds his scooter and rides to work. All the ticketing/reservation for this system would normally be done on the ubiquitous mobile phone with a system access card for using public transport. Today government authorities would have the right to control use of the card if the holder is suspected of carrying an infection. For example, the virus vaccination details would be recorded on the id card and would control the card’s use.

Fig. 2 shows activity in a warm climate with a scooter using a 1 kW lithium-ion energised motor with a battery which is rechargeable on public transport. Recharging costs would be added to the user’s card. In colder climates such as winter in Helsinki or Toronto, a similar system was suggested using a miniature air-cooled diesel engine which can also provide up to 400 W of riding suit heating through a thermostatically controlled umbilical cord.

It was also envisaged that secondary school children would be allowed to ride these scooters to and from school. Users of this system may prefer to use their own pushbike style headgear which would include and be designed to be compatible with the head shield described in Fig. 1.

8 DISCUSSION

Combating COVID-19 and other pathogens which can cause pandemics goes a long way beyond the limited scope of this paper. For example, we have experienced outbreaks of COVID-19 in large commercial organisations such as abattoirs.

In order to safeguard staff, any large company may well decide to install disinfection equipment. One commonly available form for treating air supplies is to use ultra-violet (C) lighting which sterilises viruses [5]. This could be a system which takes only a portion of the output of an air conditioner. Because UV (C) light is harmful to human skin, causing

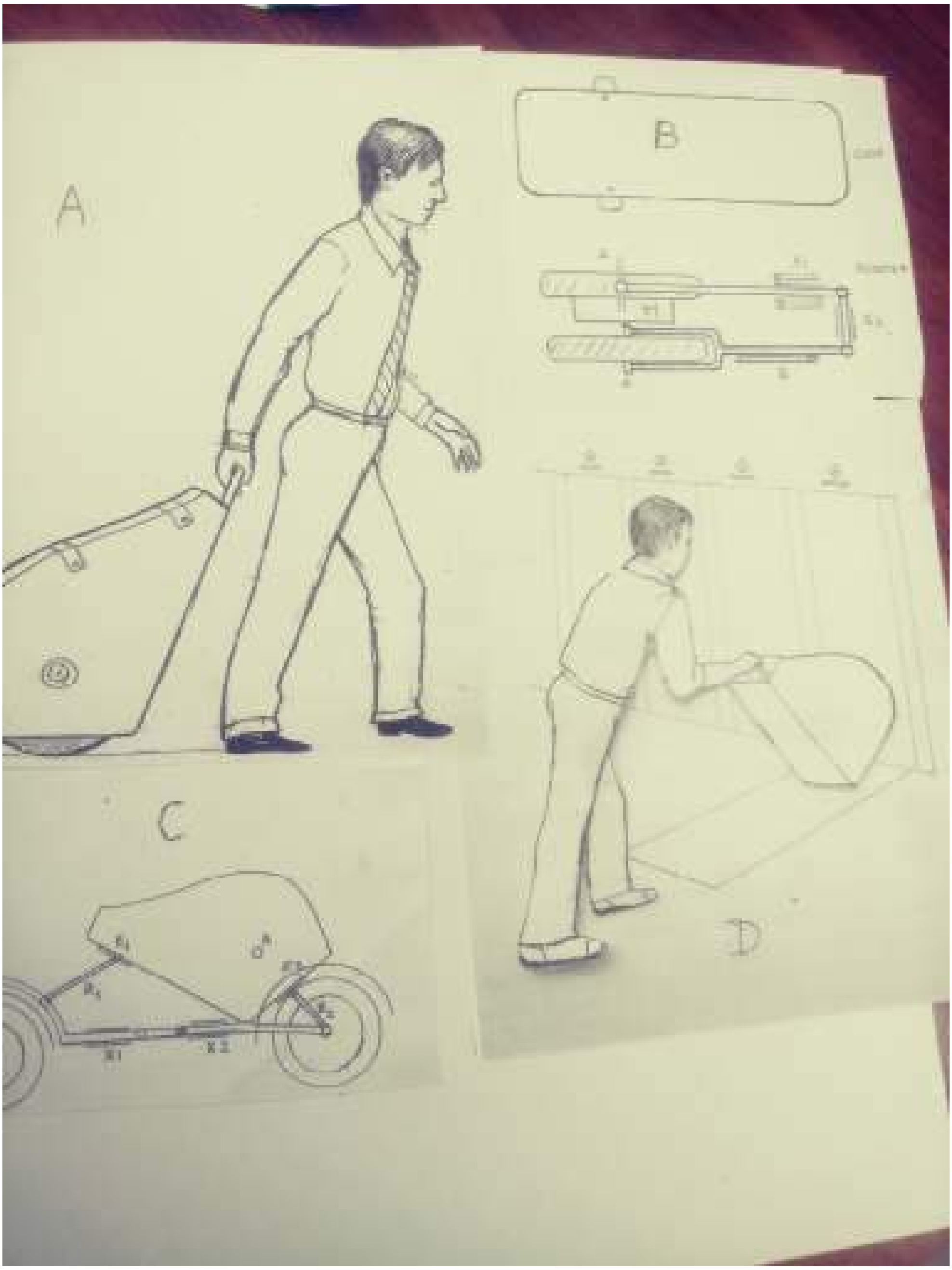

Figure 2: Summary of earlier work to improve public transport economic viability [4].

the onset of melanoma and other cancers, this form of sterilisation must take place in a closed container. Inadvertently such a process also produces dead pathogens which, in a small way, are beneficial to employees. Such a company, acting responsibly, would probably also install equipment for visual recording and identification of staff. This is to monitor and provide warning of abnormal coughing, sneezing and high skin temperature. Facial recognition technology, as widely used today in China, is now available and can be adapted easily to request anyone suspected of infection to report immediately to the appropriate authority.

It is reasonable that any organisation employing staff should be able to exercise the same rights as governments assume when ordering compulsory cessation of activity which is suspected as dangerous to public health. Because RNA based viruses are prone to random mutation, it is difficult to prescribe industrial codes of practice as an alternative precautionary measure.

The above suggestions are not new technology. Sensitive areas in hospitals such as operating theatres are often sterilised overnight with UV-C radiation when not in use. Statistical information, such as immune system cell counts from theatre staff would be of much interest in improving virus control.

Vaccines made from dead or weakened viruses are likely to be very effective. To the best of the present writer's knowledge, no vaccine manufacturer has attempted to use this approach due to lack of basic knowledge concerning the dangers of COVID-19. For example, the much-used AstraZeneca vaccine uses a harmless vector virus to transfer artificially processed genetic material into our cells to trick our immune system to respond. This, like other vaccines using new technologies may, or may not, take place correctly in different individuals.

9 OUR IMMUNE SYSTEM: A NEGLECTED AREA OF HUMAN HEALTH?

Our artificial armoury against the ravages of COVID-19 viz. lockdown, hand washing, masks, vaccines and social distancing, are only supplementary. Our normal defence against pathogens is our own immune system [6]. One might even suggest that some of the mysteries surrounding COVID-19 may even be explainable in terms of immune system behaviour if we had more accurate facts at our disposal.

Government instrumentalities worldwide seem to have ignored the importance of a healthy immune system. A most useful recent book [7] has raised this issue. This book has also drawn attention to the likely importance of deficiencies in selenium, zinc and vitamins C and D [7, pp. 37–70]. The question needs to be posed: "are immune system deficiencies the cause of the wide spectrum of COVID-19 symptoms?"

It is normal for our immune systems to decline with advancing age and a blood test and cell count analysis are available for us all from routine pathology.

In short, all this explains why any artificial interference in the inner workings of our immune system such as using vaccination or drugs must be undertaken with great care. Mammalian immune systems are believed to be the first natural biological control system to develop. Also, the complexity of our human immune system is second only to that of the human brain. At the present time, it is preferable to only stimulate our immunity externally that is by vaccination. Present approved vaccination is by new and indirect safer methods of moving immune-stimulating genetic material into our cells.

In immunology, although our immunity is a single system, it is normally considered as 2 parts. The innate system is fast acting and not specialised in defending against any specific pathogen attack. The second defence line of the system is our adaptive immune system which has advanced memory cells which act additionally from experience of previous infections. This second system is slower to respond but gives the extra boost needed in severe illness.

Through genetic mutation, pathogens try to find ways past our immunity. If our complicated immune system is overstressed, it does not work as efficiently, and adverse effects occur (see literature on excess inflammation and cytokine storms which can have fatal effects). It has been suggested [6] that the fast-acting innate part of our immune system may also have some memory capacity for past infections and presumably this could improve the effectiveness of our new vaccines.

Vaccination is the method of prime interest in stimulating immunity but there is another much neglected method of strengthening our defences. This is to optimise our immune systems such as by diet and other lifestyle methods [7, pp. 40–147]. We also suffer from many autoimmune diseases from immune systems which are oversensitive. Some infections cause immune system overload and inflammation can be so severe as to be fatal (see literature on cytokine storms).

Fortunately, we are also able to disadvantage virus pathogens by altering their environment adversely with engineered devices as described in the present paper.

10 CONCLUSIONS

1. Our basic understanding of COVID-19 is inadequate. Much has yet to be explained.
2. A comprehensive statistical analysis of past patients (both living and dead) is essential if we are to be able to cope with future pandemics.
3. Future pandemics are likely to involve the human respiratory system as the main source of infection. This makes retrofitting an economically feasible solution in re-engineering our public transport systems.
4. A policy of "add on" technology to existing public transport systems is a feasible approach in many cases.
5. Following on from item 4 above, the ventilated face shield seems to be the most useful and versatile form of protection available to us.
6. In order to offset the costs of retrofitting to upgrade protection of public health, it is recommended that simultaneously steps are taken to enlarge the patronage of public transport.
7. Consideration of immune system deficiency seems to be a neglected area of interest in offsetting future problems.
8. It is logical to plan relief from future pandemics by giving more attention to item 7.
9. Re-engineered systems can assist in controlling virus pandemics. At present progress is limited by lack of reliable basic data. Good design depends on hard facts.

APPENDIX 1: TRANSMISSION OF COVID-19

Evolution has given the human species a remarkably effective innate immune system to provide us with a very fast-operating first defence line against invading pathogens. Our skin is a major component of this. Unfortunately, we need orifices in our skin and pathogens, also exploiting the creativity of evolution, have learnt how to use these orifices to invade our bodies. A number of scientists have suggested that our throat/nose/mouth area is a particularly weak area, despite the development of its own local immune system, and is perhaps even an example of poor design compromise from the evolutionary powers of optimisation. As an intelligent species perhaps we can outwit future virus pandemics by guessing accurately that the unintelligent virus will always try first to exploit the mouth/nose/throat orifice?

APPENDIX II: SURVIVAL AND VIABILITY OF COVID-19

A few leading journals such as the *Lancet* and *New England Journal of Medicine* have reported preliminary data concerning the survival of COVID-19 virus on various surfaces. This virus can survive for several days on cleanable smooth surfaces like glass, metal and plastic whereas survival on cloth and paper is much shorter and measured in hours. Unfortunately, these presently available data are insufficient for the design of engineered equipment for use in a virus-contaminated environment.

U.S. Department of Homeland Security [8] suggest that ordinary sunlight kills off most of the virus which now contaminates our world, but we need much more precise information for design purposes. For example, for the bus shown in Fig. 1(D), should the inlet air for the ventilated facial shields be drawn in from the top of the vehicle and spent air vented beneath the vehicle? Would this be adequate for a bus when it is in an underground city centre bus terminal or should this terminal use a specially designed and adapted air conditioning system? Many reports [9], [10] are comprehensive within their stated limits but are not applicable to the inner city virus contamination we face [11]–[13].

APPENDIX III: AREAS OF UNCERTAINTY IN OUR KNOWLEDGE OF COVID-19

These have been well tabulated in the literature. Just two examples are:

- Why do infected people vary so much in the symptoms they display?
- Why do infected people vary so much regarding recovery time and why do some patients suffer "long COVID-19"?

We need to know why and how these differences occur.

Pathologists seem to have made significant contributions [14], [15] perhaps because, by the nature of their work, they may have escaped much of the trauma experienced by medical colleagues struggling in the hospital wards. Yet in order to interpret pathology data to the best effect we also need good records obtained in the hospital wards for the same patients, be they alive or dead. Perhaps this is often too much of an expectation? Brazil has been so hard pressed that there has hardly been time and space to bury their dead. At the time of writing, the experience in India has been nothing less than horrific.

APPENDIX IV: THE FUTURE OF THE AVIATION INDUSTRY

It seems that the confined passenger seating of tourist class passengers can probably be preserved. Cheap airfares will simply have to disappear if social distancing becomes necessary in airliners. There are many alternative options.

Much depends on the success of the world vaccination programme. Studies of virus infection in civil aircraft are limited and need to be more detailed. Airport terminals are not designed for virus pandemics and seem likely to be much of the problem. Alteration of flight schedules may help. Perhaps long-distance 14 hour fast flights can be replaced by shorter hops of 7 hours or so with passengers marshalled as an isolated group into hotels at night with a full-sized breakfast and evening meal in the hotel. In this way only light refreshments at midday, need be issued in rows to minimise infection. Cost estimates and all these aspects and alternatives are a matter for investigation by the airlines.

APPENDIX V: ORIGINS OF THE PRESENT PAPER

In an earlier paper [16] the present author investigated the following matter.

The hydrogen atom, i.e. a proton, remains stable for at least 10^{24} years whereas a free neutron decays into a proton with a half-life of only a few minutes. Yet both comprise three “up” and “down” quarks (in the ratio two up/one down and one up/two down respectively). These quarks are by themselves extremely unstable and cannot be isolated for detailed examination. Moreover if a free neutron enters an atom’s nucleus, which is a common event (and usually easy to accomplish) it can often increase or decrease the stability of the invaded nucleus markedly.

By way of explanation it was suggested that a self-repair mechanism seems to exist in physical matter and this also had some interesting consequences such as explaining the forward arrow of time. These matters are compatible with our observed experience.

Our present understanding of physical science is that it lacks any real creative ability in itself. Yet the very opposite is true in the biological sciences where the act of creation is commonplace. Also, in DNA based life, self-repair [17] of damaged genetic material is also prevalent and very sophisticated compared with the present author’s study [16]. Today this genetic repair technology is also carried out by ourselves [18].

Therefore it was not unexpected that evolutionary forces would have developed a highly sophisticated self-repair system in living species. Consequently, it was natural enough for the present author to take an interest in biology and especially in the human immune system where the science of self-repair is so advanced and sophisticated [17]. The best way to enter into this new, large and complicated branch of science was to first examine Wikipedia documents. These are concise, very readable and most important of all, edited vigorously to exclude uncertain or speculative science. In this way the present author was able to progress to many detailed papers. Just a few are mentioned here as examples. This handful of many other references [19]–[32] was found useful in this last study, even if much of immunology is still not well understood.

All this concludes the present author’s study of three very different systems (a, b and c) which share the same properties viz:

- The basic inner components of the system have high levels of communication (signalling) between the component parts.
- These components have a strong awareness of “self” and ability to recognise differences from their own “self”.

The studies were for:

(a) The self-testing and repair computers which are commonly used in deep space missions. This system is entirely a product of human ingenuity and is based on well-understood mathematics of probability.

(b) The proton which is a component of all matter in our known Universe. Dismissing any consideration of an explanation of the mystery surrounding the existence of any matter in our Universe, it is possible to explain how the expected lifespan of a proton is of the order of 10^{24} years [19].

(c) The final study is by far the most advanced and sophisticated system, namely the human immune system. This is also the only system known to the present author which also encompasses the ability to produce new life-forms. It includes the basis of the evolutionary development of new life, i.e., in this present day, it is the origin of creation itself.

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STUDY ON EFFECTIVENESS OF SHINKANSEN STATION CATCHMENT AREA: A CASE STUDY OF FUKUSHIMA SHINKANSEN STATION, JAPAN

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ABSTRACT

Transit-oriented development (TOD) in Thailand is the hot issue for mega-infrastructure projects, especially the high-speed rail project connecting Thailand's capital Bangkok to Nakhon Ratchasima province currently underway because TOD is a meaningful tool to promote and support sustainable development for the high-speed rail project. However, Thailand does not have the practical know-how to make it happens. Nakhon Ratchasima high-speed rail hub is one of the high-speed rail stations in the high-speed rail project and representative of Thai high-speed rail station in terms of potential and necessity of development because of large gross provincial product (GPP), municipality size, travel distance from the origin, ridership, vacant land around the hub, and availability of feeder services. Meanwhile, Japan is a proven methodology among several countries and uses TOD as a strategy for sustainable development. Fukushima shinkansen station is the best practice and lesson learned for Nakhon Ratchasima high-speed rail hub on the basis of international comparison by type of station, size of station, travel distance, and travel time perspective. On top of that, not only the research problems in the TOD do not identify but also the high-speed rail/shinkansen station catchment areas do not take into account for the first year of operation. This research evaluates the size of the Fukushima shinkansen station catchment area by utilizing a dense network and land value approach and compares it with the existing works of academic literature. The results show Fukushima shinkansen station catchment areas are 12.4 and 17.6 km based on dense network and land value, respectively. This station catchment area is denser than only California cities because of the limitation of land that led to developing the urbanization. Meanwhile, the population factor and industry factor have a significant impact to drive the change in land value.

Keywords: dense network, high-speed rail/shinkansen station, international comparison, land value.

1 INTRODUCTION

Since Thailand is located a hub of land transport connectivity among the Association of Southeast Asian Nations countries, China and Thailand jointly desire to promote the strategic partnership through the memorandum of understanding on the cooperation on Thailand's railways infrastructure development on the strategic framework for the development of Thailand's transportation infrastructure 2015–2022. The high-speed rail project connecting Thailand's capital Bangkok to Nakhon Ratchasima province (the HSR project) is one of the significant implementations in long-term benefits under the strategic framework. The project will be done on a government-to-government basis.

The HSR project was approved by the Prayut cabinet in July 2017 and expected to operate in 2024. There were two main reasons why Thailand decided to invest in high-speed rail (HSR) development. The first reason was to support the strategy of development of the international railway network and the second reason was to boost the regional economic development along the corridor [1].

However, a feasibility study of the HSR project was not feasible. Because the direct economic return was 8.56% and financial return could not evaluate, therefore, they had lower than the benchmark in economics (12%) and finance (5%) based on the Office of the

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National Economic and Social Development Council criteria [2]. In other words, Thailand's government is facing how to drive it to sustainability in the long term.

A feasibility study recommended that if the government utilized the land development surrounding the HSR stations (or transit-oriented development (TOD)), an economic return would increase from 8.56% to 11.68% and approached a criterion [1]. TOD becomes one of the alternative strategies to boost economic value, but Thailand's government does not have the practical know-how and experience in how to make it happen. TOD had several elements such as station catchment area, policy, and legislation and regulation for construction [3].

This study is a part of the TOD strategy in the HSR project in Thailand and only focuses on the station catchment area. Previous research on station catchment areas focused primarily on urban transit stations and often defined a radius of 400–800 m from the stations [4], [5]. However, HSR/shinkansen station catchment areas differ from station catchment areas of urban transit and have larger accessibility because of inter-city travel [6]. The reasonable radius for the HSR/shinkansen station catchment areas fell in the radius range of 5–25 km based on feeder systems [7], [8]. There exists very limit research on the size of the HSR/shinkansen station catchment areas for the first year of operation. Hence, this study focuses on the size of the Japanese shinkansen station catchment area to identify the radius of the shinkansen station catchment area and recommend to apply and develop on Nakhon Ratchasima HSR station (hub) based on the lesson learned from the Fukushima shinkansen station (it will explain in Section 3 why this research selected the Fukushima shinkansen station as a case study).

The objectives of this research consist of twofold: (1) to evaluate the Fukushima shinkansen station catchment area for the first year of operation (or 1982) based on dense network and land value angle; and (2) to compare the Fukushima shinkansen station catchment area with the prior HSR/shinkansen station catchment areas. The hypotheses comprised of (1) what is relevant with the Fukushima shinkansen station catchment areas based on dense network and land value perspective?; and (2) which factors contribute to the Fukushima shinkansen station catchment area? This research only focuses on population and economic growth (change in the industry) on account of the limitation of information, as well as the floor area ratio, is assumed that it did not apply in Fukushima city in the initial year (1982–1986). !

2 LITERATURE REVIEW

2.1 Transit-oriented development (TOD) concept

TOD originated a new urbanism concept at a regional scale and formed a network of high-density and mixed-use nodes of the developed link by transit corridors. New urbanists advocated in the USA to endeavor to go back to an older form of streetcar suburbs [9].

TOD was the heart of the strategy to reduce private vehicles and develop sustainability. The location of the transit stations supports the land use, while development would be increasing ridership by enhancing the land use, improving the convenience, and enhancing the users [10]. TOD was confirmed by many countries where applied it around the transit stations at the same time [11]–[15].

2.2 HSR/shinkansen station catchment area

The inter-city railway was defined as the express passenger train that serviced a longer distance than the commuter train and long-distance train but the limitation of transit stops. Consequently, HSR/shinkansen attributed an inter-city railway service that had a highly efficient and reliable communication system [11], [16], [17].

HSR/shinkansen station catchment area in this research is defined as the zone within an urban design that had a willingness to travel to and from the transit stations and the transportation modes available [17]. However, willingness to travel varies on the socioeconomic, purpose of the trip, and built environment. Therefore, the originality is to use primary feeder service which linked the hub because it is a connector and requires transportation modes to service the rail passengers.

The size of the geographical catchment area was created by a circle surface with a radius of the maximum travel distance. It influenced the travel demand to determine the ridership that used the hubs in different radius, as well as involved land value [15], [17]–[20]. The net benefit from the hubs depended on station characteristics, the income of the people, and the station catchment area [21].

2.3 Accessibility

Accessibility was defined as the ease with which people could reach destinations and activities [22]. Investment in transportation (high quality and efficiency) led to better accessibility of the area. This change in accessibility impacted land value and usage [23], [24].

The transportation systems not only enhanced the accessible range but also brought about more efficient land-use patterns for minimizing travel distance [25]. Therefore, travelers derive a good deal from the transportation systems that benefited from easier access to transportation modes.

2.4 Land value (or land price)

The land value was a fair market value of land, excluding buildings. Change in land value was the same way. The change was caused by population growth, economic development, public investment in infrastructure, change in land-use regulation, and landowner's investment. While the land value increased, the government applied the public financing method (land value capture) to solve this point [26].

Accessibility is an alternative approach to transportation systems and service evaluation. Not only increased land value but also land use has changed the result of increased accessibility. Consequently, the originality follows the above theory and utilizes the maximum average land value as an indicator to measure the station catchment area.

3 INTERNATIONAL COMPARISON

The HSR project consists of six HSR hubs, namely Bang Sue, Don Mueang, Ayutthaya, Saraburi, Pak Chong, and Nakhon Ratchasima. Bang Sue and Don Mueang HSR hub is located in the capital city of Thailand and others are placed in the regional areas.

This research merely focuses on five HSR hubs excluding Bang Sue HSR hub because Bang Sue HSR hub was studied in the feasibility study project [26]. In this research, this study focuses on the Nakhon Ratchasima HSR hub due to large GPP, municipality size, travel distance from the origin, ridership (number of HSR passengers), vacant land around the hub, and availability of feeder services [27]. However, the Thai government does not have practical know-how and experience in how to make it happen. This research uses international comparison to study the lesson learned from the best practice and outcome.

Japan is the best role model to generate TOD for sustainable development. Fukushima shinkansen station on the Tohoku shinkansen line is an optimal case study in Japan among others because it is similar in terms of station type, station size, travel distance, and travel time with Nakhon Ratchasima HSR hub [27]. Although the city policy and the surrounding area of the hub have the difference, we will ponder how to increase the potency before-after the operational HSR project.

4 RESEARCH APPROACH DATA SOURCES

4.1 Research methodology

The analysis was done by following the process depicted in Fig. 1. To begin, this study was identified the definition of the station catchment area for the HSR/shinkansen station. The representative HSR hub in Thailand was then assessed the importance of HSR hubs in terms of potential and necessity of development.

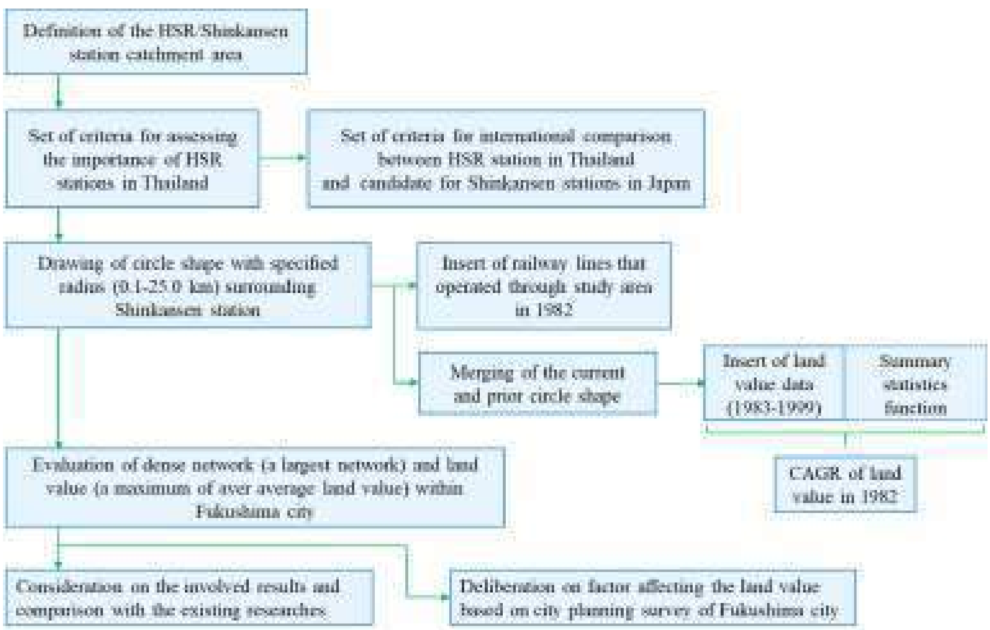

Figure 1: Process of analysis.

Following this, the representative HSR hub from Thailand was collated with the Japanese shinkansen stations by utilizing station type, station size, travel distance, and travel time because Japan was a famous and well-known TOD for its excellent mobility and sustainability. An international comparison was important for the HSR station catchment area in Thailand, where became the first developing country to invest and require to achieve sustainable development in the future.

After that, for grasping what range was required to be developed about land use under the premise of the access by dense network and land value. ArcGIS software version 10.6.1 was used as a tool to overcome the station catchment area by setting origin (city center: Fukushima shinkansen station) and destination (boundary: Fukushima city).

According to Murakami and Cervero [7] and Zhong et al. [8], the reasonable HSR/shinkansen station catchment area falls in the radius range of 5–25 km because of the inter-city railway. The circle shape was drawn by a specific radius (0.1–25.0 km) surrounding Fukushima shinkansen station. In parallel, four railway networks (Abukuma express line, Tohoku mainline, Iizaka line, and Ou main line) were inserted in the map which linked the Fukushima shinkansen station in 1982, including land value.

A dense network approach was proposed and applied for the evaluation of the Fukushima shinkansen station catchment area. On the other hand, this analysis examined the parameter that had the consistency of transport and land-use theory and had to cover long-term panel data; hence, the land value parameter was an alternative indicator to measure the station catchment area as well. This research looked more accurate than existing studies by using one decimal place of the circular surface.

However, the land value approach was a more sensitive process than the dene network perspective. After drawing a circle shape, this research merged the current and prior circle shape and then added the land value data (1983–1999), but it faced the incompleteness of the (data on) the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) website in 1982. Therefore, the compound annual growth rate (CAGR) method was an alternative way to solve this point. Next, Arctoolbox was selected for the summary statistics function. Finally, the sizes of the Fukushima shinkansen station catchment areas were examined in two points of view and collated with the existing studies [7], [8]. Factor affecting the land value was then considered in each factor (population growth and economic growth (industry)) during 1975–1986 based on the basic survey of city planning in Fukushima city.

4.2 Data sources

The precise locations of Fukushima shinkansen station and other railway stations in Fukushima prefecture were obtained from the geographic information system (GIS) shapefile provided by e-stat and MLIT website. The GIS shapefile was produced by using online satellite imagery techniques [28].

This analysis did not attempt to estimate the land value change in Fukushima prefecture whether public policies might be able to harness and leverage these trends to induce greater land value benefits. This research used the actual data extracted from the MLIT website during 1983–2019, it faced limitations of data access, namely public investment in infrastructure, change in land-use regulation, and landowner’s investment to test the factor affecting land value. Therefore, population and economic growth were considered and received from the basic survey of city planning in Fukushima city, Fukushima city hall.

5 RESULT

5.1 HSR/Station catchment area

5.1.1 The size of the Fukushima shinkansen station catchment area

Fukushima shinkansen station was imaged and connected Ou main line, Iizaka line, and Abukuma express line in 1982. A dense network was 12.4 km from the city center based on Ou main line because of the largest network and primary feeder services within the boundary of the city. However, the travel distance depended on the feeder systems in different geographies. Therefore, we believed 12.4 km was a more reasonable radius for the Fukushima shinkansen station catchment area as illustrated in Fig. 2.

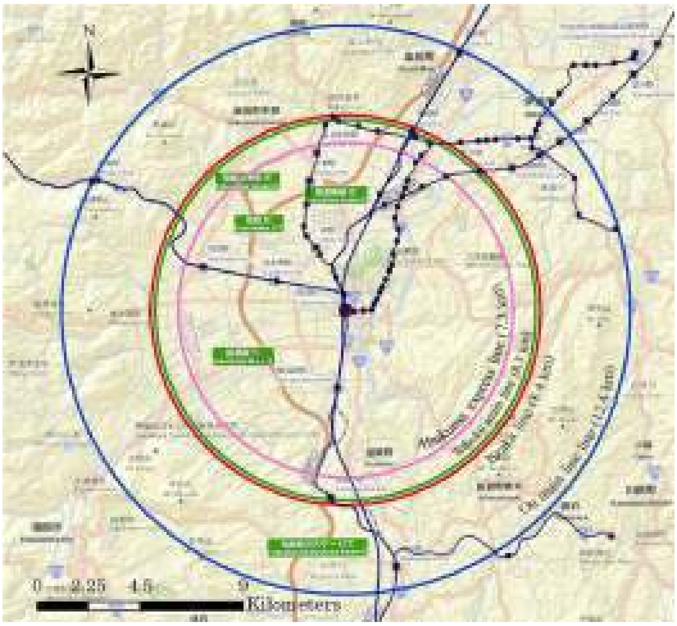

Figure 2: Fukushima shinkansen station catchment area in different feeder systems in 1982.

The Fukushima shinkansen station catchment area was simultaneously analyzed by using ArcGIS software with a maximum of average land value perspective during 1983–2019. CAGR method was selected to overcome an absence of historical data in the case of the first year of operation. Table 1 shows the relationship between the station catchment area of Fukushima shinkansen station and land value from 1982 to 1991. Fukushima shinkansen station catchment area was constant over time (17.6 km), but a maximum of average land value fluctuated between 162 and 165 Japanese yen/m^2. One reason might be the number of buildings declines in 1986.

From the above, the results illustrated that a radius of 12.4 km of the Fukushima shinkansen station catchment area captured a partial area of a radius of 17.6 km of the Fukushima shinkansen station catchment area in 1982 (or 70.45%). These data appeared to suggest that the Fukushima shinkansen station had two layers of the station catchment area. In other words, the first area was the inner catchment area were had a dense network (12.4 km), while the second area was the outer catchment area were had an impact from the inner catchment area (17.6 km) as can be seen in Fig. 3.

5.1.2 Comparison of the prior HSR/shinkansen station catchment areas

Table 2 shows the comparison of inner catchment areas among HSR hubs and HSR/shinkansen lines. The results showed that a radius of 12.4 km of the Fukushima shinkansen

Table 1: Relationship between Fukushima shinkansen station catchment area (km) and a maximum of average land value (JPY/m^2).

Year	Building (unit)	Fukushima shinkansen station catchment area (km)	A maximum of average land value (JPY/m^2)
1982	NA	17.6	165
1983	70	17.6	165
1984	70	17.6	165
1985	70	17.6	165
1986	68	17.6	162
1987	68	17.6	162
1988	68	17.6	162
1989	68	17.6	162
1990	68	17.6	162
1991	68	17.6	162

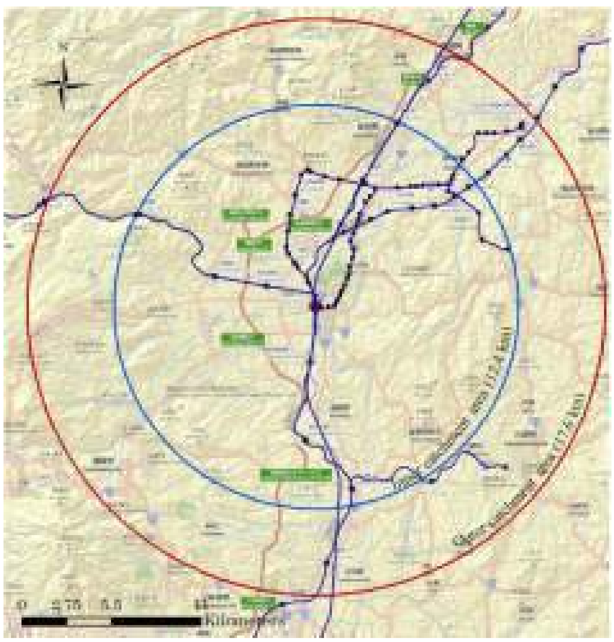

Figure 3: Inner and outer catchment area of Fukushima shinkansen station in 1982.

station was denser than a radius of 25 km of Californian cities (San Francisco Bay Area and Los Angeles), but less dense than a radius of 10 km of Spanish cities (Barcelona and Madrid) and a radius of 5 km of 17 cities of Tokaido shinkansen line, Northeast Corridor, and California HSR.

One of the main reasons was Fukushima city had the limitation of land to development and brought about population density based on the survey of city planning in Fukushima

Table 2: Comparison of inner catchment areas.

HSR hub/HSR line/ shinkansen line	Station catchment area (km)	Population (million persons)	Area (km^2)	Population density (persons/km^2)
Barcelona	10.0	4.96	7,733	641.4
Madrid	10.0	6.45	8,030	803.2
San Francisco Bay area	25.0	6.17	13,527	456.2
Los Angeles	25.0	17.30	30,783	562.0
Fukushima	12.4	0.29*	768	377.6
Tokaido shinkansen line	5.0	NA	NA	NA
Northeast Corridor	5.0	NA	NA	NA
California HSR	5.0	NA	NA	NA

Note: *Using the CAGR during 1975–1980.

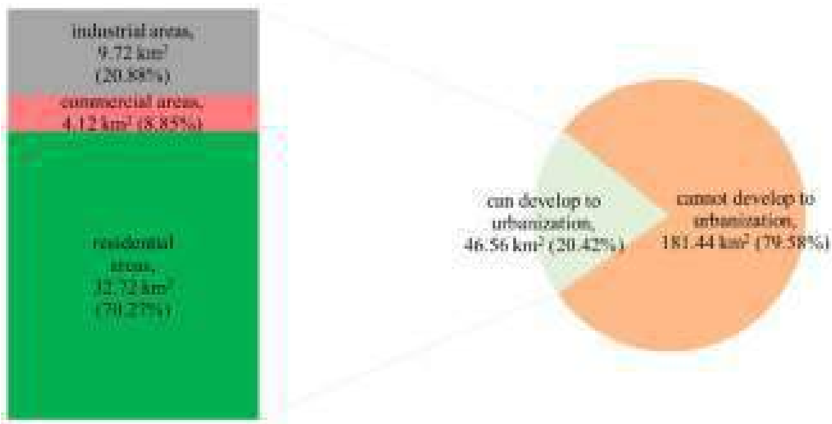

Figure 4: Ratio of land-use where can and cannot develop to urbanization.

city in 1982. It had less area to develop urbanization (46.56 km^2). This area consisted of residential areas (32.72 km^2), commercial areas (4.12 km^2), and industrial areas (9.72 km^2). In contrast, there were 181.44 km^2 of an area where could not develop to urbanization, whereas it was covered with forests, mountains, and agricultures (see Fig. 4).

5.1.3 Effect of land use and characteristics

The residential areas were the most preferred development as 53.85% of the ratio of land-use between 1980 and 1985 in Fig. 4. The mixture of residential and commercial areas accounted for 15.90% and was the second-ranking. At the same time, this research took into account the area surrounding Fukushima shinkansen station by a site visit. The result clearly illustrated that a radius of 6–8 km from the Fukushima shinkansen station was consistent with the past. Most of them are residential areas (hotels, apartments, and houses), but the commercial areas (plazas, convenience stores, and supermarkets) are quite a few.

Likewise, this research took into account around Fukushima shinkansen station and other shinkansen stations, e.g., Hakata shinkansen station, Nagoya shinkansen station, and Yokohama shinkansen station. These results appeared to contradict the above view that mainly established for commercial use, for instance, the local commercial street around station, plazas, and offices. The results perhaps led to alternative urban economic scenarios as well as urban structure formulation in each city.

However, land use surrounding the Fukushima shinkansen station was developed by using phasing investment. This issue possibly led to a limitation of the circle surface method because it could not take the geographical area surrounding the Fukushima shinkansen station into account for reality.

5.2 Factor affecting land value and attribution

5.2.1 Population

As Japanese housing and land survey from the Ministry of Internal Affairs and Communications during 1998–2003, the results indicated that the acquisition of land and housing was among people aged 15–64 years old. Meanwhile, the largest number of populations in Fukushima city by age group was consistent with the above results (or 67.79% per year) during 1975–1985 as illustrated in Fig. 5.

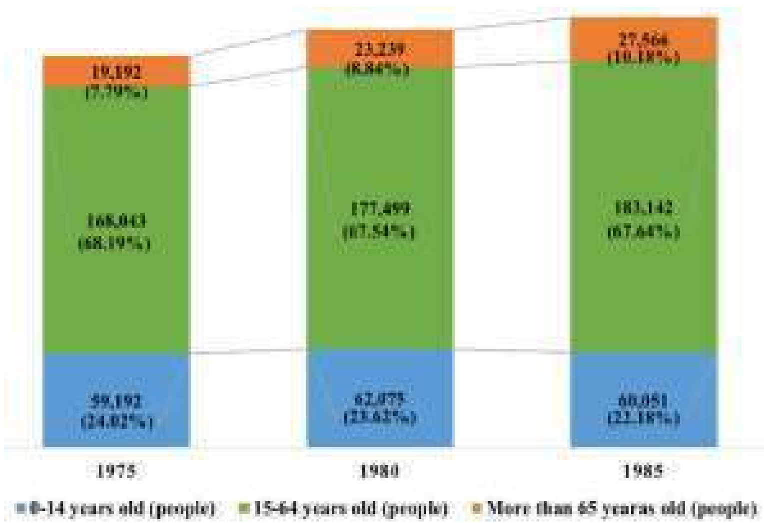

Figure 5: Population by age group.

Next, this research examined the population pyramid from 1975 to 1985 by the 5 year age group. The children's generation was gradually declining, but the elderly population was moderately grown. Therefore, it was possible to read the direction of the transition from 1975 by age group. The results presented in Fig. 5 displayed that the number of children decreased by 0.76% per year. In the case of the working-age population, it slightly grew thanks to a second baby boom since the 1970s.

Furthermore, this research collated the CAGR of the population during 1975–1985 with the land value from 1982 to 1985 (see Table 3). The results indicated that the CAGR of population and CAGR of land value was a parallel way (positive value). Hence, the population factor could affect the land value in the initial phase (1982–1985). Because the population was a demand for land and influenced the change in land use. In other words, an increase in demand for land use led to an increase in rent or buy or sell [15], [23].

Table 3: Population (people) and land value (JPY/m^2).

Year	Population	Land value
1975	246,427	NA
1980	262,812	NA
1982	NA	162.93
1983	NA	165.16
1984	NA	165.16
1985	270,759	165.14
CAGR (%)	0.97	0.45

5.2.2 Economics

The population was changed in Fukushima city during 1975–1985 because of a decline in birth rate, an increase of the elderly population, and productivity improvement, including technological innovation as a key for the Japanese economy. However, it was difficult to elucidate the main factors for economic growth.

Regarding the empirical studies, the development of HSR/shinkansen projects generated a significant impact on urban service industry agglomeration with fast flows of factor resources [29], [30]. Besides, Japan's industry structure (such as Fukushima city) shifted industrial structure from heavy industry to tertiary industry after World War II owing to a change in social structure issues as illustrated in Table 4.

Table 4: Number of employees (thousand people).

Year	Primary industry*	Secondary industry**	Tertiary industry***
1975	285	35,484	65,563
Ratio (%)	0.28	35.02	64.70
1978	522	35,888	73,181
Ratio (%)	0.48	32.75	66.78
1981	557	37,730	86,757
Ratio (%)	0.45	30.17	69.38
1986	479	38,789	92,919
Ratio (%)	0.36	29.34	70.29
Average	460.75	36,972.75	79,605.00
CAGR (%)	9.05	0.88	3.83

Notes: *Primary industry: agriculture, forestry, and fishing; **Secondary industry: mining, manufacturing, and construction; ***Tertiary industry: wholesale and retail trade, transport and postal services, accommodation and food service activities, information and communications, finance and insurance, real estate, professional, scientific and technical activities, public administration, education, human health and social work activities, and other service activities.

The primary industry was involved in the collection of resources in nature. The secondary industry was related to processing the collected resources. The tertiary sector was concerned with providing services other than the aforementioned activities. Therefore, we conformed to the empirical research that the impact looked at coming to the trend in the industrial structure.

According to the number of employees, the tertiary industry was the major industry and had 79,605 thousand people (or 68.02% per market share). The wholesale and retail trade sector ranked first. It employed 32,735 thousand people per year, following by the service sector and manufacturing sector.

In the meantime, Table 5 shows the number of offices by major groupings. A tertiary industry was the main industry and had 10,390.50 houses (or 82.71% of market share). The service sector and electricity, gas, water supply, and heat supply sector in the tertiary industry were the first rank and second rank because of one of the main industries in Fukushima prefecture. These results presumably led to GPP in Fukushima prefecture. It was clear from a macroeconomic point of view that GPP grew a little from 1.47% in 1975 to 1.50% in 1982 (or 0.30% per year).

Table 5: Number of offices (houses).

Year	Primary industry	Secondary industry	Tertiary industry
1975	34	1,931	9,319
Ratio (%)	0.30	17.11	82.59
1978	38	2,027	9,788
Ratio (%)	0.32	17.10	82.58
1981	58	2,217	10,896
Ratio (%)	0.44	16.83	82.73
1986	43	2,342	11,559
Ratio (%)	0.31	16.80	82.90
Average	43.25	2,129.25	10,390.50
CAGR (%)	5.43	1.97	2.22

Table 6 shows the CAGR of the number of offices (houses) and land value during 1975–1986. The results indicated that the CAGR of the number of primary industries, secondary industry, and tertiary industry and CAGR of land value was a parallel way (positive value). Hence, the number of offices factor could affect the land value in the initial phase (1982–1986). Because the development of HSR/shinkansen resulted in a change in accessibility for industries and residential catchment areas as well as a reduced generalized cost. In addition, land value resulted from changes in accessibility that drove the value uplift from transport investment and created the opportunity for enhanced economic activities [15]–[23].

Table 6: Number of offices (houses) and land value (JPY/m^2).

Year	Primary industry	Secondary industry	Tertiary industry	Land value
1975	34	1,931	9,319	NA
1978	38	2,027	9,788	NA
1981	58	2,217	10,896	NA
1982	NA	NA	NA	162.93
1983	NA	NA	NA	165.16
1984	NA	NA	NA	165.16
1985	NA	NA	NA	165.14
1986	43	2,342	11,559	165.15
CAGR (%)	5.43	1.97	2.22	0.34

6 CONCLUSION

HSR investment in Thailand is not feasible, but when it utilizes land development surrounding HSR hubs, the economic benefits increase and fit the benchmark. However, the Thai government does not have the practical know-how and experience in how to make it happen. This research determines to study from the lesson learned from Japan, whereas it is the best land development for sustainability.

This research uses the international comparison between a representative HSR station in Thailand and the candidate for Japanese shinkansen stations by using the criteria. Then we highlight how to evaluate the Fukushima shinkansen station catchment area based on dense network and land value approach. Because station catchment area is a vital factor to balance demand and supply of public transportation systems and relates to the land value and floor area ratio.

The present study endeavors to assess the size of the Fukushima shinkansen station catchment area when it was operated in 1982. As a case study, we draw a tentative outlook of the station catchment area surrounding Fukushima shinkansen station in terms of railway routes and land value by using ArcGIS software. In the meantime, drawing of circle surface on the ArcGIS map is a fairly good way for examining the inter-city railway, but it does not take the geography into account when the area developed at a different time as well as we cannot grasp the natural obstacle within the station catchment area.

Regarding the result, the radius of the Fukushima shinkansen station catchment area is 12.4 and 17.6 km based on dense network and land value approach, respectively. On the whole, the Fukushima shinkansen station has two layers of station catchment areas which consisted of the inner catchment area were had a large network (12.4 km) and primary feeder service within the Fukushima city boundary and the outer catchment area were had an impact from the inner catchment area (17.6 km). Since Fukushima city has a limitation of land to develop for urbanization, station catchment area beats only California cities. The specific result from the case study may not provide all factors affecting land value that influenced change in land value because of lack of sufficient data, namely public investment in infrastructure, change in land-use regulation, and landowner’s investment. For these reasons, we consider only the population and economic factors. The population, primary industry, secondary industry, and tertiary factor are a significant impact on land value from a macro point of view.

These results bring about some interesting directions for future research. Further study is hence needed to determine the multi-dimensional factors affecting travelers to access the Nakhon Ratchasima HSR hub within the station catchment area. The research outcomes, we expect to grasp the needs and design the fundamental facilities about TOD to increase people’s mobility and accessibility.

This study may be useful for developing countries to analyze the station catchment area and developing an appropriate policy relating to the improvement catchment area on HSR/shinkansen stations to make the catchment area more attractive, beneficial, and sustainable as well as consider the feeder systems and level of service for the travelers in the future.

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SECTION 10
ENVIRONMENTAL MANAGEMENT

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APPROACHES TO THE ASSESSMENT OF ECOLOGICAL AND ECONOMIC EFFICIENCY OF INVESTMENT PROJECTS: BRIEF REVIEW AND RECOMMENDATIONS FOR IMPROVEMENTS

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ABSTRACT
The implementation of investment projects has an important role to play in the development of the economy and also to be in concordance with the Circular Economy concepts, as it causes not only the flows of financial and labor resources into the regional economy, but also stimulates the development of scientific and technological progress and the emergence of innovations. A comprehensive assessment is essential approach of any investment project to achieve sustainable development and to close the loop as requested be the Circular Economy through balancing between social and economic development, as well as preservation of environment. The assessment of ecological and economic efficiency of investment projects is one of the most significant stages of project implementation as it allows to uncover the potential negative effects and possible failure of the project. So far, there are no unified approaches to assessing the effectiveness of investment projects, especially its environmental component. That fact leads to a biased assessment of the impact of an investment project on the environment. The problem is caused not only by the lack of a common, internationally accepted methodology, but also by the complexity of accounting for externalities and negative financial impact. The purpose of the study is to examine and systemize existing approaches to the assessment of ecological and economic efficiency and provide recommendations for its enhancement. The article highlights two conceptual approaches to the efficiency assessment of the project and their benefits and drawbacks.
Keywords: investment project, eco-efficiency, efficiency assessment, circular economy.

1 INTRODUCTION

Rapid economic and scientific development encourages enterprises and governments in both developed and developing countries to invest in the implementation of various investment projects. The introduction of Circular Economy (CE) in order to close the loop is also one of the most studied and developed concepts [1]–[5]. Successful project implementation implies a return on investment, obtaining commercial profit, meeting social needs, improving living standards and gaining a competitive advantage, all considering not only the economic aspects but also the environmental and possible the human health ones [6]–[9]. Investments stimulates further economic development and accelerate developments in science and technology. In spite of its socio-economic benefits, implementation of any investment project involves a great deal of risk that might have a negative impact on the final project performance.

The assessment of economic efficiency of the investment project is carried out on the initial stages of project development. The purpose of that process is to uncover potential risks in a timely matter in order to offset them. It includes not only the assessment of economic risks but also the assessment of social, financial and technical risks that may arise within project implementation. Nowadays it is also mandatory to provide the assessment of

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eco-efficiency of investment projects owing to the stable annual increase of human pressures on the environment. Therefore, the successful implementation of investment project should also consider mitigation of the negative influence of any human activities on the environment (in case of eco-modernization of the already existing facility) or achieving the minimum anthropogenic pressures on the environment as a result of the project implementation (in case of establishing a new enterprise) [10].

The approaches to economic efficiency assessment of the investment project, that are given in the scientific and methodical literature units, can be divided into two groups: discounting assessment methods and statistical assessment methods. Discounted methods are based on using a discount rate that allows to assess the project's effectiveness considering the influence of the time factor and the probability of emerging risk situations [11]–[14]. Statistical methods do not consider the time factor that makes them less in demand in the assessment process. However, statistical methods are more understandable for project stakeholders and they are often used at the initial stage of investment projects selection.

The assessment of eco-efficiency is based on evaluation of ecological dimensions of project implementation. The difficulty in assessing effectiveness is that the part of ecological dimensions cannot be measured by quantitative methods as it relates to external effects or externalities [15]. The most common approaches to the assessment of eco-efficiency of investment projects include the environmental component (e.g. environmental costs or benefits) in the calculation of economic indicators such as NPV (Net Profit Value) or PI (Profitability Index). The results of evaluation in case of using these approaches might incorrectly display the real impact of the investment project on the environment and usage of natural capital [16]. The aim of this research is to present a brief review of the existing conceptual approaches to the assessment of ecological and economic efficiency of performance, highlight their benefits and drawbacks and to propose recommendations for their improvements.

2 COMPARATIVE ANALYSIS OF THE ASSESSMENT APPROACHES OF ECOLOGICAL AND ECONOMIC EFFICIENCY IN INVESTMENT PROJECTS

The assessment of ecological and economic efficiency of investment projects involves the evaluation of ecological dimensions in monetary units. The analysis is carried out by comparing the potential economic benefits of the projects and the associated costs of potential negative impacts of the project implementation on the environment.

Ecological dimensions of the investment project include environmental benefits and environmental costs. The list of environmental costs contains [17]–[19]:

- cost of quantitative or qualitative losses of natural resources;
- abatement costs and expenditure on the environmental regeneration;
- cost of natural resource restoration;
- loss of profit and other losses.

Environmental benefits of the project implementation include potential public benefits, increase in the efficiency of natural resource use, mitigation of negative impact on the environment, all in concordance with the CE concepts. According to the World Bank Operational Policy regarding Environmental Impact Assessment, environmental costs and environmental benefits must be quantified [20].

Approaches to the assessment of economic and environmental efficiency of investment projects might vary depending on the author of the methodology or the organization that

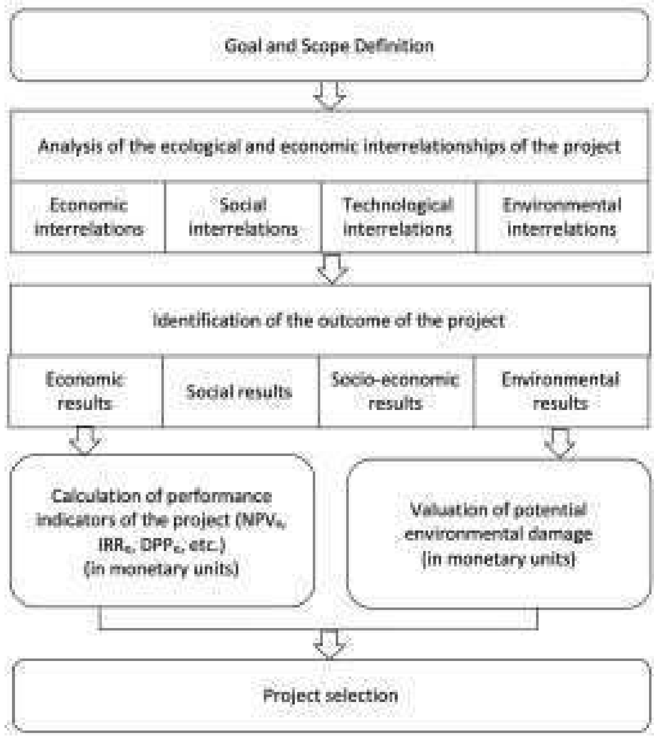

Figure 1: Framework of the assessment of ecological and economic assessment of investment projects. *(Source: Based on [6], [10], [11], [19], [22].)*

work on the same task. The common framework of the assessment of ecological and economic efficiency of investment project is provided in Fig. 1.

Social and technological aspects also have an important role to play in the process of the efficiency assessment of investment projects. The fundamental goal of any investment project is to have a return on the investment and to make a profit. However, the social responsibility of business and the increasing public focus on environmental and social challenges force investors and stakeholders to demonstrate the social significance of the project and its safety for the environment [21]. For instance, investment project implementation should improve the standard of living in the region, create new jobs, reduce environmental pollution or provide low level of negative impact on the environment, etc.

There are two main conceptual approaches that are presently used to assess the economic and ecological efficiency of the investment project, namely, cost-efficiency approach and cost-benefit approach [23]. The basic principle of both approaches is to involve all possible ecological benefits and costs in the cashflows of the investment project (Table 1).

The reviewed approaches to the assessment of economic and ecological efficiency evaluate ecological aspects in monetary units that determines the success rate of the investment project only in terms of profit considering potential ecological costs and benefits (eqn (1)) [23]–[25]:

$$(B + Be) - (C + Ce) > 0. \tag{1}$$

Table 1: Comparison of approaches to the assessment of ecological and economic efficiency of investment projects. *(Source: Based on [12], [23]–[28].)*

Approach to the efficiency assessment	Cost-efficiency approach	Cost-benefit approach
Characteristics of the approach	The method is based on a comparison of options with different cost ratios and the result obtained. The best option is considered to be the one with the lowest costs, ensuring the achievement of the necessary economic and environmental results.	The method is based on the comparison of economic and ecological benefits to the economic and ecological costs incurred.
Indicators	Indicators (eqns (2)–4): • $NPV_e = \sum_{t=0}^{T} \frac{(B_t+Be_t)-(C_e+Ce_t)}{(1+r)^t}$, (2) where *NPV* is net profit value, in value units; *B* and Be_t are economic benefits and ecological benefits respectively, in monetary units; *C* and Ce_t are economic costs and ecological costs respectively, in money units; *r* is the discount rate; *T* is the reporting period, years; *t* is the number of the year. • IRR_e: $\sum_{t=0}^{T} \frac{(B_t+Be_t)-(C_e+Ce_t)}{(1+r)^t} = 0$, (3) where *IRR* is the internal rate of return. • $PI_e = \frac{NPVe}{Investments}$, (4) where PI_e is profitability index. The following indicators are also used within the assessment process: DPP_e, *ROI,* etc.	Benefit-cost ratio (eqn (5)): $\text{Project efficiency} = \frac{(B+Be)}{(C+Ce)}$. (5)
Advantages of the approach	• the approach considers the influence of the time factor; • the approach is used when it is necessary to obtain a certain ecological result; • allows to compare the effectiveness of environmental measures within a single project.	• universality of the indicator; • ability to compare the results of alternative projects; • easy interpretation.
Disadvantages of the approach	• the difficulty of integrating all ecological benefits and costs in monetary units; • not considering the efficiency of the natural capital use, reduction of resource consumption, etc. • NPV does not allow to compare alternative investment projects, as it is an absolute indicator; • the complexity of calculations, the subjective nature of the choice of the discount rate and the impossibility of changing it due to changing environmental conditions	• low informativeness; • complexity of accounting for all environmental benefits and costs in monetary units; • not considering the efficiency of the use of natural capital, reduction of resource consumption, etc.

The benefits of the project should exceed the costs of its development and implementation: the investment project shows its effectiveness only if it has a positive closing balance.

The main drawback of the reviewed approaches is that they do not allow to provide comprehensive description of the impact of investment projects on the environment, the efficiency of natural capital use at all stages of the project life cycle and long-term consequences for the environment [29]. Both approaches do not evaluate energy efficiency of the project in physical units. Potential environmental damage within the framework of the considered approaches is estimated as the amount of emissions or costs for eliminating negative impacts on the environment, which can vary significantly depending on the country's legislation and the availability of environmental technologies, which makes the assessment of environmental impact biased and makes it difficult to compare alternative investment projects [30].

The potential benefits of the investment project may be several times higher than the expected costs of its implementation (including such ecological costs as the cost of eliminating negative impacts), which negatively affects the motivation of investors and stakeholders to continue to reduce the impact of the implementing project on the environment and invest in the development of resource-saving and environmental technologies.

Moreover, it is almost impossible to consider all the external effects of the project implementation or externalities at the development stage in the assessment process [31]. In the majority of cases, externalities and other long-term external effects are not considered due to the high degree of uncertainty of long-term consequences and the lack of official need for their assessment [32], [33]. This can lead to shortsightedness of entities and to considerable economic losses in the long term.

According to the given results, the following shortcomings of the considered conceptual approaches to assessing the ecological and economic efficiency of investment projects can be identified:

- the complexity or inability of comparing the alternative investment projects in terms of their ecological efficiency (efficiency of natural capital use, energy efficiency of the project, etc.);
- the low level of results informativeness of the ecological assessment for project investors and stakeholders;
- the assessment of ecological benefits and costs is made only in monetary units, that makes it biased when comparing alternative investment projects of different scales;
- difficulties in performing calculations and the inability to change the specified valuation parameters (for instance, the discount rate) due to changing environmental conditions.

3 RESULTS AND DISCUSSION

Strengthen the objectivity of assessing the ecological effectiveness of investment projects is a key driver for improving the existing approaches to ecological and economic assessment.

International Association for Impact Assessment (IAIA) defines and environmental impact assessment (EIA) as the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made [34]. EIA can be made in relation to any activity of any business entity, including investment projects. The ISO 14045 and ISO

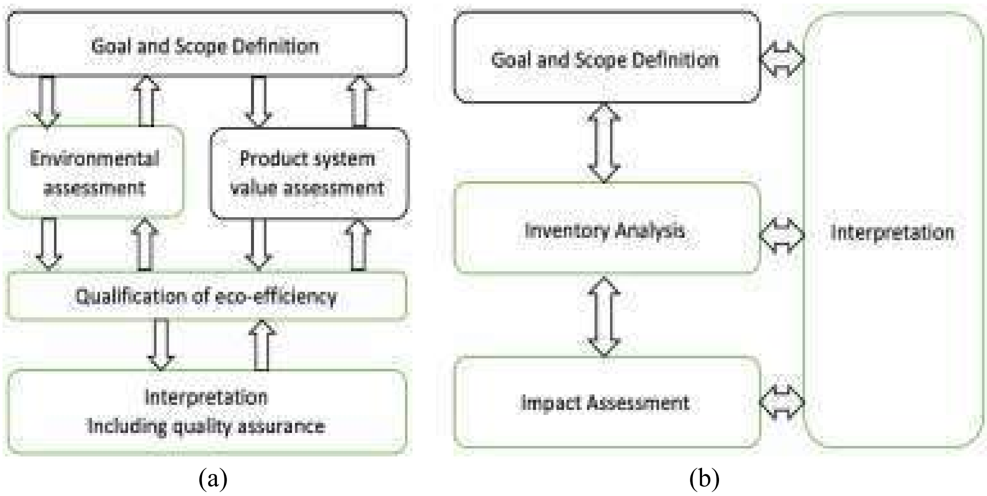

Figure 2: Frameworks of the environmental assessment. (a) Eco-efficiency assessment (ISO 14045:2012); and (b) Life-cycle impact assessment (LSIA) (ISO 14040:2006). *(Source: Based on [35], [36].)*

14040 standards contain two conceptual approaches to the methodology for assessing environmental performance (Fig. 2).

Both approaches involve a comprehensive assessment of the ecological impact of the business entity. The results of the environmental performance assessment according to ISO 14045 can be used in the development of measures to improve the efficiency of production and sales of products, strategic planning and investment analysis. Life cycle impact assessment is a more flexible and comprehensive approach to assessing environmental performance at all stages of the product life cycle, but its adaptation to the life cycle of an investment project can cause difficulties in calculating, generating cash flows, considering externalities and other environmental impacts at each stage of the project life cycle and interpreting the results obtained [37]–[39].

To improve the methods of assessing the ecological and economic efficiency of investment projects, it is proposed to:

- include ecological indicators in the assessment process in three dimensions: indicators of environmental pollution, indicators of use of natural capital, indicators of energy efficiency indicators;
- calculate ecological indicators in physical units, give preference to relative environmental indicators;
- keep the calculation of ecological and economic efficiency indicators of the project (NPVe, IRRe, DPPe, IPe), but compare them with proposed ecological indicators.

Table 2 presents a basic system of ecological indicators that can be used to assess the environmental performance of an investment project. The indicators of energy efficiency include indirectly the role of renewable energy use. The indicators of use of natural capital include indirectly the checking of the adoption of the CE principles.

Table 2: The proposed system of ecological indicators for the assessment of ecological and economic efficiency of investment project.

Group of ecological indicators	Indicators
Indicators of environmental pollution	• total greenhouse gas emissions, in physical units; • greenhouse gas emissions per unit of production; • total emissions of harmful substances, in physical units; • emissions of harmful substances per unit of production; • total water pollutants, in physical units; • water pollutants per unit of production; • total waste generation, in physical units; • waste generation per unit of production.
Indicators of use of natural capital	Resources capacity of production – a ratio of the natural resources used by the facility, to the corresponding amount of annual production (in physical units): • water capacity of production; • fuel capacity of production; • natural resources capacity of production etc.
Indicators of energy efficiency	• total energy consumption, in physical units; • energy capacity per unit of production; • total use of hydrocarbon fuel, in physical units; • use of hydrocarbon fuel per unit of production.

Comparability of alternative investment projects is achieved through the use of ratios, which allow to compare investment projects on the environmental component. All indicators should be calculated over time in order to highlight potential changes in the dynamics. The project provides effectiveness when most ecological indicators demonstrate a downward trend.

Another advantage of the proposed system is the informativeness of indicators and the simplicity of their interpretation that allows to compare alternative projects with each other. Also, the proposed system allows to compare scenarios “with the project” and “without the project”, which may provide added information on the benefits of the project in terms of environmental components. In some cases, the scenario “without the project” that means the complete rejection of the project implementation, might bring more economic and ecological benefits in comparison to the scenario when the project is implemented. Moreover, in case of eco-modernization the proposed indicators should be calculated at least twice: before eco-modernization project and after eco-modernization project.

The proposed system of ecological indicators can be also adapted to the type of investment project and the branch of the economy to which this investment project belongs. An example of adaptation is given in the paper “Improving the approach to efficiency assessment of investment projects in the energy sector” [40], where indicators of the natural capital use were adapted to the energy facility.

Fig. 3 shows the system of assessment of ecological and economic efficiency of investment projects proposed by the authors.

Several ecological indicators can be determined in terms of monetary units. These determinations are appropriate if investment projects are characterized by the same scale, level of investment and production.

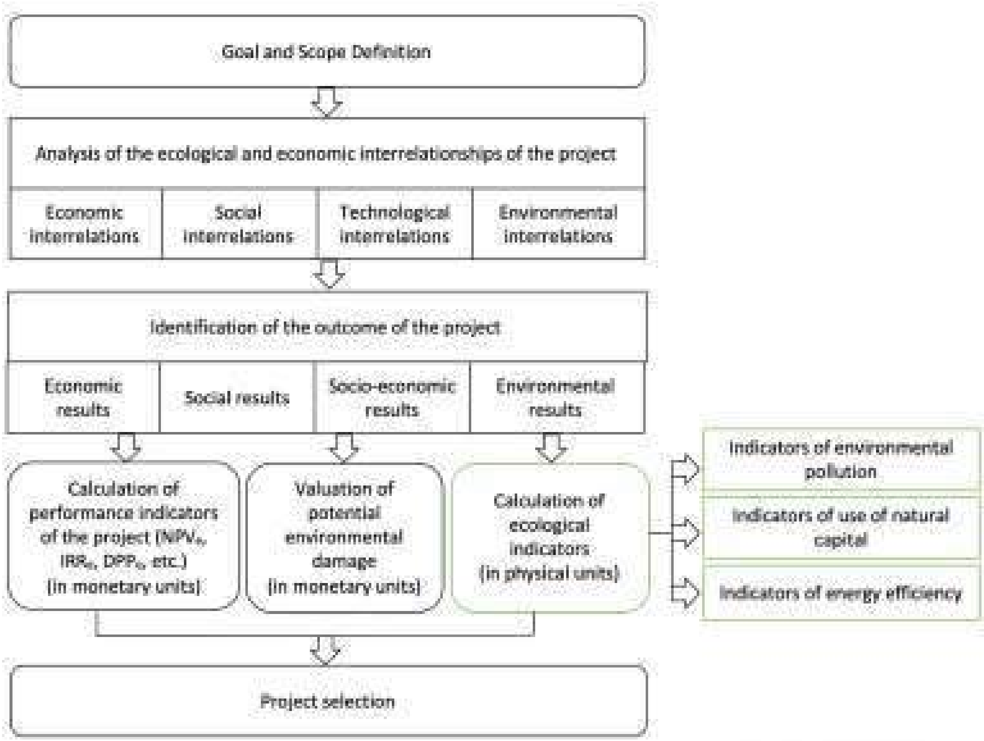

Figure 3: The proposed framework of the assessment of ecological and economic assessment of investment projects.

4 CONCLUSION

Authors proposed extended system of ecological indicators as contribution to improve the methodology for the ecological and economic efficiency assessment of investment projects. The proposed system of indicators allows for a comprehensive assessment of the impact of an investment project on the environment, energy efficiency of the project and the efficiency of natural capital use within its implementation. Advantages of the system of ecological indicators are the following:

- the possibility of comparing alternative investment projects by ecological aspects;
- simplicity of calculations and interpretation of the results obtained;
- informativeness of the results obtained and their comprehensibility for investors and stakeholders of the investment project;
- the objectivity of the system of ecological indicators in the framework of assessing the eco-efficiency of the investment project.

As a further improvement in the assessment of economic and ecological efficiency of investment projects, further development of a broader system of ecological indicators and their adaptation to various sectors of the economy. In addition, it is possible to develop an integrated indicator for assessing the ecological and economic efficiency that allows a comparison with alternative investment projects only by one criterion.

ACKNOWLEDGEMENT

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SMART HAPPY CITY

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ABSTRACT

Although people perceive architecture in a variety of ways, we firmly believe there are key elements of design that can enrich the human experience, facilitating a path towards human happiness and well-being. Through small changes, we can begin making the world a happier place, and architecture is definitely a tool to do so. The environment is essential for all of us, especially since so many of us live in cities; thus, the Egyptian Commission emphasized the value of cities in the lives of so many Alexandrians, by committing to take action in this area. Specific environments have a direct impact on the lives of millions of Alexandrian citizens, and as a result, have a significant impact on the larger environment. More change is required in Alexandria for it to be a Smart Happy City that should offer the kind of quality of life and opportunity that would make people want to live there, make businesses, and want to invest. The main goal is to make Alexandria a Smart Happy City by providing both a common ground and a common language for better understanding use of smart and happy features effectively, specifically to make Alexandria a Smart Happy City within the architecture realm. We explain smart city features, characteristics and happiness factors, and how happiness can be measured. Additionally, we provide examples of smart, happy features. Moreover, we consider what should make Alexandria a Smart Happy City, but as smart solutions cannot be fully reproduced, we evaluate the value of each field.

Keywords: Alexandria, old Alexandria, Smart City, Happy City, computer aided architectural design, architectural representation, computational design, happiness in communities.

1 INTRODUCTION

Alexandria is a four-season destination. In the winter you will enjoy the breezy mornings and cold nights, and you will also find a lot of rain if you're a winter lover. Something you need to know about Alexandria is that while summer makes perfect weather, we personally don't like it as much, as the crowds are overwhelming. Downtown Alexandria's wide waterfront road is as much a symbol of the city as any of its monuments. It's here that you get a real feel for the era of cosmopolitan elegance and decadence that marked this city, in the late 19th and early 20th centuries. Much of the architecture from this era still stands along the Corniche, though these days, much of it is heavily dilapidated and falling into disrepair. Alexandria faces problems too, in areas such as: chronic conditions, economic stability, health care access, injury, violence, mental health, neighborhoods, the built environment, obesity, nutrition, physical activity, oral health and reproductive health.

Our goal is to make Alexandria a Smart Happy City and to solve all of the above-mentioned problems by following Smart City features implementation, which will lead to a happy community.

2 ALEXANDRIA BEFORE AND AFTER

Urban public spaces function to encourage public activity. Fig. 1 shows how the environment can influence the people. Issues like public spaces, air quality and greenness are actually having a big impact on our levels of happiness and wellbeing in our life [1].

A direct view towards the sea was blocked by cafes and concrete blocks, which has a very bad effect on users (Fig. 2). Therefore, quality of life (QOL) as measured by people's self-reported happiness is a primary goal of urban design. A high QOL tends to be a virtuous cycle that attracts greater economic activity and investment, leading to improved QOL.

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Figure 1: Mehatet el Raml area, 1990. *(Source: https://www.planetware.com/tourist-attractions-/alexandria-egy-alex-alex.htm.)*

Figure 2: Mehatet el Raml area, 2021. *(Source: https://www.planetware.com/tourist-attractions-/alexandria-egy-alex-alex.htm.)*

The goal of CITYKeys was to develop and validate a performance measurement framework to promote common, transparent, and comparable tracking of Smart City solutions across many European cities. Indicators are included at two levels in the framework: city or neighborhood, and project. The former compares the before and after results of a Smart City project to assess its impact, while the latter compares the expected effect to a reference point. The latter also monitors the city's overall progress toward Smart City goals and evaluates how the project contributed to the city's goals [2]. The evaluation framework includes considerations for the three Ps (people for social sustainability, planet for environmental sustainability, and prosperity for economic sustainability), as well as governance and scalability/replicability (under the heading Propagation, in Fig. 3). For each of these five categories, correlating indicators were identified (Fig. 3). A Smart City approach to protection of the environment, for example, is evaluated using indicators such as efficiency and climate mitigation performance. From the start, cities and local governments were involved in the project, and the indicators were developed in collaboration with them. It necessarily required a multifaceted approach, devoting effort towards breaking down silos in urban project design and implementation [2].

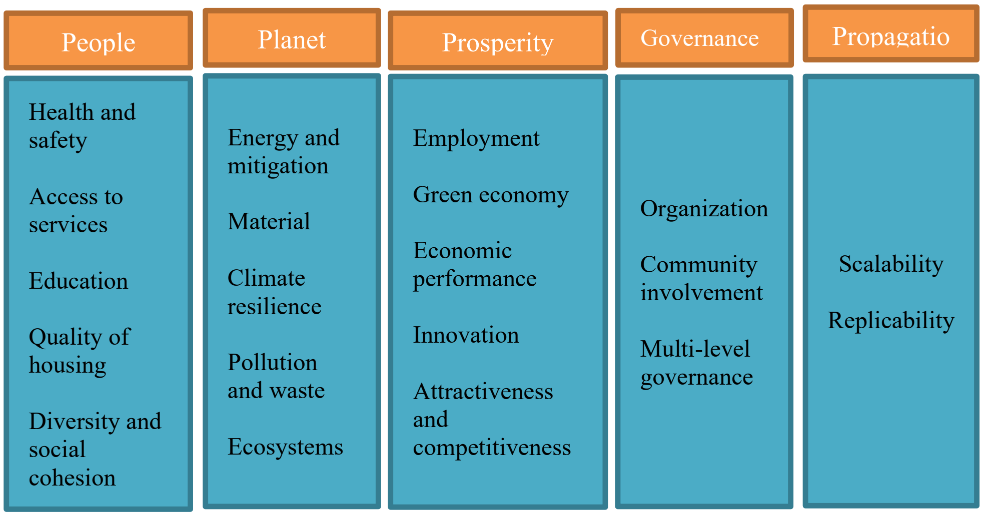

Figure 3: Five evaluation indicators categories of CITYKeys project. *(Source: Authors, 2021.)*

3 CHARACTERISTICS OF A SMART CITY WHICH LEADS TO HAPPY CITY [3]

The "Smart City" concept can be reviewed within three dimensions: Technology, Human and Institutional (Fig. 4) [3].

Figure 4: Characteristics of a Smart City. *(Source: Authors, 2021.)*

4 HAPPINESS-RELEVANT CIRCUMSTANTIAL FACTORS

Many research studies focus on the how people affect the environment, but none are researching how the environment influences the people. Issues like waste management, air quality and greenhouse gas emissions are, actually, having a big impact on our citizen's levels of happiness and wellbeing in life.

5 HAPPINESS-RELEVANT USER ACTIVITIES

Urban public parks function as a theatre for encouraging public activity. The top image in Fig. 5 shows the Al khaledeen public park in 1990 and there is happiness in its design. The architect chooses to respect the nature of this by not removing any trees from the park. This design makes a gentle transition between the park, square and the historic neighborhood in Alexandria. The bottom image in Fig. 5 shows Al khaledeen public park after development: We notice that there are no green areas like before, it was transformed to a concrete building with cafes.

Figure 5: Al khaledeen public park. Top image shows the park before development in 1990; the bottom image shows the park after development, in 2021. *(Source: www.facebook.com/AlexandriaCitizens/posts/3608311959296086/.)*

(a) (b)

Figure 6: Al khaledeen public park elevation to the sea side 2021. *(Source: https://ar-ar.facebook.com/alexhabebti/posts/3280973638608074/.)*

6 HAPPINESS IN THE CITY

Plato's statement that "the city is what it is because our citizens are what they are" serves as a good reminder of how important people are in any consideration of a city; thus, the well-being of people in the city is essential. This is especially important because cities are expected to house 75% of the world's population by 2050. Such perspectives contrast with definitions that lack the spirit of a city, such as being "an urban geographical area with one (or more) local government and planning authorities" [4].

Gehl believes that urban planners should strive to create cities that are livable, safe, sustainable and healthy, emphasizing four characteristics. A walk should be useful, safe, comfortable and interesting to a citizen. Thus, walking is encouraged, increasing the likelihood of social interactions as people pass each other at walking pace, rather than speeding by within the physical barrier of cars [5].

The difference now is that, as digital technology becomes more widely available, it provides even more opportunities to improve one's QOL. The world is currently experiencing the fourth industrial revolution (4IR), in which technology is fusing the physical, digital and biological worlds, promising people even more value through city planning (physical, organizational, informational, etc.); which must therefore support the aforementioned benefits of a city. Technology may be used to enhance such support, potentially leading to a happier city [6].

6.1 Feedback loop: Measures, tools and interventions

At various levels of sophistication, any organization operates a feedback loop in which actions are based on some reasoning and insight extracted from data. This is the classic feedback loop where data for a Smart City (or otherwise) can be obtained from a variety of sources, including observation; surveys; and digital sources such as the Internet, database systems, even general knowledge. Processing and insight collection can be carried out manually, using rudimentary algorithms, or using artificial intelligence (AI). The solution could take several forms, including the immediate provision of personalized services or the modification of general service settings to improve efficiency. A Smart City with advanced feedback loops is also known as a conscientious and responsive city, using data-driven urbanism, which describes how cities are becoming increasingly instrumented and networked, their systems interconnected and merged, and where vast troves of data generated are used to manage urban life. Data-driven cities are becoming more common in the Fourth

Industrial Revolution (4IR). Section 6 describes many analog and digital factors, also feedback loop examples, that civic leaders may use to realize the promise of hugely complex ways to interact with residents, not just by asking, but providing direct rebuttals to behavioral data as well, while creating an efficient city that works to deliver happiness [7].

6.2 Digital and analog aspects of the feedback loop (Fig. 7)

1. Measure: Gather behavioral data (e.g., telecommunications, retail data) and reported data (e.g., satisfaction scores).
2. Process: Analyzing data and input, then converting them into insights and recommendations (e.g., modeling and evaluation tools).
3. Respond: Act in response to insights, automatically or manually, based on set criteria (e.g., activities, interventions and policies).

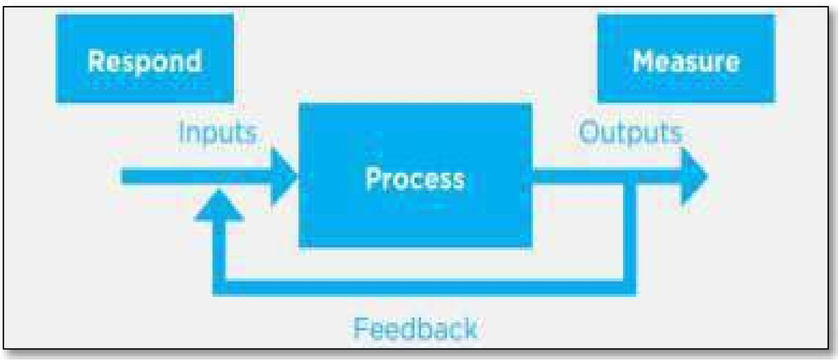

Figure 7: Digital and analog feedback loop [7].

6.3 Case: SHAPE Tool (Dubai, United Arab Emirates (UAE))

Dubai's technological journey began in 1998 with the declaration of its first information and communications technology (ICT) strategy, and has since been followed by the establishment of Dubai Internet City, Dubai e-government, Dubai Smart Government, and most recently, the Smart Dubai initiative, which was started up in 2014. Dubai's numerous digital transformation initiatives fuel public acceptance and adoption of ICTs in all aspects of life over the last two decades. Today, Dubai, a city of 2.5 million people and one of the seven Emirates of the UAE, has one of the highest levels of ICT adoption in the region. According to His Highness Sheikh Mohammad Bin Rashid Al Maktoum, vice-president and prime minister of the UAE and ruler of Dubai, technology, as a framework for solutions, is merely an enabler, rather than the primary goal. The Smart Dubai initiative is bringing to fruition His Highness' vision of making Dubai "the happiest city on the planet".

Dubai unveiled Smart Dubai 2021, a five-year strategy, in 2017. The new strategy explicitly shifts the strategic focus from enabling, to having a significant positive impact on the city through digital transformation.

The "Smart Happiness Index" (SHI) was developed in partnership with the Gallup Organization. Happiness is linked to the six elements of the Smart Dubai 2021 Strategy, via this compound index derived from quantitative data research: economics, people and society, governance, mobility, environment and living. Since then, the project moved on to the next stage, which is the development of a decision tool known as the Smart HAppiness Project Evaluation tool (the SHAPE tool considers different key performance indicators (KPIs) within the city plan's six pillars and provides weighting, based on the relationship between these KPIs and sample satisfaction, using data from over 4,300 Dubai residents as a representative sample (chosen from all segments of society, includes resident expats and citizens)).

When calculating the SHI index for each project, the program takes into account a number of other factors: One is adaptation, where the tool takes into account how long the benefits will last, as well as how quickly and to what extent people will adapt to new projects or service improvements. Finally, based on the cost of the project under consideration, the SHAPE tool computes a cost-effectiveness ratio. This ratio denotes the expected increase in happiness for each dirham that is spent. Users simply respond to a series of structured questions via a simple online interface, and the program computes the SHAPE score and the cost-effectiveness ratio, so they can then compare to other projects. Instead of being overly arbitrary, this gives the user a sense of the relative meaning of the figures. These findings can offer data-driven insight into how much their project contributes to a city's happiness vision, enabling project managers to fine-tune and improve their projects, thereby increasing their effectiveness. Use of the tool facilitates planning and decision-making procedures in both public and private sectors, by allowing organizations to tailor their projects for maximum durability and impact on happiness [8].

7 ENVIRONMENT

The quality of a city's natural environment has a significant impact on the happiness of its residents. This, on the other hand, has a direct local as well as a global impact. As a result, several environmental issues, including air quality, waste, sustainability, energy and water use must be addressed.

Some programs, such as Quito's carbon and water footprint calculator, contribute to the city's overall environmental KPIs. The goal is to raise public awareness of the city's environmental impact.

7.1 Case: Goodwill Waste (Seoul, South Korea)

City managers in Seoul's "Sharing City" faced the challenge of finding a workable balance between waste collection and disposal. The method proposed that a Volume-based Garbage Collection Fee (VGCF) replace the previous system, which was a property-based tax. The new system is based on the co-production principle, which is a collaboration between citizen and city similar to volunteering, giving residents a sense of civic engagement. Another consideration was the fee, determined by the amount of waste collected. These two factors provide residents with an indirect incentive to recycle, by encouraging them to sort their waste prior to collection, reducing the fee they paid. From the start of the scheme in 1994 to its end in 2000, this scheme was successful in changing citizen's behavior, resulting in a 30% reduction in waste per capita. The scheme also increased the amount of recyclable material collected, as well as increasing residents' sense of civic engagement, which is a strong contributor to enhancing well-being. This is in addition to the fact that people were aware they were helping the environment, as well as the actual physical benefit of achieving a more sustainable city. The role and responsibility of the various stakeholders are listed in Table 1 [9].

Table 1: Distribution of city waste-diminishing functions. *(Source: Authors, 2021.)*

Entity	Role and responsibility
Ministry of Environment	To establish regulatory framework and develop strategies and policies. To provide technical and financial support to local government.
Ministry of Trade, Industry, and Energy	To foster resource circulation industry. To develop new and renewable energy.
Ministry of Land, Infrastructure and Transport	To promote the use of recycled construction wastes. To introduce quality certification system for recycled aggregate.
Ministry of Oceans and Fisheries	To manage ocean waste including marine plastics.
Ministry of Agriculture, Food and Rural Affairs	To manage compost and animal feed produced from organic wastes to produce energy from biomass.
Province, Metropolitan city	To provide financial support to municipalities. To coordinate projects among municipalities.
City, County, District	To collect and dispose of municipal waste. To install and operate waste disposal facilities.
Business, Developer	To dispose of industrial waste. To treat waste generating from development project.

8 LIVING ENABLERS

Though life in the city is influenced by many activities, there also exists the location and space itself as the physical substrate, plus the many other urban structures that enable living in the city. These structures take various forms, concepts and scales; such as green and blue spaces, housing, safety, infrastructure, urban planning and connectivity [7].

9 HAPPINESS INDICATORS FOR GROSS NATIONAL HAPPINESS INDEX (GNH)

The Global Happiness Index is a research-based indicator for measuring happiness in countries across the world. Happiness is shaped by a range of factors. The United Nations (UN) General Assembly adopted a resolution in 2011 imploring states to assess the happiness of their citizens in order to guide policy. The UN began its work on happiness and well-being in 2012, with the goal of building a clear economic structure to support it. Dubai formed the world's first Ministry of Happiness in 2016.

What elements affect to people's happiness? Individual and national wealth do not entirely define the global happiness standard; however, other indicators are highlighted in the classification method given in Table 2 [10].

10 THE LONDON SUSTAINABLE DEVELOPMENT COMMISSION (LSDC)

This commission was set up in 2002 to provide advice to the Mayor of London on ways to make the city more sustainable. An independent organization, it reaches policymakers in order to encourage a better lifestyle for all Londoners, now and in the future, while taking into consideration London's globalized impacts. The Commission is comprised of

Table 2: Gross National Happiness Index (GNH) classification mechanism. *(Source: Authors, 2021.)*

Living standards	Ecological diversity and resilience	Psychological wellbeing	Health	Time use	Community vitality	Education
Assets	Ecological issues	Life satisfaction	Mental health	Work	Donations (time/money)	Literacy
Housing	Responsibility towards the environment	Positive emotions	Self-reported health status		Community relationships	Schooling
	Rural wildlife damage					
Household per capita income	Urbanization issues	Negative emotions, spirituality	Healthy days	Sleep	Family	Knowledge
			Disability		Safety	Value

Table 3: London Sustainable Development Commission (LSDC) indicators [11].

Social indicators	Economic indicators	Environmental indicators
• Education: Primary • Education: Secondary • Childcare • Crime • Decent housing • Life expectancy • Physical activity • Satisfaction with London • Happiness • Voting • Volunteering • Healthy life expectancy • Social integration • Travel	• Gross value added • Income inequality • Employment rates • Business survival • Human capital • Innovation • Child poverty • Fuel poverty • Housing affordability • London living wage • Carbon efficiency • Low carbon and environmental jobs • Skills	• Traffic volumes • Air quality • Travel to school • Access to nature • Bird populations • Ecological footprint • Flooding • Household recycling • Water consumption • Waste • Business/development recycling • NOx emissions • CO_2 emissions

individuals with expertise in London's economic, social, environmental, and governance sectors. The LSDC aims that the QOL measures will be useful to other Londoners. These indicators are supervised by the Mayor, cities, businesses, central government, and other private and public sector stakeholders all throughout London (Table 3) [11].

Hence, QOL indicators play an important role in the development of urban communities through the following stages. A proposal for indicators is illustrated in Fig. 8.

11 CONCLUSIONS

When discussing the concept of a Smart Happy City, people may consider technology to be a key component; however, in order to avoid an exclusive focus on technology, a broader and more inclusive scope is worth considering, in order to redefine smart cities. In this context, smarter means making better use of resources, methods and techniques, including high technology. The results of the analysis of the definitions and concepts of the Smart City suggest that there are three key issues:

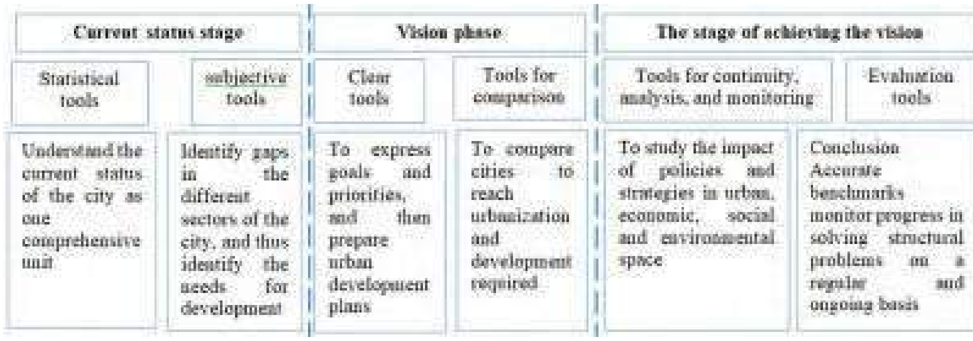

Figure 8: Proposed quality of life (QOL) indicators. *(Source: Authors, 2021.)*

1. Infrastructure is central to the Smart City concept. Technology is an enabling factor for smart cities, but it is not always the most critical factor. It is critical to combine, connect and maintain the integrity of systems and infrastructure in order to create a Smart City. The primary systems are not discrete and separate, but rather are transformed into a multifaceted system of connected systems in a synergistic manner that distributes better performance.
2. Processes (how a Smart City arises) play a key role in advancing definitions. A huge change in the way services are delivered is an important factor for a Smart City. A Smart City is primarily important for the development of services, rather than technology.
3. A vision for a better future is important. A Smart City must be able to forecast a smart economy, smart governance, smart mobility, a smart environment, smart people, smart living, and how they will interact. Yet having a vision for intelligent advancement is insufficient; actions in the fields of legislation, policy, and organizational change are required. On the other hand, infiltrating intelligence into each subsystem of a city is insufficient to create a Smart City; these dimensions must be considered as an organic whole. Our key point is that cities must be responsive to the context in which they operate, and what constitutes intelligence is dependent on a variety of contexts (texture and context), such as the political system, geographic conditions, and technology diffusion. Smart solutions, in fact, cannot be copied and must be valued from within different fields. Cities cannot easily copy good methods, but they must develop approaches that are appropriate to their conditions, because there are no two cities with the same conditions. For now, we can foresee that these factors and strategies will become reference tools to make Alexandria a Smart Happy city, as it will aim to design positive user experiences and set the city to shaping a Happy City policy through future planning and design for Alexandria.

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ADJUSTED ENERGY BENCHMARKING SYSTEM UNDER COVID CONDITIONS: DUBAI AS CASE STUDY

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ABSTRACT

Since COVID-19 emerged in late 2019, governments and local authorities have drawn up policies to mitigate the impact of the virus and protect their population. They implement preventive measures that include sanitary guidelines and rules related to people's mobility and social interactions. Such efforts have disrupted business, educational, and social activities, requiring the adaptation of the people to a new reality that, consequently, has shifted their energy demand patterns. These changes in the energy demand bring challenges to the energy benchmarking efforts, which has been an effective steppingstone for improving the energy performance, allowing users to compare their consumption relative to others and detect the opportunities for improvement from the current state. Also, the changes in the consumption patterns also make it challenging to identify and target underperforming users. Consequently, in this study, we propose an adjusted benchmarking system that accounts for the impact of COVID-19 on the energy consumption patterns of Dubai using available public data. We utilized monthly electrical consumption and dwelling profile data from 1,841 residential buildings between January 2020 and June 2021. We built two different statistical models, a pre-covid and post-covid model, according to different characteristics of the dwellings such as gross floor area, number of users, a cooling source, and time-dependent weather variables such as outdoor temperature. Finally, we compare both models to underline the significance of COVID-19 in the adjusted energy benchmarks. The resulting adjusted model serves to estimate the average consumption of residents in Dubai throughout the year. Furthermore, both models' difference helps define the adjusted range of the users over/underperforming. The findings and conclusions of this study demonstrate the need for built adjusted benchmarking systems to continue effectively categorizing users' energy consumption under unusual conditions such as COVID-19.

Keywords: energy consumption, Dubai, COVID-19, energy benchmarks.

1 INTRODUCTION

COVID-19 has challenged the traditional ways of living and interacting around the world. Since the virus appeared in late 2019, it has resulted in more than 200 million recorded cases and over 4.3 million deaths as of August 2021 [1]. As a response to the health crisis, governments and local authorities restricted mobility and social interactions by implementing curfews, full lockdowns, and border closing [2]. Social interactions have been reduced by either closing most public events and facilities, or limiting their capacities [3]. Such measures have disrupted everyday activities both for businesses and people, requiring them to adapt to new social dynamics, and consequently, shifting their energy demand patterns. With reduced mobility, there is a wide acceptance of work from home, distance learning, and online shopping that transferred many daily urban activities to households.

Understanding the impact of the pandemic on energy demand trends in cities is important for government and policy developers as it can help to quantify and forecast the effect of the implemented policies but also provide insight for future adaptations and energy efficiency policies. Dubai took a proactive and dynamic response to mitigate the effects of COVID-19, implementing multiple measures that reshaped its population's activities. Protocols were introduced timely and updated through the development of the pandemic. As an example, in

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the National Disinfection Program and social distancing program targeted at the pandemic, Dubai closed all international borders on March 23, 2020 [4], had a curfew period between March 30, 2020 and June 24, 2020, and a full lockdown between April 4, 2020 and April 26, 2020 [4]. Additionally, on March 25, 2020 [5] most non-essential businesses were asked to close and only until April 26, 2020, businesses such as cafes and dine-ins were allowed to resume activities limited to 30% of their capacity [4]. A comprehensive and fast vaccination program was introduced since December 2020 to ensure the safety of the public and accelerate the back-to-normal path.

In the same way, as part of the Exceptional Rules and Regulations, the authorities defined a series of guidelines to promote remote work and digital transformation of businesses through virtual environments [6]. Consequently, changes in the habits of the population of Dubai were reflected in other reports such as Google's COVID-19 Community Mobility Reports, where they estimated that for the month of April 2020 there was a –65% average reduction of activity in retail and recreation, grocery and pharmacy, parks, transit stations and workplace areas, while the overall time people spent in their residence had an average increase of 30% [7]. The main actions taken by the local government are presented below which result in the timeline shown in Fig. 1.

Figure 1: Timeline for COVID-19 containment actions in Dubai.

With the dynamic response towards COVID, people adapt to a new lifestyle and therefore potentially shift their consumption patterns [8]. This poses a challenge to existing benchmarking systems, which are commonly used as an indicator to identify low performers and guide retrofitting efforts. The variation of energy consumption caused by unique events such as pandemics undermine the accuracy of the benchmarking system. It needs to be addressed and included in the energy benchmarking system to ensure the accuracy and set the correct path for efficient retrofits. This study aims to study the variation of consumption records during COVID period and establish an adjusted benchmarking system to account for the unique incident.

2 LITERATURE REVIEW

Some countries like Poland and Australia experienced an increase of 16% and 15% respectively of the household energy demand due to the COVID-19 pandemic [8], [9]. On the other hand, sectors such as the information and technology sectors have benefited due to increase in the usage of technology for remote work and business transactions [10]. Overall, the information technology sector has grown during the pandemic. The share of the IT sector went up by nearly 24% for the first two-quarters of 2020 [11]. Such changes in the location and nature of business activity inevitably alters the energy demand patterns [12].

With the variation in energy consumption caused by the pandemic, it raises a question of whether existing benchmarking system needs to be adjusted to ensure accurate comparison. Energy benchmarking has been widely used to evaluate the energy performance of buildings around the world. Two approaches are commonly taken to establish the benchmarking system, a data-supported top-down approach and a simulation-based bottom-up approach [13]. For instance, Tereci et al. [14] benchmarked German residential buildings with different configuration through EnergyPlus. Same simulation tool is used in Shabunko et al. [15] to benchmark residential buildings in Brunei. Results are compared with actual consumption to identify retrofit opportunities. On the other hand, Ding and Liu [16] reviews existing data-driven methods for benchmarking. Arjunan et al. [17] use public data to suggest potential improvement for the Energy star portfolio manager program.

Existing literature has shown the importance of an accurate benchmarking system and the approaches to establish them. Under the influence of the global pandemic, we aim to investigate the need for an adjusted benchmarking system using user information and consumption data in Dubai. Results will serve to guide future benchmarking efforts and retrofitting opportunities.

3 METHOD

This study used anonymized data generated from a survey conducted by the Dubai Electricity and Water Authority (DEWA) as part of its "My Sustainable Living" program [18] which targets only residential users. This initiative aims to enhance the efficiency of electricity and water consumption of residential customers and support them to adopt a sustainable lifestyle. We listed the questions and answers options in Table 1.

The results are combined with the anonymized monthly electrical consumption, published by DEWA on the public data sharing portal of Dubai [19] by matching the account number of registered users. Ideally, higher frequency data such as hourly or by minute would reveal changes in daily patterns. However, publicly available data for Dubai is only shared on a monthly scale. Since we aim to investigate the need for an adjusted benchmarking system, only users with continuous records from 2019 onwards are selected in this study. August 2020 shows missing consumption records for most users. Therefore, this month is excluded from the analysis. 1,841 residential accounts result after matching users that have had continuous records in both years, and that are also registered in the "My sustainable living" survey.

Typical benchmarking structures use energy utilization index (EUI) which expresses the buildings' energy use as a function of their gross floor area in kWh/m^2 per year. However, given the structure of the survey collects gross floor area as a categorical variable, this study decided to define the variable of interest as the absolute consumption of the household in kWh instead of the EUI [20]–[23].

The methodology followed initially plots consumption values to find its general distribution. Additional consumption plots are made against the survey results to identify

Table 1: Survey questions.

Questions	Answer options
Can you estimate the surface area of your home (in m²)?	I don't know Less than 50 50–100 100–150 150–200 200–300 More than 300
If you live in a villa, do you have your own swimming pool?	Y/N
If you live in a villa, do you have your own garden?	Y/N
How many people live in your home?	Incremental increase from 0 to 8 with 9 and above
How many people under 18 live in your home?	Incremental increase from 0 to 8 with 9 and above
How many bedrooms are there in your home?	Studio, Incremental increase from 1 to 8 and 9 and above
Your air conditioning consumption is	Included in your electricity bill Separated by district cooling Included in your rent I don't know
During the year, which months do you usually go out for vacation?	Multiple choices for months in the year
How long is your vacation per trip?	Less than 1 week 1 week 2 weeks 3 weeks and more

relevant groupings and patterns that explain the observed distribution and unveils energy drivers. Secondly, effects of covid on the monthly consumption distribution are studied with statistical tests in between the two years. Thirdly, a regression model is generated using energy driver variables and a dummy variable that identifies months when the Emirate declared reduced mobility policies. Finally, the generated model and the characterized distributions will serve to benchmark energy consumption for residential users in Dubai.

4 RESULTS AND DISCUSSION

When observing the distribution of the consumption in kWh in Fig. 2, the double hump pattern shows there are at least 2 variations of user accounts. In Dubai, there are several ways to bill users' electricity and cooling consumption as shown in Table 1. People who use district cooling as their main cooling sources have separate bills for cooling, leaving it excluded from their electricity bills. It therefore reveals the baseload of users in the electricity bills. The rest either has the cooling consumption included in their monthly electricity bills or being a part of their rent. When generating a distribution plot for all the variables, it is noticed that separating users whose cooling is included as part of their bill, and users that separate their cooling needs from their electricity bills, either by having a separated district cooling service or including cooling costs in their rent (Fig. 3), the double hump distribution of consumption is decomposed to two distributions.

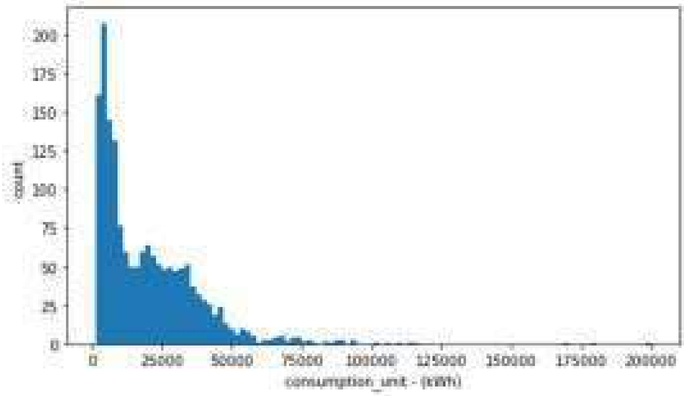


Figure 2: Annualized consumption distribution (kWh).

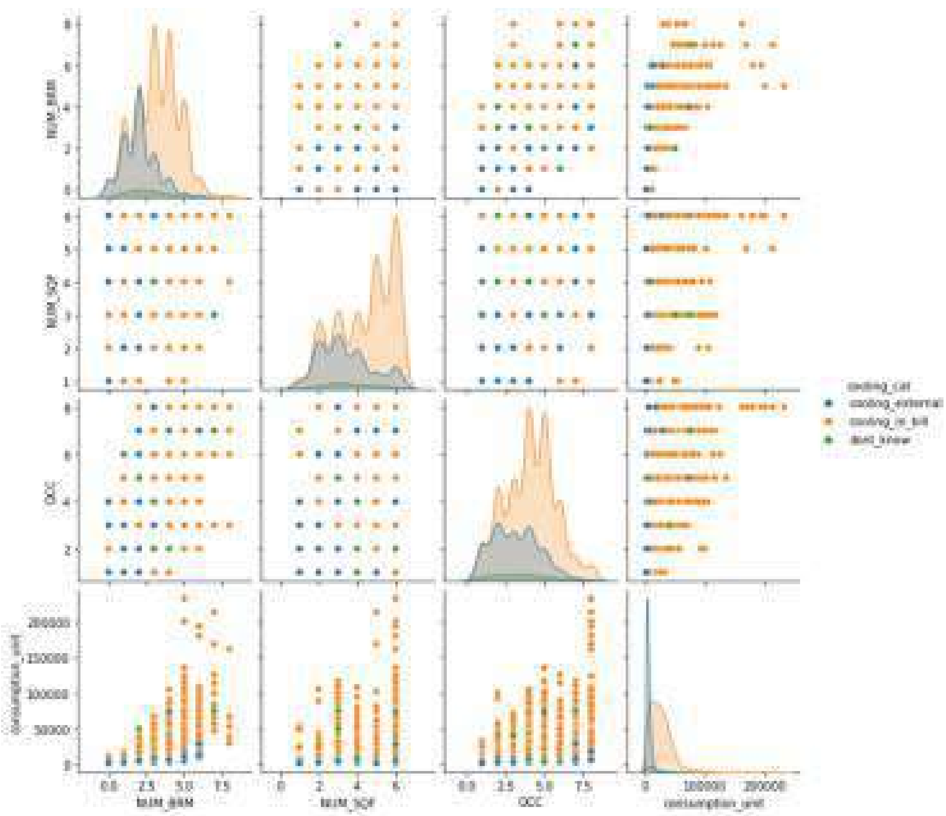


Figure 3: Variable relationships.

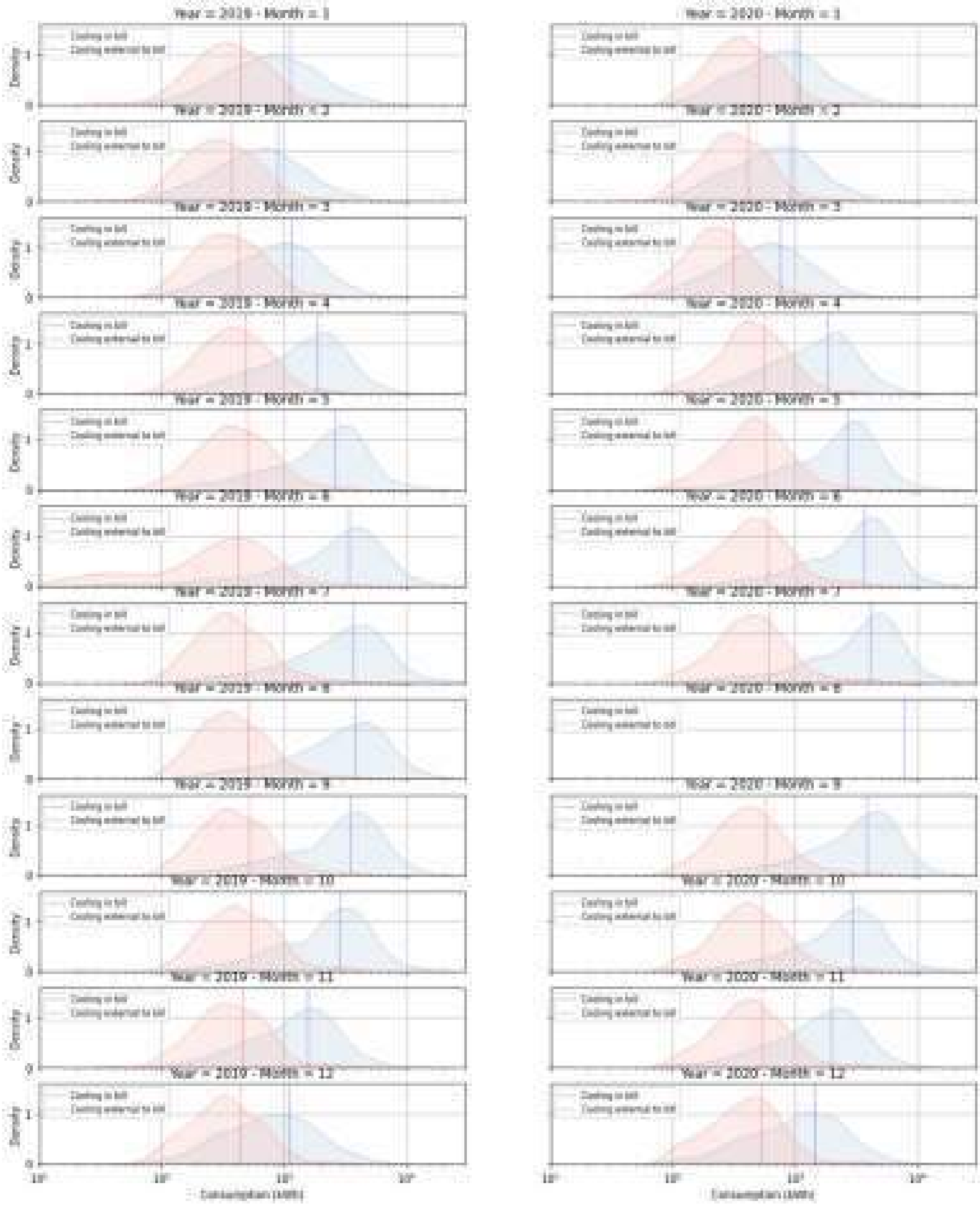


Figure 4: Monthly consumption according to cooling category. Vertical line shows means.

As a result of the close relation between cooling consumption and seasonal weather, monthly consumption distributions were plotted according to their cooling category (Fig. 4). Logarithmic scale is used to better observe the distribution difference. On one hand, it can be observed that users who use district cooling their consumption centers around 500 kWh regardless of seasonal changes. This is typically defined as the electricity baseload which refrains from changing throughout the year. On the other hand, users that have cooling as part of their electricity bill shift their consumption in accordance with the summer and winter seasons between 3,500 kWh and 1,000 kWh respectively. The modulating effects of cooling show the need of integrating a variable that reflects this relationship appropriately. Therefore, for a monthly analysis, mean outdoor temperature is included as a variable that reflects seasonal weather variations.

Monthly distributions of users with district cooling in 2020 were compared against the monthly distribution of the previous year. Differences between them were assessed using the Mann–Whitney U test, which is a non-parametric test to estimate differences in between distributions (Tables 2 and 3). The alternative hypothesis of the test states that one distribution is stochastically greater than the other, indicating there is a difference between the two distributions. Mann–Whitney U p-values in Table 2 show that there is significant evidence to consider the monthly distributions of summer 2020, which were affected by COVID, different from the consumption distributions of 2019. Given Dubai's government implemented COVID restrictions at the end of March 2020, it is unlikely that the drastic variation in March 2020 is attributed to COVID effects. More information is needed to

Table 2: Monthly distributions mean values and Mann–Whitney U p-val for users with externalized cooling in 2020.

Month	Mean 2019	Mean 2020	Mann–Whitney p-val	Year to year change
Jan. (01)	441	504	0.1433	14%
Feb. (02)	370	409	0.1383	10%
Mar. (03)	431	317	0.0000*	–26%
Apr. (04)	487	562	0.0011*	15%
May (05)	500	580	0.0009*	16%
Jun. (06)	423	601	0.0000*	42%
Jul. (07)	492	610	0.0001*	24%
Sep. (09)	516	573	0.0509	11%
Oct. (10)	547	540	0.7915	–1%
Nov. (11)	467	544	0.0018*	16%
Dec. (12)	432	531	0.0002*	23%

Table 3: Monthly distributions mean values and Mann–Whitney U p-val for users with cooling included, 2020.

Month	Mean 2019	Mean 2020	Mann–Whitney p-val	Year to year change
Jan. (01)	1,118	1,082	0.7853	–3%
Feb. (02)	889	921	0.0372*	4%
Mar. (03)	1,155	760	0.0000*	–34%
Apr. (04)	1,875	1,831	0.4213	–2%
May (05)	2,632	2,676	0.2703	2%
Jun. (06)	3,392	3,669	0.0004*	8%
Jul. (07)	3,675	4,144	0.0000*	13%
Sep. (09)	3,462	3,874	0.0002*	12%
Oct. (10)	2,865	2,944	0.5268	3%
Nov. (11)	1,586	2,013	0.0000*	27%
Dec. (12)	1,105	1,465	0.0000*	33%

investigate the sudden dip of electricity consumption in March 2020. It is important to mention that the monthly average residential consumption increased by 25% between April and July 2020 compared to the previous year, which correlates with the lockdown and home curfew policies implemented during the period. This observation is in line with existing literature where residential energy demand increased over the lockdown period. For instance, a 14% of increase in the residential sector is recorded in Victoria, Australia comparing to pre-lockdown period [9].

We developed a model with the explanatory variables given in Table 4. To reflect the effects of COVID, we define a dummy variable representing if the current month was affected by a curfew or lockdown order due to the pandemic, i.e. April, May and June of 2020 in Dubai. Two OLS (Ordinary Least Squares) regression models were generated for each cooling category, i.e., cooling included or excluded (district cooling) from the electrical bill. Finally, the predicted variable, electricity consumption, is transformed to the logarithm scale to reduces the skewness of the original distribution. Both models are defined according to eqn (1).

$$\begin{aligned}\text{Log}(consumption) = B_o + B_{occ} \cdot OCC + B_{temp} \cdot T + B_{room} \cdot BRM \\ + D_{GFA} \cdot SQM + D_{covid} COVID + \varepsilon.\end{aligned} \tag{1}$$

Table 4: Model variable definitions.

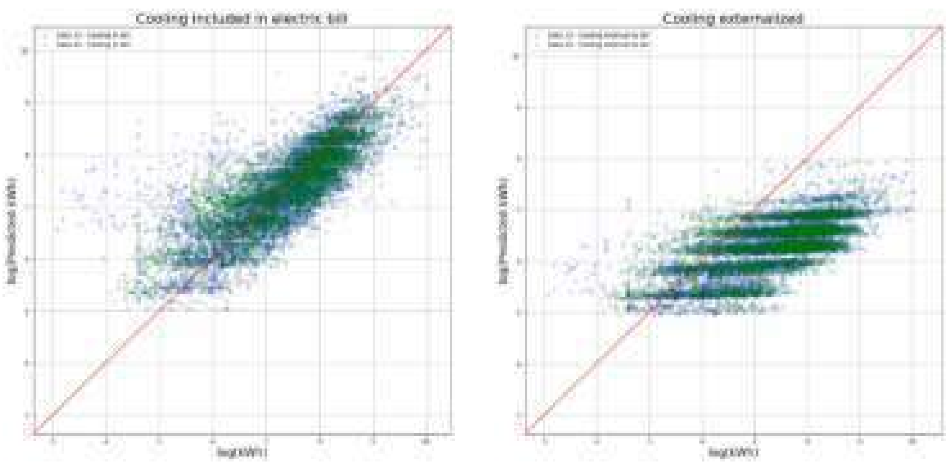
Variable	Type	Abbreviation
Monthly consumption	Float	consumption
Number of occupants	Integer	OCC
Number of bedrooms	Integer	BRM
Gross floor area	Categorical (6)	SQM
COVID restrictions were in place	Boolean (2)	COVID
Average outdoor temperature	Float	T

Linear model results are shown in Table 5. As expected, the model that includes cooling seems to better explain the consumption of the user ($R^2 = 0.648$), while the model that targets for district cooling users performs poorly ($R^2 = 0.357$). Furthermore, the prediction power of the models is presented in Fig. 5, where the x axis denotes the actual electricity consumption of users, and the y axis represents the corresponding predicted values. The model that includes cooling have the data along the 45° line, while the cooling excluded model has a greater spread away from the diagonal line and deviates the most on the high consuming accounts. This result makes sense when comparing the t values of the coefficients with 99.9% confidence ($t > 3.291$). The most significant variable for cooling included and district cooling model is outdoor temperature and the intercept baseload respectively. While being statistically significant, the temperature coefficient for the district cooling model is minimal (0.01), suggesting the seasonal change has very little influence on the electricity consumption of these accounts. Such results are in line with the facts that the accounts are either a weather driven (cooling included) or baseload driven (district cooling).

When comparing the COVID effects for both models, the covid variable is insignificant for the model that includes cooling while its significant for the district cooling one. On one hand, the lack of significance for the cooling model can be explained through the fact that residents in Dubai tend to leave their HVAC systems on even during unoccupied times especially in summer due to extreme weather conditions. Moreover, cooling takes more than

Table 5: Linear model parameters.

	Cooling included	Cooling excluded	Cooling included	Cooling excluded
R^2	0.648	0.357		
σ – log(kWh)	0.6314	0.6306		
	Coeff		t-value	
Bo	2.98	4.77	86.3*	101.9*
$D_{GFA}(2)$	–0.07	0.00	–2.3	0.0
$D_{GFA}(3)$	0.08	0.11	2.6	3.0
$D_{GFA}(4)$	0.25	0.22	8.3*	5.7*
$D_{GFA}(5)$	0.35	0.20	11.7*	4.7*
$D_{GFA}(6)$	0.44	0.21	14.3*	4.8*
B_{occ}	0.09	0.05	30.6*	10.1*
B_{temp}	0.09	0.01	125.5*	6.2*
B_{room}	0.30	0.30	71.8*	36.3*
D_{covid}	–0.02	0.20	–1.8	11.3*



(a) (b)

Figure 5: Actual vs predicted log (consumption) (kWh).

70% of the electricity consumption in Dubai, leaving the baseload variation shadowed under the cooling needs. Therefore, most changes can be attributed to cooling related variables such as temperature as cooling plays a more significant role than any other drivers including COVID restrictions. On the other hand, when observing the COVID effects for the users that have district cooling, the influence of COVID becomes significant. This can be explained that measured consumption of the district cooling users represents their baseload consumption. Changes in their dwelling patterns as well as the need of distance learning/working will impact directly on their electrical baseload.

Since the OLS benchmarking model shows limited fit for users with district cooling, and there is no other information available at the current state, multiple distributions were fitted to the baseload consumption in hope to define a basic benchmarking model. Fig. 6 shows the top five best fits for the data where the *exponentially modified Gaussian distribution* (exponnorm) displayed the minimum sum of square errors (Table 6). The probability density function of the exponnorm distribution follows eqns (2) and (3) with fitted parameters to be $K = 6.30$, $\mu = 122.56$ and $\sigma = 59.16$. This distribution will serve as the preliminary benchmark to rank users that have separate electricity and cooling bills and reflects the distribution of their baseload.

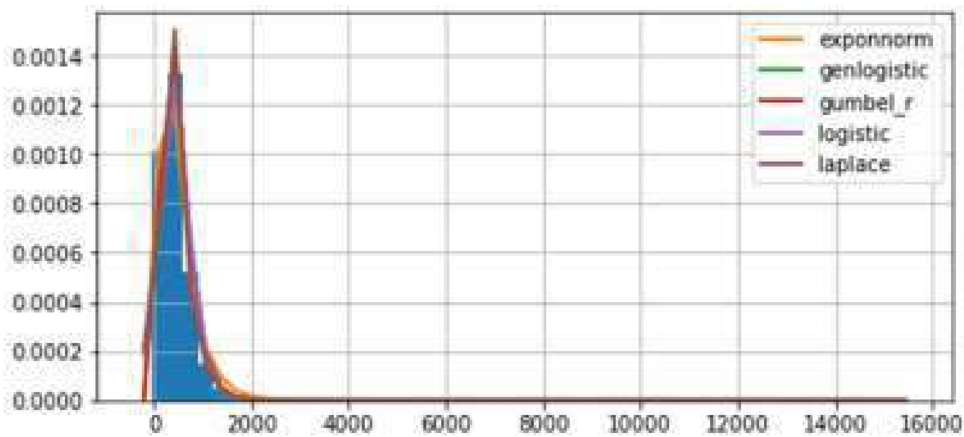


Figure 6: Fitted distributions to consumption with externalized cooling.

Table 6: Distribution fitness for externalized cooling consumption.

Distribution type	Sum square error
exponnorm	2.55e-08
genlogistic	4.66e-08
gumbel_r	4.70e-08
logistic	1.38e-07
laplace	1.73e-07

$$f(x; \mu, \sigma, \lambda) = \frac{\lambda}{2} e^{\frac{\lambda}{2}(2\mu + \lambda\sigma^2 - 2x)} erfc\left(\frac{\mu + \lambda\sigma^2 - x}{\sqrt{2}\sigma}\right), \quad (2)$$

$$K = \frac{1}{\sigma\lambda}. \quad (3)$$

The above results show that the influence of COVID policies is better highlighted through a baseload analysis which ignores the weather effects on cooling [9]. Similar situation is observed in China, where baseload end uses such as cooking and lighting demand increased over the lockdown period [24]. In Raman and Peng [25] daily new cases of COVID are found to be a dominant driver for Singaporean households energy demand.

When cooling is included in their utility bill, the weather turns to be the biggest energy driver which masks most of the effects of COVID. Furthermore, in this case study, the electrical utility provider operates separately from the district cooling providers. Consequently, it is a complex task to get a holistic understanding of changes both in the baseload and in the variable load. Such challenge raises the importance for analyzing users through disaggregated loads and smart meters that will allow to better identify the drivers for users and the changes in their energy patterns.

Finally, it is important to know that even though this study investigates the benchmarking system with consumption records (kWh), a typical benchmarking analysis is usually based on energy use intensities (EUI, kWh/m^2). Such limitation is a result of the available survey data which collected gross floor area information under categorical options. Further analysis requires the gross floor area as continuous variable for each user. Such information can be obtained by generating a new survey campaign or integrating user information from other agencies such as the Dubai Land Department.

5 CONCLUSIONS

The results show that integrating consumption records with user profiles is valuable to disaggregate consumers. Effects of the main energy drivers will be better observed when grouping the users according to their profiles.

When grouped with cooling sources, Mann–Whitney tests demonstrate there is a significant difference in consumption between 2019 and 2020, particularly for months under movement restrictions. This suggests the need to incorporate the influence of COVID in energy benchmarks to ensure accuracy during affected months. Two OLS models including COVID influence as a dummy variable are made separately according to their cooling category. For district cooling users, the significant coefficient of COVID effect confirms the need of adjusting benchmarks during months that are under the influence of COVID curbing polices.

However, COVID effects are insignificant when analyzed for users who include cooling in their electrical consumption. As 70% of the electricity consumption of buildings are comprised of cooling in the region [26], its variation outweighs any effects of COVID policies. Consequently, the need of an adjusted benchmark system for users with cooling included in their electricity bills is not as prominent as the one for baseload users in Dubai.

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SOCIO-ECONOMIC MODELS TO ASSESS AND POLICY INSTRUMENTS TO STEER THE IMPACT OF NATURE-BASED SOLUTIONS: A REVIEW

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ABSTRACT

Urban challenges, such as climate change, economic development and land conversion, are increasing and attracting more attention, consequently widening the complexity of urban planning and decision-making processes. Nature-based solutions (NBS) are considered to contribute to resolving these emerging urban problems. While models are available to assess the impacts of NBS on urban heat, air quality, flooding and water quality, there are few models that evaluate their socio-economic impacts. Even though statistical models could provide insight in their actual (ex-post) socio-economic impacts, simulation models represent a key tool to urban planning as they provide the opportunity to assess the expected (ex-ante) socio-economic impacts of NBS and, thus, allow better informed decision making before implementation. This paper provides, first, a review of socio-economic models that can assess the impact of NBS (either statistical or simulation) and, second, a review of socio-economic models that assess the effectiveness of policy instruments to steer urban development patterns. Results show that there is a lack of spatially explicit simulation models with the ability to assess the socio-economic impacts of different NBS. Most models that assess socio-economic impacts include statistical (ex-post), non-spatially explicit or use non-European case studies. Socio-economic impacts evaluated include urban sprawl, housing prices and gentrification. Furthermore, there is a lack of models that have the potential to assess socio-economic impacts of NBS as well as the impact of policy instruments that influence urban development patterns. Hence, it is concluded that there is need for simulation models that allow to assess the expected (ex-ante) socio-economic impacts of NBS as well as the effectiveness of land use policy instruments.

Keywords: nature-based solutions, policy instruments, simulation model, socio-economic model.

1 INTRODUCTION

Urbanization is taking place at an unprecedented rate, being expected that in 2050 almost 70% of the world's population will be living in cities. It is likely that half of that urban area is yet to be developed, providing an opportunity for planning and decision-making processes to be developed that increase resilience and create sustainable cities [1], [2]. Hence, urbanization is one of the most urgent challenges as it has serious environmental, social and economic impacts, such as biodiversity loss, air and water pollution, noise, flooding, extreme events, crime, social inequalities, poverty, degraded urban environments and loss of natural spaces in urban and peripheral areas [3]–[5].

Therefore, large parts of the population are exposed to urban environmental conditions that pose threats to their health and well-being. Urbanization processes decreases the available green space for the citizens, increasing environmental injustice, criminality, exclusion of vulnerable groups, raises infrastructure costs and excessive land conversion [6]. This paves the way to support the growing need for the implementation of urban sustainability principles, embedded in social, economic and environmental patterns. The economic dimension entails growth, consumption, productivity and development without

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hindering future demands, while the social dimension encompasses the necessity to meet citizen's needs and promote equality [7].

Unplanned urbanization leads to scattered, low density, discontinuous, leapfrog development, named urban sprawl. This phenomenon is the outcome of individual cumulative decisions involved in land use development, as citizens wish to improve their residential location and property size as well as proximity to urban centres and environmental amenities subject to land availability, income, housing and commuting costs [8]–[10]. Urban sprawl is associated with excessive land and resources consumption, air and water pollution, soil erosion, global warming, loss of natural green space, environmental degradation, biodiversity decline, excessive car use, weakened economies, services provision hampering, health problems, housing shortage, income inequality, segregation and polarization – thus decreasing urban resilience to climate change [11]–[13]. This has become a key environmental and socio-economic challenge and a primary concern for urban planners and policy-makers. In fact, land use change is acknowledged to be one of the main indicators of socio-economic and environmental change [11], [14], [15]. This is a critical and growing issue, creating irreversible impacts in communities worldwide – even where the population is not growing [16], [17]. This leads to segregation and inequality across socio-economic groups, promoting vulnerable citizens to be exposed to environmental hazards and different access to natural amenities and housing conditions, increasing health risks and decreasing life quality [18], [19].

Hence, urbanization is considered the main responsible phenomenon for natural space degradation in cities and is increasing the demand for green spaces [20], [21]. Nature-based solutions (NBS) are a recent concept emerging in European contexts that are considered solutions to increase cities' resilience, defined by the European Commission as "solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience" [22], [23]. This concept is related to and integrates other concepts, such as Green and Blue spaces, Ecosystem Services and Ecosystem-Based approaches [24]. NBS provide several environmental, economic and social benefits and co-benefits. Besides the benefits related to air and water quality, flooding control, temperature reduction and biodiversity promotion, they are acknowledged for addressing socio-economic challenges, namely improving the quality of life of vulnerable populations and promoting health, food production, cultural and spiritual benefits, green jobs, recreation and promoting social inclusion [3], [25], [26]. Therefore, NBS can be considered attractive features or amenities that influence citizens' residential location, as households care about the quantity and quality of natural environment surrounding their living spaces to benefit from their ecosystem services. Ergo, having a potential impact on the urban configuration, namely urban sprawl, urban density, housing and land prices [19], [21], [27].

Urban planning and policy are crucial to promote quality of life related to environmental concerns and land use [28]. Nonetheless, policies to steer urbanization processes and promote NBS implementation are yet to be fully integrated in urban planning and decision-making processes [29], [30]. Policy instruments are governance tools that have the potential to steer urbanization and socio-economic patterns [8] and to influence NBS adoption and natural space protection [31], [32]. These can be divided in planning, economic and information instruments. The first include regulations, laws, restrictions, directives, plans and other command and control strategies, imposing behaviours. Economic instruments include taxes, subsidies, trading permits and other payment systems, encouraging behaviours while internalizing externalities. Information instruments entail education, training and other communication and stakeholder engagement actions, such as workshops, surveys and certifications [8], [33], [34]. Dorst et al. [35] advocate that a holistic governance direction, including different planning and economic policies, is the way to implement urban sustainability solutions. According to Ferrari et al. [36], integrated planning that consider land and spatial development can contribute to NBS implementation. Berre et al. [37] and Du et al. [38] also underpin the importance of planning, legislation and regulations in curbing urban sprawl. Moreover, Mendonça et al. [8] demonstrated that economic instruments, such as land and property taxes as well as public transport subsidies, have the potential to curb urban sprawl, gentrification and work alongside amenities. Land, property and transport taxes and subsidies have also been considered effective anti-sprawl policies by other authors [10], [14]. Several other authors demonstrate the crucial role that information instruments have in NBS implementation and sustainability promotion [34], [39], [40].

However, there still is limited integrated research on socio-economics, land use patterns and NBS [13], as NBS are considered a recent concept and sprawled urbanization is still a major concern [16], [23]. Policy instruments, despite acknowledged as capable of steering urbanization patterns, are mostly superficially addressed, and their connection with NBS is rather thin [34]. Moreover, NBS literature focusses mostly on environmental benefits, while few studies assess social and economic benefits as well as policies [23]. Hence, there is a need to develop a robust evidence-base and framework regarding NBS socio-economic benefits and their integration in urban policy [3].

Modelling is a relevant tool to build an evidence-base, advise policy makers on the potential impacts of NBS and NBS policies on urbanization, socio-economic and environmental dynamics [8]. Statistical models facilitate ex-post assessments and are based on large amounts of observed data to derive statistical relationships [41]. With simulation models, ex-ante assessments are possible, allowing for long-term predictions of different scenarios without the need for large amounts of observed data [8], [42]. Simulation models are increasingly used to assess urban policy, urbanization and environmental development patterns [43], [44]. Statistical and simulation models can be economic or not, depending on whether they are based on agents that maximize their utility in an optimization perspective, assessing their willingness to pay for goods [42]. Economic models are crucial in modelling environmental amenities, socio-economic behaviour as well as policy and pricing dynamics. In fact, non-economic models struggle to integrate decision making, can only assess socio-economic patterns implicitly and fail to simulate diffused urban forms [28], [45], [46].

Finally, both can be spatially explicit, using a real case study and heterogeneity across space or not. Nonetheless, spatially explicit models allow for a better understanding of future trends and are more realistic, thus with more applicability, namely for socio-economic dynamics, land use change and policy [8], [47]. Overall, economic spatially explicit simulation models are preferred to model different socio-economic and urbanization patterns as well as NBS under policy instruments scenarios [8], [48].

Nevertheless, these models are still considered scarce in literature, as NBS is a relatively recent concept and most studies are empirical, reviews or conceptual with lack of modelling and mostly related to other topics than socio-economic dynamics. Moreover, there is a shortage of studies that assess NBS environmental, social and economic impacts together [23]. There is also a shortage of studies that have assessed urban sprawl containment with different economic and socio-demographic structures and policies effectiveness [17]. Castro et al. [42] also argues that social patterns are less studied than other aspects and that more than one dimension should be evaluated at the same time.

On the other hand, there is also a lack of reviews that aim to understand the availability and current trends of models that can assess socio-economic patterns as well as NBS and policy instruments. Castro et al. [42] and Irwin [49] review economic models of land use change, the latter including policy analysis. Walter and Schaper [50] and Michetti and Zampieri [48] analyse economic models with amenities, but neither assesses socio-economic patterns or policy instruments. Deng and Li [47] and Ren et al. [46] review on spatially explicit simulation models, but without any consideration for economic models or NBS-related concepts nor instruments, while Noszczyk [41] focus on statistical models of land use change. Finally, Huang et al. [51] assess economic simulation models, land use change and socio-economic patterns, but not spatially explicit models neither NBS nor instruments.

Hence, the present study aims to tackle this literature gap by providing, first, a review of socio-economic models that can assess the impact of NBS, considering the dichotomies statistical/simulation, economic/non-economic, spatially explicit/non-spatially explicit and, secondly, which of these models also have the potential to assess the effectiveness of policy instruments to steer urban development patterns. To this end, a literature review and content analysis was performed.

The next section presents the methodology, followed by the results and discussion section that entails the model characteristics (Section 3.1) as well as the content (Section 3.2) and instrument (Section 3.3) analysis and, finally, the conclusion section.

2 METHODOLOGY

A snowball literature search was carried-out based on the literature review in Mendonça et al. [8], following [52]. The search includes all papers that cited the previously used papers in this paper up to 2020. As only English written peer-reviewed papers were found, papers were only excluded by content after analysis.

A total of 571 papers was found during the initial search and all abstracts were read. Considering Fig. 1, it is possible to observe that, during that process, 427 papers were excluded for being out of scope, i.e., not using socio-economic models for NBS assessment. In turn, all remaining 144 papers were fully read, leading to an additional exclusion of 12 papers for not meeting the same criteria. Hence, for the present study, 132 papers were analysed – covering the period 2004 to 2020. The policy instruments were then assessed within the previously selected papers, not representing itself an exclusion criteria. All NBS related concepts were accepted, including green spaces, green infrastructure, amenities, and open space, under the assumption that models that assess these types of concepts can assess NBS as well (considering NBS is an umbrella concept and that NBS is still a recent concept [23], [35]). Socio-economic impacts assessed include urban sprawl and related concepts, such as densification, housing location, urban expansion, segregation, income, quality of life, housing, land price and transport costs. Finally, despite most papers mentioning policy, only papers that assessed policy instruments were considered for the instrument analysis. For space-saving reasons, not all the papers present in the analysis (and results) were included in the discussion of the results.

For the analysis, a data sheet was developed with the author, paper and content information, including type of model (simulation/statistical, economic/non-economic, spatially explicit/non-spatially explicit), type of socio-economic impact, location of the study (European or not), and instrument assessment (planning, economic and information). This information was collected to understand the availability of socio-economic models, current trends and policy instruments integration in the socio-economic and NBS urban planning.

Figure 1: Literature review process.

3 RESULTS AND DISCUSSION

This section presents the results analysis and discussion, first assessing the overall model characteristics (Section 3.1), then the content of the papers regarding the socio-economic impact (Section 3.2) and, finally, the instrument analysis (Section 3.3).

3.1 Model characteristics

For the model characteristics, Fig. 2 shows the quantitative analysis of the models' features, including if they are statistical/simulation, economic/non-economic and spatially explicit/non-spatially explicit as well as the case study being European or not. Most of the assessed papers are statistical (58%), economic (70%) and not spatially explicit (62%). In addition, most papers do not include a European case study (76%).

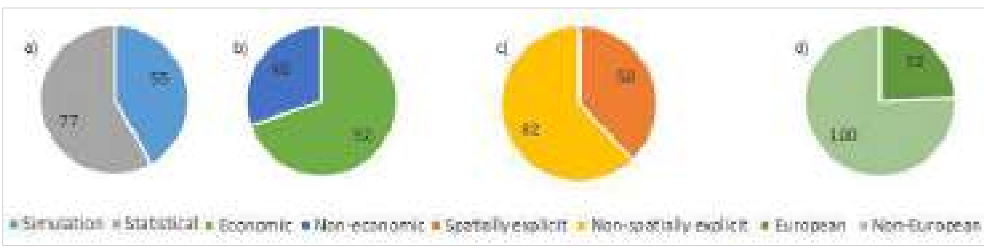

Figure 2: Model characteristics of all papers. (a) Simulation/statistical; (b) Economic/ non-economic; (c) Spatially explicit/non-spatially explicit; and (d) European/ non-European case study.

Fig. 3 presents the model characteristics that are considered more suitable, according to the assessed literature, of socio-economic models to assess NBS and policy instruments, including simulation, economic, spatially explicit as well as models that combine more than one of these characteristics. It is shown that, within the 132 papers analysed, 32% of the papers are simulation and economic models, 11% are simulation and spatially explicit models, 17% are economic and spatially explicit models and, finally, less than 2% of the papers are simulation, economic and spatially explicit models.

These results show that, even though simulation and spatially explicit models are considered most suitable to assess socio-economic patterns and NBS, these are rarely used in literature [17], [48], [53]. This is in line with Hanson et al. [23] and Wang and Xiang [13] results, which find that simulation and spatially explicit models that assess NBS and

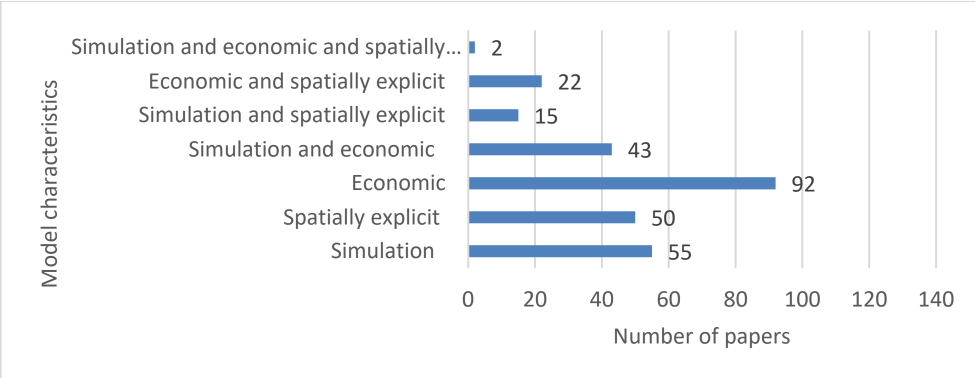

Figure 3: Model characteristics and combinations of the assessed simulation, economic and/or spatially explicit papers.

socio-economic impacts are scarce. Nevertheless, most of the assessed papers used economic approaches, which is expected as socio-economic impacts were a criteria for the papers selection. This highlights the fact that these are the most relevant models for socio-economic and environmental approaches as they consider the integration of individual behaviour, representing NBS attractiveness and citizens' willingness to pay for them [8], [46]. Despite most models being economic, there is a lack of economic, spatially explicit and simulation models – pinpointing the scarcity of simulation and spatially explicit models. In fact, besides the SULD (Sustainable Urbanizing Landscape Development) model used by [8], [54], [55], only other model was found in two papers that was simulation, economic and spatially explicit [45], [56], constituting a literature gap that was highlighted by other authors and evidencing the need to develop models able to predict urbanization patterns, focusing on NBS socio-economic connections with spatial distribution and optimization [48], [57].

Other significant trends found in literature consist in most papers not having a European case study. This is noteworthy because urbanization is considered specific in Europe, where high income households live in city centres and not in peripheral areas (which is the case in America) – an aspect that needs to be taken into consideration when steering NBS adoption and socio-economic trends [58]. Moreover, this study did not use NBS as the sole selection criteria, including other related concepts that represented the vast majority. This might explain why the selection has more non-European case studies than if only the NBS concept was considered, as NBS is a key concept in Europe. This also highlights the novelty of the concept, showing that it is not yet that well embedded in urbanization and socio-economic modelling literature [23].

3.2 Content analysis

For the content analysis, Table 1 presents an overview of the socio-economic impacts found in the assessed papers. Note that in one paper more than one socio-economic impact can be modelled. The impacts were grouped by proximity of concepts, as different terminologies were used in different studies. It is possible to see that the impacts related to urbanization, such as urban sprawl, housing location choices and urban density, were the most evaluated,

Table 1: Socio-economic impact assessed in the reviewed papers.

Socio-economic impact	Number of papers
Urban sprawl/housing location/density	87
Housing, land or transport prices	49
Segregation/income	19
Life quality	9

followed by price related impacts (housing, land and transport), segregation and income impacts and, finally, the least assessed impact is related to citizens' life quality.

The most simulated impact was urban sprawl and related concepts, such as housing location choices, density and compactness. This trend could be expected as this impact is directly related to land use and conversion modelling – a field that is well developed [46]. Moreover, it is widely acknowledged that NBS and overall amenities have a key role in urban form, as households make residential choices regarding the location of these attractive places [16], [57]. In fact, amenities are recognized to be able to influence urban sprawl, depending on their location, size and attractiveness [8], [59]. In addition, the lack of amenities leads to a more sprawled urban area [9]. Only one study did not find a significant relation between amenities and land conversion, despite being a statistical study based in China [60].

The second most assessed impact is related to housing, land and transport prices. Accruing from the NBS attractiveness and housing location choices, households are willing to pay more to be near these places – consequently increasing the land and property prices as widely mentioned in literature [32], [61]. Transport costs are also acknowledged to have an impact on household decisions and, thus, on urban form – influencing their willingness to pay to be near attractive places and changing their commuting costs [62].

The least mentioned impacts include segregation, income and quality of life. This is in line with Hanson et al. [23] findings, stating that the least addressed subjects are related to social justice and equality. NBS are acknowledged to have a significant impact in these subjects, as half of the NBS's value is related to recreational purposes [63]. Overall, NBS can increase quality of life and welfare, depending on the population characteristics, such as income [16]. In fact, low-income households usually have less access to highly attractive places, leading to segregation, which might be promoted or attenuated by NBS implementation [4], [18].

3.3 Instrument analysis

The second part of the review included the study of the presence of policy instruments (planning, economic or information) in the assessed papers. Within the 132 papers evaluated, 37 (28%) modelled the impact of policy instruments on socio-economic and NBS dynamics. Fig. 4 presents the type of model used in these papers, including the considered desired characteristics as well as combinations. Results show that most papers that evaluate policy instruments are simulation (68%) or economic (84%), while only few are spatially explicit (16%). The majority are simulation and economic models (60%) but not economic and spatially explicit (8%) or simulation, economic and spatially explicit models (0%).

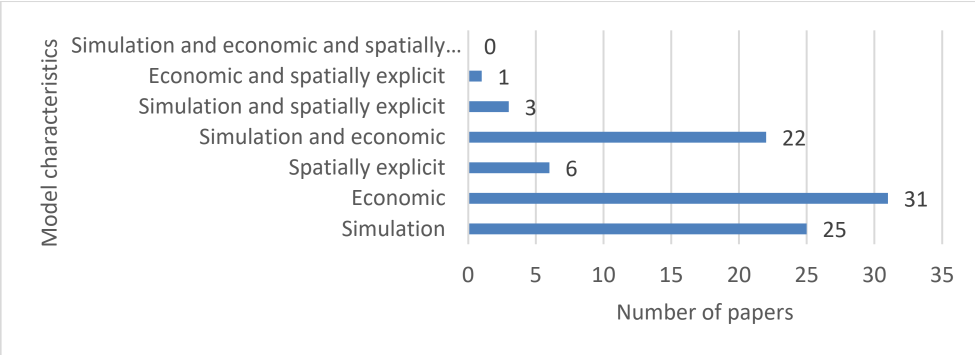

Figure 4: Model characteristics of the papers that include policy instrument analysis.

Regarding the type of policy instrument, Table 2 shows the instrument types modelled in the 37 papers. Results show that economic instruments were the most assessed (54%), followed by planning (32%) and planning and economic instruments (14%); no information instruments were found.

Table 2: Instrument type assessed in the reviewed papers.

Instrument type	Number of papers
Planning	12
Economic	20
Information	0
Planning and economic	5

Most of the analysed models did not model policy instruments, which is in line with Sarabi et al. [34] and Hanson et al. [23] findings, that most policy instrument related literature is superficial and theoretical. However, contrary to the overall models results, most models that assess policy instruments as well as socio-economic patterns and NBS are simulation and economic models. Indeed, it is acknowledged in literature that simulation models are the desired approach to assess their effectiveness and predict different scenario outcomes [43], [44]. Most models are also economic, which is expected due to the socio-economic criteria and because most instruments found were economic. However, most papers do not adopt a spatially explicit approach, which decreases the applicability and understanding of future trends and patterns [8], [47]. Moreover, combinations of simulation and spatially explicit as well as economic and spatially explicit are almost non-existent, and no paper was found that combine a simulation, economic and spatially explicit approach. In this sense, the SULD model continues to be the only model found with these characteristics that can model socio-economic patterns, NBS while assessing policy instruments [8], [54], [55].

Regarding the instrument types assessed, the most modelled in literature are economic. This is as expected given urbanization is often considered a market failure related to the under-pricing of natural resources [13]. Most mentioned economic instruments include property, land and transport taxes as well as transport subsidies. Property prices were found to be effective anti-sprawl policies, influencing the city form and living space [8], [14], [64]. Conversely, the effectiveness of land taxes is not straightforward – some authors found it effective in curbing sprawl [64]–[66] while others found it ineffective or even promoting sprawl and segregation [53], [67]. Its effectiveness might be case specific, depending on population characteristics and land prices [8], [53]. Transport pricing is also acknowledged to have an influence on urban design [62], [68]. However, its urbanization-steering potential depends on the complex relation between car and public transport use. Overall, transport taxes might lead to sprawl while public transport subsidies might encourage compactness [8], [10].

Regarding planning instruments, it includes urban growth boundaries, zoning and land acquisition to control development. Despite considered as effective anti-sprawl policies by some non-European authors [69], [70], others consider that they might work but impose high costs on households by reducing housing supply and increasing land prices [71] or even that they hardly can control major expansions [72]. In fact, authors that model both economic and planning instruments found, in general, that a combination might be adequate [73], but economic instruments are considered more effective in controlling urbanization by encouraging behaviour (rather than imposing them) and increasing citizens' quality of life [53], [74]. No information instruments were found in the literature, which is most likely related to the fact that these are related to citizen's engagement and awareness promotion, hence difficult to model despite being considered essential in urbanization dynamics [33], [34], [40].

4 CONCLUSION

Overall, there is a need for more research on socio-economic urban development patterns and NBS as well as to promote effective policies to steer these. This study has the objective to perform a literature review on socio-economic models that assess NBS and potential policy instruments. The study includes a snowball research on Mendonça et al. [8], as to grasp the literature developments and gaps. Even though most assessed models are economic, they are also mostly statistical, non-spatially explicit and use non-European case studies, while only one simulation economic spatially explicit model was found. However, this model did not assess policy instruments in a spatially explicit way. In fact, policy instruments were only found in 28% of the analysed studies, mostly economic and simulation (68%) but not spatially explicit. No simulation economic and spatially explicit models were found that assessed socio-economic impacts, NBS and policy instruments. Hence, the SULD model, used in Mendonça et al. [8] is considered the most suitable option to simulate socio-economic patterns, NBS adoption and policy instruments effectiveness in a spatially explicit perspective. Most papers use non-European case studies, most likely because NBS-related concepts represent the majority used, allowing to conclude that NBS (widely used in Europe) are yet to be fully integrated in this field. For the content analysis, most assessed socio-economic impacts include urban sprawl, housing, land and transport prices followed by segregation and income, in which NBS are acknowledged to have an impact. Regarding policy instruments, economic instruments were the most modelled, followed by planning and combined economic and planning. In fact, no information instruments were found and economic instruments are considered most effective in steering socio-economic patterns.

Hence, there is a need for more studies regarding the integration of NBS and policy instruments in socio-economic planning trends, namely of social impacts in European case studies. There is also a shortage of simulation, economic and especially spatially explicit socio-economic models that can integrate NBS and policy instruments.

In conclusion, current urbanization patterns pave the way for an increasing necessity of a more socio-economic-driven urban planning – integrating NBS and policy instruments to attain sustainable development goals. Economic spatially explicit simulation modelling might have a crucial role by allowing an ex-ante prediction of different scenario outcomes.

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EXAMINING THE EFFECTS OF THE COVID-19 LOCKDOWNS ON REDUCING POLLUTANT CONCENTRATIONS IN US URBAN AREAS: EVIDENCE FROM LOS ANGELES, SEATTLE AND NEW YORK CITY

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ABSTRACT

Reductions in air pollution benefit the health of both humanity and the environment. Understanding the contributing factors to air pollution is critical for devising actions aimed at reducing pollution. This study examines the effectiveness of the 2020 COVID-19 lockdowns in reducing air pollution in US urban environments. It focuses on three cities – Los Angeles, Seattle, and New York City – and utilizes city-level daily pollutant data for carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and particulate matter smaller than 2.5 microns ($PM_{2.5}$). Each city had three time periods (pre-lockdown, lockdown, and post-lockdown) determined by the enactment and relaxation of gathering restrictions. T-tests were used to compare air pollution measured during the three periods against a baseline created from the mean pollutant concentrations from 2015 to 2019. The results show that the lockdowns were effective in reducing CO concentrations in all three cities. Reductions in NO_2 during lockdowns were supported by results from New York and Seattle, the cities with colder and more humid climates. Only Los Angeles, the warmest and driest city, saw reductions in O_3 concentrations during the lockdowns. Reductions in $PM_{2.5}$ concentrations during lockdowns were observed in Los Angeles and New York, but not in Seattle. These findings support devising policies to reduce CO, NO_2, and $PM_{2.5}$ through discouraging private vehicle travel in large urban areas. The research also suggests that those policies' effectiveness is varied for each pollutant type and climate.

Keywords: air pollution, lockdowns, COVID-19, health, urban environments.

1 INTRODUCTION

Air pollution is directly responsible for over 4.2 million deaths per year as well as many types of lung diseases and cancers [1]. Labelled a leading cause of death worldwide by the World Health Organization (WHO), air pollution is also responsible for worsening environmental phenomenon such as wildfires and acidic rain, which, in turn lead to additional health risks and environmental damage [2]. The reduction of air pollution is a necessity for the health of the planet and sustainability of humanity.

Among many factors, emission from transportation is the largest contributor to air pollution, followed closely by electricity production and industrial activities [3]. Thus, policy solutions to air pollution often include implementing stringent emission standards and reducing automobile travel.

From late Winter to Spring 2020, numerous US cities experienced their sharpest decline in consumer transportation in over 30 years, a result of "lockdowns" enacted in response to the COVID-19 pandemic [4]. At the same time, news media reported an increase in the 'clarity' of the atmosphere, quickly attributing it to the lockdowns' effects in reducing consumer and industry activities [5], [6].

If the COVID-19 lockdowns are effective in reducing air pollution via reductions in civilian and industry activity, then it may be worthwhile to investigate policies similar to lockdown restrictions, i.e., activity-controlling policies, to improve the air quality of communities.

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However, determining the effects of the COVID-19 lockdowns on air pollution is difficult because of a seasonal pattern of air pollution, which many of those casual observations of air quality change fail to account for. Urban air pollution tends to clear up from a colder season (e.g., winter) to a warmer one (e.g., spring) due to changes in urban activities and weather [7]. A study done in 2018 found that rural-residential coal combustion (RRCC), a seasonal activity that occurs mostly in the winter, contributed to over 60% of ground-level particulate emissions in residential areas of Shandong, China during that season [8]. Similarly, data from the US Environmental Protection Agency shows trends of decreasing concentrations of carbon monoxide and nitrogen dioxide from winter to spring in many US cities [7].

Therefore, the perceived improvements in air quality during the COVID-19 lockdowns relative to the months before them may not be sufficient evidence for the lockdowns' effects on air pollution, because the lockdowns coincided with the transition from winter to spring.

Consequently, this study seeks to find the effects (not the feasibility) of the COVID-19 lockdowns on air quality in urban environments. The findings could be informative for policymakers and urban planners as they consider how to promote urban sustainability and health.

2 MATERIALS AND METHODOLOGY

2.1 Study areas

Three cities were examined in this study: Los Angeles, New York City, and Seattle. These cities were chosen based on climate, population density, and data availability. Table 1 shows the details of the chosen cities.

Table 1: City details.

	Population density [9] (people / km^2)	Climate [10]
Los Angeles	2,700	Hot, Dry
New York City	10,800	Temperate, Humid
Seattle	3,500	Temperate, Wet

Each of the cities underwent a roughly 3-month-long lockdown period when policies were enacted to restrict civilian activities. This study defines that a city's lockdown period started when the city/state government issued a stay-at-home order; and the lockdown period ended when those orders were lifted or relaxed. The study time frame was then divided into three periods based on lockdown dates specific to each city: pre-lockdown, lockdown, and post-lockdown. Time periods for each city are shown in Table 2.

Table 2: Lockdown period classifications by city.

	Pre-lockdown	Lockdown	Post-lockdown
Los Angeles [11], [12]	1 Jan.–19 Mar.	19 Mar.–24 May	24 May–1 Aug.
New York City [13], [14]	1 Jan.–22 Mar.	22 Mar.–8 Jun.	8 Jun.–1 Aug.
Seattle [15], [16]	1 Jan.–11 Mar.	11 Mar.–1 Jun.	1 Jun.–1 Aug.

2.2 Data sources

The pollutants examined were daily concentrations of carbon monoxide (measured in parts per million CO), nitrogen dioxide (AQI points NO_2), ozone (AQI points O_3), and particulate matter smaller than 2.5 microns (μ g/m^3 $PM_{2.5}$). The US Environmental Protection Agency (EPA) defines Air Quality Index (AQI) as a scale that measures the concentration of the pollutant relative to their health concerns [7]. Data for pollutant concentrations came from the World Air Quality Index (WAQI) project. The WAQI is a non-profit organization that aggregates air quality data from local governments and agencies in cities around the world. This study uses data collected by the following agencies: the New York State Department of Environmental Conservation (NYSDEC), California Air Resources Board (CARB), and Washington State Department of Ecology. Data was collected in 24-hour averages at the city level from roughly 60 sensors distributed evenly throughout each city.

2.3 Analysis and hypothesis

A series of 2-sample paired t-tests were conducted to examine if an air pollutant's concentration levels during 2020 lockdowns were significantly different from its baseline conditions of matching timespans. The baseline conditions were estimated by averaging corresponding pollutant concentrations over a 5-year window (2015–2019). The purpose of these statistical analyses was to examine whether changes in a pollutant's concentrations existed independent of the impacts of potential seasonal factors underlying the transition of those periods. Considering that seasonal patterns likely impacted how lockdowns affected air pollution, the following hypothesis was developed and tested: A pollutant's concentration level is significantly lower than its baseline during the in-lockdown period. The pre-lockdown and post-lockdown periods' comparisons can help provide context for understanding the magnitude of the difference between 2020 and the baseline.

3 RESULTS AND DISCUSSION

The results of the t-tests are presented graphically using pairs of boxplots. The darker boxplot represents the distribution of observations during the baseline period (2015–2019), while the white boxplot represents the distributions of observations during 2020 (the lockdowns). Summary statistics for each pair of boxplots' comparison are shown, with Δx representing the difference in means between a 2020 period and its corresponding baseline, p the significance level of the mean difference, ΔM the change in median, M_1 the median of observations during the baseline, M_2 the median of observations during 2020, and n the number of paired observations.

3.1 Los Angeles

In all three periods (pre-lockdown, lockdown, and post-lockdown), Los Angeles saw significant reductions in mean CO concentrations in this year compared to the baseline conditions. The pre-lockdown mean CO concentration had a significant decrease of 1.24 ppm ($p < 0.001$), the lockdown period had a significant decrease of 1.47 ppm ($p < 0.001$), and the post-lockdown period had a significant decrease of 0.84 ppm ($p < 0.001$). The largest reduction was during the lockdown period. The data support the hypothesis that the lockdowns were effective in reducing pollution (Fig. 1).

The mean nitrogen dioxide (NO_2) concentration during the pre-lockdown period had a significant increase of 7.17 AQI points above the baseline ($p < 0.001$), while the lockdown

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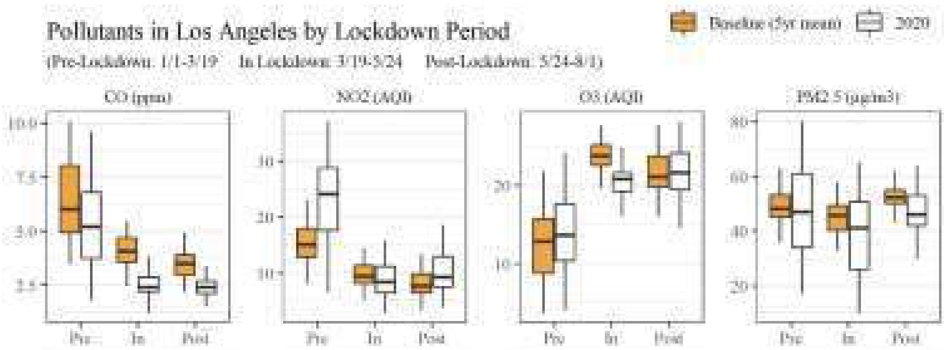


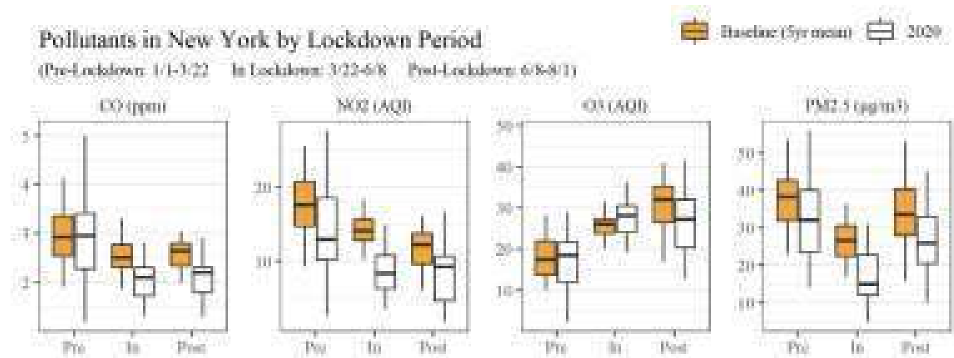
	Pre	In	Post	Pre	In	Post	Pre	In	Post	Pre	In	Post
p:	0.000	0.000	0.000	0.000	0.414	0.383	0.066	0.000	0.608	0.127	0.002	0.000
Δx:	-1.24	-1.47	-0.84	7.17	0.65	0.75	1.38	-3.27	0.39	-3.33	-6.36	-5.92
ΔM:	-0.88	-1.61	-1.00	9.00	0.20	0.68	0.76	-3.06	0.64	-1.00	-4.50	-6.00
M_1:	6.08	4.11	3.50	15.10	9.55	8.62	12.84	23.86	20.96	49.00	45.50	52.00
M_2:	5.20	2.50	2.50	24.10	9.75	9.30	13.60	20.80	21.60	48.00	41.00	46.00
n:	79	66	69	79	66	69	79	66	69	79	66	69

Figure 1: Pollutants in Los Angeles by lockdown period.

and post-lockdown periods had no significant changes in mean concentration. The drying of soil in warm, dry climates emits NO_2 [17], which could offset NO_2 reductions due to activity changes and explain how NO_2 concentrations did not change significantly. The reduction in mean NO_2 concentrations from the pre-lockdown period to the lockdown period was significantly larger than the baseline, supporting the hypothesis of the effectiveness of the lockdown. However, when lockdown measures were relaxed, NO_2 levels did not return to higher-than-baseline values (similar to the pre-lockdown period). A possible explanation could be that the NO_2 emitting activities may not have fully recovered following the relaxation of restrictions.

Mean ozone (O_3) concentrations in Los Angeles observed no significant change in tte pre-lockdown and post-lockdown periods compared to their respective baselines. The lockdown period observed a significant decrease in mean O_3 concentrations of 3.27 AQI points ($p < 0.001$) relative to the baseline. The only significant decrease being during the lockdown periods provides supporting evidence that the lockdown was one of the factors that caused a reduction in this pollutant.

Mean particulate matter smaller than 2.5 microns ($PM_{2.5}$) concentrations in Los Angeles were significantly lower in the lockdown and post-lockdown period. The pre-lockdown mean concentration of $PM_{2.5}$ was not significantly different from the baseline. During the lockdown period, mean $PM_{2.5}$ levels had a significant decrease of 6.36 μg/m^3 ($p < 0.05$) relative to the baseline. During the post-lockdown period, $PM_{2.5}$ decreased 5.92 μg/m^3 ($p < 0.001$). This supports the hypothesis that the lockdown was effective in reducing pollutant concentrations and suggests that activities did not return to normal following the relaxation of restrictions, since there was still a significant reduction in $PM_{2.5}$ concentrations relative to baseline conditions.



	CO Pre	CO In	CO Post	NO2 Pre	NO2 In	NO2 Post	O3 Pre	O3 In	O3 Post	PM2.5 Pre	PM2.5 In	PM2.5 Post
p	0.545	0.000	0.000	0.046	0.000	0.000	0.035	0.385	0.000	0.014	0.000	0.003
$\Delta\bar{x}$	0.11	-0.55	-0.59	-2.02	-5.35	-2.84	-1.63	0.67	-16.75	-3.45	-9.20	-6.81
ΔM	0.13	-0.41	-0.50	-3.24	-5.90	-2.98	0.60	1.34	-6.02	-5.20	-11.50	-6.30
M_1	2.97	2.51	2.66	17.64	14.30	12.28	17.40	25.86	33.22	38.20	27.00	33.80
M_2	3.10	2.10	2.15	14.40	8.40	9.30	18.00	27.20	27.20	33.00	15.50	27.50
n	82	78	54	82	78	51	82	78	54	82	78	54

Figure 2: Pollutants in New York by lockdown period.

Overall, mean pollutant concentrations during the lockdown period in Los Angeles were significantly lower than their respective baselines. Similar reductions were present after the lockdowns for CO and $PM_{2.5}$ only. A possible explanation for why only these two pollutants observed a “lingering” impact from the lockdowns is their connection to automobile use, which may not have returned to normal levels following the relaxation of lockdown measures. The climate of Los Angeles is dry and lacks frequent rainfall that can potentially clean the atmosphere. This could allow the effects of emission reduction to remain more evident in the atmosphere. The findings in Los Angeles provide support for the hypothesis that the lockdowns were effective in reducing air pollution for all pollutants, even more so for CO and $PM_{2.5}$.

3.2 New York

Mean carbon monoxide (CO) concentrations in New York were lower than baseline levels during the lockdown and post-lockdown period. Pre-lockdown CO concentrations were not significantly different than the baseline. During the lockdown period, the mean CO concentration was 0.55 ppm lower than the baseline ($p < 0.001$). During the post-lockdown period, CO concentrations were 0.59 ppm lower than the baseline ($p < 0.001$). This pattern is similar to the observation of mean $PM_{2.5}$ concentrations in Los Angeles, where the reductions in pollutant concentrations during the lockdown period were also present in the post-lockdown period (Fig. 2).

Overall, mean nitrogen dioxide (NO_2) concentrations in New York were significantly lower than the baseline in all three periods, contrary to observations in Los Angeles. In the pre-lockdown period, the mean concentration of NO_2 was 2.02 AQI points lower than the baseline ($p < 0.05$). During the lockdown, mean NO_2 concentrations were significantly lower ($p < 0.001$) than the baseline by 5.35 AQI points. The mean post-lockdown period

NO_2 concentration was 2.84 AQI points lower than the baseline ($p < 0.001$). Because the NO_2 concentrations were lower throughout all periods examined, an external factor could have induced an overall decrease in pollutant concentration. However, the largest decrease (5.35 AQI points) in mean NO_2 concentrations was during the lockdown period, which suggests that even in the presence of an external factor, the presence of a lockdown was effective in reducing the mean NO_2 concentration. In the post-lockdown period, the reduction in mean NO_2 concentration was larger than the pre-lockdown period by 0.82 AQI points. This suggests that reductions in NO_2 emitting activities did not recover to levels before the lockdown.

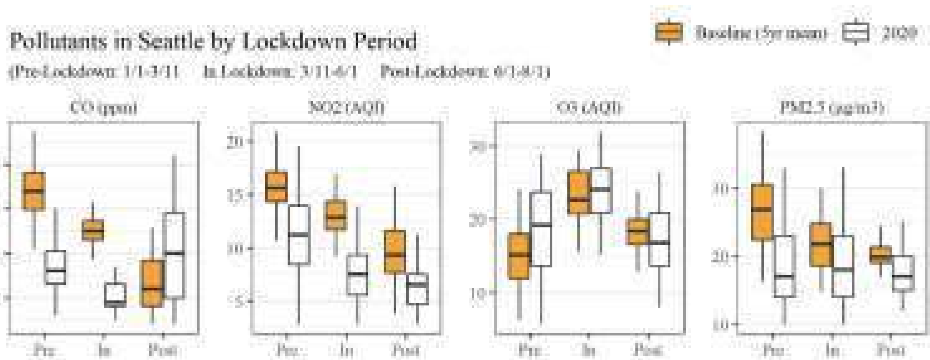
Mean ozone (O_3) concentrations in New York were lower than the baseline prior to and following the lockdown. However, the mean O_3 concentrations were not significantly different compared to the baseline during the lockdown period. In the pre-lockdown period, there was a 1.63 AQI point decrease in O_3 concentrations compared to the baseline ($p < 0.05$). During the lockdown period, there was no significant change in O_3 concentrations. There was a significant ($p < 0.001$) decrease in O_3 concentrations of 16.75 AQI points following the lockdown. Large decreases in atmospheric NO_2 concentrations induce increases in the formation of atmospheric O_3 [18], which could explain the lack of O_3 concentration decreases during the lockdown period.

The mean concentrations of particulate matter smaller than 2.5 microns ($PM_{2.5}$) in New York were lower than the baseline in all three periods examined. In the pre-lockdown period, there was a significant ($p < 0.05$) decrease of 0.014 μg/m^3 in mean $PM_{2.5}$ concentrations compared to the baseline. The mean concentration of $PM_{2.5}$ during the lockdown period was 9.20 μg/m^3 lower than the baseline ($p < 0.001$). In the post-lockdown period, the mean concentration of $PM_{2.5}$ was 6.81 μg/m^3 lower than the baseline ($p < 0.05$). The continued decrease in mean $PM_{2.5}$ concentration compared to the baseline suggests that an external factor was present. However, the largest decrease in mean $PM_{2.5}$ concentration (9.20 μg/m^3) was during the lockdown period, similar to the trend observed for mean $PM_{2.5}$ concentration in Los Angeles. This provides further evidence that the presence of lockdown was effective in reducing pollutant concentrations alongside other factors.

Mean CO, NO_2, and $PM_{2.5}$ concentrations in New York were significantly ($p < 0.05$) lower than their respective baselines during the lockdown period. Following the lockdown period, mean concentrations for all pollutants examined were also significantly lower than their baselines. Mean NO_2 and $PM_{2.5}$ concentrations in New York were lower in all periods, but both experienced their largest decreases compared to their baselines during the lockdown periods. The findings from New York provide further evidence that the lockdowns were effective in reducing CO, NO_2, and $PM_{2.5}$. Ozone concentrations were not positively impacted by the presence of lockdown relative to the baseline. A possible explanation is the interaction of atmospheric NO_2 and O_3 as mentioned above.

3.3 Seattle

Mean carbon monoxide (CO) concentrations in Seattle were lower than the baseline in the pre-lockdown and lockdown periods but increased following the lockdown. In the pre-lockdown period, the mean CO concentration was 1.63 ppm lower than the baseline ($p < 0.001$). During the lockdown, there was a significant ($p < 0.001$) decrease in mean CO concentration of 1.47 ppm compared to the baseline. However, in the post-lockdown period, mean CO levels were 0.63 ppm higher than the baseline ($p < 0.05$). The immediate rebound in mean CO levels following the relaxation of the lockdown measures suggests that



	CO Pre	CO In	CO Post	NO2 Pre	NO2 In	NO2 Post	O3 Pre	O3 In	O3 Post	PM2.5 Pre	PM2.5 In	PM2.5 Post
p:	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.716	0.464	0.000	0.424	0.040
$\Delta\bar{x}$:	-1.63	-1.47	0.63	-4.55	-4.90	-3.08	3.97	-0.21	-0.52	-7.33	-0.93	-1.59
ΔM:	-1.74	-1.53	0.85	-4.42	-5.36	-2.80	4.16	1.43	-1.44	-9.20	-2.90	-2.00
M_1:	4.44	3.53	2.30	15.62	12.86	9.30	15.04	22.67	18.24	27.20	21.90	20.00
M_2:	2.70	2.00	3.15	11.20	7.50	6.50	19.20	24.10	16.80	18.00	19.00	18.00
n:	73	82	58	73	82	61	71	82	61	71	82	61

Figure 3: Pollutants in Seattle by lockdown period.

the lockdown presence was effective in reducing some amount of pollutant emission, and following the relaxation of the lockdown, immediately stopped suppressing pollution (Fig. 3).

The mean nitrogen dioxide (NO_2) levels in Seattle were significantly lower than the baseline in all periods examined. In the pre-lockdown period, the mean NO_2 concentration was 4.55 AQI points lower than the baseline ($p < 0.001$). During the lockdown, there was a 4.90 AQI point decrease in NO_2 concentrations compared to the baseline. After the lockdown, there was a decrease of 3.08 AQI points compared to the baseline. The constant overall difference in mean concentration suggests that an external factor reduced overall NO_2 emission for this year. The presence of lockdown was associated with the largest reduction in NO_2 concentrations of all periods (4.90 AQI points).

There was no significant change in mean ozone (O_3) concentration during the lockdown and post-lockdown period in Seattle. In the pre-lockdown period, the mean O_3 concentration was 3.97 AQI points greater than the baseline ($p < 0.001$). Based on the results from New York, the significantly decreased NO_2 concentration during the lockdown period would predict that the O_3 concentrations would be much higher during the lockdown period, though, this was not the case. The presence of the lockdown could be the explanation for why the ozone concentrations were not higher than the baseline during the lockdown period. However, the data does not strongly support this hypothesis since increases/decreases in pollutant concentrations can rapidly switch directions (as shown O_3 changes in Los Angeles).

There were significant decreases in mean particulate matter ($PM_{2.5}$) concentrations in all periods but the lockdown period in Seattle. In the pre-lockdown period, there was a significant ($p < 0.001$) decrease of 7.33 μg/m^3 in the $PM_{2.5}$ concentrations. During the lockdown period, there was no significant change in mean $PM_{2.5}$ concentration compared to the baseline, whereas there was a 1.69 μg/m^3 ($p < 0.05$) decrease in mean $PM_{2.5}$ during the post-lockdown period. The absence of change in $PM_{2.5}$ concentration in response to

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the lockdown could suggest that the lockdowns were ineffective in reducing the pollutant. However, the levels of $PM_{2.5}$ in Seattle are already incredibly low compared to the other cities examined, suggesting a 'diminishing returns' effect in Seattle when the lockdowns are coupled with the city's already low emissions. Seattle also observes frequent light rainfall, which can increase $PM_{2.5}$ concentrations [19]. This could counteract the effectiveness of the lockdowns.

Pollutant concentration trends in Seattle were similar to the other examined cities in some areas. Mean pollutant concentrations were lower than their baselines for CO and NO_2 during the lockdown period, but not for O_3 nor $PM_{2.5}$. O_3 concentrations in Seattle were increased during the pre-lockdown period but returned to the baseline level during the lockdown. $PM_{2.5}$ concentrations were not reduced during the lockdown but were instead very low during the entire year. Seattle's extremely wet weather heavily impacts the reliability of data in measuring the impact of the lockdown because of the weather events that can potentially reduce pollution naturally. Seattle's findings strongly support the hypothesis that the lockdowns were effective in reducing CO and NO_2 concentrations.

4 CONCLUSION

The aim of this research was to explore the effectiveness of the COVID-19 lockdowns in reducing pollutant concentrations in US cities. It was hypothesized that the lockdowns were effective in doing so.

Daily concentrations of carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and particulate matter smaller than 2.5 microns ($PM_{2.5}$) were examined for three cities: Los Angeles, New York City, and Seattle. Data for each city was split into three periods: pre-lockdown, lockdown, and post-lockdown according to the date that lockdown policies were enacted. Pollutant concentrations were compared to a baseline created from the average of the concentrations from 2015–2019 during the same time periods using paired t-tests ($\alpha = 0.05$).

Table 3 summarizes changes in mean pollutant concentrations from 2020 relative to the baseline (2015–2019) during the lockdown period for each city. Insignificant changes are replaced with NAs.

Table 3: Significant changes in mean pollutant concentrations during lockdown period of 2020 compared to 2015–2019.

	Los Angeles	New York	Seattle
CO (ppm)	-1.47	-0.55	-1.47
NO_2 (pts AQI)	NA	-5.35	-4.90
O_3 (pts AQI)	-3.27	NA	NA
$PM_{2.5}$ (μg/m^3)	-6.36	-9.20	NA

The results show that all three cities exhibited significant declines in CO concentrations during the lockdowns, consistent with results from other cities [20]–[22]. Vehicle and industrial activity are the largest sources of CO emissions in US cities [23], and significant declines in both during the lockdowns is very likely what resulted in decreased CO concentrations. Thus, it is reasonable to assume that activity-controlling policies could be effective in reducing CO concentrations in urban areas.

All cities except for Los Angeles experienced significant declines in NO_2 concentrations during the lockdowns. The largest source of NO_2 is from the burning of fuel, especially in vehicles [24]. Los Angeles experienced a much lower decrease in vehicle miles traveled during the lockdowns compared to New York and Seattle (a comparison of vehicle miles traveled (VMT) data provided by Streetlight Data for the three cities found that Los Angeles experienced a less than 20% decrease in VMT during the lockdowns, compared to New York and Seattle, both of which saw more than 40% decreases), which could explain the lack of a significant decrease in NO_2 for this city. Another possible explanation could be that, in warm, dry climates, frequent drying of soil could emit NO_2 [17] to offset reductions during the lockdown, and Los Angeles's climate is much warmer and dryer than the other cities examined. These findings could suggest two things: 1. For activity-controlling policies to be effective in reducing NO_2, they must cause a significantly great decrease in vehicle travel. 2. Warm, dry climates could reduce the effectiveness of activity-controlling policies in reducing NO_2.

In contrast to the observed NO_2-change pattern, only Los Angeles exhibited declines in O_3 concentrations during the lockdowns. Industrial and vehicle activity are sources of Volatile Organic Compounds (VOCs) that can form O_3 [25]. However, Los Angeles did not experience as great a reduction in vehicle travel as the other cities (mentioned above), suggesting that vehicles may not play as significant a role in O_3 formation in cities. Atmospheric NO_2 and O_3 are balanced in a rate reaction, where a decrease in one may induce an increase in the atmospheric production of the other [18]. It is possible that the NO_2 reductions experienced by New York and Seattle had increased atmospheric O_3 formation to offset any reduction in O_3 resulting from declined vehicle uses during their respective lockdowns. These findings may not support activity-controlling policies as an effective method in reducing O_3 concentrations, similar to findings in other cities [21], [22], [26]. Further research on the relationship between vehicle usage and O_3 concentration is in need to inform policies addressing issues associated with this particular air pollutant.

$PM_{2.5}$ concentrations were lower in all cities but Seattle. The largest source of $PM_{2.5}$ emissions in cities is from power generation and vehicles [27]. The fact that Seattle's significant decline in vehicle usage didn't result in $PM_{2.5}$ reduction has two possible explanations. First, this could be due to a 'diminishing returns' effect of $PM_{2.5}$ reductions in Seattle's already extremely low baseline $PM_{2.5}$ pollution. Second, Seattle's frequent, light rainfall during its lockdown period [28] could agitate ambient particles that may increase $PM_{2.5}$ concentrations [19], which may offset any lockdown-induced $PM_{2.5}$ reduction. The results suggest that activity-controlling policies may be somewhat effective in reducing $PM_{2.5}$ concentrations in cities depending on local baseline situation and weather, which is in line with findings from other studies [20], [26], [29].

Overall, this study provides evidence supporting the hypothesis that the lockdowns were effective in improving air quality in general. It offers a nuanced understanding of how lockdowns could affect specific pollutants in urban environments. The lockdowns were most effective in reducing CO concentrations, somewhat effective in reducing NO_2 and $PM_{2.5}$ concentrations, and least effective in reducing O_3 concentrations. The findings are applicable to most urban areas in the world and support devising policies to reduce CO, NO_2, and $PM_{2.5}$ through discouraging private vehicle travel and promoting non-automobile transport. Since the feasibility of frequently implementing activity-controlling policies similar to the lockdowns is relatively low, policies that strongly encourages public transit usage and micro-mobility (e.g., walking, biking, scooters, etc) are likely successful to address CO, NO_2, and $PM_{2.5}$ concentrations in many cities.

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PUBLIC KNOWLEDGE AND PERCEPTION OF CLIMATE CHANGE AND GLOBAL WARMING IN THE CONTEXT OF ENVIRONMENTAL CHALLENGES AND POLICIES IN SAUDI ARABIA

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ABSTRACT

The adverse impacts of climate change have been experienced across the world including the Dammam City in Saudi Arabia. While there are many efforts targeted to fight climate change, their success is dependent on the public having sufficient knowledge about the issue. Hence, the fight against climate change urgently requires an increase in public awareness for effective mitigation measures. Thus, this study seeks to identify level of knowledge and awareness of the people of Dammam about climate changes, causes and impacts on humanity. The study involved 310 respondents who are residents of Dammam and gave their responses by completing an online questionnaire. The findings revealed that 90% of the respondents were aware of the contemporary climate change problem and they had acquired that knowledge from conventional sources like social media and 67% were very worried about the impacts of climate change. The results also showed that 33% had no awareness knowledge at all about the causes of climate change and its impacts. The study concluded that slightly above quarter of the respondents have good knowledge, understanding, and awareness of climate changes. The study recommends more efforts to be directed toward expanding public knowledge on climate change.

Keywords: awareness, cause and impacts, climate change, knowledge, Saudi Arabia.

1 INTRODUCTION

Climate changes experienced globally today are mainly caused by human activities [1]. The effects of these changes, such as global warming, is on the rise in the past few years, and it is generally accepted that environmentally unfriendly human behaviour is the cause of rapid climate changes [2]. The main effect of human activities on environmental pollution is global warming. Industrialization and the carbon emission of locomotives have led to the increase of greenhouse gases in the atmosphere [3]. The use of fossil fuels, reduction of vegetation covers, and cutting down of trees have increased the carbon prints in the air, leading to the accumulation of greenhouse gases [4]. The greenhouse gases are responsible for the global warming in the world, which has led to climate changes [5]. The effects of climate changes vary and could result in drought, floods, and depletion of the ozone layer. The term global warming is used to illustrate the increase in temperature due to climate changes. Increased levels of temperature have been noted in the past few decades [6]. A report by United Nations on global emissions revealed that the earth is headed for temperature spike by three degrees by 2030 since pre-industrial levels [7]. These estimates were predicted by the Intergovernmental Panel on Climate Change (IPCC) which is a United Nation's body responsible for highlighting the changes in temperature and forecasting climate changes that might happen in the future [8]. Knowledge and awareness on climate change are essential as it involves knowing the current situation of climate change, the causes, the impacts and the role of human involvement in climate change. Up to date knowledge is obtained by conducting regular assessments and analysis of data using scientific methods. On the other hand, public awareness is created by publishing the findings of data analysis and

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interpretation of how the findings affect future risks. UN Alliance on Climate Change Education, Training and Public Awareness focuses on educating the public on issues about climate change [9]. Creating awareness allows people to understand the real problem of climate change and the need to address the issue urgently by adapting their behavior and implementing mitigation measures.

People's knowledge of climate changes is essential in adapting to the new life provided by temperature changes. Knowledge acts as a base for human decision-making [10]. Change demands that human beings adapt accordingly to the new way of life created by the changes in the ecological space. The ecological knowledge development demands practice and belief of several important components. The attainment of ecological knowledge is dependent on the transfer of knowledge from one generation to another. People's attitudes on how to act can be formed by increasing the ecological knowledge they have. The increase in knowledge of the environment will ensure the human activities that contribute to climate changes are minimized and that human life will be spared from the harm of climate changes eventually [11]. Globally, Human beings are the main contributors to global warming [12]. The activities run by human beings affect the natural resources, biodiversity and make the environment unconducive and inhabitable for living things. The solution to adverse climate conditions lies in the hands of people by reducing environmental polluting activities. The main challenge is that most people do not know that their behaviours are causing environmental problems.

It is expected that the impact of climate change will affect all parts of life within the KSA, including water, health, food production and agriculture, fisheries, biodiversity, forestry and farmed areas [13]. The Government and many components of the Saudi society, including private sector institutions, science and technology and, to a lesser extent, civil society have taken many measures to decrease adverse climate changes. In ensuring the sustainability of water resources, the KSA government has implemented various initiatives. In terms of water policies, the main objectives set in KSA's Ninth Development Plan (2010–2015) are: preservation of non-renewable water tanks in sensitive areas by limiting their usage of drinking, Established 74 dams and increasing the overall storage capacity of the country to 1,349 miniature circuit breakers, promoting the recovery and reuse of wastewater and strengthen agricultural water conservation measures [13]. The KSA attempts to ensure food security through execution of the newly developed Agriculture Strategy (2010–2030) and address the worldwide market's food shortfall while minimizing price risk through forming strategic reserves and developing programs for low-income social security network members [13]. The Agriculture Strategy (AS) also supports Saudi farming investments in partnership with countries with relatively high agricultural production. It primarily aims to produce food but also to save an irrigation water of 8.5 billion cubic metres by 2030. Predicted adverse impacts of climate change on forest land over the coming 50 to 100 years are: increased frequency and patterns of environmental disturbances such as drought, sandstorms, fires, fluxes, increased forest and woodlands die-back, disease transmission, change in species composition and wealth, decreased biodiversity productivity. In 2009, the KSA finances the Clean Development Mechanism National Committee (CDM), which is the designated national authority in the KSA [13]. Besides these sectors, Saudi also experiencing climate changes due to oil pollution and carbon emissions. KSA is attempting to minimize greenhouse emissions and producing cleaner fuels by enhancing refineries. The Kingdom also supports climate change mitigation by improving and distributing solar energy from the year of 2020 [13]. The Madinah Landfill Gas Capture project, carried out with the technical help of Swiss company Vitol with in the KSA and aims at fostering best practices in waste management, contributes to the transfer of technology and reduces greenhouse gas emissions [13]. It is important to raise people's awareness and knowledge about climate change to preserve all of Saudi Arabia's climate and inexhaustible resources. People, with proper knowledge and perception towards climate change, therefore, can help the government to save the environment. This research will explore public knowledge and perception of climate change in the context of environmental challenges and policies in Saudi Arabia. Human beings represent the main stakeholders in reducing adverse conditions of climate change because their decisions will determine how the climate conditions are reduced [14]. According to Wolf and Moser [15], mitigation efforts can be made only if all populations are aware of the impact of climate change. Providence of information about climate change and creating awareness of it to all people will fasten the process of curbing climate change. There must be a distinction between those who understand, perceive, and assume responsibility for climate change.

2 MATERIALS AND METHODS

The study analyses the research output of the Dammam city. Dammam city is the largest city and is the capital of Saudi Arabia's Eastern Province region. It is bordering with the Arabian Gulf, and is 380 km away from national capital, Riyadh [16]. Dammam possesses numerous oil reserves, and their discovery in 1,938 led to the rapid development of the region from a small postal settlement to a major seaport. It is also one of the hubs of natural gas and petroleum centers in Saudi Arabia. As per 2021 statistics, a total of 1,279,000 people were residing in the city of Dammam [17]. The area covered by the city is approximately 800 km^2. The total GDP per capita of this city was USD 23,352 in the year 2020 [17]. The research used quantitative methods to collect and analyse data. A particular, a questionnaire was used to collect data from the respondents. The questionnaires were deployed using the QuestionPro between January and March 2021 (www.questionpro.com). online surveys were chosen because are faster, less costly, and protect the confidentiality of the respondents [18]. The sample population was obtained using snowball sampling method. Also, snowball sampling was applied to distribute the link to the survey via email and social media, with the recipients of the survey link sharing it with their acquaintances living in the area. By the end of March, the number of people that had expressed their willingness to participate in the study was 310 individuals. That number was considered sufficient based on the Cochran's formula given that the city has a population of 1.17 million people and significance level adopted was 0.05 [19]. Notably, only those that willingly volunteered to participate in the study were included in the final sample population. Caution was taken to protect the confidentiality of the respondents. That was achieved through the application of the snowball sampling technique which enables a researcher to study a huge population anonymously with a high response rate [20]. The method was critical in reaching out to participants and distributing the questionnaires, especially to female respondents [21]. According to Saudi Arabia's cultural norms, there are rules that guide social interactions especially those between opposite sex and breaking these rules could offend the population being investigated [22], [23]. In addition, the survey was conducted during the COVID-19 pandemic, a period where field surveys have become problematic hence online survey was the best alternative [24].

The study examined the awareness the Dammam city residents have of climate changes. The investigation had a broad scope from knowing whether they knew the differences between weather and climate, causes of climate conditions, effects of climate changes, possible remedies to global warming, and ways of reducing the carbon emitted into the atmosphere. The study opted to use a close-ended questionnaire that was grouped into four distinct sections. The questionnaire contained several important sections that constituted the different aspects of information required for the survey. The age, education, and social information of the respondents dominated the first part of the questionnaire. The research also wished to find out how many people in the city had heard of global warming or climate change. This information was included in the self-reported knowledge section of the questionnaire. It was also important to inquire if they had any beliefs about climate change and whether they were worried. Three elements 0, 1, and 2 were used to analyze the beliefs of the respondents on climate changes ("0" referred to people who believed supernatural forces cause climate changes, "1" depicted the ones who believed nothing supernatural controlled climate changes, while "2" represented those who were not sure whether supernatural beings affected climate conditions or not). The study assessed the residents' knowledge of the "greenhouse effect" and how conversant they were about its effects. The questionnaire provided four options on the level of knowledge on the greenhouse effect. It was also essential to know what percentage of people in Dammam could differentiate between weather and climate. The information on how they could distinguish the two was important in knowing how aware and knowledgeable they are. The Dammam city residents' knowledge of fossil fuels and their effects were investigated in the study. The sample of 310 respondents was expected to explain whether they knew what fossil fuels are and their effect on the environment. The final part of the questionnaire contained questions that tested whether the respondents understood the causes and impact of climate changes and the recommendations to the problems arising from these changes. The questionnaire gave numbers between 1 to 5 indicating how knowledgeable one is on the causes and impact of climate changes (1 = not knowledgeable at all; 2 = a little knowledgeable; 3 = moderately knowledgeable; 4 = knowledgeable on the causes but not very knowledgeable on effects of climate conditions; and 5 = knowledgeable in both causes and effects of climate conditions).

Reliability analysis was conducted for the questionnaire of the study on the pilot sample of (30) respondents, we used Cronbach's alpha and Pearson's Correlation for internal consistency and validity. Results of Cronbach's Alpha shown in Table 1 below.

Table 1: Cronbach's alpha reliability result.

Questionnaire items	No. items	Cronbach's Alpha
	6	0.761

For the pilot data collection the sample size was (30) respondents, the calculated Cronbach's Alpha was (0.761) for Likert items in the questionnaire (6 items); this results indicate a good reliability for the questionnaire, Cronbach's alpha ranges from r = 0 to 1, with r = 0.7 or greater considered as sufficiently reliable [25]. For reliability analysis, "the tendency towards consistency found in repeated measurements of the same phenomenon is referred to as reliability" [26]. Thus, the researcher may be sure of the validity and reliability of the questionnaire and thus became suitable for the application of the all sample. Pearson's correlation was conducted to assure the validity between each item and the total degree of the questionnaire. Results shown in Table 2.

Table 2 shows the acceptable internal consistency for all statements of the questionnaire, from which we found that all correlation coefficient (r) > 0, ranged between 0.351 as minimum value and 0.670 as maximum value. According to Cohen [27]; (r = 0.10; small, r = 0.30 medium, r = 0.50 large). All Pearson's correlation coefficient significant with p-value ≤ 0.05.

Table 2: Acceptable internal consistency for the items of the questionnaire.

	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation
1. Knowledge of the difference between climate and weather among the respondents	13.67	13.333	0.351
2. Level of worry regarding climate change among the respondents	13.67	11.885	0.582
3. Beliefs regarding the causes of climate change among the respondents	14.20	13.959	0.472
4. Level of understanding regarding greenhouse effect among the respondents	13.67	11.540	0.556
5. Awareness of respondents on the nature and effect of fossil fuels on the environment	13.67	11.195	0.670
6. Awareness of knowledge of causes and impact of climate change among the respondents	13.47	11.775	0.443

3 RESULTS

The data collected were analyzed using the SPSS software package (IBM, Armonk, NY, USA). This statistical package is mainly used to analyze descriptive statistical data [28]. The software produced analyzed data after calculating the mean, frequencies, and standard deviation. Fig. 1 displays the education level of the respondents of the online questionnaire. The respondents varied from people who had a primary level of education to those who had

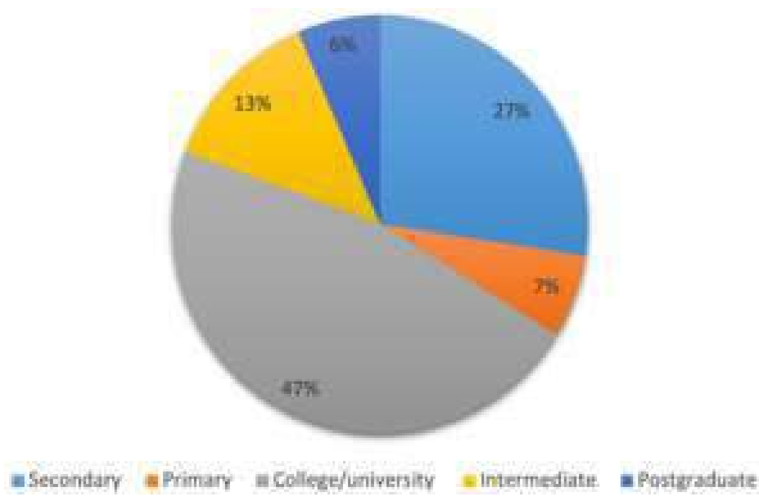

Figure 1: Level of education the respondents.

college/university level education. 47% of the respondents had college and university-level education, while 7% of respondents had only primary levels of education. The conclusion from this was nearly half of the respondents have university or college level degree which shows that they may acquire knowledge from their school level or college level education regarding climate changes at one point of time. The self-reported knowledge of climate changes, their impact, and their effects on human life are represented in Fig. 2. A very high percentage (90%) of the respondents were aware, through hearing from various forums such as social media, about climate conditions and global warming. In conclusion to this figure, most of the respondents have self-reported knowledge on the climate changes.

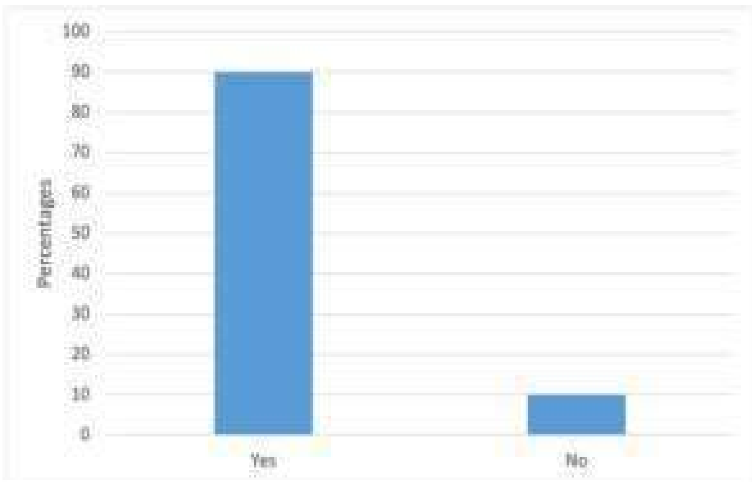

Figure 2: Self-reported knowledge on climate change among the respondents.

Figure 3: Knowledge of the difference between climate and weather among the respondents.

After this, we have shown the distribution of how the respondents responded to their knowledge of the differences between weather and climate (Fig. 3). The Dammam residents who participated in the research could not clearly distinguish between weather and climate. Only 26% of the total respondents were clearly able to answer this question, while 48% had partial knowledge of the difference between these two words. From this, most of the respondents do not have accurate knowledge on the difference between climate change and weather.

After checking the respondent's knowledge, we have gone further to check the respondent's level of worriedness regarding climate change. Fig. 4 describes the level of worry among Dammam residents on the climate changes witnessed in the past few years; 67% of the residents are apprehensive about the changes in climate conditions, 7% are less worried, while 3% do not care about the issue. Thus, the level of worry is quite high among the majority of residents of Dammam, as seen from the responses given by the 310 respondents. In conclusion, most of the respondents were very worried about the climate changes.

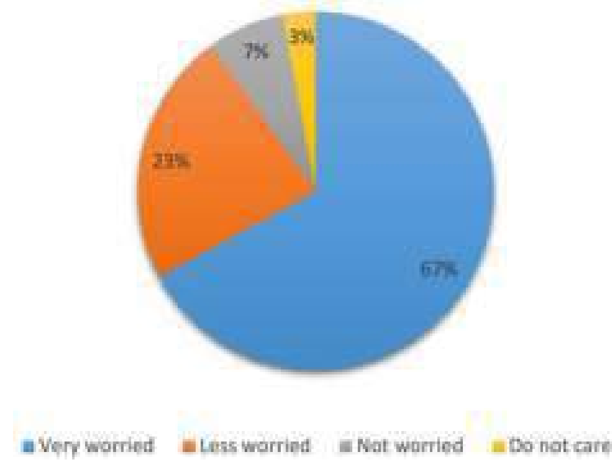

Figure 4: Level of worry regarding climate change among the respondents.

Further, we have observed the respondent's beliefs about the causes of climate change and their knowledge regarding greenhouse gases effect in the environment (Figs 5 and 6). The study displayed several abilities and knowledge levels of the Dammam city residents regarding climate change. While 10% of the respondents believed that climate changes are associated with supernatural forces, a much higher percentage (75%) did not believe that supernatural forces were behind the existence of climate changes (Fig. 5). A total of 120 respondents out of 310 were very knowledgeable about the effect of greenhouse gases on the environment and their contribution to climate change; however, 6.4% of respondents did not have any knowledge of the greenhouse effect (Fig. 6). From these two figures, the conclusion was most of the respondents do not believe that supernatural forces were behind the existence of climate changes, instead they were aware about the greenhouse gases effects on climate change.

Along with the greenhouse gases effects, we have also checked the respondent's awareness about the fossil fuels effects on the climate. As shown in Fig. 7, less than 10% of

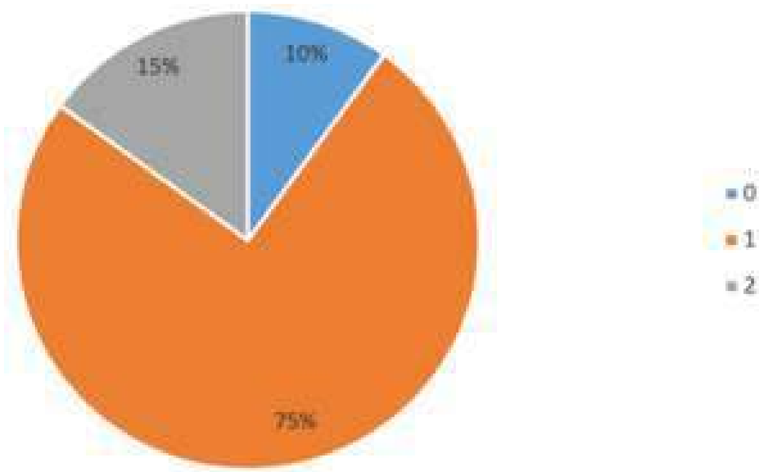

Figure 5: Beliefs regarding the causes of climate change among the respondents.

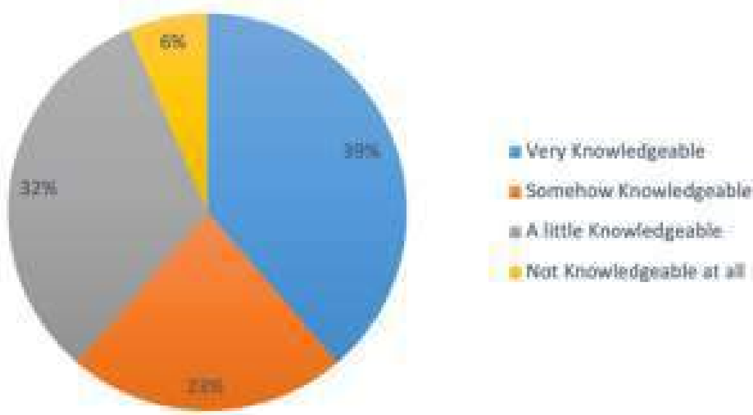

Figure 6: Level of understanding regarding greenhouse effect among the respondents.

the respondents did not have any knowledge of the nature and effects of fossil fuels. Almost two-thirds of the respondents were either very knowledgeable or somewhat knowledgeable about the nature and impact of fossil fuels on the environment. Respondents are aware of the fossil fuels effects on climate change, however, less number of respondents were aware of this compared to the number of respondents who were aware of greenhouse gases effects on climate change.

At last, we have checked the statistics about respondent's awareness on knowledge of causes and impacts of climate change. Fig. 8 shows the level of knowledge of the respondents regarding climate changes and their impact on human lives. 14% of the respondents were knowledgeable in both causes and effects of climate conditions, 21% were identified to have good knowledge of the causes of climate changes but were not aware of its impact on the environment and human lives. Thus, 33% of the respondents were clueless about the causes and impact of climate changes. Most individuals showed little knowledge of climate changes, and they were less informed about its causes and effects. The lack of knowledge and awareness regarding climate change resulted in unsatisfactory recommendations from the respondents on mitigating the impacts of climate change.

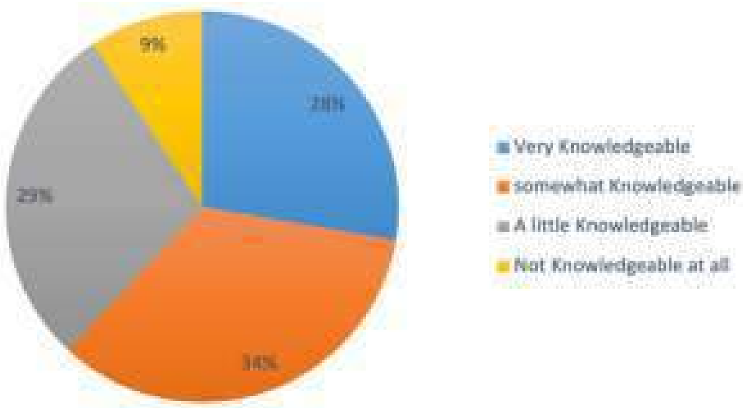

Figure 7: Awareness of respondents on the nature and effect of fossil fuels on the environment.

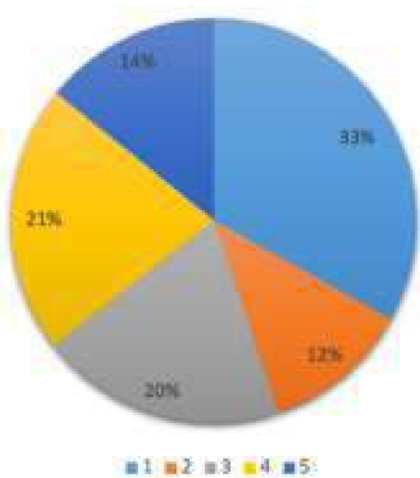

Figure 8: Awareness of knowledge of causes and impact of climate change among the respondents.

Altogether, our results suggested that the respondents were worried about the climate changes and know about the impacts of greenhouse gases and fossil fuels on the environment, however, less than quarter of the respondents were only aware of the knowledge of causes and impacts of climate change. Although the respondents completed college or university level education, most of them are not fully aware of causes and impacts of climate change and this may be due to lack of promoting awareness on causes of climate change by the government or lack of communication among the Saudi people to get the knowledge on it.

4 DISCUSSION

The responses from the questionnaire displayed the level of knowledge and awareness of the people about climate change in Dammam Saudi Arabia. The people of the city of Dammam showed a moderate level of understanding of climate change and the causes and effects of global warming, and their proposed solutions on how to tackle the problems were inadequate, appropriately the inadequacy of their knowledge is due to their reliance on traditional sources of knowledge about climate change. A huge flaw of such sources is that they have little impact on people's attitudes or behaviors because they do not account for the recipient's level of education or background [29]. Almost equal or slightly higher than to quarter of the respondents were either very knowledgeable or somewhat knowledgeable about the nature and impact of fossil fuels on the environment. The study shows that most people do not know that human activities and behavior directly impact the environment and climate. According to Boillat and Berkes [30], climate conditions and environmental behavior are linked to human behaviors. In current study, the major reason behind most individuals not being able to access knowledge on climate change is their use of traditional resources to get climate information. The traditional resources of data are linked to the level of education and ability to read and write [31]. However, modern forms of communication such as social media and YouTube can help even the less educated people acquire the knowledge they want. Better ways of gaining knowledge such as experience and significant elements by the Saudi people will work better than the traditional knowledge sources. The Saudi people's level of knowledge and awareness on climate change can be increased by adopting the channels of communication. The government of Saudi Arabia and other stakeholders need to work together to ensure more people are exposed to knowledge about climate change and global warming. When the number of knowledgeable people increases, it will be easier to handle the climate complications and environmental degradation [32].

Most of the respondents showed moderate knowledge of traditional climate change, such as social media not government or official, and were less aware of the causes and effects of climate change. Saudi governments have to raise awareness and implement policies regarding causes and effects of climate changes [33]. Saudi Arabia could view other countries as models of how local governments can encourage their participation in the reduction of effects of climate changes. The urban environment and climate change need to be looked at mutually. This would mean more inclusive and comprehensive urban planning practices with possible environmental impacts such as land use, transport strategies, waste and water management, green development, public health, and service placement [33]. Local government has also a clear chance to become more aware of climate change, of local mitigation and adaptation efforts, and to help societies to adopt energy efficient lifestyles and reduce household greenhouse gas emissions. Indeed, Saudi Arabia can potentially move toward creating a less oil-centered, more environmentally friendly economy, with the recent launch of its 2030 national vision, which significantly reduces conventional dependency on petroleum [33]. By 2030 the Kingdom is also committed by investing in clean energy projects including solar energy masses to cut the annual energy emissions to 130 million tons [33]. Saudi Arabia also partnered with international stakeholders in the fight against climate change and was part of the international effort. The Paris Agreement, which called on the nations to join forces for a common cause, against climate change and mitigation, was officially endorsed in November 2016 by Saudi Arabia [33]. The Saudi Environmental

Society is also building a broad base of volunteers and are helping to strengthen the private sector role in environmental issues such as the conservation of nature and wildlife.

5 CONCLUSION

The residents of Dammam City, Saudi Arabia, displayed fair knowledge and awareness of the causes and effects of climate changes. The insufficient knowledge and awareness on climate change shown in the study reflected that the city residents had little background information on pollution, global warming, and environmental conservation. The research findings will help in the decision-making processes needed to reduce the adverse effects of climate change and global warming. Further research needs to be done in other regions to identify the percentage of people who are knowledgeable and aware of climate change issues. Research in the future will also need to measure the perception, awareness, and knowledge of different people in the community, for example, farmers. This will give a public portray of the level of knowledge, perception, and awareness of Saudi citizens on climate change. The scope of the study should be widened to obtain a clearer picture of the level of knowledge and awareness regarding climate change of the entire population of Saudi Arabia.

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SECTION 11
WASTE MANAGEMENT

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PROPOSAL FOR THE MANAGEMENT OF SOLID WASTE GENERATED IN A UNIVERSITY CAMPUS: A CASE STUDY

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ABSTRACT

Sustainable development goals 3, 6, 7, 9, 11, 12, 13, 14, and 15, promoted by the United Nations, address the issue of waste management as a basis for preserving ecosystems. This paper states the management of recyclable and non-recyclable solid waste generated by 19,032 people on the university campus of the Escuela Superior Politécnica del Litoral (ESPOL) in Ecuador. The objective of this study is to present proposals for the integral management of solid waste in ESPOL, based on the estimation of per capita production (PCP in kg/hab-day). The applied methodology was: (i) revision of the Ecuadorian legal and technical regulations applicable to the Guayaquil canton on solid waste management; (ii) analysis of the current status of ESPOL and characterization of solid waste; (iii) projection of the population growth of the university and estimation of the PCP of residues; (iv) development of proposals for the collection, handling, processing, transformation, transport and final disposal of recyclable and non-recyclable solid waste; (v) presentation of solid waste management proposals. According to the result, the production of solid waste in ESPOL reaches 780.31 kg/day (28,481 ton/year); the classification and quantification of waste indicate that 61.82% is organic, followed by plastic with 18.79% and paper with 13.05%, the remaining 6.34% is metal, glass, tetra pack, electronics, and other types. Among the proposals for the management and use of waste includes capacitation for people who work at the campus and the continuous disclosure to the students. To advance towards the goal of zero waste and circular economy, first, it is necessary to achieve the sustainable environmental culture of the entire polytechnic community.

Keywords: proposals, management, solid waste, recyclable, sustainability.

1 INTRODUCTION

The generation and disposal of solid waste have been a problem since humanity began and its inadequate management causes diverse environmental, social, economic, and public health impacts [1]. As an answer, sustainable development implies sound management of all wastes to minimize waste generation through prevention, reduction, recycling, and reuse. In general, the range of products and materials in circulation present numerous challenges at all stages of the waste management journey. Effective waste management as a whole should be based on the correct identification and subsequent sorting of waste materials. However, there remains a huge amount of uncertainty over how different types of waste should be sorted and distributed [2]. Developed societies generally produce large amounts of municipal solid waste (e.g., organic, plastic, metal, paper, electronic) [3]. Once generated, wastes must be managed through reuse, recycling, recovery, and disposal.

The challenges imposed on cities such as non-generation, reduction, reuse, recycling, treatment, and environmentally adequate allocation of growing volumes of waste are also matters that concern universities [4]. In particular, in this study, university campus produces

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waste that requires proper management [5]. According to Tangwanichagapong et al. [6], universities require services and infrastructures, including waste management at the scale of a small city due require services like those, including accommodation, transportation, shopping, leisure, and waste management [7].

The university leaders in environmental and social responsibility should be to consider integrated waste management as a key element for their sustainable development [8]. Universities and colleges are obliged by state and international organizations to adopt sustainable development strategies in all their operations, in order to have a positive impact on the socio-economic and environmental well-being of their communities [9]. The universities must ensure more sustainability through the integration of three strategies, namely: University Environmental Management System (EMS); public participation and social responsibility; and promoting sustainability in teaching and research [10]. The first step to implement an efficient waste management system on a university campus is to know the composition, quantity, and recycling potential of the waste it generates [11], [12].

Several universities across the globe already have successful cases of solid waste management, in terms of waste characterization and the implementation of actions to reduce waste generation. Some examples are Universitat Jaume I in Spain [13], the University of Brasilia in Brazil [14], the Autonomous University of Baja California in Mexico [15], Harvard University in the United States [16], Catholic University of Chile [17], Prince George campus of the University of Northern British Columbia in Canada [18], the University of British Columbia in Canada [19], among other. In the case of Shenyang University in China, they have implemented in their campus, a ground source heat pump with less frequently gas to operate their heat pumps; a system wastewater recycling, it includes cascade reuse, waste minimization, and source reduction; integrated solid waste management (such as the collection of discarded PET – polyethylene terephthalate- bottles, etc.), green education and research [20]. According to Evans et al. [21], engaging university students in real-world sustainability challenges is worthwhile [22].

Circular economy (CE) is a concept currently promoted by the EU, by several national governments including China, Japan, UK, France, Canada, The Netherlands, Sweden, and Finland as well as by several businesses around the world [23]. A circular economy is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems [22].

In the case of the Gustavo Galindo Campus of ESPOL (Guayaquil, Ecuador) (Fig. 1), it currently has a program in place to guarantee its sustainability. The General Services area and the Physical Infrastructure Management, concerned about the generation of waste and solid waste, seek their efficient management. So far, students who do community service practices have developed previous work and collected data on waste and solid waste.

In addition, there are little-known initiatives by the students and teachers at the university that have not been adequately disseminated or have not been carried out in an institutional manner.

The objective of this work is to develop a plan for the integral and sustainable management of the non-hazardous solid waste that is generated in ESPOL, based on the correct characterization of these and the participation of the 19,032 people that make up the university community. In addition, the definition of intervention actions for the short, medium, and long term is contemplated for scenarios with and without COVID.

2 METHODOLOGY

To carry out this work, 5 phases were considered, which can be seen in Fig. 2:

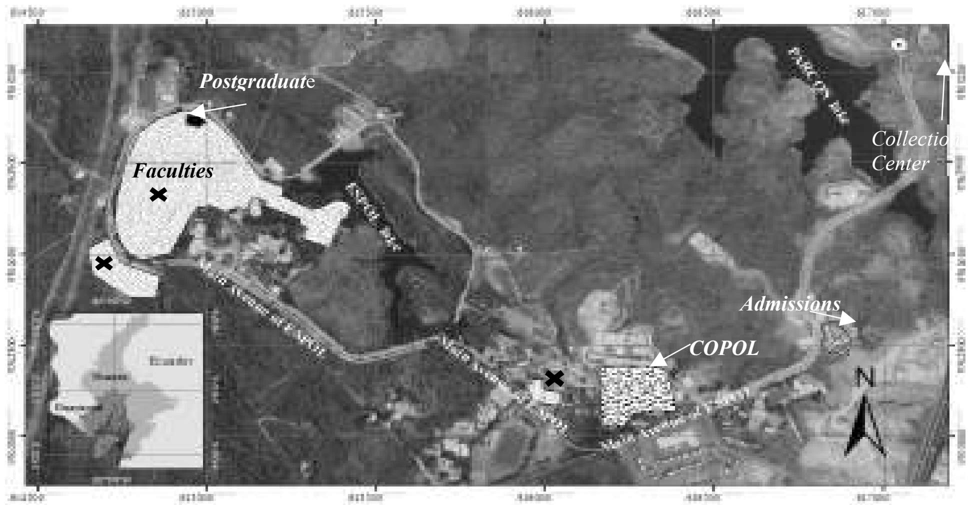

Figure 1: View of the ESPOL University Campus.

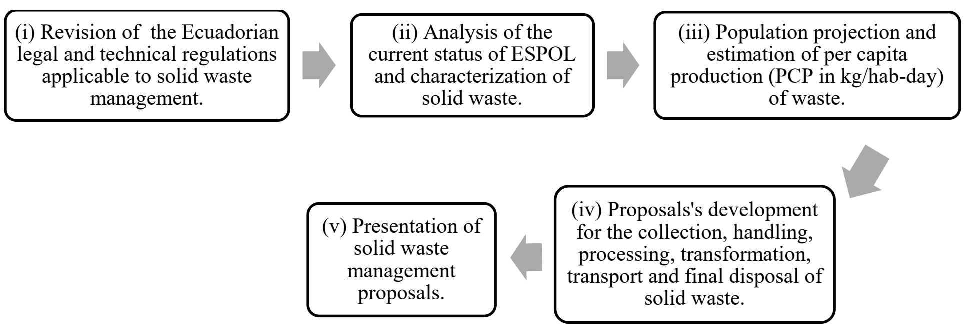

Figure 2: Methodology to be followed for the proposal of the solid waste management plan.

In the first phase, the Ecuadorian legal and technical regulations applicable to the Guayaquil canton on solid waste management were reviewed to analyzing information that deals with the correct management of solid waste from its generation at the source to its treatment and final disposal, as well as the degree of compliance by the university.

In the second phase, analysis of ESPOL's actions such as its Sustainability Program was carried out, with the aim of collecting information on the initiatives it has about solid waste management and the different activities that are already being carried out (interviews with the staff of the restaurants and reports of community practices). Finally, the waste generated in 5 of the 8 faculties was estimated for the year 2019. Thus, a projection was made to estimate the annual amount generated by the campus.

In the third phase, the analysis of the population of 2019 was carried out, having only data on the generation of garbage for that year; the projection of the future population, as well as the estimation of the PCP ESPOL. Based on data in 2019 the population of undergraduate students and faculties workers was obtained [24]; for students of admissions, polytechnic college (COPOL), and postgraduates, information was obtained from Cruz

Cabrera and Hidalgo Calva [25]. In parallel, the data of future populations that are in the development of the Master Plan of Water and Sewerage of the ESPOL were analyzed, and the Special Zone of Economic Development (ZEDE) in an agreement with the Municipality of Guayaquil. To estimate the growth of this population, it was projected to 15 years.

In the fourth phase, proposals were made for the collection, transfer, handling, processing, transformation, transport, and final disposal of the solid waste. The proposals presented are easy to apply and implement, with relevant impact; under low budget and active participation of students, workers, teachers, administrators, and managers of the university.

Finally, the plan developed was presented to the Area of Sustainability and Management of Physical Infrastructure of the ESPOL. In addition, this plan was presented to students from different faculties so that they can contribute their knowledge through community internships in semesters 1 and 2 of the period 2021–2022. Specifically, assigning students tasks related to the proposed waste management plan.

3 RESULTS

3.1 Legal regulations

Ecuadorian legal and technical regulations applicable to Guayaquil on waste management are shown in Table 1.

Table 1: Regulations for solid waste management in force in Ecuador.

Points to solve	Normative	Article/Chapter
Duties of citizens and the correct management of solid waste from its generation to its final disposal.	Constitution of the Republic of Ecuador.	43, 815
	Organic Code of Territorial Organization and Autonomy and Decentralization.	186
	Book VI, Annexes 6 of the Unified Text of Secondary Environmental Legislation (TULSMA)	3
Garbage collection bins	NTE INEN 2841	Anexo 1
	Book VI, Annex 6 of the Unified Text of Secondary Environmental Legislation	4.4.4, 4.4.5
	Municipal Council of Guayaquil.	14
Storage, presentation, transport in dump trucks or similar solid waste	Ordinance of the municipal council of Guayaquil.	13, 16 21

3.2 Analysis of the current status of ESPOL and characterization of solid waste

The initiatives for solid waste management of ESPOL's Sustainability Program are shown in Table 2.

ESPOL has 85 non-hazardous solid waste collection stations. Each station is made up of three plastic buckets with a capacity of 195 liters each [26]. In contrast to the NTE INEN 2841 standard, which indicates the standardization of colors, the ESPOL uses colored containers: red (paper and cardboard), green (organic), and blue (plastics and glass) [27]. During the inspection, it was found that: (i) some containers had no relationship between the colors and the expected labels; (ii) that they are close to each other, their arrangement was not adequate since some were very full and others almost empty.

In 2019 the students of community service made the characterization in five of the eight faculties; without considering the restaurants, the following results were obtained (Table 3).

Table 2: ESPOL initiatives for solid waste management.

Project's name	Year
Baseline survey of campus waste management as a buffer zone for the Prosperina Protective Forest	2019
Hammermill	2020
Baseline survey of the entire process and machinery used for the composting of the Bosque Protector la Prosperina Program.	2019
Metal bottle locations for source separation, PET	2019
Proposal for the implementation of a solid waste management system at the Gustavo Galindo Campus	2019
Campus Gustavo Galindo ESPOL Recycling Proposal, phase I	2019
"Innovation" final presentation – phase II	2019
Solid waste management guide in canteens and cafeterias	2009

Table 3: Characterization of garbage in FIEC, FCSH, FICT, FIMCP and FADCOM.

Type	FIEC[1] (kg/day)	FCSH[2] (kg/day)	FICT[3] (kg/day)	FIMCP[4] (kg/day)	FADCOM[5] (kg/day)	Total (kg/day)	Total %
Organics	13.58	14.10	54.65	80.91	34.47	197.71	61.82
Plastics	12.39	5.50	20.95	12.78	8.48	60.10	18.79
Paper	12.26	9.75	5.80	7.45	6.49	41.75	13.05
Metals	1.45	0.35	1.80	1.34	0.26	5.20	1.63
Glass	2.20	0.72	2.70	1.82	2.8	10.24	3.20
Tetrapak	0.55	0.15	0.30	0.14	0.34	1.48	0.46
Electronics	0.23	0.00	0.00	0.25	0.31	0.79	0.25
Others	1.20	0.27	0.00	0.31	0.77	2.55	0.80
Total (kg/day)	43.86	30.84	86.2	105	53.92	319.82	

[1]Faculty of Engineering in Electricity and Computing.
[2]Faculty of Social and Humanistic Sciences.
[3]Faculty of Engineering ini Earth Sciences.
[4]Faculty of Engineering in Mechanics and Production Sciences.
[5]Faculty of Art, Design and Audiovisual Communication.

3.3 Population projection and estimation of per capita production (PCP in kg/hab-day) of waste

For the estimation of the ESPOL population in the year 2035, 4 methods were used: arithmetic, exponential, geometric, and of simple interest (as shown in Fig. 3). Then the distribution plots were made and the value of R^2 was obtained (a statistical measure that explains how close the data are to the adjusted regression line). With this, was determined that the arithmetic and exponential methods were the ones that best followed the trend, therefore, in the end, the average of these two values was calculated. To this value, was added the population of the ZEDE, which gave a total of 23,449 people.

$$Población\ 2019\ =\ 19{,}032\ \text{people}$$
$$Population\ 2035 = average(arithmetic\ m.: exponential\ m.)$$
$$Population\ 2035 = (20{,}903: 22{,}610) = 21{,}757$$

$$Total = 19032\ people$$
$$Population\ 2035 = students\ 2035 + population\ ZEDE\ 2035.$$
$$Population\ 2035 = 21{,}757 + 1{,}692 = 23{,}449\ people$$

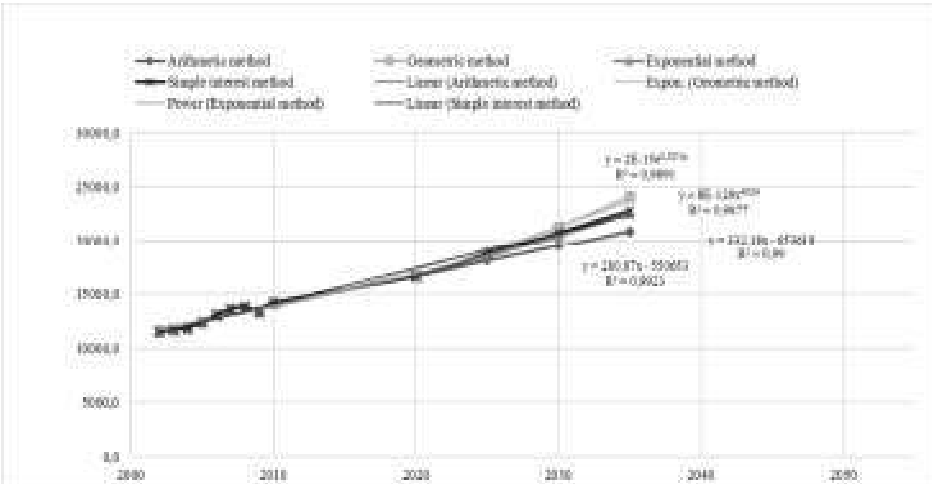

Figure 3: Estimation of the growth of the population.

With the population data and the production in kg/day of the year 2019, the PCP of the 5 faculties and the total production of the ESPOL that are observed in Table 4 were obtained. For the total PCP, 2 results were found, the first, 0.041 kg/hab-day, was obtained by dividing the total production in kg/day for the total population of the 5 faculties; while the second value, 0.050 kg/hab-day, was obtained from the average of the PCP of the 5 faculties.

Table 4: Solid waste production by faculty.

N.	Faculties	Total (hab.) – 2019	Production (kg/día)	PCP (kg/hab-day)	Mean PCP (kg/hab-day)
1	FICT	1,030	86.2	0.084	0.050
2	FADCOM	720	53.92	0.075	
3	FIMCP	1,975	105	0.053	
4	FIEC	2,173	43.86	0.020	
5	FCSH	1,917	30.84	0.016	
	Total	7,815	319.82	0.041	

To obtain 2019 daily and annual garbage production generated in other faculties, COPOL, admissions, and postgraduate; The PCP of 0.041 and 0.050 kg/hab-day was multiplied by the total population in 2019 for each of them, see Table 5.

To obtain the daily and annual production of 2035, the PCP of 0.041 and 0.050 were multiplied by the total population in 2035. The production in kg/day was calculated for 365 days of the year is instead of 260 days (working days), because it is in the extreme event (Table 6).

Table 5: Solid waste production in different areas of ESPOL in 2019.

Areas	Habitants (hab.) – 2019	PCP (0.041 kg/hab-day)		PCP (0.050 kg/hab-day)	
		Production (kg/day)	Production (ton/year)	Production (kg/day)	Production (ton/year)
Faculties	11,662	478.14	174.52	583.10	212.83
COPOL	1,256	51.50	18.80	62.80	22.92
Pre-university	4,769	195.53	71.37	238.45	87.03
Postgrade	1,345	55.15	20.13	67.25	24.55
Total	19,032	780.31	284.81	951.60	347.33

Table 6: Projected production of solid waste generated in ESPOL in 2035.

Habitants (hab.)	PCP (kg/hab-day)	Days of year	Production (kg/day)	Production (ton/year)
23,449	0.041	365	961.41	350.91
	0.050		1,172.45	427.94

Additionally, the average PCP was calculated between 0.041 and 0.050 kg/hab-day, to obtain a standard PCP figure that serves to compare ESPOL's production with other universities (Fig. 4).

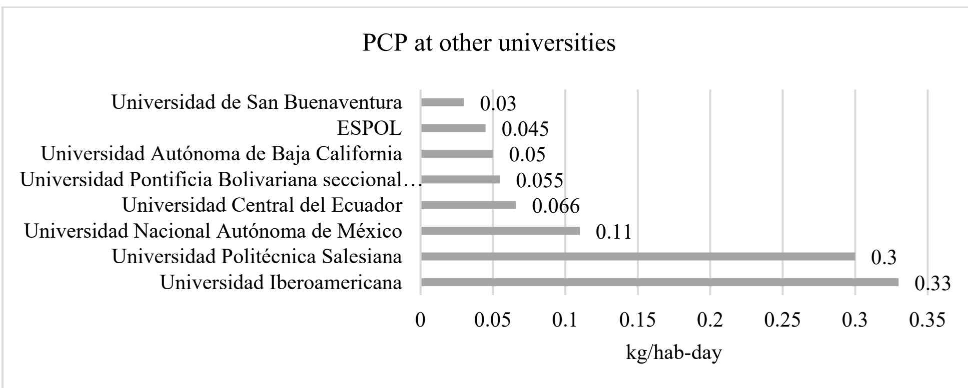

Figure 4: PCP at other universities.

3.4 Proposals' development for the collection, handling, processing, transformation, transport, and final disposal of solid waste

3.4.1 Proposals on waste management in open areas and food place of ESPOL

1. Definition of color and type of garbage can for the different areas.
   Trash liners in the same color as the bins must be provided (Fig. 5).

2. Selection of collection points and waste collection centers
   a) Reduce the number of collection points and replace old containers with new ones.

   b) Paint and label waste collection points that are lacking in maintenance.
   c) Build a collection center for recyclable waste to separate, package and sell them.
   d) Identification of waste from cleaning grease traps.
   e) The Municipality of Guayaquil through Ordinance of 12–23–2010, recommends that "they must use the lemon green cover, 1.5 thousandths of an inch, mixing the accumulated fat with sand and lime".

3. Enabling deposits for organic waste.
   Restaurants must have an exclusive cold deposit to store these wastes until they are collected by the collection car, thus avoiding bad odors.

4. Waste and residue control
   Have a record of the garbage that originates daily, this record will be made by the people who will transport the garbage to the collection center.

5. Staff training aware of the new waste collection provisions and the mandatory use of personal protective equipment (as shown in Table 7).

6. Acquisition of machinery and appropriate equipment.
   Change the current vehicle for another with a capacity greater than 1,000 kg that does not allow the spillage of waste. It must have internal compartments, to be able to separate the garbage.

7. Implementation of methods and schedules
   a) In the dining rooms, plastic bottles, lids, papers, cardboard, etc. should be washed, so that they can be recycled. Then, the waste must be located in each bin.
   b) Conduct a survey with general services personnel to agree on the waste collection schedule and discuss the materials to be used for collection.

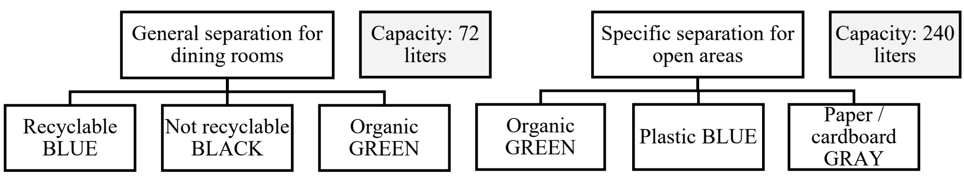

Figure 5: Color of trash cans and covers for dining rooms and open areas of ESPOL.

Table 7: Personal protective equipment.

Uniform	Gloves	Footwear	Respirator
Jean pants; long sleeve t-shirt, light color; overalls or apron; legionnaire type cap, resistant and waterproof.	ALY4960 Power cut Rubber	Rubber shoes Steel tip	Filter mask Organic gas respirator.

3.4.2 Proposals on the integral management for PET plastic waste

1. Installation of metal stations
   a) Location of 35 recycling stations (metal bottles) around the entire campus [24], [26].

b) Measurements: 1.60 m high and 0.75 m wide.
c) Materials: Galvanized closing mesh and smooth rod.
d) It must have a label that identifies its numbering in sequence.
e) Each bottle will include an infographic with the types of bottles allowed.

2. Assignment of waste transfer tasks
   a) Students designated by competent authorities, such as student associations, will be in charge of cleaning the recycled bottles on a weekly basis at the stations of each faculty. For this, they must have garbage bags and PPE. After cleaning them, they will crush them in order to reduce their volume and they will collect them again in plastic bags that must be temporarily stored in each faculty.
   b) The general services staff will be in charge of collecting and placing the bottles at the PARCON collection center on a weekly basis and the recycling company will be in charge of collecting the PET material from the same center.

3. PET waste management monitoring: Community internship students must also monitor the weight of PET plastic that will be sold to the recycling company so that sales and income from this activity are controlled.

3.5 Management proposals of the solid waste

Two main axes were addressed: "Cultural Change Program" and "Solid Waste Management". The activities indicated in each axis will be carried out in the short (2 to 4 months), medium (4 to 8 months), and long-term (8 to 12 months), which were organized as follows (Table 8).

4 DISCUSSION OF RESULTS

Regarding regulations, ESPOL needs to apply more rigorously the guidelines for the efficient management of solid waste. From the analysis of the 85 stations, some do not receive enough garbage that could be collected for transport. This could be because there is not enough public influx in those sectors, so they should relocate to a more suitable place.

About the population, it was found that FICT is the second faculty with the smallest population and, even so, it presents the highest garbage production in kg/day. One explanation is that many of the students circulate through this faculty, due to the forced path to the campus bus station.

The waste management plan presented in this work, when compared with that of other universities [13]–[19], presents similar procedures regarding: (i) knowledge of the generation and composition of waste and (ii) the use of tools monitoring control to establish the traceability of waste (origin, evolution in school years). In other words, corroborating the importance of a plan of improvement measures that, on the one hand, increases selective collection and, on the other, minimizes the waste generated.

The best way to promote environmental culture is through the creativity of students and teachers, to create awareness in the polytechnic community, and thus, adopt new habits in the handling of garbage. It is important to note that later it is intended to address the management of liquid waste and emissions into the atmosphere. Specifically, in the new period 2021–2022, with the participation of the new community work groups.

Table 8: Plan of activities.

	Activities	Months	Careers	Profiles
Cultural change program	Elaboration of the social advertising campaign for the different areas of ESPOL.	4	Graphic Design, Production for Media	Junior Illustrator, Junior Diagrammer, Junior Art Director, Junior Creative Writer, Junior Digital Designer, Junior Graphic Designer, Junior Post-Producer, Junior Community Manager
	Induction and training for new entrants and the polytechnic community in general.	4		
	Launch and control of the social advertising campaign in the different áreas (services in general)	12		
	Follow-up of restaurants, cafes, and bars to update information and verify the correct recycling processes.	4	Civil Engineering	Technical Drawing
	Creation of an internal mechanism to encourage workers to participate in waste collection.	2	Business Management	Administrative Analyst
Solid waste management	Identification and characterization of non-hazardous solid waste (in times of COVID). GIS	4	Civil Engineering	Technical Drawing, Hydraulics
	Relocation and/or signaling of garbage collection stations at strategic points and maintenance or replacement of damaged cans.	4	Mechanical Engineering	Mechanical Maintenance Assistant
	Optimization of food handling processes in restaurants.	8	Food Engineering	Assistant in Food Processing
	Creation of a management plan for waste collected at campus stations.	4	Civil Engineering	Geotechnics
	Analysis of possible infiltration point in the area where the temporary recovery center will be implemented. Structural design of the temporary recovery center.	4	Geology, Civil Engineering	Geological Threats, Structures
	Working group: Identify program implementation time with its due *Reference Budget.*			

5 CONCLUSIONS

Ecuadorian and municipal regulations of the Guayaquil canton helped considerably in the elaboration of the proposals for the management of solid waste from ESPOL. By taking small steps, the great objective of having a zero-waste university can be achieved. That is why it must bet on cultural change and waste management that is maintained over time.

Organic waste and PET plastics are the ones with the highest production, the possibilities of use in the short-term proposals are directed to them; however, in the medium and long term, it seeks to recycle, reuse or produce energy with all waste.

ESPOL produced an approximate total of 285 to 347 tons of waste in 2019. For the future population of 23,449 people in 2035, a generation between 350 to 428 tons/year is expected, of which 80% is expected to be used sustainably. The average PCP in the university is 0.045 kg/hab-day, ranking it as the second-best among other universities in America.

It is expected that the proposed change of color bins, stipulated by the INEN-2014, in the open áreas of ESPOL, Will achieve an acceptable response among students and workers, to create a differentiation of the garbage effectively.

The implementation of these proposals cannot be carried out if there is no commitment from each of the people who make up the polytechnic community. If we all collaborate for the good of the university, we will effectively be able to create good habits of differentiation from garbage, for which the cultural change program is the greatest challenge within the plan.

Finally, for 2021 it is intended to characterize liquid waste and emissions into the atmosphere, in such a way that new possibilities of use and/or creation of energy sources are achieved. With the implementation of this, it is intended that ESPOL University can become a zero-waste campus in the medium and long term.

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SOLID WASTE MANAGEMENT: A CASE STUDY OF PHUKET OLD TOWN NIGHT MARKET, THAILAND

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ABSTRACT

Phuket Old Town Night Market is a beautiful market in Thailand. The market is located among picturesque Sino-Portuguese houses in Phuket Old Town. The spaces between the buildings are packed with stalls selling traditional local foods and beverages, Thai handicrafts, modern fashions, and souvenirs. Solid waste is produced from the many activities within the market area. Therefore, this paper aimed to study solid waste management at the night market in Phuket Old Town and aimed to study the types and quantities of solid waste, waste storage, waste collection, transfer and transportation, and disposal of the waste products. The waste selected from 24 bins at 14 bin points in the market area produced four types of waste: organic waste (52%); general waste (40%); recyclable waste (7%); and hazardous waste (1%). The average generation rate of the waste was 0.03 kg/person/day. The waste materials from the bins were collected by six employees of the municipality who wore unsuitable protective suits while working. They collected waste materials from transparent plastic bins that were 50 and 70 litres in size and green plastic bins that were 240 litres in size. All bins were fitted with black or transparent plastic bags. All waste materials were carried and transferred for disposal by two municipal employees in a vehicle provided by the municipality. According to the government guidelines, the transport workers wore unsuitable clothing. Furthermore, the waste materials were transferred and transported without separation at the source. The waste was taken to an incineration plant for disposal. The municipality, president of Phuket Old Town, and the organizer should manage the solid waste materials more strictly according to the 3Rs to reduce the amount of waste for incineration. They also need to prepare PPE suits for the waste handlers. Also, volunteers should be available to advise visitors on waste segregation within the market.

Keywords: solid waste management, Phuket Old Town, night market.

1 INTRODUCTION

Phuket province in southern Thailand is a famous and popular destination for both Thai and foreign tourists. In 2020, the number of tourists who visited Phuket was 14,454,187 and the income from the tourism was 471,606 million Thai baht [1]. Phuket is the largest island in Thailand, and it has many beautiful natural resources such as Patong Beach, Promthep Cape, and Mai Khao Beach, which is near the airport. There are also traditional foods, sweets, beverages, clothing, and local traditional and historic architecture, especially the Sino-Portuguese architecture of the buildings in Phuket Old Town.

In Phuket Old Town, Thalang Road is lined with colourful 19th-century shophouses and Sino-Portuguese buildings, and it is the location of Phuket Old Town Night Market (POTNM). The market is open every Sunday afternoon until evening (4.00 pm–10.00 pm). Most visitors come into the market ahead of time for sightseeing of the old Sino-Portuguese buildings that line the 350-metre-long street [2]. Within the market, the visitors can take photos of street art graffiti and old colourful Portuguese houses. In addition, inside the market, various foods, beverages, goods, and souvenirs are sold, such as Thai traditional foods and sweets, fruit juices, ice cream, Thai handcrafts, and gifts [3]. In addition, visitors can participate in activities within the market and listen to musical performances. Phuket Old Town Night Market is therefore a kind of street night market that is popular and attracts groups of Thai and foreign tourists. However, the impact of the tourists produces an

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important environmental urban problem related to solid waste. Therefore, this research aimed to study solid waste management in Phuket Old Town Night Market. The information and collected data included the types and quantities of waste, waste storage and collection, waste transfer and transport, and waste disposal.

2 METHODOLOGY

2.1 Area site

The waste materials were produced in the Phuket Old Town Night Market in Phuket province in southern Thailand. This market is located among the picturesque Sino-Portuguese houses in Phuket Old Town. The spaces between the buildings are packed with stalls selling traditional local food and beverages, Thai handicraft, modern fashions, and souvenirs (Fig. 1).

(a) (b) (c)

Figure 1: Phuket Old Town Night Market in Phuket, Thailand. (a) Market overview; (b) Goods and souvenir zone; and (c) Food and beverage zone.

2.2 Survey methods and sampling

Meetings were conducted with the president of Phuket Old Town, waste handlers and employees of Phuket City Municipality, and the organizer who managed and operated the market. The results of the meetings provided information for the methods of performing the research. The exploration included studies in the types and quantities of waste, waste storage and collection, waste transfer and transport, and waste disposal.

2.3 Sampling scope

The waste materials were identified according to the types and quantities by segregation and weighed on 29 December 2019 between 4.00 pm and 10.00 pm while the market was open on a Sunday afternoon. The waste was collected from 24 bins at 14 bin points within the market in two zones, which were the goods and souvenir (gs) zone and the food and beverage (fb) zone.

3 RESULTS AND DISCUSSION

3.1 Types, components, and quantities of waste materials

The total amount of waste materials in Phuket Old Town Night Market was 703.95 kg from the gs zone and fb zone and were separated into four types of waste, i.e., organic waste, general waste, recyclable waste, and hazardous/infectious waste. The average generation rate of the waste was 0.03 kg/person/day. The greatest percentage of waste was organic waste at 52% (365.32 kg), and hazardous/infectious waste was the lowest percentage at 1% (7.62 kg) (Fig. 2). Although POTNM is different from fresh markets, street food markets, or traditional food markets, the amount of organic waste was similar to those sources of solid waste. The high quantity of organic waste was similar to a study by Aye and Widjaya [4] and Huang [5] that reported waste compositions from traditional food markets in Bandung, Jakarta, and street food markets in mainland China.

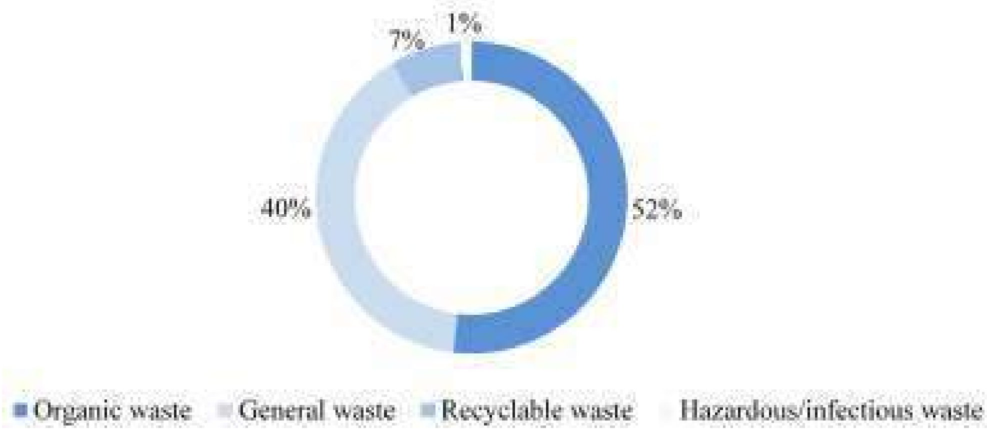

Figure 2: Percentages of waste materials in Phuket Old Town Night Market.

The amounts of waste in the gs zone and fb zone were 374.58 kg and 329.37 kg, respectively. The types, components, and quantities of all waste materials are shown in Tables 1 and 2.

Table 1 shows the categories, components, and the amounts of waste from the gs zone. The highest amount was represented by organic waste at 213.98 kg that included coconuts and food waste. The second highest amount of waste was general waste at 123.75 kg that included cups, plates, glass, straws, paper, single use plastic, such as bags, boxes, cups, spoons, and straws, wooden skewers for ice cream and meat balls, chopsticks, shoe, and foam. Next, the amount of recyclable waste was 29.23 kg that included bottles (glass and plastic) and aluminium cans. Hazardous/infectious waste included expired cosmetic products, diaper, and sanitary napkin. The source of these waste products was found to be from people living in the nearby buildings who took them to the bin points within the market.

Table 2 shows the categories, components, and the amounts of waste from the fb zone. General waste represented the highest amount at 155.28 kg that included paper cups and plates, glass, and straws), paper, single use plastic, such as bags, boxes, cups, spoons, straws, wooden skewers for ice cream and meat balls, chopsticks, foil, foam and a telephone case. The second highest amount of waste was organic waste at 151.34 kg that included coconuts and food waste. The amount of recyclable waste was 22.75 kg that included bottles (glass and plastic) and aluminium cans. Hazardous/infectious waste products were not found in this area. Interestingly, the percentages of waste at the gs zone and fb zone were similar (Fig. 3).

Table 1: Types, components, and quantities of waste in goods and souvenir zone.

Types and components	Wet weight (kg)	Percentage by weight
1. Organic waste		
- Coconuts	161.90	13.90
- Food waste	52.08	43.22
Total	213.98	57.13
2. General waste		
- Paper cups/plates/glass	36.20	9.66
- Papers	25.40	6.78
- Plastic bags	18.01	4.81
- Plastic boxes	15.14	4.04
- Plastic cups	15.13	4.04
- Paper straws	6.73	1.80
- Wooden skewers for ice cream and meatballs, chopsticks	2.78	0.74
- Plastic spoons	1.83	0.49
- Plastic straws	1.79	0.48
- Shoe	0.40	0.11
- Foam	0.34	0.09
Total	123.75	33.04
3. Recyclable waste		
- Glass bottles	18.14	4.84
- Plastic bottles	7.21	1.92
- Aluminium cans	3.88	1.04
Total	29.23	7.80
4. Hazardous/infectious waste		
- Expired cosmetic products	6.80	1.82
- Diaper	0.80	0.21
- Sanitary napkin	0.02	0.01
Total	7.62	2.03
Overall total	374.58	100.00

3.2 Waste storage and collection

The waste from 24 bins at 14 bin points in the two main zones in POTNM were not separated at the sources. All waste materials were mixed together inside the bins. However, the waste handlers were permitted by the municipality to segregate recyclable waste from the bins before moving the waste to a storage location. Most of the waste materials were collected and carried to the storage location by six waste handlers.

Before the market opened at 4.00 pm, the waste handlers put plastic bags inside 24 bins and carried them to the 14 bin points within the market (six bin points in the gs zone and eight bin points in fb zone). The types of bins consisted of (1) transparent plastic bins of two sizes (50 and 70 litres); and (2) green 240-litre plastic bins. All bins had transparent or black plastic bags. When the bins were full, the waste handlers collected the waste and moved it to the storage point. Next, they placed new plastic bags inside the bins at all bin

Table 2: Types and components of solid waste in food and beverage zone.

Types and components	Wet weight (kg)	Percentage by weight
1. Organic waste		
- Coconuts	76.44	23.21
- Food waste	74.90	22.74
Total	151.34	45.95
2. General waste		
- Paper cups/plates/glass	47.40	14.39
- Papers	38.22	11.60
- Plastic bags	18.25	5.54
- Plastic cups	16.42	4.99
- Wooden skewers for ice cream and meatballs, chopstick	10.85	3.29
- Plastic boxes	10.53	3.20
- Paper straws	6.14	1.86
- Plastic spoons	4.82	1.46
- Plastic straws	2.42	0.73
- Foil	0.20	0.06
- Foam	0.02	0.01
- Telephone case	0.01	0.01
Total	155.28	47.14
3. Recyclable waste		
- Glass bottles	12.40	3.76
- Plastic bottles	8.87	2.69
- Aluminium cans	1.48	0.45
Total	22.75	6.91
4. Hazardous/infectious waste	Not detected	–
Overall total	329.27	100.00

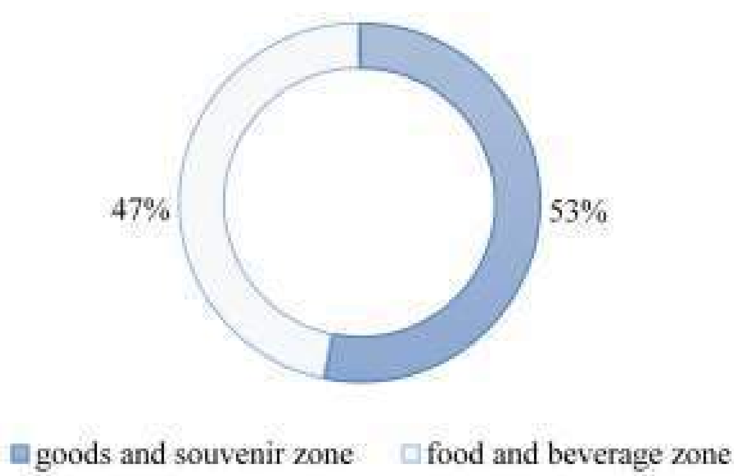

Figure 3: Percentages of waste at the goods and souvenir zone and food and beverage zone.

points. They were repeated this procedure until the market was closed. At the storage point, a 1.44 tonne compactor garbage truck provided by the municipality waited outside the market to receive the waste. The waste handlers wore unsuitable protective clothing while working. They did not wear breathing masks, gloves, rubber boots, medical caps, or eye goggles. They wore only a short apron that did not conform to the guidelines by the Ministry Regulation on General Waste management B.E. 2560 (2017) [6].

(a) (b)

Figure 4: Waste storage and collection. (a) Waste collection by waste handler; and (b) Waste storage by compactor garbage truck.

3.3 Waste transfer and transportation

All waste from the 24 bins at the 14 bin points were transferred to the storage point by six waste handlers using carts. The waste materials were then transported from the storage point by a compactor garbage truck for disposal. The vehicle for waste transfer and transport was suitable and correct according to the laws of Thailand [6]. This waste was moved for disposal by incineration by two waste handlers in two round trips. The first trip was at around 9.00 pm. The final trip was conducted after the six waste handlers had completely cleared and cleaned any residue waste within the market.

The waste handlers wore unsuitable protective clothing during waste transfer and transportation. They did not wear breathing masks, gloves, rubber boots, medical caps, or eye goggles. They wore only a short apron that did not conform to the guidelines set by the Ministry Regulation on General Waste management B.E. 2560 (2017) [6].

(a) (b)

Figure 5: Waste transfer and transportation. (a) Waste transfer by cart; and (b) Waste transportation by compactor garbage truck.

3.4 Waste disposal

Most waste materials from the market were mixed together and moved for disposal by incineration. However, some of the recyclable waste was separated out by the waste handlers who were permitted by the municipality to segregate the waste before moving it to the storage point. The recyclable waste was taken to recycling shops for disposal. The handling of recyclable waste was carried out correctly according to the requirements [6]. On the other hand, the hazardous/infectious waste materials were not separated according to the type of bin and disposal method. The waste contaminated with pathogens from diapers and sanitary napkins and toxic substances from expired cosmetic products should not be incinerated with the general waste. Furthermore, it was not possible to burn some of the waste. A flow chart of solid waste management at the POTNM is shown in Fig. 6. Most of the waste materials were not separated at the source. Unfortunately, some waste was contaminated with toxic substances and pathogens from hazardous/infectious waste. The waste products were put into a total of 24 bins by visitors who came to the market. Six waste handlers collected and transferred the waste to a storage location. The waste handlers segregated some of the recyclable glass and plastic bottles by removing them from the bins. The waste materials were then taken to the storage point where a compactor garbage truck was parked outside the market. When the market closed at 9.00 pm, two waste handlers transported the waste to an incinerator plant for disposal using a compactor garbage truck. It was observed that all eight waste handlers wore unsuitable protective equipment. Solid waste management at the POTNM can be compared to a study by Huang [5] that reported on the solid waste disposal process in street markets in mainland China. That process could be classified into three stages: (1) storage: setting containers in designated locations for scheduled pickups; (2) collection and transportation: solid waste was carried out using various types of vehicles that depended on the type of collection bin and width of the road; and (3) final disposal: three important waste disposal methods were incineration, biochemical treatment, and landfill.

4 CONCLUSION AND RECOMMENDATIONS

The waste at the POTNM was classified into four categories from 24 bins at 14 points in two main zones. The types of waste in the gs zone consisted of organic waste, general waste, recyclable waste, and hazardous/infectious waste. The fb zone included organic waste, general waste, and recyclable waste. The percentage values of the waste materials at the gs and fb zones were similar. None of the waste handlers wore suitable protective clothing according to the laws of Thailand. However, the compactor garbage truck and disposal methods, ie incineration and recycling shop, were correct according to the Thai government guidelines. In Phuket, the final disposal methods of solid waste are mainly incineration and sanitary landfill for non-combustible waste.

However, the best practices for solid waste management in this case are to reduce and separate waste at the source, especially organic waste. Visitors should buy only sufficient food, fruits, sweets and beverages to be consumed without waste. The high water content of organic waste in a highly humid environment adds wet weight to the waste and becomes more difficult to incinerate. Therefore, organic waste needs to be separated from general waste to avoid adding wet weight that makes incineration less efficient. Since waste materials are usually stored at the incinerator plant for a long time before incineration, reducing the amount of organic waste going to the incinerator plant also makes the overall solid waste management more efficient.

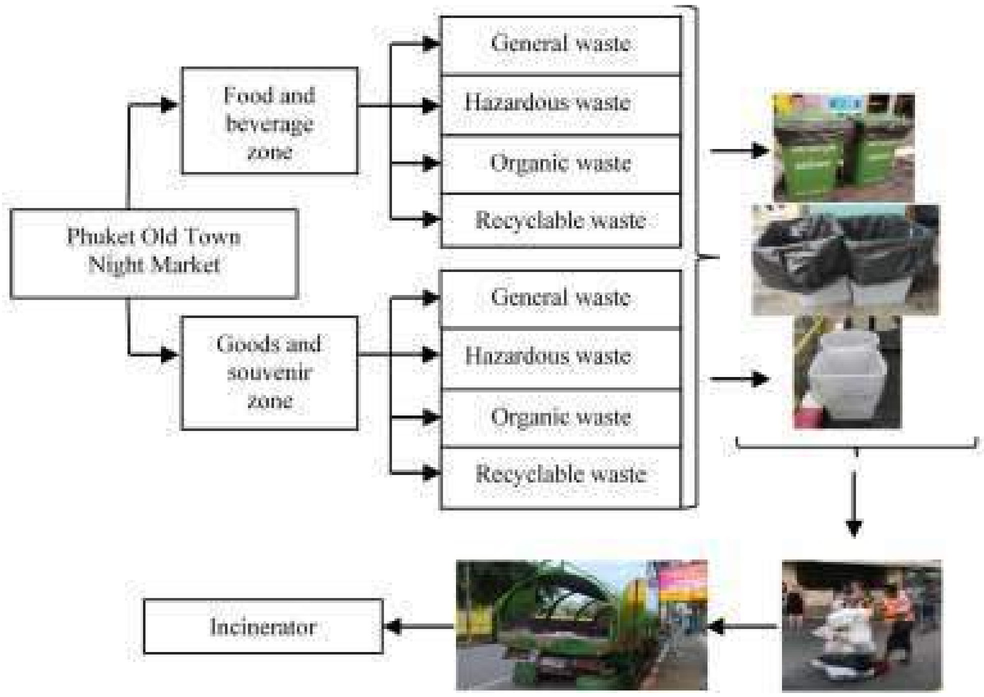

Figure 6: Flow chart of solid waste in Phuket Old Town Night Market.

The following are the recommendations for solid waste management at the POTNM: (1) The municipality, president of Phuket Old Town, and the organizer should plan to more strictly control and manage solid waste according to the 3Rs, ie Reduce, Reuse, and Recycle to reduce the quantity of waste for disposal by incineration and select proper methods for disposal of each type of waste. Bins need to be clearly labelled as organic waste, general waste, and recyclable waste for proper segregation. Special containers or bins inside the market are needed for hazardous/infectious waste for easier transfer to a special incinerator facility that is located near the general waste incineration facility; (2) Public announcements on solid waste management are needed within the market in at least three languages, such as Thai, English, Chinese, and Korean, for travellers and traders; (3) A team of volunteers should be available to advise visitors on waste segregation and control and management of the waste within the market; and (4) Suitable personal protective equipment and clothing need to be provided for the waste handlers.

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SECTION 12
URBAN AGRICULTURE

POTENTIAL THREATS OF PERI-URBAN TUONG-MANGO PRODUCTION AND POLICY IMPLICATIONS FOR HEALTHY AGRICULTURE FOR HEALTHY ECOSYSTEMS

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ABSTRACT

Understanding both positive and negative influences of urban agriculture (UA) could encourage countries to have suitable strategies in UA development, especially in developing country's cities. The study used the environmental impact quotient (EIQ) model to identify potential risks of agro-inputs usage on urban ecosystems (human and ecology). The paper concentrates on influencing agrochemicals on farmers, consumers and ecosystems in Tuong-mango cultivation in the peri-urban area of southern Vietnam. The results show that nitrogen fertilizer plays an important role in mango production but it can cause nitrate poisoning in the surrounding community, and is especially dangerous to infants, pregnant women (birth defects and miscarriages) and adults (stomach and esophageal cancers). In addition, the fungicide makes up the highest proportion of the total agro-inputs usage. The findings indicate that active ingredients of the paclobutrazol, mancozeb, probineb, ziram and carbenazim are high in Tuong-mango cultivation in southern Vietnam. Paclobutrazol and ziram are category II (moderately hazardous), and the mancozeb, probineb, carbendazim are in the list of category U (unlikely to present acute hazard when in regular use). Besides, the ecosystem EIQ triple the farmer EIQ, are fivefold the consumer EIQ for the seasons 1, 2, and 3. The field use EIQ average value of season 1 is the highest, followed by season 2, and season 3 is the lowest. For policy solution, stakeholder reference and policy dialogue should be discussed regularly before UA is carried out in cities. Sustainable progression of UA in cities require coordination between health, agriculture and environmental departments, education and training. Moreover, urban farmers need to be supported in technical advice, training, credit access, and collection economic development.
Keywords: Tuong-mango, peri-urban, agro-inputs, ecosystem.

1 INTRODUCTION

The concept of urban agriculture (UA) has become popular during decades recent. According to Mougeot [1], UA is agricultural production activities to take place intra-urban or peri-urban of a metropolis, a city, or a downtown. It is involved in activities of farming system, product process and delivery of food and non-food products to provide the commodities and services to residents in city. Overall, agricultural production in city is divide two main categories (urban agriculture and peri-urban agriculture). UA is conducted inside a city or a town with two levels. First, use of empty lands in city that is unappropriated for construction can be used for UA provisionally. Second, UA is carried out smaller scale level such as public gardens, garden houses, kindergartens, and roof gardening. Peri-urban agriculture is established in suburb or the vicinity of city. Farming area of farmers and agricultural companies in peri-urban are bigger than the farms intra-city and are market-oriented well [2].

The most outstanding feature of UA making it different from rural agriculture is its propinquity with city environmental and economic activities [1]. This has negative and positive influences on farm worker, consumer and environment in city [2]. It pays attention of academics, policymakers by both adverse and desirable effects. There is not any difficulty to understand why the role of UA is appreciated in sustainable development of academics, policymakers. Firstly, UA contributes to meet increasing demand of food and nutrition by

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growing city populations [3], [4]. Secondly, it is against several negative ecological and economic impacts of urbanization through income generation, organic waste reuse, green belts establishment, and landscape conservation [5], [6].

Although UA has a plethora of opportunities, it also has some challenges for sustainable development and cities management. Applying chemical agro-inputs in UA do harm to humans and ecosystem, especially is farm workers and the public health of neighboring communities. Initially, one noticeable damage of UA is environmental dangers. In detail, contamination of local water resources results in a part of agrochemical (fertilizers and pesticides) overuse; the excessive use of nitrate rich fertilizers can cause underground waters pollution. Subsequently, health dangers is mentioned as a potentially adverse aspect of UA. If UA relies heavily on agrochemical (fertilizers, herbicides, insecticides and fungicides) use, it will bring about contaminated river water and soil. This creates health problems for producer and consumer in city. They become vulnerable to contaminants by peri-urban agriculture. More specific, unsafety agricultural products with pathogenic organisms stem from polluted irrigation; Human diseases transferred from disease vectors by agricultural activities; pollution of agri-food and drinking water by agrochemical residues [7].

UA is one of the much discussed topics of researchers, policymakers, and practitioners during decades last. It is like sides of a coin, which runs parallel both positive and negative influence. Identifying its motivations and considering measures can help multiply benefits and mitigate risks. The study applies Environmental Impact Quotient (EIQ) model to give a measure of the ecosystem impact characterizing Tuong-mango production activities in the southern Vietnam where is considered Vietnam's main orchard. The model provides a better lens for analyzing health (human and ecosystem) issues related to UA. It focuses attention on impacting agrochemicals use on producer, consumer and ecosystem in Tuong-mango production in peri-urban area of the southern Vietnam. Beside, different policy perspectives is suggested for the sustainable development of intra- and peri-urban agriculture.

2 MATERIALS AND METHODS

2.1 Sampling techniques

Primary data in the study not only focuses on Tuong-mango cultivation but also is collected in peri-urban area of cities (Fig. 1). First of fall, members of research group discussed directly with agricultural extension workers in province and district levels to choose big mango villages near urban region. The result found out various areas such as Cho moi district next to Long Xuyen city (An Giang), Cao Lanh district next to Cao Lang city (Dong Thap), Cai Be district of Tien Giang province next to Vinh Long city (Vinh Long), Vung Liem district of Vinh Long province and Can Long district next to Tra Vinh city (Tra Vinh), Chau Thanh A of Hau Giang province next to Can Tho city, Xuan Loc district next to Long Khanh city (Dong Nai). Next, the paper carried out seven discussion groups (4 people per group) in seven Tuong-mango farming locals to design appropriate questionnaire. Finally, simple random technique was employed to collect 435 of sampling observations in the non-cooperative grower group (138, 158 and 139 for the seasons 1, 2 and 3, respectively), and 295 of sampling observations in the cooperative grower group (100, 90 and 105 for the seasons 1, 2 and 3, respectively) with the total 730 of sampling observations.

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Figure 1: Study area in southern Vietnam.

2.2 Environment impact quotient model

The environment impact quotient (EIQ) model was developed by Kovach et al. [8] at Cornell University to evaluate effects of pesticide on ecosystems. The model is as a helpful tool for measurements of ecological risk of agrochemical use [9] as well as suggest policy for sustainable farming towards human health and ecosystem protection [10], [11].

A list of 11 items (Table 1) is used for measurement of farmer, consumer and ecosystem EIQ. These items are classified into three levels (scores 1, 3 and 5). The EIQ model refers to agro-inputs impacts on three main group including farmer, consumer, and ecosystem. For example, the farmer (applicator and harvester), consumer (exposure and groundwater effects), and environment (fish, birds, bees, other beneficial insects).

The farmer EIQ (eqn (1)) is established by three indicators (long-term health effects, dermal toxicity (Rat LD50), soil residue half-life (TI/2)). The consumer EIQ (eqn (2)) is computed based on five indicators (long-term health effects, plant surface half-life, soil residue half-life (TI/2), mode of action, leaching potential). The EIQ of ecosystem (eqn (3)) is worked out from seven indicators (fish toxicity (96h LC50), surface runoff potential, bird toxicity (8 day LC50), plant surface half-life, soil residue half-life (TI/2), bee toxicity, beneficial arthropod toxicity). The total EIQ is the average of the three components, and it is calculated for each pesticide active ingredient (eqn (4)) (see Table 2).

The field use EIQ is calculated based on information on the dose, formulation or percentage of active ingredient and the frequency of application [12]. Total impacts of agrochemical usage in each season can be measured by summing up the product of individual field use EIQ. The equation is presented in eqn (5). In this study, the theory EIQ values are done from using Cornell University's online EIQ calculator in May 2020 [13].

Table 1: Definition for symbols and ratings for each toxicity category [8].

Variables	Symbol	Score 1	Score 3	Score 5
Long-term health effects (chronic)	c	Little–none	Possible	Definite
Dermal toxicity (Rat LD50)	dt	> 2,000 mg/kg	200–2,000 mg/kg	0–200 mg/kg
Bird toxicity (8 day LC50)	d	>1000 ppm	100–1,000 ppm	1–100 ppm
Bee toxicity	z	Non-toxic	Moderately toxic	Highly toxic
Beneficial arthropod toxicity	b	Low impact	Moderate	Severe impact
Fish toxicity (96h LC50)	f	>10 ppm	1–10 ppm	< 1 ppm
Plant surface half-life	s	1–2 weeks	2–4 weeks	> 4 weeks
Soil residue half-life (TI/2)	p	< 30 days	30–100 days	>100 days
Mode of action	sy	Non-system	Systemic	
Leaching potential	l	Small	Medium	Large
Surface runoff potential	r	Small	Medium	Large

Table 2: EIQ equation environmental components [8].

EIQ equation component	Equation
Farmer (applicator + harvester)	c×((dt×5) + (dt×p)) (1)
Consumer (exposure + groundwater effects)	(c×(s + p)/2×sy) + (l) (2)
Ecosystem (fish, birds, bees, other beneficial insects)	(f×r) + (d×(s+p)/2×3) + (z×p×3) + (b×p×5) (3)
Total EIQ = farmer + consumer + ecosystem {[c×(dt×5)+(dt×p)]+[(c×(s+p)/2×sy)+(l)+[(f×r)+(d×(s+p)/2×3)+(z×p×3)+(b×p×5)]}/3 (4)	
Field use EIQ = EIQ × % active ingredient × rate/ha (5)	

3 RESULTS AND DISCUSSION

3.1 The situation of synthesis fertilizer use in Tuong-mango production

Nowadays, synthesis fertilizer plays essential role in agricultural production, contributes to cropping productivity increase, and are sprayed directly on fields and orchards. These fertilizers do harm to human health and ecosystem. Research by Sobsey et al. [14] indicates that synthetic fertilizers overuse occur excess nutrients, which can enter waterways, aggravating algae progression, leading to harmful algal blooms more frequent. For instance, there were 169 toxic algal blooms in the United States in 2018 while there were only three cases in 2010 [15].

Table 3 shows consumption of chemical fertilizer (nitrogen, phosphorus, potassium) in Tuong-mango cultivation of the non-cooperative and cooperative farmer groups. Mango trees absorb nutrition from chemical fertilizer by manuring into root and on leaves. In general, the season 2 consumes fertilizer more than the seasons 1, and 3, and the non-cooperative farmers use fertilizer more than the cooperative farmers in the three seasons. More specific, chemical fertilizer for root, the number of fertilizer of the cooperative grower category in the second season is 1.58, and 1.35 times more than the first and third seasons. Similarly, these figures of the non-cooperative grower category is 1.12 and 1.20 times. For spraying chemical fertilizer on leaves for flowering stimulation, liquid fertilizer use of the non-cooperative grower category in the season 2 is 1.08 and 1.19 times higher than in the seasons 1 and 3. In the cooperative grower category, liquid fertilizer consumption in the season 2 is 1.4 times higher than in the season 3, but it is lower than in the season 1 about 0.91 time.

Table 3: The number of chemical fertilizer in Tuong-mango production. *(Source: Field Survey Data, 2018.)*

Items	**Season 1**			**Season 2**			**Season 3**		
	Non-coop (n=138)	**Coop (n=100)**	*T-test*	**Non-coop (n=158)**	**Coop (n=90)**	*T-test*	**Non-coop (n=139)**	**Coop (n=105)**	*T-test*
Root fertilizer									
N: nitrogen (kg/ha)	285.1	209.2	*	305.4	185.2	**	250.5	154.3	**
P: phosphorus (kg/ha)	177.5	142.2	ns	208.3	122.4	***	166.8	117.0	ns
K: potassium (kg/ha)	194.6	163.2	ns	224.0	176.1	ns	196.6	88.2	**
Microelements (gr/ha)	0.0	0.1	ns	0.0	1.0	ns	0.6	1.2	*
Leaf fertilizer (liquid) for flowering stimulation									
N: nitrogen (kg/ha)	5.8	5.5	ns	7.6	5.0	ns	6.1	3.2	***
P: phosphorus (kg/ha)	4.0	1.4	*	3.4	1.0	*	3.6	0.5	**
K: potassium (kg/ha)	11.6	10.5	ns	12.2	9.8	ns	9.8	7.5	ns
Microelements (gr/ha)	76.8	49.5	ns	150.7	62.8	**	197.6	41.4	*

* Significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level, ns: non-significant.

For the root fertilizer consumption, the total root fertilizer (N, P, K) of the non-cooperative farmer group is 657.2 kg/ha greater than 2.15 times that of the cooperative farmer group (305.4 kg/ha) in the season 1. In the season 2, this number of the non-cooperative farmer group (737.7 kg/ha) is one and half times compared with the cooperative farmer group (483.7kg/ha). In the season 3, consumption of the root fertilizer of the non-cooperative and cooperative grower groups are 613.9 kg/ha, and 359.5 kg/ha (more than 1.71 times). For the leaf fertilizer usage, the number of liquid fertilizer of the non-cooperative growers are higher than 1.23; 1.47, and 1.74 times that of the cooperative growers for the seasons 1, 2, and 3 respectively. The findings show that the number of applied synthesis fertilizer in Tuong-mango cultivation is relatively high compared to the result of [16] (624.8 kg/ha in Egypt, 301.5 kg/ha in China, 121.4 kg/ha in India, and 106.9 kg/ha in Indonesia). Moreover, nitrogen fertilizer plays essential role in agricultural production in general and mango farming in particular. In Tuong-mango production, used nitrogen fertilizer volume (root fertilizer) of the non-cooperative growers are 1.36, 1.65, and 1.62 times compared with that of the cooperative growers for the seasons 1, 2 and 3, respectively. These numbers of leaf fertilizer are 1.05, 1.52, and 1.91 for the seasons 1, 2, and 3 respectively.

The result of study shows that fertilizer consumption in Tuong-mango cultivation of the non-cooperative farmers are greater than the cooperative farmers, especially is nitrogen fertilizer. Its misuse leads to air pollution by nitrogen oxides (NO, N2O, NO2) emissions. Importantly, nitrate fertilizer can get into the waterways like groundwater and surface runoff to take nitrate poisoning for surrounding community, especially is dangerous to infants, pregnant women (birth defects and miscarriages) and adults (stomach and esophageal cancers) [17]. In short, city that is dense population area is sensitive with impacts around. Hence, agro-inputs of UA need to manage strictly to ensure minimum negative influences in citizens and ecosystem in urban. By contrast, it can occur negative impacts on human health (farm worker, consumer) and ecosystem (soil, water, air, terrestrial and aquatic ecosystems).

3.2 Human health and ecology impacts in Chu-mango production

Based on the classification of the World Health Organization (WHO) [18], agrochemicals usage in Tuong-mango production in the southern Vietnam, none are classified in category Ia (extremely hazardous). Category Ib (highly hazardous) is the abamectin, category II (moderately hazardous) comprises: the paclobutrazol, papraquat, 2,4 D, cypermethrin, chlorpyrifos, emamectin, imidacloprid, permethrin, ziram, difenoconazole, tebuconazole. Glyphosate and metaxyl are the list of category III (slightly hazardous), and mancozeb, probineb, carbendazim, azoxystrobin and trifloxystrobin are in category U (unlikely to present acute hazard when in regular use).

The result in Table 4 compares agrochemicals EIQ between the non-cooperative and cooperative farmer groups in the season 1. The field use EIQ average value of the non-cooperative and cooperative farmer groups are insignificant disparity approximately 59.8 kg/ha, in which fungicide EIQ of the cooperative farmer group is 107 kg/ha more than that of the non-cooperative farmer group. On the other hand, paclobutrazol, herbicide, and insecticide EIQ of the cooperative farm group is less than those of the non-cooperative farmer group. The four active ingredients are used the most regularly in Tuong-mango cultivation including: paclobutrazol, mancozeb, propiconazole, and ziram, with remarkable proportion of these components making up about 86.4% for the non-cooperative farmers, and 90.9% for the cooperative farmers in total of agrochemicals usage.

Table 5 compares the pesticides EIQ in the season 2 of the non-cooperative and cooperative grower groups. Overall, there is no significant difference in both farmer groups. In detail, the field use EIQ average value of the non-cooperative grower group is 1,028.59 kg/ha, higher than approximately 15.32 kg/ha compared with the cooperative grower group. The consumer and ecosystem EIQ of the non-cooperative growers are more than those of the cooperative growers approximately 50.87 and 31.45 kg/ha. By contrast, the farmer EIQ of the non-cooperative grower group is 36.41 kg/ha lower than that of the cooperative grower group. Furthermore, the study indicates the greatest proportion of agrochemicals is consumed by fungicide, at 57.9% for non-cooperative farmers and 48.1% for cooperative farmers. Less than, namely 33.8% and 45.9% for non-cooperative and cooperative farmers, is found out from paclobutrazol. The insecticide makes up 6.5% and 4.1% of agrochemicals usage for non-cooperative and cooperative farmer groups, leaving herbicide at only 1.7 and 1.9 for non-cooperative and cooperative farmer groups.

There is a considerable disparity in the field use EIQ between the non-cooperative grower and the cooperative grower categories (Table 6). Specifically, the farmer, consumer and ecosystem EIQ of the non-cooperative growers are 1.20, 1.55, and 1.37 times, respectively, more than those of the cooperative growers. Additionally, the field use EIQ average value of

Table 4: The practical values of the health and ecosystems impacts (EIQ) in the season 1. (Unit: kg/ha.) *(Source: Field Survey Data, 2018.)*

Active ingredient	EIQ component value						Average EIQ value	
	Farmer		Consumer		Ecosystem			
	Non-coop	*Coop*	*Non-coop*	*Coop*	*Non-coop*	*Coop*	*Non-coop*	*Coop*
(1) Paclobutrazol	**549.55**	**534.13**	**168.99**	**164.25**	**1,327.43**	**1,290.18**	**681.90**	**662.77**
(2) Herbicide	**18.55**	**11.57**	**5.00**	**3.21**	**33.67**	**27.59**	**19.07**	**14.12**
Glyphosate	3.56	4.41	1.33	1.65	15.57	19.30	6.82	8.45
Paraquat	7.62	5.70	1.51	1.13	8.57	6.41	5.90	4.41
2.4-D	7.37	1.46	2.15	0.43	9.52	1.89	6.35	1.26
(3) Insecticide	**18.95**	**12.45**	**8.71**	**6.25**	**163.71**	**101.74**	**63.79**	**40.14**
Cypermethrin	7.70	4.91	3.29	2.10	49.87	31.80	20.29	12.94
Chlorpyrifos	5.40	1.91	1.80	0.64	65.28	23.15	24.16	8.57
Emamectin	3.48	2.84	1.55	1.26	25.45	20.75	10.16	8.28
Abamectin	1.22	1.53	0.35	0.43	7.65	9.55	3.07	3.84
Imidacloprid	1.15	1.20	1.72	1.80	15.46	16.13	6.11	6.38
Permethrin	0.00	0.06	0.00	0.03	0.00	0.36	0.00	0.15
(4) Fungicide	**247.27**	**316.25**	**196.99**	**241.00**	**791.08**	**1,000.60**	**411.75**	**519.24**
Mancozeb	107.82	145.74	43.29	58.51	259.78	351.14	136.94	185.11
Propiconazole	54.02	76.70	85.53	121.44	287.65	408.41	142.38	202.16
Ziram	53.31	69.87	19.99	26.20	94.29	123.58	55.86	73.21
Carbendazim	12.99	5.52	21.04	8.94	44.69	18.98	26.24	11.15
Difenoconazole	9.75	7.86	15.27	12.31	55.89	45.04	26.97	21.74
Tebuconazole	5.51	6.72	8.54	10.42	19.29	23.52	11.11	13.55
Azoxystrobin	3.21	3.34	2.40	2.49	26.42	27.44	10.68	11.09
Metalaxyl	0.57	0.40	0.85	0.60	2.58	1.82	1.33	0.94
Trifloxystrobin	0.09	0.12	0.08	0.10	0.50	0.67	0.22	0.30
Field use EIQ	**834.32**	**874.40**	**379.69**	**414.72**	**2,315.89**	**2,420.11**	**1,176.51**	**1,236.27**

Table 5: The practical values of the health and ecology impacts (EIQ) in the season 2. (Unit: kg/ha.) *(Source: Field Survey Data, 2018.)*

Active ingredient	**EIQ component value**						**EIQ average value**	
	Farmer		**Consumer**		**Ecosystem**			
	Non-coop	*Coop*	*Non-coop*	*Coop*	*Non-coop*	*Coop*	*Non-coop*	*Coop*
(1) Paclobutrazol	**280.34**	**374.56**	**86.21**	**115.18**	**677.15**	**904.75**	**347.86**	**464.77**
(2) Herbicide	**13.06**	**11.10**	**3.87**	**3.87**	**35.48**	**42.13**	**17.47**	**19.03**
Glyphosate	6.30	9.09	2.36	3.41	27.58	39.75	12.08	17.41
Paraquat	4.97	1.32	0.99	0.26	5.59	1.49	3.85	1.03
2.4-D	1.78	0.69	0.52	0.20	2.30	0.89	1.53	0.59
(3) Insecticide	**19.52**	**13.02**	**10.44**	**6.23**	**172.02**	**106.19**	**67.32**	**41.81**
Cypermethrin	6.26	5.57	2.68	2.38	40.54	36.04	16.49	14.66
Chlorpyrifos	4.38	2.34	1.46	0.78	52.98	28.29	19.61	10.47
Emamectin	4.85	2.55	2.15	1.13	35.46	18.65	14.15	7.44
Abamectin	1.56	1.57	0.44	0.44	9.78	9.82	3.93	3.95
Imidacloprid	2.47	1.00	3.71	1.49	33.25	13.39	13.14	5.29
Permethrin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(4) Fungicide	**351.71**	**302.35**	**295.80**	**220.17**	**1,140.45**	**940.57**	**595.94**	**487.65**
Mancozeb	140.41	159.91	56.37	64.20	338.30	385.28	178.34	203.10
Propiconazole	83.98	71.19	132.98	112.72	447.22	379.08	221.37	187.64
Ziram	76.76	56.15	28.79	21.06	135.77	99.32	80.44	58.84
Carbendazim	27.93	2.58	45.24	4.18	96.07	8.87	56.42	5.21
Difenoconazole	12.03	6.78	18.85	10.62	68.97	38.87	33.28	18.75
Tebuconazole	5.88	3.19	9.11	4.95	20.57	11.18	11.85	6.44
Azoxystrobin	3.22	1.68	2.40	1.26	26.44	13.83	10.69	5.59
Metalaxyl	1.22	0.69	1.83	1.04	5.58	3.15	2.88	1.63
Trifloxystrobin	0.28	0.18	0.23	0.15	1.53	0.99	0.68	0.44
Field use EIQ	**664.63**	**701.04**	**396.32**	**345.45**	**2,025.10**	**1,993.65**	**1,028.59**	**1,013.27**

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Table 6: The practical values of the health and ecology impacts (EIQ) in the season 3. (Unit: kg/ha.) *(Source: Field Survey Data, 2018.)*

Active ingredient	EIQ component value						EIQ average value	
	Farmer		Consumer		Ecosystem			
	Non-coop	*Coop*	*Non-coop*	*Coop*	*Non-coop*	*Coop*	*Non-coop*	*Coop*
(1) Paclobutrazol	**137.91**	**136.27**	**42.41**	**41.90**	**333.13**	**329.16**	**171.13**	**169.09**
(2) Herbicide	**12.64**	**9.05**	**3.72**	**2.95**	**29.17**	**30.64**	**15.18**	**14.21**
Glyphosate	4.36	6.27	1.63	2.35	19.06	27.44	8.35	12.02
Paraquat	3.50	2.27	0.69	0.45	3.94	2.56	2.71	1.76
2.4-D	4.78	0.50	1.39	0.15	6.17	0.65	4.11	0.43
(3) Insecticide	**17.62**	**8.94**	**8.72**	**4.32**	**150.96**	**78.39**	**59.10**	**30.55**
Cypermethrin	5.34	2.04	2.28	0.87	34.56	13.20	14.06	5.37
Chlorpyrifos	3.88	2.32	1.29	0.77	46.92	28.10	17.36	10.40
Emamectin	4.85	2.69	2.16	1.19	35.51	19.65	14.17	7.84
Abamectin	1.92	1.12	0.54	0.32	12.01	7.00	4.82	2.81
Imidacloprid	1.63	0.78	2.45	1.16	21.97	10.45	8.68	4.13
Permethrin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(4) Fungicide	**346.86**	**273.80**	**307.02**	**184.57**	**1,160.66**	**786.84**	**604.79**	**415.04**
Mancozeb	135.94	126.31	54.58	50.71	327.53	304.33	172.66	160.43
Propiconazole	91.57	51.74	144.98	81.93	487.60	275.54	241.36	136.39
Ziram	65.55	81.55	24.58	30.58	115.94	144.24	68.69	85.46
Carbendazim	32.10	4.10	52.01	6.65	110.43	14.12	64.85	8.29
Difenoconazole	11.38	3.34	17.82	5.23	65.22	19.12	31.47	9.23
Tebuconazole	5.86	5.22	9.08	8.09	20.50	18.27	11.81	10.52
Azoxystrobin	3.55	1.12	2.65	0.84	29.16	9.21	11.78	3.72
Metalaxyl	0.83	0.30	1.25	0.45	3.79	1.37	1.95	0.70
Trifloxystrobin	0.09	0.12	0.07	0.10	0.49	0.64	0.22	0.29
Field use EIQ	**515.03**	**428.06**	**361.87**	**233.74**	**1,673.92**	**1,225.04**	**850.20**	**628.89**

the non-cooperative grower category (850.20 kg/ha) is 1.35 times compared to the cooperative grower category (628.89 kg/ha). Noticeably, the fungicide occupies the highest percentage of the total agrochemical usage, at 71.1% and 66.0% for the non-cooperative and cooperative grower groups, while the opposite is true of the herbicide (1.8% and 2.3% for the non-cooperative and cooperative growers). Paclobutrazol ranks second in terms of popularity, at 20.1% and 26.9%, follows by insecticide with 7.0% and 4.9% for the non-cooperative and cooperative grower groups. In particular, the active ingredients of the paclobutrazol, mancozeb, probineb, ziram and carbenazim are applied popular in Tuong-mango farming, which account for approximately 84.5% and 89% of the total pesticide use for the non-cooperative and cooperative grower groups. Therefore, farmers can reduce agrochemicals use in Tuong-mango production, thereby controlling these active ingredients efficiently in their farming process.

It is noticeable that the EIQ of ecosystem is the highest in all three EIQ components (farmer, consumer and ecosystem) in the three seasons. It means ecosystem is undergone heavily by impacting negative agro-inputs. For example, the ecosystem EIQ triple the farmer EIQ, are fivefold the consumer EIQ for seasons 1, 2, and 3. The field use EIQ average value of the season 1 is the highest, next is the season 2, and the season 3 is the lowest.

Although pesticides (herbicide, insecticide, fungicide) can help grower control harmful organisms efficiently in farming, its negative impacts should be not ignored by health complications (especially children and pregnant women), comprising neural and hormonal chaos, congenital malformation, cancer and other diseases [19], [20]. Besides, farmers are susceptible to disease related to nausea, dizziness, and cancer because they are regular exposure to various agrochemicals from farming and harvesting process [21], [22].

Different from rural agriculture production, UA is a complex interaction between various ecosystems (farmer, consumer, ecology) in urban. Its policy and action planning involve multi-stakeholders and several sectors such as irrigation, food security and nutrition conditions, agricultural research and economic forces. Stakeholder references and policy dialogue should be discussed regularly before UA is carried out in cities. This paves the way for municipal authorities to have properly action planning and how to address the real needs of community members. It is an important pre-condition for its contribution to urban sustainable development. Hence, understanding both positive and negative influences of UA could encourage countries to have suitable strategies in UA development, especially is in the developing country's cities where little is known about urban and peri-urban agriculture as well how to develop UA in city sustainably. For instance, sustainable progression of UA in city requires coordination between health, agriculture and environmental departments, education and training. Moreover, farmers in urban need be supported technical advice, training, credit access, and collection economics development. The study shows that collective economics contributes importantly to fertilizer and pesticide control in fruit cultivation.

4 CONCLUSIONS

The number of chemical fertilizer is applied in Tuong-mango farming of the non-cooperative farmer group more than the cooperative farmer group, in which nitrogen fertilizer play important role in mango production. However, the nitrogen fertilizer can take nitrate poisoning for surrounding community, especially is dangerous to infants, pregnant women (birth defects and miscarriages) and adults (stomach and esophageal cancers).

For agro-inputs, there is not significant disparity of the field use EIQ between the non-cooperative farmer group and the non-cooperative farmer group for the seasons 1 and 2; however, there is a considerable difference in the field use EIQ of the non-cooperative and cooperative grower categories. Particularly, the fungicide makes up the highest proportion of the total agro-inputs usage. The result of study indicates that the active ingredients of the paclobutrazol, mancozeb, probineb, ziram and carbenazim are applied popular in Tuong-mango cultivation in the southern Vietnam. Paclobutrazol and ziram are category II (moderately hazardous), and mancozeb, probineb, carbendazim are the list of category U (unlikely to present acute hazard when in regular use).

Importantly, the study shows that collective economics should be encourage to develop in UA because it allows producers to manage agrochemicals better.

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URBAN AGRICULTURE AS A SUSTAINABLE OPTION FOR SOLID WASTE MANAGEMENT: CASE STUDY OF AN INDIAN CITY

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ABSTRACT
The rapid growth of India's urban population coupled with food security concerns has driven urban agriculture into Indian cities. It is also commonly known that urban local bodies are struggling with the ever-increasing municipal solid waste, and in managing its segregation, transportation, and treatment. Inadequate organic waste management causes a slew of issues like gas emissions and health risks to the community. Since household wet wastes are full of nutrient-rich organic matter favorable for growing plants, urban agriculture provides an excellent opportunity of bridging the gap by reimagining waste as a resource. This study is based on the premise that decentralized urban waste management can be achieved through reusing and recycling organic waste that can benefit urban food production. It has conducted a qualitative and quantitative assessment of the organic waste usage in urban agriculture in the Indian city of Mumbai, Maharashtra. This paper presents the results of the study and examines the existing and potential capacity of urban agriculture in consuming organic urban waste in Mumbai's context. This case study also helps in visualizing circular economy against a real-life urban scenario and how the production–consumption loop may gainfully sustain each other. Based on the learning, the paper recommends mainstreaming urban agriculture into the sustainable city framework.
Keywords: compost, organic waste, recycling, solid waste management, urban agriculture.

1 INTRODUCTION

Urban populations are growing rapidly worldwide [1], [2], adding a strain on existing waste collection and disposal infrastructure [3], [4]. Research has shown that billions of tons of waste are produced annually by municipalities and industries the world over [5]. In India, no city can claim to have 100% trash segregation at the household level, and on average, only 70% of waste is collected, with the remaining 30% gets absorbed by the urban system. Again, just 12.45% of the garbage collected is scientifically processed, while the rest is dumped in open landfills [6]. In India, 90% of municipal solid waste (MSW) produced is disposed of in landfills and/or open dumps [7]. Furthermore, unscientific and conventional waste disposal practices such as open dumping and burning not only pollute the environment and degrade the city landscape but also hinder long-term, environmentally responsible waste management [8]. In addition to endangering the environment's quality (land, air, and water pollution) and community health, landfills also result in the depletion of nutrients contained in the waste, which is a financial loss [9], [10]. Landfills may also trigger fire hazards, as had happened in the Deonar landfill, the 132-hectare largest garbage dump in Mumbai receiving around 4,000–5,000 tonnes of waste/day. It had caught a severe fire in January 2016 that lasted for more than four days [11].

Environmental experts and activists began to criticize waste management practices in the mid-1970s. As a more effective management system, a waste management hierarchy was devised [12], [13]. This is indicated in Fig. 1 and can be described as "all actions taken to reduce the negative environmental impact of waste by reusing, recycling, and recovering resources before final disposal" [14].

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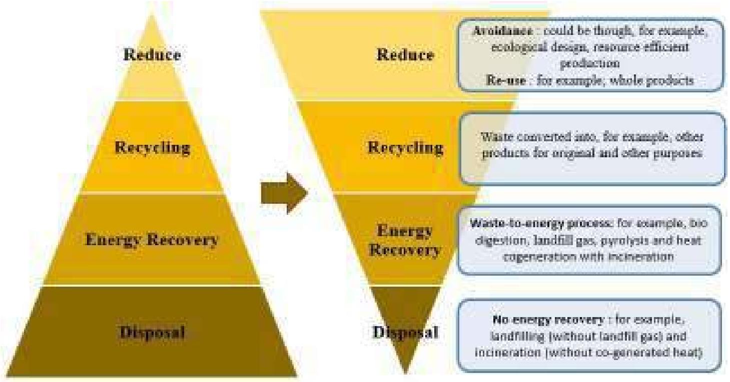

Figure 1: Effective hierarchy of waste management model [14].

By reversing the behaviours at the top and bottom of the hierarchy of waste management, those at the top (reduce, reuse, recycle) are given priority [15], [16]. The main idea is that preventing waste is more efficient than reusing, which is better than recycling, and recycling, in turn, is better than incineration or landfilling [12], [14]. Thus, urban agriculture offers opportunities for using recycled organic waste to power local food production. By utilizing nutrients from composted waste, it has the potential to help cities close the production–consumption loop and transition from “plate-to-landfill” to “plate-to-plate” practices.

The current study is based on this very idea of reusing organic waste after source segregation and recycling it for urban agriculture (UA) in the Indian city of Mumbai, Maharashtra. The objectives of the study are to understand the solid waste management practices of the residential communities that reuse their kitchen waste in their own kitchen gardens, assess the annual quantities at the different stages of the waste-to-compost process, and finally, examine the potential capacities of urban agriculture in consuming organic urban waste based on these results.

2 LITERATURE STUDY

The literary and scholarly works of organic waste management integration with UA in India and other countries were studied to understand its various dimensions. Studies on Mumbai city were taken up first. The generation of MSW in Mumbai is very high, which is about 7,000 metric tonnes per day [17]. In India, about 40–60% of MSW in urban areas consists of compostable organic materials [7], [18]. It was estimated that Mumbai generates 62% of organic waste, the largest volume of urban organic waste in India [19]. Composting is an easy and cost-effective technology for treating the large organic fraction of MSW produced in Indian cities, due to the high proportion of biodegradable, organic waste generated [18], [20]. By conducting proper composting after suitable segregation, the final waste volumes are stated to be reduced by 50–85% [7]. Thus, appropriate composting will minimize the load for collection and transportation, as well as the burden on landfills [7], [19]. Integration of waste management with UA can be seen as one of the most environment-friendly and sustainable alternatives to conventional waste disposal and energy recovery methods [21]. MSW usually contains a high amount of organic material and nutrients that can be used as a fertilizer in urban agriculture. Rooftops, backyards, pot culture, and any small parcel of open spaces can be used for food production [22]. UA can also ensure a resilient urban food system as dependence on external imports can be reduced during exigencies. This is exemplified during World War II in the United States when families planted Victory Gardens producing 55 kg of fruit and vegetables annually [23]. Similarly, after the fall of the Soviet Union in Cuba, the government set a goal of cultivating 10 m^2 of urban land for every resident to address the public health issues. The country achieved sufficiency in food production by 2,000 with the urban farms providing up to 50% of caloric intake, thus reducing fuel consumption for food distribution and refrigeration [24]. It is compatible with green energy harvesting from organic waste and can also give other benefits to the circular economy (as indicated in Fig. 2), including job opportunities [25].

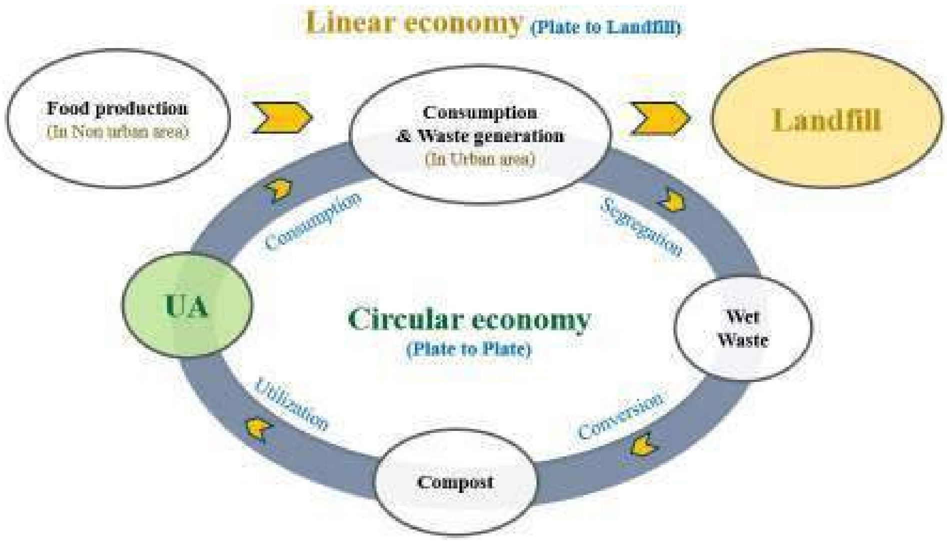

Figure 2: Circular economy with solid waste management along with UA.

Since India is an agrarian nation, UA had long been a household tradition that began with the management of kitchen food waste, but it slowly got lost in the current patterns of urbanization. Some of the UA initiatives that have succeeded in Mumbai are the International Institute of City Farming founded by Dr. Doshi in 1994, Urban leaves, Green souls, Fresh and local, *Swachha Parle Abhiyan*, and others [26]. Studies have argued in favour of local bylaws for the regulation and evaluation of conforming measures, such as source separation of garbage or penalties for public dumping, to promote "best practices" in waste management. Compost being an agricultural input, the Ministry of Food and Agriculture may prepare quality standards, marketing plans, and relevant policies. Linking urban and peri-urban agriculture to urban management through the composting of urban trash can improve the urban environment while also providing a beneficial product for farmers [27]. It is also believed that the installation of decentralized solid waste processing units in metropolitan cities/towns and the development of the formal recycling manufacturing industry are essential in developing countries like India [28].

3 MATERIALS AND METHODS

The literature review was followed by the preparation of a theoretical framework for the study with the relevant qualitative and quantitative aspects of waste management and UA. Each of these is further classified into sub-aspects. The aspect of resources is quantitative.

The framework is presented in Table 1. The specific case studies in Mumbai were then identified. The data collected was processed and collated thereafter for scientific reporting, as presented in this paper.

Table 1: Theoretical framework of the study.

Aspects	Sub-aspects
A. Qualitative	
Segregation of solid wastes	a. Wet/Biodegradable/Organic waste
	b. Dry/Non-biodegradable waste
	c. Domestic hazard waste
Conversion of organic kitchen waste into compost	a. Aerobic composting
	b. Vermicomposting
	c. Anaerobic composting (Bokashi)
	d. Anaerobic digester
The utilization of this compost in UA in the same premises	a. Within premises – Rooftop
	b. Within premises – Balcony/window sill
	c. Within premises – Campus landscapes
	d. Community gardens
B. Quantitative	
Resources: Quantitative measures of the above	Average annual organic waste generated (tonnes/year)
	Average annual compost produced (tonnes/year)
	Average annual compost utilized (tonnes/year) in Rooftop farming

3.1 Selection of case studies

Mumbai is the state capital of Maharashtra, one of the megacities of India and the financial capital of the country. It is well connected, well developed, and densely populated. A total of 22 case studies covering 21 co-operative housing societies and one community farm were studied at Vile Parle-East, Ward-KE (sub-divisions 84 and 85) of Brihanmumbai Municipal Corporation (BMC), Mumbai. The population density of the ward is between 26,518–54,296 persons/km^2 [29], [30]. The coming into force of the solid waste management rules in 2016 along with the implementation of the Mumbai Municipal Corporation (MMC) Act, 1888 and Greater Mumbai Cleanliness and Sanitation Bye-laws, 2006 [31]–[33] has resulted in a marked improvement of waste management in the city of Mumbai. The combination of strict penalties and generous rewards of rebates in property taxes has brought the change. The ward KE was chosen as the majority of its housing societies have implemented “good practices” very successfully with the help of an organization named “*Swachha Parle Abhiyan*”, a community farm that has trained and inspired many people of the neighborhood to compost their organic waste and utilize it for UA. They have been widely recognized and rewarded by the Municipal Corporation and other public forums for setting an excellent example of closing the material cycling loop by completing the entire process of waste segregation, composting organic waste, and utilizing the same for growing vegetables in the same premises. The 21 housing societies house 1,328 families, out of which 1,177 (about 89%) households practice waste segregation. The waste management practices of these 1,177 households spread over these 21 co-operative housing societies (CHS) were surveyed. These case studies are named CHS 1, CHS 2, and so on, till CHS 21, and their locations are marked in the ward map in Fig. 3.

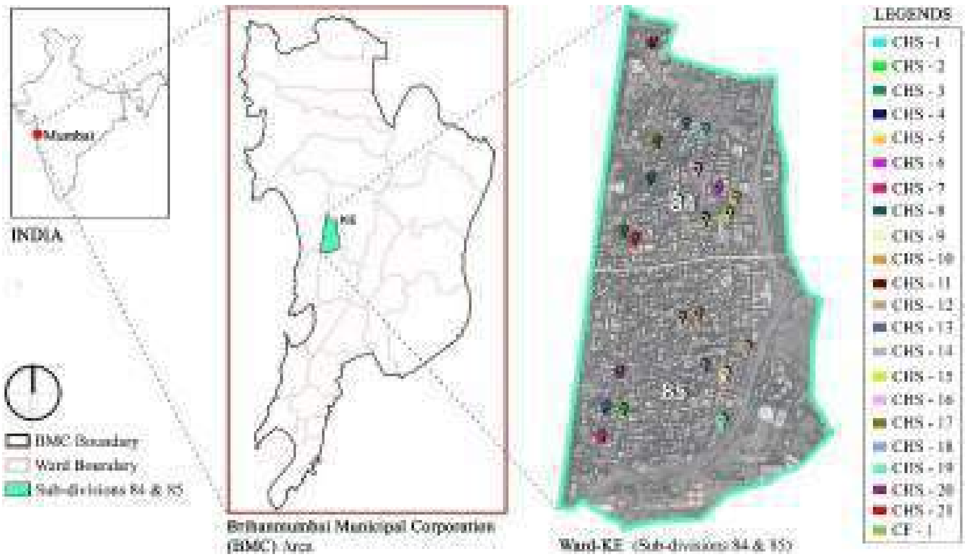

Figure 3: Map showing the locations of the case studies in the KE Ward, Mumbai.

3.2 Methods of data collection

A detailed field survey through an in-depth interview with the key informants, where applicable, was conducted from January to March 2021. The open-ended questionnaire was designed based on the theoretical framework. The interviews focussed on their organic waste management practices, the challenges faced and the benefits obtained by integrating their organic kitchen waste with urban agriculture in a decentralized manner. The relationships between segregation–conversion–utilization of organic kitchen waste and urban agriculture as observed in the case studies are expressed in Fig. 4.

Figure 4: A conceptual system of solid waste management along with UA.

Primary data was also collected through field observations, photo documentation, and informal discussions. Important information was obtained on methods for conversion of segregated organic waste (composting, vermicomposting, and anaerobic digester), innovative techniques applied in the converted compost in UA. The interviewees were members of the

1,177 households within the housing societies who were practicing some form of organic waste management with urban agriculture at the time of the study. Other informants consisted of solid waste management (SWM) experts, environmental engineers, architects, staff of the cleaning and solid waste department, and UA practitioners.

4 RESULTS AND DISCUSSIONS

All data collected on the case studies are arranged in two sections: (i) qualitative and (ii) quantitative. The quantitative section further presents a projection of five potential benefits that can be accrued from urban agriculture practiced in the form of rooftop farming. This is based on the amounts of organic waste obtained through the survey.

4.1 Qualitative findings

The qualitative findings have been organized under the previously mentioned three aspects of SWM: (a) segregation of solid waste; (b) conversion of organic waste into compost; and (c) utilization of compost for farming. Remarks and observations are written against each aspect.

4.1.1 Overall segregation, conversion, and utilization scenario in the case studies

All the case studies are following the three stages of SWM i.e. segregating the wet waste, converting it into compost, and utilizing it on the same premises, although partial in some cases. It is also found that 86% of the case studies (18) are utilizing their compost within their housing premises. This is depicted in Fig. 5.

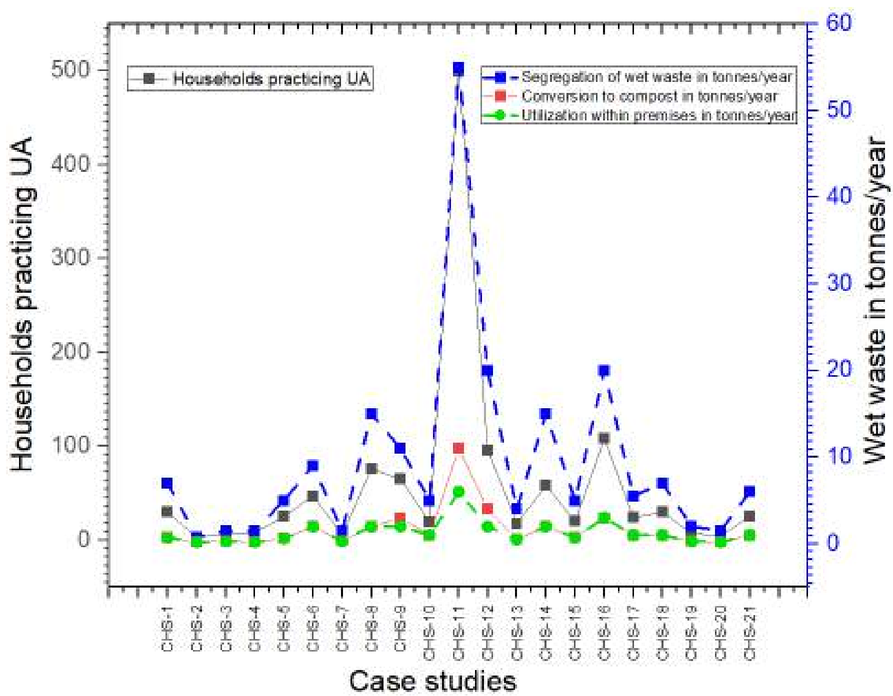

Figure 5: Number of households in the case studies who practice UA with segregation, conversion, and utilization.

4.1.2 Conversion of organic waste to compost scenario

As shown in Fig. 6, 81.05% (15) are using the aerobic method, 11.81% (4) using vermicomposting and only 7.14% (2) are using anaerobic (Bokashi) methods for composting.

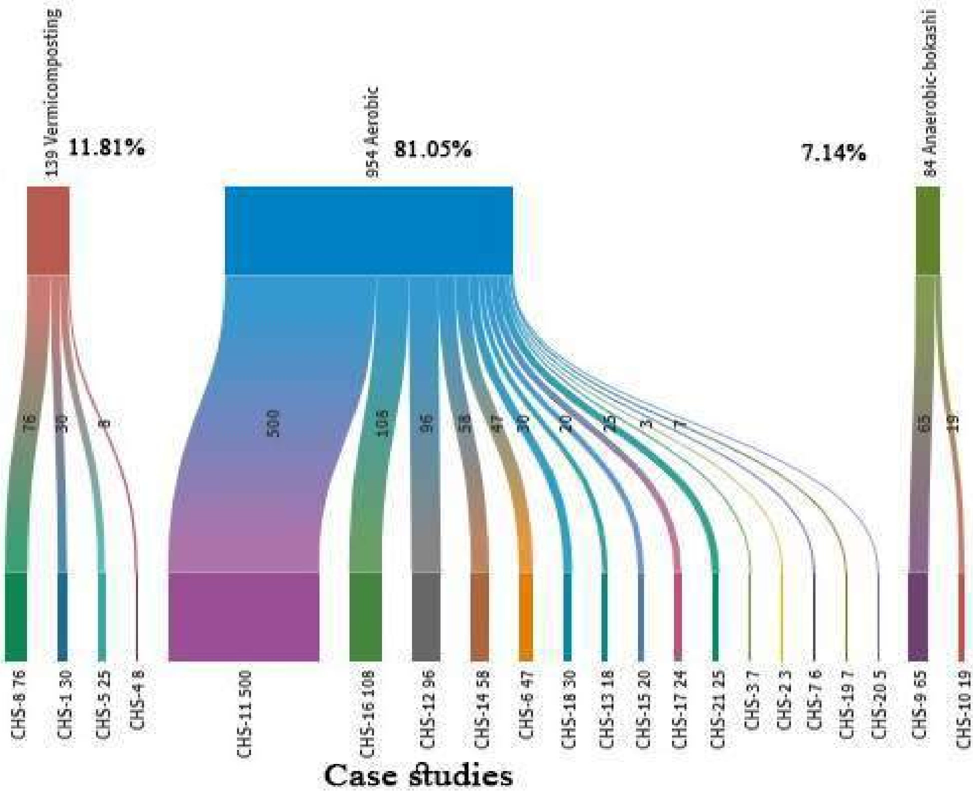

Figure 6: Percentage breakup of the conversion of segregated wet waste into compost.

4.1.3 Utilization of the compost in UA through the roof, balcony, and community gardens

At the utilization stage, it is found that only 38% of the case studies (8) are utilizing the compost for rooftop farming (RTF) and the remaining 62% (13) are using their compost for their balcony plant pots or campus landscapes, and as mentioned earlier, 14% (3) are utilizing the compost for the community gardens. This is indicated in Fig. 7.

4.2 Quantitative findings

The quantitative study looked into the average annual wet waste usage pattern for the 1,177 households within the 21 housing societies:

a. Average annual organic waste generated = 198 tonnes/year.
b. Average annual compost produced = 35 tonnes/year.
c. Average annual compost utilized for rooftop farming = 7 tonnes/year (on cultivating area of 280 m^2).

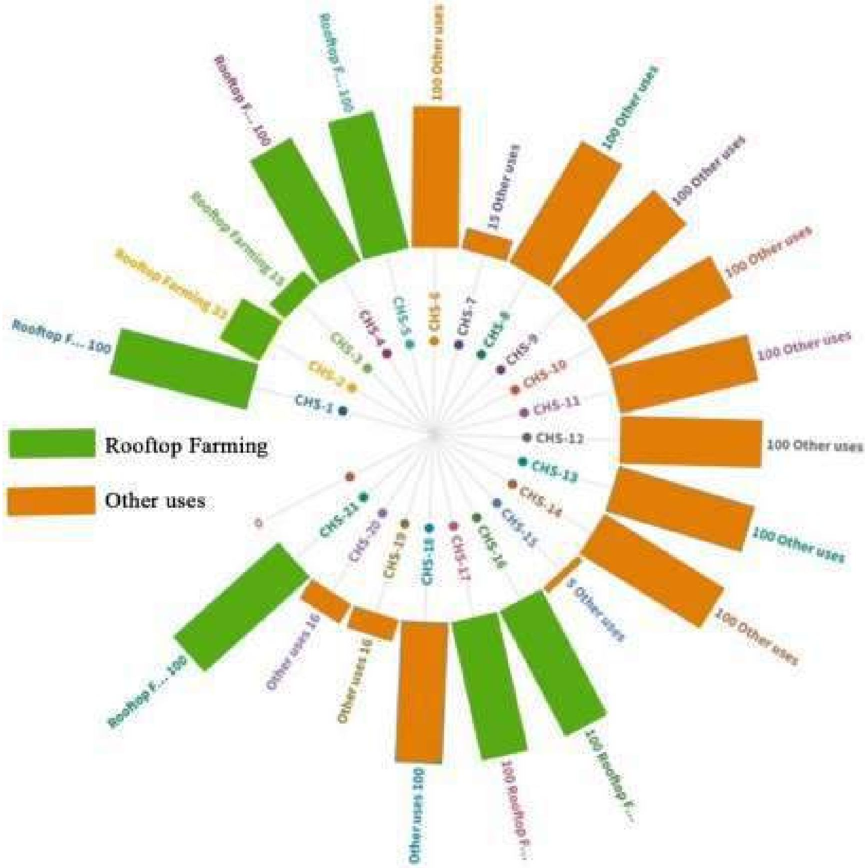

Figure 7: Percentage breakup of the utilization of compost in UA.

4.2.1 Proposed model with the projection of potential benefits through rooftop farming

1. Based on the above survey findings of the 1,177 households, a typical seven-story building with a similar number of households is assumed in the same municipal ward of Mumbai. Considering 50 m^2 of floor area per household and 168 households/floor, the rooftop area works out as 8,400 m^2. It was further assumed that 40% of this rooftop would be designated for social purposes and the remaining 60% or 5,040 m^2 would be used for rooftop farming (RTF). Again, 80% of this RTF area would be used for actual farming i.e. 4,032 m^2 is the net cultivable area.
2. In absence of any published work on the valuation of RTF benefits in India, the methodologies and standard values for their estimation are derived from a Canadian study [34]. The five-point potential benefits of RTF based on this study are: property value increase, food production, stormwater retention, air quality improvement, and carbon sequestration. All the values are calculated in Indian currency (where 1 \$ = Rs. 74.35/-, based on the rate of 30 August 2021). The details of the calculation of such benefits for the assumed seven-story building with net cultivable area of 4,032 m^2 are as follows.

4.2.1.1 Property value, $b_1 = 0.07 \times v$
In this formula, "b_1" denotes the value of the benefit and "v" presents the value of the RTF host property.

As RTF enhances the worth of a property as well as the marketability of surrounding properties, it favors both the owner and the environment. The property worth of a building with a green roof rises by 7% if it is efficient and by 11% if it is recreational. This is substantial considering the rising real estate values of the area.
$b_1 = 0.07 \times v$ (per m^2 of carpet area) $\times$ 4,032 m^2 = 0.07 × 4,707.46 \$/m^2 × 4,032 m^2 = 1,328,633.51 \$ (Rs. 98,783,901/-)

4.2.1.2 Food production value, $b_2 = P \times g \times a$
In this formula, P = productivity (\$2 per m2 per month and for lettuces, herbs, and flowers (high case scenario) \$20 per m^2 per month), g = duration of growing; as crops were grown all the year so it is taken as 12 months and a = roof area covered by farming.

As in Indian cities, crops are grown all over the year and the RTF mostly produces both vegetables and fruits, so the total worth of production is likely to be at the lower end of this range i.e. \$2 per m^2 per month.

$$b_2 = P \times g \times a = 2\ \$/\text{m}^2/\text{month} \times 12 \text{ months} \times 4{,}032\ \text{m}^2 = 96{,}768\ \$\ (\text{Rs.}7{,}194{,}701/\text{-})$$

4.2.1.3 Strom water retention value, $b3 = (R + E) \times C \times a$
In this formula, R = retention basin \$1,059.44/m^3 (highest value) and \$20.13/m^3 retention pond (low cost), E = erosion mitigation value i.e. \$13.66/m^3, C = retention capacity = 42.7 liter/m^2 [35] and a = roof area covered by farming.

As Mumbai is prone to urban flooding, this value assumes significance as it could bring in multiple co-benefits.

$$b_3 = (R + E) \times C \times a = (1{,}059.44 + 13.66)\ \$/\text{m}^3 \times 42.7\ \text{litre/m}^2 \times 4{,}032\ \text{m}^2$$

$$= 184{,}752\$\ (\text{Rs.}13{,}736{,}311/\text{-})$$

4.2.1.4 Air quality value, $b_4 = (g/12 \text{ months}) \times (Hsg \times asg + Htg \times atg + Hd \times ad)$
In this formula, Hsg, Htg, Hd represents the health benefits for short grass pollution absorption (0.0521 US\$ per m^2), for tall herbaceous plant pollution absorption (0.0673 US\$ per m^2), and deciduous plant pollution absorption (0.0839 US\$ per m^2) per year respectively. Asg, atg, and ad are the areas under grasses, herbaceous crops, and deciduous plants respectively.

In India, vegetation grow all through the year. Considering the proposed RTF model to be semi-extensive with leafy vegetables and fruits, the average worth of annual pollutant removal health benefit for several types of RTF has been considered as 0.0678 US\$ per m^2.
$b_4 = (g/12 \text{ months}) \times (Hsg \times asg + Htg \times atg + Hd \times ad)$ = 12 month/12 month × 0.0678 \$/m^2 × 4,032 m^2= 273.37 \$ (Rs. 20,325/-)

4.2.1.5 Carbon sequestration value, $b_5 = Sd \times ad + Sg \times ag + Sf \times af$
In this formula, Sd, Sg, and Sf represent the carbon sequestration values by deciduous plants (\$39.11/ha), by grasses (\$28.46/ha), and by productive farming (\$28.59/ha), ad, ag, and af are the areas covered by deciduous crops, grasses, and productive agriculture respectively.

Considering RTF as semi-extensive with leafy vegetables and fruits, the estimation of carbon sequestration for the RTF works out to be \$32.05/ha.

$$b_5 = Sd \times ad + Sg \times ag + Sf \times af = 32.05\ \$/\text{ha} \times 0.4032\ \text{ha} = 12.92\ \$\ (\text{Rs.}961/\text{-})$$

The survey results of the existing case studies and findings of the proposed model with the projection of RTF benefits as indicated in Fig. 8 suggest that utilization of organic waste through urban agriculture has positive environmental as well as financial implications in dense urban contexts. Further, the proposed model has high success potential in ever-expanding cities like Mumbai, and can also be replicated in other Indian cities where municipal solid waste management has emerged as one of the biggest urban challenges from resource depletion and public health points of view.

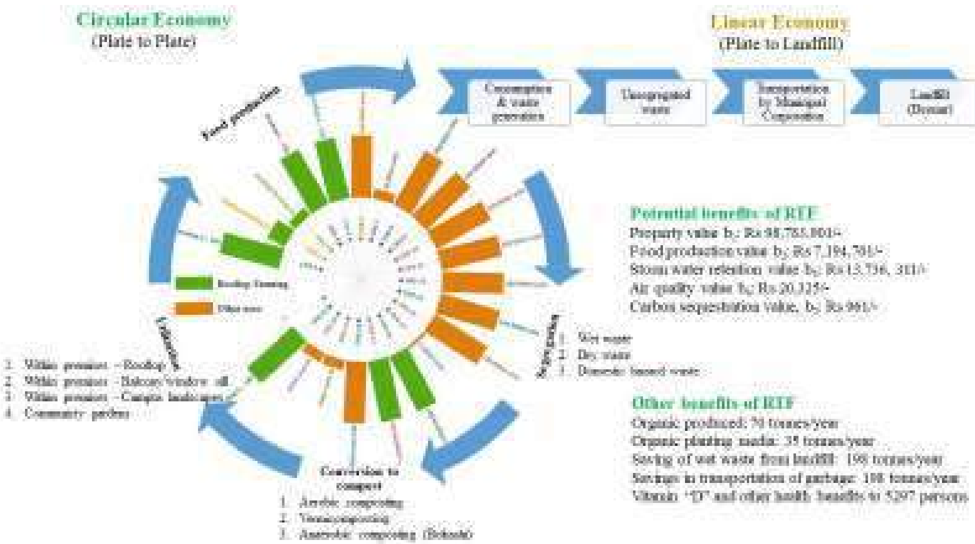

Figure 8: Proposed model for decentralized organic waste management in conjunction with UA and potential RTF benefits for the KE Ward, Mumbai.

5 CONCLUSION

Although utilization of organic waste in agriculture is common in rural India, it is rare in densely populated middle/upper-class city areas. This paper presented case studies in the Indian city of Mumbai to establish urban agriculture's current and potential capacity to consume and transform organic waste of a community into food as well as generate multiple environmental and economic benefits. The study shows how the inhabitants of Mumbai's dense neighbourhoods have evolved methods to segregate, compost, and grow food efficiently in the very limited confines of their city tenements. The concept of decentralized organic waste management in conjunction with UA emerges as a neighbourhood-level sustainable and replicable model. The study visualizes circular economy based on the real-life survey results and how the unsustainable plate-to-landfill approach can be successfully replaced by plate-to-plate practices, with production–consumption gainfully sustaining each other. The lessons learned can be used to encourage greater integration of urban agriculture with the urban economy, management, and governance. The findings of this research can be significant for policymakers, urban local bodies, city planners, private entrepreneurs, and others in integrating solid waste management with urban agriculture for a sustainable urban future.

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Urban Transport Systems

Edited by: ***G. PASSERINI****, Marche Polytechnic University, Italy and* ***C. BORREGO****, University of Aveiro, Portugal*

Better urban transport systems are needed to achieve a healthier environment and as a result, a wide range of research has originated from many different countries. These studies highlight the importance of innovative systems, new approaches and original ideas, which need to be thoroughly tested and critically evaluated before they can be implemented in practice.

To address the need to solve important pollution problems the papers included in this book focus on the relationship with urban transport. There is also a growing need for integration with telecommunications systems and IT applications in order to improve safety, security and efficiency.

The variety of topics covered in this volume reflects the complex interaction of the urban transport systems with their environment and the need to establish integrated strategies. The aim is to arrive at optimal socio-economic solutions while reducing the negative environmental impacts of current transportation systems.

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