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Key Performance Indicators for Evaluating the Bikeability of a Trip

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Abstract

Especially in urban contexts, cycling is considered as one of the most sustainable travel options. However, its use is subject to several morphological, physical, cultural and environmental constraints. A lack of knowledge about comprehensive benefits (not limited to the financial ones) from potential users is one of the most critical aspects. To overcome this issue, the project CICLO! develops a calculator of economic performance guaranteed by bicycle compared to other transport solutions. As a first step, the bikeability needs to be evaluated, to verify whether a bike can be considered a valid option for a specific trip. In this contribution, we analyze the metrics adopted by literature to extract a set of Key Performance Indicators that allow understanding whether the minimum conditions of bikeability for a specific user are achieved. The results of our analysis confirm the existence of multi-faceted aspects to be considered within the concept of bikeability, which we included into the following macro-categories: user characteristics, accessibility, security, convenience and possibility of moving. The outcomes of this phase are the basis for the next step, leading to the economic evaluation of the differences between bicycle and other transport options, which makes users informed about the real impacts of their choices and, thus, bicycle a more appealing option.

Keywords: Soft mobility; modal shift; calculator; economic benefits; indicators; users.

1. Introduction

In recent years, sustainable mobility has emerged as a main objective of urban planning. As cities continue to grow, transportation systems face increasing pressure to mitigate negative externalities without compromising overall mobility. Among the most pressing challenges, air and noise pollution and traffic congestion are largely attributed to the dominance of motorized transport (Gavanas, 2024). These impacts not only harm ecological systems but also affect public health and quality of life (Bruzzone et al., 2023a; Cavallaro and Nocera, 2024).

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In this context, the bicycle stands out as one of the most sustainable and efficient means of transport for short- and medium-distance travel, including first and last mile segments of intermodal connections (Bruzzone et al., 2025). Cities with higher rates of cycling benefit from improved air quality, lower healthcare costs, and enhanced urban livability (Maltese et al., 2021). Additionally, cycling supports local economies and reduces the burden on road infrastructure. Yet, the widespread adoption of cycling is hindered by a combination of infrastructural deficiencies, cultural norms, and limited public awareness (Ferretto et al., 2021). In several countries, despite a high number of bicycles, cycling remains underutilized (Privitera, 2020).

Although infrastructural improvements are crucial, they alone are insufficient to drive meaningful change (Pucher et al., 2010). Resistance to cycling often stems from individual preferences and a lack of knowledge about its benefits (Woodcock et al., 2009). Many individuals remain unaware of cycling's positive effects on health, environmental sustainability, and urban life (Götschi et al., 2016). Educational and motivational tools are essential to support behavior change. One promising solution involves the development of tools that visualize the benefits of cycling (Poliziani et al., 2023). Theoretically, these tools have the potential to foster lasting changes in travel behavior; in practice, they remain insufficiently deployed. For a potential user, understanding if bicycle is an option is the first step towards the assessment of its economic convenience. This evaluation, also known as "bikeability", allows perceiving bike as a valid option to perform a given trip. Defined as the ability and convenience of reaching destinations by bicycle, bikeability provides a multidimensional framework for evaluating cycling environments (Grigore et al., 2019). Unlike walkability, bikeability accounts for the specific spatial and infrastructural needs of cyclists (Muhs & Clifton, 2016). Recent advancements in geospatial technologies and data analytics have led to the creation of indices and models that measure bikeability using street view imagery, open data, and automated workflows (Ito & Biljecki, 2021). However, the field still lacks a universally accepted definition, and many models fail to fully incorporate emerging trends such as electric bicycles, bike-sharing systems, and dynamic environmental data (Castañon & Ribeiro, 2021).

Rather than a generic evaluation, the proposed approach is based on an auto-assessment of the propension to use bicycle: the choices of potential cyclists depend on different physical and behavioral characteristics, along with the adopted bike and infrastructure, which need to be known to make informed choices. To this aim, the first step is the selection of a set of relevant Key Performance Indicators (KPIs), among the numerous metrics indicated by the literature. This approach is rather common when approaching a new topic (see e.g. Bruzzone et al. 2023b). Accordingly, this contribution aims at selecting the most relevant impacts according to a comprehensive review of the articles dealing with the issue of impacts deriving from the use of bicycle, clustering them and proposing a subset able to include the most important aspects in the evaluation. Such indicators will be used to define the architecture of the calculator, which is a general tool valid for any geographical context. Within this first phase, we define only those characteristics that define in a straightforward way if the trip that a user wants to evaluate can be considered suitable or not to the bike. The contribution is articulated as follows: after this introductory section, the literature review focuses on the factors that need to be considered when evaluating bicycle as a potential option. Then, a critical selection of such indicators is presented and applied to a selected case study. A final section explores the next step of the research.

2. Metrics for bikeability: Literature review

KPIs play a crucial role in evaluating and enhancing policies that promote bicycle usage as a sustainable transport mode. They can measure aspects such as how often and long individuals' cycle, how well cycling infrastructure is constructed and utilized, accident statistics or the contribution to the environment to support data-based decision making. This transformation from general cycling objectives to specific KPIs is a crucial step to make sure the selected indicators can represent real world conditions in a comprehensive way. Besides assessing current circumstances, KPIs also enable the comparison between trends in time, making them particularly important when analyzing the ongoing and expected evolution from motorized transport to bicycle. However, the list of potential indicators for bikeability is long, sometimes too detailed and it is not always straightforward to select the most appropriate ones. For this reason, a critical appraisal of the academic contributions on the topic can be useful.

To select such contributions, a semi-automated method is adopted. The search is limited to English-language documents indexed in Scopus, whose abstracts, titles, or keywords followed this query: (TITLE-ABS-KEY (cycling) OR TITLE-ABS-KEY (Bicycle) AND TITLE-ABS-KEY (User) AND TITLE-ABS-KEY (Mobility) OR TITLE-ABS-KEY (Transport) AND TITLE-ABS-KEY (Commute) AND TITLE-ABS-KEY (Choice) OR TITLE-ABS-KEY

(Preference) AND TITLE-ABS-KEY (Safety) OR TITLE-ABS-KEY (Environment) OR TITLE-ABS-KEY (Urban) OR TITLE-ABS-KEY (Health) OR TITLE-ABS-KEY (Sustainability) OR TITLE-ABS-KEY (Behavior) OR TITLE-ABS-KEY (Motivation) OR TITLE-ABS-KEY (Accessibility).

This led to the extraction of 75 contributions, which is followed by a manual selection of those based on the actual relevance of the abstracts. Automatic extraction has undoubted advantages from a computational point of view, but it suffers from precision (i.e., the ability to extract only those studies that are relevant to the topic under investigation). The main reasons for exclusion of contributions are a) lack of indicators specific to the bicycle mode; b) inclusion of indicators not specific to the individual user; and c) indicators not decisive for the choice of bicycle over other modes. Of the initial 75 contributions, 36 are considered fully consistent with the purpose of the research. These contributions are intended as primary references. The indicators and the metrics adopted by each of them is provided in Table 1.

Table 1. KPIs influencing bicycle choice.

Indicator	Specification	Author	Area & Scope*		Approach#	U.m.
Presence of Cycling Infrastructure		Pucher and Buehler (2012)	EU & AU	E	Y/N	
Length of segment	Percentage of marked bike paths.	Menghini et al. (2010)	CH	U	QN	%
	The proportion of the route with designated bike lanes or paths.	Manum et al. (2017)	SW	S	QN	M
		Gholamialam and Matisziw (2019)	USA	S		Mi
		Krenn et al. (2015)	AT	S		
Separation	From road users.	Krenn et al. (2015)	AT	S	Y/N	
	From pedestrians e.g. Furniture, vegetation; height difference; different surfaces.	Manum et al. (2017)	SE	S	QL	
	Lane dedicated exclusively to cyclists.	Lin and Wei (2018)	TW	S	Y/N	
Parking	For Bikes.	Torrisi et al. (2021)	IT	U	Y/N	
	For cars.	Manum et al. (2017)	SW	S	Y/N	
Type of Cycling Infrastructure	e.g. Bike lane; shared path; protected track.	Manum et al. (2017)	SW	S	QL	
		McNeil (2011)	USA	S		
		Grigore et al. (2019)	CH	U		
Bicycle lane	Number of Lanes	Gholamialam and Matisziw (2019)	USA	S	QN	No.
	Width	Lowry et al. (2012)	USA	S	QN	Mi
		Lin and Wei (2018)	TW	S		M
		Manum et al. (2017)	SE	S		
Bicycle lane surface material	e.g. Asphalt; concrete; Natural stones; Gravel.	Manum et al. (2017)	SE	S	QL	
Horizontal curvature	Radius of curvature.	Manum et al. (2017)	SE	S	QN	Deg
Segment connected to junction	The distance between the starting point and the cycling infrastructure.	McNeil (2011)	USA	S	QN	M
	Road connectivity.	Winters et al. (2013)	CA	E	Y/N	
	The segment links directly to an intersection.	Manum et al. (2017)	SE	S	Y/N	
		Gholamialam and Matisziw (2019)	USA	S	QN	Mi
Distance between junctions		Manum et al. (2017)	SE	S	QN	M
Slope		Manum et al. (2017)	SE	S	QN	%
		Menghini et al. (2010)	CH	U		
Bus stop		Manum et al. (2017)	SE	S	Y/N	
Entrances along segment	The number and type of access points.	Manum et al. (2017)	SE	S	QN	No. / 100 m
Presence of greenery		Krenn et al. (2015)	AT	S	Y/N	
Traffic volumes	The number of vehicles passing through a segment.	Buehler (2012)			QN	No. vehicles / h
		Gholamialam and Matisziw (2019)	USA	S		
		Lowry et al. (2012)	USA	S		
		Torrisi et al. (2021)	IT	U		
		Antonakos (1994)	USA	E		
		Winters et al. (2011)	CA	E		
Speed limits		Gholamialam and Matisziw (2019)	USA	S	QN	Mi / h
		Grigore et al. (2019)	CH	U		Km / h
		Lowry et al. (2012)	USA	S		
Presence of Signage		Grigore et al. (2019)	CH	U	Y/N	
Comfort of the Riding Environment	e.g. smoothness, safety, and aesthetics.	Grigore et al. (2019)	CH	U	QL	
Land use	e.g., residential, commercial, industrial.	Winters et al. (2013)	CA	E	QL	
		Saghapour et al. (2017)	AU	U		

		Stinson and Bhat (2004)	CA & USA	E		
Heavy Vehicles	The proportion in relation to total traffic.	Lowry et al. (2012)	USA	S	QN	%
Ozone Level	The concentration in the air.	Parkin et al. (2008)	UK	S	QN	Average O3
		Lin and Wei (2018)	TW	S		
Presence of security cameras		Akar and Clifton (2009)	USA	S	Y/N	
Law enforcement activities	The presence of police or security.	Akar and Clifton (2009)	USA	S	Y/N	
Tree canopy coverage	The percentage of the cycling route shaded by trees.	Parkin et al. (2008)	UK	S	QN	% of mq
Saving time on the bike		Parkin et al. (2008)	UK	S	QN	Min
Availability of a vehicle	Car.	Barberan et al. (2017)	ES	U	Y/N	
	Bicycle.	Muñoz (2016)	ES	U	Y/N	
Fuel cost		Litman (2022)			QN	€/ km
Cost of the vehicle		Litman (2022)			QN	€/ km
Starting flexibility	The ability to choose when to begin a cycling trip.	Torrisi et al. (2021)	IT	U	QN	Min
Age		Torrisi et al. (2021)	IT	U	QN	No.
Health's state		Torrisi et al. (2021)	IT	U	QL	
Reason for displacement	e.g. leisure, exercise, or relaxation rather than commuting.	Heinen et al. (2012)	NH & USA	E	QL	
Awareness of environmentalism	The cyclist's understanding and concern for environmental issues.	Pucher et al. (2010)	USA	E	Y/N	
Barriers	Presence of structural elements that impede cyclability (e.g. traffic, terrain, or infrastructure quality).	Wahlgren and Schantz (2011)	SE	U	QL	
		Saghapour et al. (2017)	AU	U		
	Individual factors that hinder cycling.	Gatersleben and Appleton (2007)	UK	E	Y/N	
Attitude	A cyclist's perception, motivation, and willingness to ride.	Gatersleben and Appleton (2007)	UK	E	Y/N	
Training		Tomalty (2019)	CA	E	QN	H
Travel time		Stinson and Bhat (2004)	CA & USA	E	QN	Min
Bicycle facilities	e.g. traffic calming, road or bike signage.	Winters et al. (2013)	CA	E	QL	
		Stinson and Bhat (2004)	CA & USA	E		
	Number of traffic lights.	Menghini et al. (2010)	CH	U	QN	No.
	Presence of illumination.	Lin and Wei (2018)	TW	S	Y/N	
Access to a restricted traffic zone		Heinen and Buehler (2019)			Y/N	
Cyclist Speeds		Wahlgren and Schantz (2011)	SE	U	QN	Km / h
Traffic Conflicts		Wahlgren and Schantz (2011)	SE	U	QN	No.
Exhaust Fumes	Emissions from motor vehicles.	Wahlgren and Schantz (2011)	SE	U	QN	µg/m³
Noise Levels		Wahlgren and Schantz (2011)	SE	U	QN	Db
Landscape aesthetics	e.g. natural features, urban design, and green spaces.	Winters et al. (2011)	CA	E	QN	LQI
Rainfall	Precipitation in an hour.	Nosal and Miranda-Moreno (2014)	CA & USA	U	QN	Mm / h
		El-Assi et al. (2017)	CA	U		

*E=extraurban; U=urban; S=suburban. #QN=Quantitative; QL=qualitative; Y/N=Yes/No.

3. Analysis of results

The indicators presented in Table 1 capture the conditions that make cycling feasible, such as the availability of dedicated infrastructure, road safety, travel time, and route connectivity. Rather than emphasizing the advantages of cycling—such as health benefits, cost savings, or environmental impact—these indicators primarily point to the possibility of using the bicycle as a viable transport mode. This focus reflects a functional perspective, where the presence or absence of enabling factors determines whether cycling is even an option for individuals.

The nature of the single indicators complicates measurement and interpretation in urban planning. Some indicators, such as the availability of cycling infrastructure, are assessed qualitatively using a binary yes/no approach (Pucher and Buehler, 2012; Krenn et al., 2015), while others quantify infrastructure components by measuring distances (Manum et al., 2017; Menghini et al., 2010), allowing for a more detailed analysis of network connectivity.

Additionally, some indicators blend qualitative and quantitative elements: Grigore et al. (2019), Winters et al. (2013), and Saghapour et al. (2017) assess cycling environments based on smoothness, safety, and aesthetics, while factors like noise pollution and exhaust emissions (Wahlgren and Schantz, 2011) are expressed quantitatively.

Ultimately, while many indicators recur across studies—suggesting a consensus on their importance, their diverse representations, units, and methods of assessment underline the need for greater standardization in cycling infrastructure evaluation to enable more reliable comparisons and informed planning decisions. These studies often interpret the same indicator in different ways. For instance, Menghini et al. (2010) define the "*segment length"* as the percentage of the bicycle route that is marked, while Manum et al. (2017), Gholamialam and Matisziw (2019), and Krenn et al. (2015) consider it as the portion of the road that includes a designated bicycle route. Similarly, "*bicycle lane*" is not uniformly defined. Gholamialam and Matisziw (2019) consider the number of lanes, whereas Lowry et al. (2012), Lin and Wei (2018), and Manum et al. (2017) adopt the lane width as the key measure. "*Barriers*" to cycling are not univocally defined. Wahlgren and Schantz (2011), Saghapour et al. (2017) emphasize structural barriers, such as physical obstacles or road design. In contrast, Gatersleben and Appleton (2007) highlight individual or perceived barriers that affect a person's willingness or ability to cycle, impacting overall bikeability. The proximity to origin is a recurring factor influencing accessibility, but different studies measure it using diverse units of measures. Manum et al. (2017) assess horizontal curvature in degrees, linking it to comfort and safety, while Gholamialam and Matisziw (2019) express the same feature in miles. Such methodological differences complicate direct comparisons. Similarly, "Distance between junctions" appears in both Menghini et al. (2010) and Manum et al. (2017), measured consistently in meters, underscoring its relevance to ride fluidity and stop-start frequency.

Passing from the single indicator to the list of indicators, the concept of "bikeability" is defined in different ways. In general terms, "bikeability" refers to how conducive an environment is to cycling based on infrastructure, accessibility, comfort, safety, and the overall user experience. Practically, it is declined with different meanings. The "*Comfort of the Riding Environment*" (Grigore et al., 2019; Winters et al., 2013; Saghapour et al., 2017; Stinson and Bhat, 2004) is one of the most representative indicators of bikeability, encompassing ride quality, safety perception, and visual surroundings. It integrates multiple dimensions that affect whether cycling is enjoyable and sustainable. "*Road connectivity*" (Winters et al., 2013; Manum et al., 2017; Gholamialam and Matisziw, 2019) contributes to bikeability by determining how easily and directly cyclists can move through a network. High connectivity minimizes detours and interruptions, making trips more efficient and convenient. "*Presence of cycling infrastructure*", including "*Percentage of marked bike paths*" (Menghini et al., 2010; Manum et al., 2017; Gholamialam and Matisziw, 2019; Krenn et al., 2015), and "*Number of lanes*" (Gholamialam and Matisziw, 2019; Lowry et al., 2012; Lin and Wei, 2018; Manum et al., 2017), are also central for bikeability. These reflect the physical presence of dedicated space for cyclists, which is a crucial factor for both perceived and actual safety. Environmental elements also contribute strongly to bikeability. The "*Presence of greenery*" (Krenn et al., 2015; Buehler, 2012; Gholamialam and Matisziw, 2019; Lowry et al., 2012; Torrisi et al., 2021; Antonakos, 1994; Winters et al., 2011) and "*Landscape aesthetics*" (Grigore et al., 2019; Winters et al., 2013; Lin and Wei, 2018; Saghapour et al., 2017) improve the visual and physical quality of routes, which has a positive impact on willingness to cycle—especially for longer or leisure-based trips. Finally, indicators such as "*Traffic conflicts*", "*Noise levels*", and "*Exhaust fumes*" (Wahlgren and Schantz, 2011) address safety and environmental health, both of which are essential to making cycling not just possible but desirable. Together, these indicators reflect a comprehensive view of bikeability, showing that a bike-friendly environment is not only built with infrastructure but also shaped by comfort, connectivity, and environmental quality.

Given these discrepancies in the definition of indicators and sets of indicators, the comparability of cycling studies is hindered. Without a unified measurement approach, results risk being interpreted in different ways, complicating the implementation of scalable and replicable evaluation systems. A standardized methodology would enhance cross-comparisons and provide policymakers with better insights for optimizing cycling infrastructure.

4. KPI proposal

Given the inconsistent nature of cycling-related indicators across the literature highlighted in the previous sections, it is essential to develop a more structured and coherent framework for evaluating cycling conditions. We extract a streamlined set of KPIs that assess whether the minimum conditions required for cycling are met for a given user profile. The concept of KPIs differs from indicators (as presented above) and is rooted in performance management. KPIs represent a focused set of measurable values used to gauge the effectiveness and efficiency of specific actions, strategies, or systems (Parmenter, 2011). Unlike broader performance metrics, KPIs must be carefully selected to ensure clarity and avoid redundancy. A concise list — ideally fewer than 10 — prevents overlapping indicators and allows for more meaningful evaluations (Hope and Fraser, 2003). From a technical point of view, KPIs must satisfy six conditions (Sinha et Laci 2007). First, they must be appropriate (they must be relevant for the service examined). Second, they must be measurable (they must be formulated in an objective, unambiguous way and possess the precision and reliability appropriate for a particular transport service). Third, they should be sizable (they must be clear and comparable over time and place); Fourth, they must be pragmatic (they must be possible to estimate; they cannot be too time-, cost-, or effort-consuming). Fifth, they need to be defensible (being simple, evident, and communicable). Sixth, they should be forecastable (reliably estimated for the future using existing tools).

Remembering the purpose of our research mentioned in the introduction, we aim to understand whether a specific trip is suitable for bicycles according to the nature of the respondent and the characteristics of the infrastructural network. This phase serves as the requisite for a more rigorous quantification of the potential impacts that derive from the adoption of bicycles over other means, which is more quantitative. Accordingly, we exclude from this phase all purely quantitative indicators. This choice is motivated by the need to focus on qualitative and semi-qualitative aspects that better capture the user's experience and perception of cycling conditions—factors often overlooked in purely metric-based assessments. Our aim is not to dismiss the value of quantitative data (which is the core of the following step about the quantification of economic impacts of choosing bicycle), but rather to ensure that subjective and experiential dimensions, such as comfort, safety perception, and visual environment, are more fully integrated into the evaluative framework. The literature review highlighted the multifaceted nature of cyclability. To better organize this complexity, we grouped the selected KPIs into five distinct categories, drawing inspiration from previous studies — particularly Wang et al. (2014). *User characteristics* consider the diverse needs of cyclists, including differences in age, ability, gender, and experience, ensuring that cycling infrastructure is inclusive for all. *Accessibility* focuses on how easily cyclists can reach destinations through connected networks and proximity to essential services. *Safety and security* encompass both the reduction of crash risks through protected infrastructure and the prevention of theft or personal harm through well-lit, monitored, and secure environments. Finally, *convenience* and *mobility feasibility* assess how practical cycling is as a mode of transport, considering directness of routes, availability of amenities, and overall efficiency compared to other travel options.

In line with these principles, we identify 9 KPIs (Table 2), evenly distributed among the five thematic categories mentioned above. These indicators are designed to offer a comprehensive yet manageable toolkit for assessing whether an environment meets the minimum conditions required to support and promote cycling. The outcome of this categorization process forms the basis for subsequent stages of analysis, including the comparison of economic performance guaranteed by different transport alternatives. By translating qualitative and experiential aspects into defined KPIs, this framework facilitates a clearer comparison between cycling and other transport modes. It equips users and policymakers alike with insights into the real-world impacts of mobility choices—whether in terms of cost, time, safety, or quality of experience—enabling more informed and sustainable decisions in urban mobility.

Table 2. KPIs for the evaluation of the minimum conditions of bikeability.

Section	KPI	Specification	Approach
User characteristics	Reason of displacement	Reason why a person commutes by bike.	Work; study; entertainment; other.
	Health status	Identification of the type of bicycle user.	Daily; occasional; vulnerable; companion; none.
Accessibility	Cycling Infrastructure	Whether there is bicycle infrastructure.	Y/N
	Barriers	Whether there are structural impediments.	Y/N
		If it is compatible with physical condition.	Y/N
Security	Separation of the bike path	From road users.	Y/N
		Lane dedicated exclusively to cyclists.	Y/N
	Bicycle facilities	Whether the routes have safety elements (e.g. traffic calming, signage, illumination).	Y/N
Convenience	Car Parking	For Bikes.	Y/N
		For cars.	Y/N
	Comfort	Whether the trip is compatible with bike.	Y/N
Mobility options	Availability of a vehicle	Car.	Y/N
		Bicycle.	Y/N

5. Conclusions

Understanding the extent to which people are willing and able to cycle is crucial for promoting cycling as a sustainable form of transport, thus reducing negative externalities caused by motorized traffic. This paper presents the complexity and variation in indicators used in literature to measure bikeability, which is a requisite for the proper evaluation of bicycle impacts. To tackle this issue, we have proposed a framework of KPIs that weaves together five thematic areas: User Characteristics, Accessibility, Security, Convenience, and Mobility Feasibility. With emphasis on qualitative indicators, this framework not only embraces functional characteristics of the cycling infrastructure but also integrates users' perceptions and experiences in a first appraisal to understand whether cyclability can become an option for users' trips. This set of KPIs represents a key milestone towards the development of a more comprehensive calculator that compares cycling performance to other transport modes. This allows a better comprehension of the implications in using bicycle. To this aim, the qualitative indicators mentioned above are not sufficient. In the next phases of the CICLO! project, once the bikeability of a trip has been verified, the economic impacts (not only the financial ones) deriving from the use of the bike are evaluated in a quantitative way. In the end, creating transparent, human-centered metrics for both users and policymakers will be crucial for empowering more informed decision-making and encouraging a larger cultural shift toward active mobility. Understanding if the infrastructural network and the environment allow this, is a first unavoidable step towards this goal.

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