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On the Digitalisation Processes in the Adriatic Region

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Abstract. Nowadays, a fast and challenging digitalisation process is underway within the maritime domain. Many disruptive technologies will cause a radical modification of the operations, of the logistics and of the labour market in the near future. With particular attention to the Adriatic region, this work provides an extensive review of the disruptive innovations that might be applied by port authorities, shipping companies and terminal operators. The analysed technologies, dealing with both freight and passenger transport, are divided into three digitalisation macro trends: informatisation, big data and automation. In the further stages of this research activity, the most promising technologies to be implemented in the Adriatic area will be selected by prime stakeholders and then subject to impact analysis. The planned methodology is here presented and discussed.

Keywords. digitalisation, informatisation, big data, automation, maritime industry

1. Introduction

In recent years, the digitalisation processes have been applied to passengers and freight mobility, radically transforming the transport sector through the introduction of incremental and disruptive innovations. The first are small improvements on existing products available in the mainstream market and they are necessary to maintain a competitive position. On the contrary, the latter innovative technologies, starting from lower performances than existing technologies and serving a niche, causes the so-called "disruption" of the market when becoming a mainstream product in the mainstream market [1]. Concerning digitalisation in the maritime domain, disruptive innovations can be grouped into three main macro trends: informatisation processes, data management and automation. Informatisation deals with the increasing importance acquired by Information and Communication Technologies (ICT) in production and distribution processes, systems and networks [2]. The increasing amount of data extracted from digital systems leads to data management issues. To extract information from large datasets or deal with unstructured data, machine learning, data mining and advance analytics ap-

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plications are in fast development. Additionally, the digitalisation process is leading to an even higher level of automation [3] through the development of systems and applications capable to operate with minimum human assistance (machine-human interaction) or even capable to replace human beings in manufacturing, transport, utilities, operations, etc.

The three trends are together at the base of any digitalisation process and are strictly interconnected one to each other. In fact, the informatisation process creates the pathway for data collection, which needs particular tools to be managed and analysed, i.e. big-data analytics [4]. Their elaboration drives to better mobility planning and procurement, leading also to the development of higher levels of automation.

The present work deals with the most interesting short-mid term digitalisation trends in maritime transport and ports. Both passengers and freight mobility will be considered with reference to a specific geographical area, i.e., the Adriatic sea. This paper is part of a wider research project, aiming at identifying the most promising technologies which could be applied within 3-5 years in the focused area. Following a comprehensive desk research review, a large set of innovations will be submitted to relevant stakeholders from the Adriatic region in order to select the most promising ones and evaluate their impact on the labour market and operations. The paper shows first the results of the first phase, consisting of an extensive collection of innovations that can be applied in the Adriatic area. Innovations are classified according to three macro trends (informatisation processes, big data and automation). Then, the overall methodology of the research project and the expected results are presented and discussed.

2. Innovation Trends: a review

In the present section, the innovations which could be adopted by port authorities, terminal operators and shipping companies in the Adriatic region are identified. As mentioned, disruptive innovations are often not ready to be adopted in the mainstream market. The main reasons are a difficult technical implementation and the market resistance in their adoption (e.g. their high implementation costs, the low profitability in the short term and/or the conservative attitude of stakeholders). Moreover, outside the Adriatic region, many promising digital technologies have already reached a consolidated stage of development and could swiftly be transferred in the geographical area of interest. This is why, both already on-going disruptive innovations and the not yet transferable ones have been herein identified and analyzed, thus, providing a wide vision of their potential development in the Adriatic region.

2.1. Informatisation processes

The most significant innovations related to informatisation processes are identified in Table 1. Most of them, are then briefly discussed. These digital technologies can have a strong impact on operations, safety & security and/or environmental protection. Nevertheless, the basis of the digital revolution is the increased capability to acquire and store data. Recently, a remarkable number of monitoring systems have been developed in the maritime domain to manage a number of issues on the base of data collected by sensors, e.g. [5-7]. These systems increase the situational awareness during operations, providing more complete and reliable information to seafarers, port authorities and operators.

Table 1. Analysed innovation related to informatisation trend

Innovation	Sector	Transferability
Augmented Reality	F	not ready
Smart contracts with blockchain	F	not ready
5G data flows	P/F	not ready
Cybersecurity	P/F	not ready
DSS	P/F	not ready
E-Navigation	P/F	not ready
GIS and drones	P/F	not ready
IIoT platforms	P/F	not ready
Systems Integration	P/F	not ready
Biometric devices for Safety/Security	P	not ready
Mobile solutions for Mobility	P	not ready
Mobile solutions for Safety/Security	P	not ready
Passenger PCS	P	not ready
Wearable devices for Safety/Security	P	not ready
CWS	F	ready
Digital cargo ID	F	ready
E-Tendering platforms	F	ready
PCS	F	ready
Stowage planning	F	ready
TOS	F	ready
WMS	F	ready
Document digitalisation	P/F	ready
GIS systems and digital cartographies	P/F	ready
Sensors/Monitoring Systems	P/F	ready
Ship to Ship/Shore Connectivity	P/F	ready
V2V and V2I connectivity	P/F	ready
VBS	P/F	ready
Weather routing systems	P/F	ready
EnMS	P	ready
Onboard Emergency DSS	P	ready

Sectors: P: Passenger; F: Freight

Moreover, an improved situational awareness can reduce the occurrence of human errors which are the main source of casualties in the maritime domain [8].

However, even the most complete information defining the asset/operation status could lead to human error: the subjective synthesis process of all heterogeneous information could lead to neglect or underestimate many crucial aspects. The application of decision-making techniques can mitigate this problem, replacing the subjective synthesis process with an objective one [9]. By adopting a DSS, both safety and the economic performances of assets can be optimised. Thus, the time required to analyse its current and future status and to produce proper decisions/counteractions can be substantially reduced. Several DSSs addressing specific issues are already under development. For instance, an interesting application in the maritime domain is the onboard emergency DSS: a system capable to recognise the damage extent [10,11] in an early flooding stage and simulate progressive flooding in the time domain [12]. The simulation is then used to provide the final state of a damage scenario and its duration, thus, allowing the master to decide if evacuation is needed. In port facilities, another interesting application deals with DSS for environmental impact monitoring and prediction. In the Adriatic basin, the interest on those tools is rising and some ports have already introduced this solution. Moreover, an Adriatic network is under design, based on a shared DSS devoted to increasing the decisions' effectiveness.

Informatisation can also aid to manage the evacuation procedure [13] on passenger ships/terminals as well as other safety & security issues. In detail, solutions based on

biometrics (e.g. fingerprint/iris/facial recognition) or wearable devices [14] can be adopted to authorise access to cabins or to count passengers during mustering operations. However, for this purpose also the exploitation of mobile technology can be a viable solution [15]. Onboard or in a passenger terminal, mobile applications could collect data in order to reduce crew and passengers reaction time during an emergency. In fact, mobile applications can be developed to localise passengers onboard, to identify easily unauthorised access to restricted areas, to guide people during evacuation procedures and/or to communicate to the crew a potentially dangerous situation. Moreover, mobile technology could also optimise passengers' flows. Mobile applications offer the perfect solution to provide people with information while approaching a port facility or inside a terminal. These applications could guide people reducing congestions occurrence and could provide information about nearby interest points (e.g. services, cultural attractions, etc.). Mobile solutions connected to a multi-actor system can also organise data flows and provide real-time information with great benefits for both port terminals and passengers' experience. Besides, the passenger experience can be further augmented through the adoption of virtual reality and by developing a dedicated Port Community System (PCS). PCS consists of a shared digital platform connecting multiple systems operated by a variety of organisations, operators and stakeholders that make up a digital port community. PCS can play a major role as EU countries move towards the Single Window environment and contribute to the harmonisation and coordination of reporting formalities, processes and procedures.

Information technology can have also a positive impact on environmental protection in the maritime domain. The monitoring and management of different energy resources can be performed by means of Energy Management Systems (EnMS). The development of an EnMS in a port facility [16] can allow to optimally integrate and allocate different energy resources, e.g. electric grid, renewable energy resources, local energy storages, etc. Concerning ships, EnMSs are in constant development for naval ships [17], due to the high peak demands required by future weapon systems. Moreover, the electrification of ships and the development of hybrid propulsion systems [18], encourage the adoption of EnMS on merchant ships too, leading to a fuel consumption reduction. Another way to reduce fuel consumption, while increasing navigation safety, is the adoption of weather routing systems [19] capable to consider future weather condition in marine operations planning. In particular, weather routing applications are based on Geographic Information Systems (GIS) and digital cartography and provide the best ship route and speed taking into account currents, sea states and winds in order to minimize fuel consumption and/or potential navigational hazards. Even better results could be achieved by integrating the weather routing system, the ballast allocation system [20] and the EnMS leading to a holistic approach to fuel consumption reduction.

Many of the innovations so far discussed are based on ship connectivity. Nowadays, the connectivity and information exchange between ships and shore is assured by radio and satellite communications. The exploitation of these technologies is the key for smart handling of maritime operations and it is even more important in case of emergency. The communication of position, speed and planned route are already transmitted by Automatic Identification System, installed on cargo ships over 300 gross tonnages and on all passenger ships. The development of the E-Navigation, introduced by IMO since 2008 [21], will improve ship/shore data exchange, allow a smart traffic monitoring and harmonise port operations, making possible to reduce congestions, the collisions' occurrence, the standby time and the pollutants emissions by selecting a proper ship speed on the base of the expected timing to access to port facilities. How-

ever, these applications will require the development of new common interfaces between ships, ports and shipping companies. Moreover, not only port operators might develop applications based on ship/shore connectivity but also ship-owners which is a very challenging task. Some applications are already underway: prime companies are developing onshore fleet operations centres, devoted to remote monitoring of their ships and to provide assistance in case of emergency. It is expected that these onshore facilities in the near future will gain even more responsibility on ship conduction, moving towards autonomous ships.

In ports, the communication between vehicles (V2V) and between vehicles and infrastructures (V2I) is also quite promising since leads to many benefits (reduction of injuries, cost reduction, 24/7 operations, etc.) and since the application within a fully controlled environment could boost its adoption rate. In advanced terminals, there are already self-driving vehicles operating, however, especially in the Adriatic region, widespread adoption is lacking. Finally, the communication between different objects should be included in cooperative intelligent transport systems where terminal operators, hauliers, port authorities and others could cooperate in order to increase the port efficiency. In fact, data flows from the port authority, through the terminal operator, and then to the shipping line in a real-time dynamic way. Companies have begun experimenting with a range of connectivity and data-enabled technologies. These technologies form the Internet of Things (IoT), which represents a convergence between the physical and digital worlds. 5G networks will allow unlocking the full potential of industrial IoT for transport and logistics.

Furthermore, the informatisation offers promising technologies specifically developed for freight transport. E-tendering platforms (so-called Uber for Freight) integrated into the logistics business network provide users with access to transportation rates from digitally activated carrier fleets so as to get real-time quotes and guaranteed freight capacity. This supports easier and faster decision-making based on real-time pricing and consequently increase visibility and transparency of relevant freight transport information for all stakeholders. Moreover, e-tendering processes produce significant environmental benefits to the extent to which they optimize existing transport capacity, thus, reducing the number of circulating vehicles.

In container terminals, Terminal Operation Systems (TOSs) optimise their efficiency through real-time routing, dispatching and monitoring of straddle carriers, terminal tractors and other internal vehicles of container terminals. Additional modules consist of optimization systems automatically generating stowage plans for ships. Besides, TOSs can automate yard planning, by distributing containers throughout the yard based on predefined rules. Finally, TOSs enable terminals to understand the real-time and historical performance of their business with comprehensive and agile analytics reporting. Vehicle Booking Systems (VBSs) allow terminal operators to match terminal resources with landside demand. Terminals can configure timeslots, work-day calendars and business rules, and create and maintain customer details. By minimising manual data entry and virtually eliminating paperwork, VBSs streamline operations from ship to gate[2]. The immediate economic advantages obtainable through the reduction of congestions and cues at terminals and warehouses should be canalized in order to

[2] For example, when the quayside is busy, landside resources can be adjusted to support best use of equipment. Equally, when quayside activity is lower, landside operations can be ramped up to support clearing for the next vessel arrival.

Table 2. Analysed innovation related to the big data trend

Innovation	Sector	Transferability
Automatic detection of logistics' level of service	F	not ready
Loading/unloading optimisation	F	not ready
Big Data Analytics	P/F	not ready
Big data/data management	P/F	not ready
Data standardization	P/F	not ready
Digital twin	P/F	not ready
Machine Learning	P/F	not ready
Anomalies detection & predictive maintenance	P/F	ready
Georeferenced data	P/F	ready
Port traffic management	P/F	ready
Energy Efficiency	P	ready
Passengers flow analysis	P	ready

Sectors: P: Passenger; F: Freight

incentivise the adoption in the short term. Container Weight Systems (CWSs) seamlessly integrate load monitoring technologies onto existing container handling equipment to deliver accurate weight verification data within ports and terminals. Following IMO SOLAS regulations, CWSs represent the pathway to compliance. Technical and commercial options are available, presenting cost-effective, robust and accurate solutions.

Warehouse management systems (WMSs) support and optimize warehouse functionality and distribution centre management. These systems facilitate operation management in their daily planning, organizing, staffing, directing, and controlling the utilization of available resources, to move and store freight into, within, and out of a warehouse, while supporting staff in the performance of material movement and storage in and around a warehouse.

Finally, in the freight sector, another promising disruptive innovation is the blockchain applied to logistics [22], where the application of smart contracts could increase the overall trust within the value chain and the speed of operations, with the reduction of intermediaries and paperwork.

2.2. Big Data

The most relevant innovations related to the big-data trend are identified in Table 2. Most of them, are then briefly discussed hereinafter.

Data standardization plays a major role when dealing with big data management. Industry tasks are usually performed based on proprietary data collection, storage and management systems. However, they need to be integrated along the logistics chain and among different actors. For instance, several world's largest carriers, (including Maersk and MSC) have established the Digital Container Shipping Association (DCSA) to create common information technology standards, as a common foundation for technical interfaces and data for the maritime industry. At the same time, port authorities, terminal operators and shipping companies are already leveraging data to intelligently plan their operations.

Big Data Analytics technologies collect and analyse customs data, ports agents, freight forwarders and traders to predict individual ship movements and cargo flows. Machine learning employs big data to feed algorithms to assess, for instance, speed, the correlation of logistics data to detect anomalies and errors and to predict bottlenecks based on recognized patterns.

Recently big-data analytics have been applied also on a new field that is gaining attention in maritime domain: digital twin. The digital twin of an asset is a model capable to reproduce close to real-time its state and its behaviour in reaction to external operating context. A digital twin allows the extraction of insights and information from assets monitoring systems with the aim to ease inspections and maintenance, to perform an early damage detection, to harmonize the interaction of multiple assets, to optimize operations etc. Machine learning and big-data analytics can increase substantially the knowledge extraction capability from large and heterogeneous outputs collected by sensors [23].

Besides, Big-data analysis can provide considerable benefits to energy efficiency, increasing ship performances during navigation. The target can be achieved through monitoring fuel consumptions, emissions, other services' electric load together with the floating position of the ship, the shaft speed, the weather condition [24]. These data can be analysed in order to minimise fuel consumption or emissions, identifying an optimal ballast water allocation or the optimal propeller pitch (for controlled pitch propellers). Moreover, for complex systems governed by EnMSs such as naval or cruise ships, the big data analysis offers a very powerful instrument for its configuration.

Concerning the freight sector, Loading/unloading optimisation systems provide more efficient procedures and tools, which can include planning of resources based on real-time data and artificial intelligence (AI). The automatic detection of logistics' level of service can be performed through systems based on data detection and management technologies such as radio frequency identification (RFID).

Finally, georeferenced (big) data can be employed to assess the impact of events or scenarios and gain time and overall resource savings before implementing an actual project. Vessel traffic management systems provide real-time information for port security on the basis of sensor networks and collaborative control rooms.

2.3. Automation

The most relevant innovations related to the automation trend are summarised in Table 3 and briefly described hereinafter.

There are many technologies related to automation which could be applied in passenger transport. For instance, on ferries and cruise ships and passenger terminals, most of the crew is devoted to providing services to the passengers (cleaning, cooking, entertainment, etc.). The development of robotics is moving the simplest jobs from humans to robots leading to a reduction of personnel costs. Moreover, also the automation level of the main machinery and auxiliary systems can be further developed. For instance, the adoption of sensors devoted to detecting/counting people in a specific room can be exploited to control the lighting system and optimise the load of air conditioning system in order to reduce the global energy demand.

Automation is expected to have an even more relevant impact in freight transport leading to the adoption of several disruptive innovations. Among them, fully automated container terminals systems will include automated application interfaces between the already mentioned VBSs, terminal in/out gates, automated container carriers (ACCs), automated stacking carriers (ASCs) and quay cranes. All these technologies are under control fo an already mentioned TOS. However, container terminal automation is still at relatively early stages since, currently, only 1% of terminals are fully automated and 2% are semi-automated. Still pertaining to container terminals, innovative automated

Table 3. Analysed innovation related to automation trend

Innovation	Sector	Transferability
Automatic container carriers/truck handling systems	F	not ready
Drones for WMS	F	not ready
Electrified Lift Solution	F	not ready
Fully Automated Container Terminal	F	not ready
High Bay Storage Systems (BOXBAY)	F	not ready
Maritime transport chain	F	not ready
Smart Connected Lift Trucks	F	not ready
Autonomous Trucks/Busses	P/F	not ready
Autonomous tugboats	P/F	not ready
Event data certification	P/F	not ready
Unmanned ships/autonomous vessel	P/F	not ready
Automatic digital identification of passengers	P	not ready
ALP	F	ready
ASC	F	ready
Deliverables Planning	F	ready
Remote Cranes	F	ready
Unmanned bulk cargo terminal	F	ready
WMS with voice integration	F	ready
Unmanned warehouse	F	ready
Automated mooring technologies	P/F	ready
Autonomous vehicles in port area	P/F	ready
Autonomous vessels for coastal navigation	P/F	ready
ETA, Delivery of Notification	P/F	ready
RPAS drones to check ship emissions	P/F	ready
Automated Lighting and air-conditioning systems	P	ready
Unmanned services	P	ready

Sectors: P: Passenger; F: Freight

systems for container storing and handling are being developed. For example, the High Bay Storage Systems (e.g., BOXBAY), where containers are placed in individual racks – making each one directly accessible – instead of stacking them on top of each other.

Moreover, several technologies are increasing the automation of warehouses, which are critical nodes in transportation processes. The coupling of voice technologies with WMS is growing in number of adoptions since they increase personnel efficiency during picking operations. The avoidance of looking at monitors and the feeling of listening instructions by a human voice foster the speed and decrease the alienation, letting the operator to use both hands. In recent times, warehouses are experimenting the usage of drones, especially for periodic inventory procedures. With drone technology it is possible to check the consistency of stock more frequently and during the night, when there is no/less activity inside the warehouse.

Finally, special attention is due to another disruptive innovation that is expected to have a deep impact on port operations and navigation in the next decade: the autonomous vessel. The autonomous vessel a ship requiring minimum human intervention in its conduction. This concept can be developed with different degrees of automation up to the unmanned vessel: a ship without a crew onboard, based on completely automated systems or remote-controlled. For short repetitive routes and coastal navigation fully autonomous vessels are becoming reality (first pilot projects are on the way), but it is expected a wider application in near future, provided that some open issues will be resolved [25]. In particular, in addition to the relevant technological challenges, also some legal and regulatory issues shall be solved before unmanned ships can reach the mainstream market in freight and, even more, in passenger transport. However, the economical benefits (ship's life cycle cost could decrease by minimum 5-22% mainly

due to fuel and crew cost reduction [26]) and safety-related benefits (reduction of casualties related to human error) will certainly lead to a wider application of remote-controlled vessels [27] and finally to fully autonomous ones.

3. Proposed Methodology

The innovations connected to digitalisation processes have been identified through desk research and interviews with innovation experts and stakeholders. Innovations have been gathered in a common repository, which includes a brief description and the categorization according to the three macro trends. Next research activities will consist of collecting, through questionnaires, feedback from relevant stakeholders in order to come up with the selection of most attractive innovations for the Adriatic region. Finally, an impact analysis will be carried out on the set of selected technologies.

3.1. Most attractive innovations

The selection of most attractive innovations dealing with digitalisation, big data and automation will be performed by means of an online questionnaire. Relevant stakeholders (mainly port authorities and institutions from Italy and Croatia) will choose the most promising technologies in terms of positive effects on passengers/freight mobility and deployment easiness. In detail, each innovation will be ranked per importance on a five step scale, i.e. 1 - not at all relevant; 2 - not very relevant; 3 – no opinion; 4 – relevant; 5 - extremely relevant. Moreover, the effort required to implement innovation in the current environment will be also ranked according to the following scale: 1 - very difficult to implement; 2 - somehow difficult to implement; 3 - no opinion; 4 - somehow easy to implement; 5 - very easy to implement). Stakeholders will be also required to add other technologies not included in the collection herein presented if considered relevant for their business area.
Then, the innovations gathered in the collection phase will be represented in a matrix (Fig. 1) highlighting both the relevance and the implementation easiness/difficulty. This study will allow selecting the most promising digitalisation processes for the area of interest, in order to carry out a best practises analysis, which can guide their deployment and can be the base for next steps of research action.

	Easy to deploy	***Difficult to deploy***
High importance	Innovation 1 Innovation 2 …	Innovation 3 Innovation 4 …
Low importance	Innovation 5 Innovation 6 …	Innovation 7 Innovation 8 …

Figure 1. Ranking matrix sample.

3.2. Impact analysis

In this phase, an impact analysis will be carried out on the most promising innovations selected in the previous stage. In particular, Adriatic port authorities will focus on the impacts on the labour market - highlighting the effects of the innovation deployment on the number of employees and their required expertise. The impacts on port/maritime operations will be assessed as well in the research. In fact, the adoption of a disruptive technology could produce remarkable benefits in terms of the reduction of time of operations, increased energy efficiency, reduction of emissions/pollution, increased capability to prevent or face safety & security threats, reaching a more harmonic integration of infrastructures, community and means of transport or increasing revenues and profits in mid-long term.

Finally, the impact analyses will include brief guidelines for the sector stakeholders in order to rapidly react and face the digital revolution in maritime passenger/freight transportation. It is planned that the most promising technologies identified will be implemented into specific pilot projects leading to better exploitation of digital technologies in the Adriatic region for both freight and passenger sectors.

4. Conclusions

The present work presents and discusses the main on-going and not ready to be transferred innovations, applicable in the digitalisation processes within the Adriatic region. The research activity, carried out by involving prime stakeholders from the area of interest, provides at this stage a complete review of technologies dealing with the three digitalisation macro trends: informatisation, big-data and automation. The review represents the basis for the selection of the most promising technologies by means of the methodology herein presented, aiming at defining the guidelines for their implementation and assess their impact on the labour market and on maritime operations. Therefore, this paper can help institutions, port authorities and shipping companies in facing the challenges related to the current digital revolution, which is rapidly modifying the operations, logistics and technology in the maritime industry.

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