Towards a Multidimensional Assessment of Urban Bikeability: Integrating GIS and User Perception

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Abstract. Cycling is widely acknowledged as a key component of sustainable urban mobility, but its adoption remains limited in many high-motorization Mediterranean cities. In these contexts, bikeability cannot be evaluated only through cycling infrastructure provision, but should be interpreted as the result of the interaction between spatial, environmental, and perceptual dimensions.

This paper proposes a multidimensional framework for the assessment of urban bikeability through the integration of spatial evidence and user perception data. The analysis is applied to the case study of Catania, combining the current and planned cycling network derived from the official Biciplan with the distribution of vegetated areas obtained from regional cartography as a proxy for environmental quality and survey-based evidence on mobility habits, perceived barriers and cycling incentives.

The findings point out a fragmented existing cycling network and a broader but still spatially uneven planned configuration. Moreover, they highlight an unequal distribution of vegetated areas, with more extensive green coverage in peripheral zones than in the dense urban core. Survey findings show that cycling still plays a marginal role in everyday mobility and the most relevant barriers are safety-related concerns due to the interaction with motorized traffic and inadequate infrastructures.

The study reveals a mismatch between planning intentions and experienced cycling environments by users. Thus, improving bikeability requires an integrated approach which combines infrastructure provision, environmental quality and perceived safety. The proposed framework can be transferred to other urban contexts characterized by high motorization rates and limited cycling uptake.

Keywords: Bikeability · Cycling Infrastructure · Perceived Safety · Green Infrastructure · GIS · Sustainable Mobility

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O. Gervasi et al. (Eds.): ICCSA 2026 Workshops, LNCS 16765, pp. 531–546, 2027.
https://doi.org/10.1007/978-3-032-30536-7_34

1 Introduction

Cycling is ever more recognized as a key component of sustainable urban mobility because it can contribute to reduce emissions, mitigate congestion, improve public health and use urban space more effectively. This perspective has also been strengthened at the European level by the European Declaration on Cycling, which recognizes cycling as a fully-fledged transport mode and as a relevant component of wider urban sustainability strategies [1]. This broader view is consistent with studies that frame sustainable urban development as an integrated process involving transport systems, green infrastructures, and new forms of metropolitan governance [2].

Despite the growing attention, the transition toward cycling-oriented mobility remains highly uneven across cities. In many Southern and Mediterranean urban contexts, cycling still plays a marginal role in daily mobility because of a mix of structural, cultural and institutional barriers. These include high motorization rates, fragmented or insufficient cycling infrastructure, low perceived safety and the in general car-oriented travel habits. Recent review reports confirm that the built environment strongly affects cycling behaviour, with street connectivity and the presence of cycling facilities among the most consistent explanatory factors [3].

In this regard, Catania offers a relevant case. The city and its wider metropolitan area are characterized by a strong dependence on motorized private transport and a weak cycling demand, with the existing cycling network limited and discontinuous. The Biciplan of the Metropolitan City of Catania explicitly identifies safety, connectivity, and network coverage as key conditions for increasing cycling demand and acknowledges that cycling usage is currently well below national averages in the metropolitan area. Therefore, the plan outlines cycling promotion as part of a broader transition toward more sustainable and inclusive mobility.

However, beyond infrastructure, urban cycling conditions are also influenced by the environmental quality of routes. Recent studies suggest that green infrastructure and linear green elements may influence route attractiveness, environmental comfort and perceived safety, indicating that bikeability should be understood not only through network provision but also through the quality of the surrounding urban landscape [4]. This is particularly relevant in Catania, where the relationship between environmental awareness, mobility behaviour and urban sustainability has already emerged in recent survey-based and governance-oriented studies [5]. Therefore, assessing cycling conditions only in terms of network extension may provide an incomplete picture. An existing route may still be unattractive or weakly used if it is fragmented, embedded in adverse traffic conditions, or located in urban environments with poor environmental quality. Likewise, planning strategies may grow the cycling network, but their practical effectiveness depends on how those interventions are perceived and experienced by users. This is especially important in cities where cycling demand is still weak and where cultural and perceptual barriers remain substantial. More generally, this is coherent with broader approaches to urban sustainability that emphasize the need to consider environmental resources as active components of regeneration, livability, and local development [6, 7].

Against this background, this study proposes a multidimensional framework for assessing urban bikeability by integrating GIS-based spatial evidence with user perception data, applying to the case of Catania. The work investigates to what extent the current and planned cycling networks provide spatial continuity and territorial coverage within the urban context, whether existing and planned routes are in areas characterized by adequate vegetation coverage and environmental quality, and whether the environmental context may act as a potential driver of bikeability. Moreover, we explore how this spatial picture can be linked with users' perceptions about safety and comfort. By jointly addressing these issues, the paper aims to capture bikeability considering the interaction between network structure, environmental context and user experience.

In this regard, the study contributes to the broader literature by combining three dimensions that are often examined separately: the spatial structure of the current and planned cycling network, the distribution of vegetated areas as a proxy for environmental quality and survey-based evidence on users' perceptions. Although applied in a specific Mediterranean context, the proposed framework is intended to be transferable to other cities characterized by high motorization rate and, limited cycling uptake with ongoing efforts to expand cycling infrastructure.

2 Literature Review

2.1 Bikeability as a Multidimentional Concept

The concept of bikeability has progressively evolved from a limited focus on cycling infrastructure toward a broader understanding of the urban conditions that make cycling feasible, attractive and safe. Relevant studies showed that bikeability depends on a combination of variables related to the built-environment, including connectivity, topography, land-use patterns and, thus, the availability of cycling facilities. In this regard, bikeability is not linked only to the presence of bicycle lanes, but the extent to which an urban environment supports cycling as a viable and desirable transport mode for daily movements. One of the most influential attempts to operationalize this concept is the work by [8], who developed a spatial tool to map bikeability considering infrastructure, slope, connectivity and attributes related to the destination. Their later work on Bike Score further demonstrated that bikeability measures are associated with cycling mode share both within and across cities, highlighting the usefulness of composite measures for planning and policy support [9].

More recent studies confirm that cycling behaviour is influenced by multiple dimensions of the built environment. Street connectivity and cycling infrastructure are among the strongest correlates of cycling uptake, but the literature also emphasizes density, accessibility, route directness and the quality of urban design [3]. This multidimensional reading is especially relevant in contexts where cycling remains marginal. In such cases, isolated routes or short infrastructural interventions may have limited impact unless they are part of an intelligible system able to support continuous trips. For this reason, recent contributions increasingly argue that bikeability should be assessed as the combined outcome of infrastructural provision, spatial continuity, and the broader quality of the urban environment [10]. This is also consistent with urban studies that highlight the standing of integrated planning approaches, especially in metropolitan contexts where

mobility, environmental quality and governance are strongly interconnected [11]. In this respect, bikeability cannot be interpreted only as a transport-related attribute, but also as a component of wider sustainable urban transition processes.

2.2 The Role of Perceived Safety in Cycling Behaviour

Alongside objective spatial conditions, perceived safety has emerged as one of the most important determinants of cycling behaviour. A substantial body of literature shows that potential and actual cyclists respond not only to measurable infrastructural attributes, but also to how safe, stressful, or comfortable a route feels in practice. This implies that objective provision and subjective experience do not necessarily coincide [12].

The distinction between observed and perceived cycling safety has been discussed explicitly in recent research. The authors [12] show that cycling safety can be assessed through both objective and perception-based methods, and that these two dimensions capture different but complementary aspects of the cycling experience. Their contribution is especially relevant because it supports the need to integrate infrastructural assessment with users' perceptions in order to obtain a more realistic understanding of cycling conditions.

More broadly, recent reviews on safety technologies and cyclist behaviour suggest that users consistently value solutions that improve safety, especially in contexts where traffic exposure and interaction with motorized vehicles are perceived as critical. However, these studies also indicate that technological or behavioural improvements alone are insufficient if the broader infrastructural and traffic context remains hostile [13–15].

This line of research is particularly important in cities with weak cycling cultures. In such contexts, perceived risk associated with traffic, discontinuous routes, and low-quality urban environments can strongly discourage bicycle use even where some form of infrastructure exists. For that reason, bikeability cannot be assessed through network maps alone; it must also account for how routes are perceived in terms of safety, continuity, and comfort. This is in line with recent evidence from Catania showing that mobility choices are also influenced by environmental awareness and by users' broader attitudes toward sustainable transport options [16].

Therefore, the perceptual dimension is not an accessory component of bikeability assessment, but a necessary complement to spatial analysis, especially where cycling demand is still weak and user confidence remains limited.

2.3 Green Infrastructure and Cycling Environment

A third and more recent strand of literature concerns the relationship between cycling and green infrastructure. While traditional bikeability studies have focused mainly on infrastructure and land use, growing attention is now being devoted to the environmental quality of cycling routes, including shading, landscape attractiveness, thermal comfort, and the presence of green corridors [17, 18].

In this regard, green infrastructure is not simply an aesthetic addition to cycling provision. It may influence how routes are experienced, how comfortable they are under local climatic conditions, and how safe they feel, especially for more vulnerable or less

confident cyclists. Recent research on linear green infrastructure suggests that green elements can positively affect perceived cycling safety and improve the overall quality of the cycling environment.

Evidence from route-based and spatial analyses also suggests that green areas can interact with the built environment in shaping cycling patterns. In particular, the co-location of cycling routes, attractive destinations, and green areas may foster more supportive urban conditions for everyday cycling, especially when these factors operate together rather than in isolation [4].

For Mediterranean cities, this issue is particularly relevant. Climatic exposure, summer heat, and the uneven distribution of urban greenery may affect the attractiveness of cycling routes more strongly than in cooler contexts. This makes the integration of cycling planning and green infrastructure relevant, not only in terms of visual quality but also in relation to comfort, urban livability and daily network serviceability. In this regard, Copenhagen is often cited as a leading example of integrated cycling planning. Its planning framework clearly considers green cycle routes as an alternative to congested roads, combining mobility and recreational functions while improving route quality and user experience. Official planning documents describe green cycle routes as corridors running through green areas or along the harbour, thus offering more pleasant and less stressful cycling conditions [19, 20]. Such examples are useful not because they demonstrate that cycling policy can move beyond the simple provision of lanes and incorporate environmental quality into route design. For cities like Catania, where cycling conditions are still fragile and uneven, this is valuable as a strategic benchmark.

The literature suggests that bikeability should be interpreted as a multidimensional concept resulting from the interaction among network structure, perceived safety, and environmental quality. However, these dimensions are often investigated separately. This paper addresses that limitation by integrating the spatial configuration of the current and planned cycling network, the distribution of vegetated areas, and user perceptions within a single analytical framework, with specific attention to a high-motorization Mediterranean context.

3 Materials and Methods

The methodological approach combines spatial and perception-based evidence in order to develop a multidimensional assessment of bikeability. The analysis is based on three main data sources: the cycling network, cartographic information on vegetated areas, and survey data on users' mobility habits and perceptions, with the aim of comparing the planned spatial structure of cycling provision with the conditions experienced by users.

3.1 Study Area

Catania is a Mediterranean urban context characterized by high levels of private motorization and a still limited role of cycling in everyday mobility. As highlighted in the Biciplan of the Metropolitan City of Catania, cycling in the area remains well below national averages, while the current transport system is still strongly oriented toward

motorized travel. Local planning documents identify cycling as a strategic component for the transition toward safer and more sustainable mobility.

In this regard, Catania represents an interesting and relevant case for the assessment of bikeability. On the one hand, the city is characterized by structural constraints typical of high-motorization urban contexts, including discontinuous cycling provision and, thus, weak cycling habits. On the other hand, the recent Biciplan provides a clear strategic vision aimed at expanding and reorganizing the cycling network at the metropolitan scale, with particular attention to aspects related to safety, connectivity and territorial coverage. In addition, the study area is characterized by a marked spatial heterogeneity in environmental conditions, e.g. the uneven distribution of vegetated areas across central, peripheral and peri-urban zones. This aspect is remarkable in Mediterranean contexts, where environmental quality and climatic exposure may influence the attractiveness and comfort of cycling routes.

3.2 Data Sources

Cycling Infrastructure
We reconstructed the spatial layout of the cycling network from the official Biciplan of the Metropolitan City of Catania, accessed through the institutional online interactive map and supported by the related technical report. The network was not available as a fully georeferenced analytical dataset for direct quantitative network processing. Nevertheless, the sources provide a reliable representation of existing routes, planned corridors and local interventions. The Biciplan explicitly distinguishes between the current network, the planned metropolitan-scale cycling system and additional local projects and it frames cycling planning in terms of safety, connectivity, and coverage.

Vegetated Areas
Vegetation data were derived from the official regional technical map (i.e. CART2000) provided by the Sicilian Regional Geographic Information System ("Sistema Informativo Territoriale Regionale" - SITR). The vegetation layer includes different types of vegetated areas and was used as a proxy for environmental quality in the study area. In particular, the analysis considered both structured vegetation classes (G1), representing more defined and organized green areas, and more general vegetated surfaces (G0), which may also include natural and agricultural land uses. The dataset does not distinguish between public, accessible, and non-accessible green areas; therefore, it was interpreted as a representation of vegetated environmental context rather than as a measure of urban public green provision.

Survey Data
Survey data were collected through a structured questionnaire aimed at investigating mobility habits, cycling behaviour, and user perceptions related to bicycle use and technological innovation. The questionnaire consisted of 24 questions and was organized into three main sections: (i) travel habits and transport mode preferences, (ii) knowledge and propensity toward technological innovation in cycling, and (iii) socio-demographic characteristics.

The survey was administered in 2025 online using Google Forms. It was disseminated through multiple channels, including cycling associations and informal networks, in order to reach both regular cyclists and non-cyclists. The participation was voluntary and anonymous. A total of 56 responses were collected. Although the sample is not statistically representative of the entire population because it could be affected by potential biases, it provides useful evidence on mobility patterns, perceived barriers and attitudes toward cycling within the analyzed local context. This is a work in progress, and thus future survey waves will enlarge the sample to reduce potential bias and increase the robustness and interpretability of the results.

3.3 Analytical Framework

The study implements a multidimensional analytical framework where bikeability is considered through the integration of spatial evidence and user perception. Therefore, this approach is grounded with the assumption that cycling conditions cannot be adequately captured only through infrastructural provision but rather emerge from the interaction between physical network structure, environmental context and how these elements are perceived by users.

In this work, the spatial dimension considers the current and planned configuration of cycling network, as identified by the Biciplan, and on its relationship with the distribution of vegetated areas. The analysis was developed within a GIS environment and is based on a qualitative spatial interpretation of the network, considering aspects such as territorial distribution, continuity and coverage. Attention is given to the comparison between the existing network and the planned configuration, in order to identify differences in spatial structure and potential improvements in connectivity.

Due to the features of the available data, the cycling network could not be processed as a fully georeferenced analytical network suitable for the computation of formal graph-based indicators. For this, the analysis relies on an interpretative spatial assessment of fragmentation, concentration, and expansion patterns. This exploratory and planning-oriented approach aims to evaluate the spatial logic of cycling provision.

The environmental component is integrated by considering the distribution of vegetated areas derived from the regional technical cartography. Vegetation is interpreted as a proxy for environmental quality, allowing the analysis to characterize the context in which cycling routes are embedded. The combined analysis between cycling infrastructure and vegetated areas allows us to identify whether current and planned routes are located in more favorable environmental conditions, particularly with respect to the distinction between central urban areas and peripheral or peri-urban zones.

The perception-based dimension is integrated through the analysis of survey data, with the aim of capturing users' attitudes, constraints and expectations regarding cycling. The questionnaire results investigated mobility habits, frequency of bicycle use, perceived barriers, and factors that may encourage a greater adoption of cycling. A focus is given to aspects related to safety, which are consistently identified as key determinants of cycling behaviour, as well as to the relative importance attributed to infrastructural improvements and other potential incentives.

From a methodological perspective, the integration of spatial and perception-based evidence represents the core. The study develops a comparative analysis aimed at identifying convergences and divergences between the spatial structure of cycling provision and users' perceptions. In particular, the analysis explores whether areas characterized by higher potential cycling demand are supported by adequate infrastructure and environmental conditions, and whether these align with factors that users consider most relevant for cycling.

Thus, through this integrated approach, bikeability is interpreted as a multidimensional concept resulting from the interaction between infrastructural, environmental, and perceptual components. This allows the analysis to move beyond a solely infrastructure-based evaluation and to highlight possible mismatches between planning strategies and actual conditions experienced by users.

4 Results

This section presents main findings by combining spatial and perception-based evidence. Firstly, we focus on spatial configuration of the current and planned cycling network and the distribution of vegetated areas. Secondly wet report the main survey results related to cycling behaviour, perceived barriers and incentives. The final subsection integrates these dimensions in order to provide a multidimensional interpretation of bikeability in Catania.

4.1 Spatial Analysis

Figure 1 shows the spatial distribution of vegetated areas in Catania, derived from the regional technical map (i.e. CART2000). The dataset includes both structured vegetation, identified asG1, which represents more defined and organized green areas, and more general vegetated surfaces named G0, which may include natural and agricultural land uses.

The spatial pattern highlights a clear irregular distribution of vegetation across the study area. More extensive and continuous vegetated areas are mainly located in peripheral and peri-urban zones, while the central urban area is characterized by a limited presence of green spaces. In addition, structured vegetation (G1) appears more spatially concentrated and discontinuous, whereas general vegetation (G0) covers larger portions of the territory, particularly outside the dense urban core. This configuration provides an initial representation of the environmental context in which the cycling network is embedded, allowing for a qualitative assessment of the relationship between cycling infrastructure and surrounding landscape conditions.

Figure 2 shows the cycling infrastructure in Catania based on the official Biciplan of the Metropolitan City. Existing routes drawn in blue, planned network in purple and local interventions in orange are represented over the urban road system. As shown in Fig. 2, the current cycling infrastructure in Catania is mainly concentrated in the central area and consists of several disconnected segments. This spatial pattern is consistent with the limited role of cycling reported in local planning documents, which remains significantly underneath the national average.

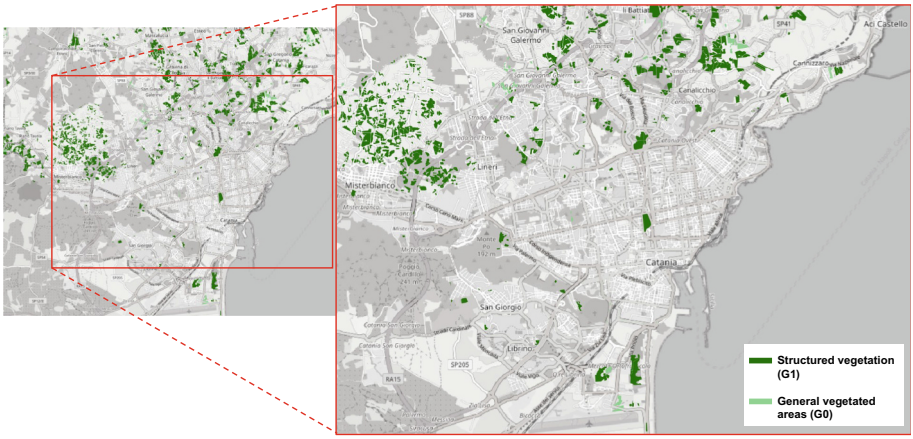

Fig. 1. Spatial distribution of vegetated areas in Catania derived from the regional technical map (CART2000)

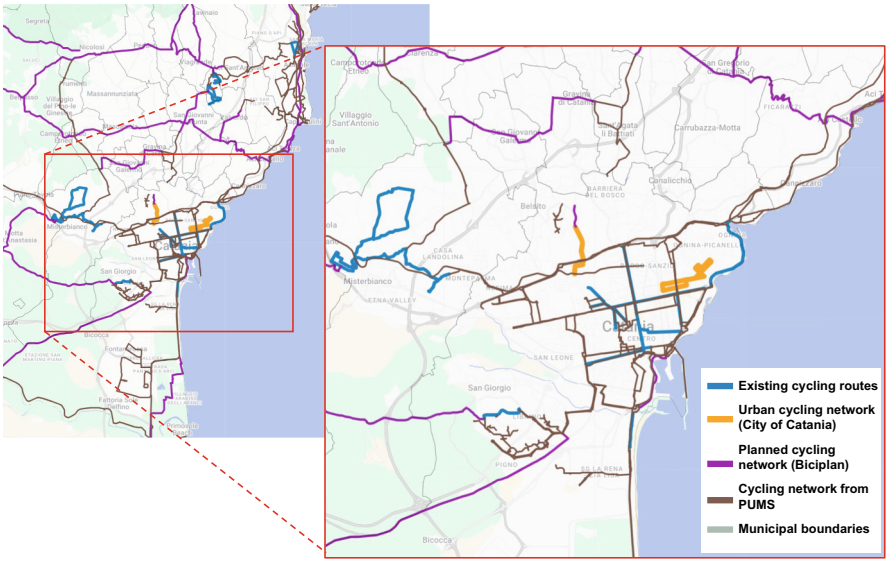

Fig. 2. Cycling infrastructure in Catania based on the official Biciplan of the Metropolitan City.

Peripheral and peri-urban sectors appear less served by dedicated cycling infrastructure, while some interventions are spatially isolated from the main network.

This fragmented configuration contrasts with the more extensive network proposed in Biciplan, which aims to improve connectivity across the metropolitan area. This planned configuration increases territorial coverage and introduces a more structured network layout. The presence of isolated interventions indicates that some discontinuities remain within the current spatial configuration. Therefore, understanding how users perceive the

cycling environment becomes essential to assess the actual effectiveness of the planned interventions and to support the transition toward more sustainable mobility patterns.

4.2 Perception Analysis

This subsection examines the perceptual dimension of bikeability through survey-based evidence. Attention is given to mobility habits, frequency of bicycle use, perceived barriers and conditions considered most effective for encouraging greater cycling uptake.

The sample shows a noticeable dependence on private motorized transport for daily travel. As illustrated in Fig. 3, cars and motorcycles are the prevalent modal choice associated with the daily trip, accounting for 71% of responses, while walking and personal bicycle use represent about 9%, and public transport remains marginal at around 5%. These results confirm the limited role that cycling has in daily mobility patterns.

This overview is consistent with the frequency of bicycle usage emerged by respondents. A substantial share of them declared that they do not use a bicycle on a regular basis, while only a smaller group reports occasional or frequent usage. More specifically, 42.9% of respondents state that they do not use a bicycle, whereas the remaining share is distributed between occasional and more regular usage. This confirms again the marginal role of cycling.

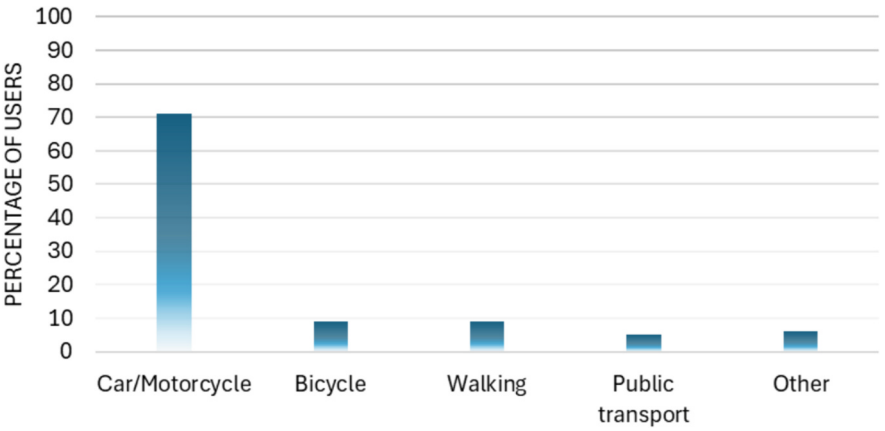

Fig. 3. Distribution of transport modes for the most relevant daily trip

Perceived barriers to bicycle use are summarized in Fig. 4, which presents a qualitative ranking based on the relative importance attributed to different deterrents. Safety-related factors emerge as the most critical obstacles; in fact, traffic danger is identified as the main barrier, with 43% of respondents assigning a high level of importance, followed by the lack of cycling infrastructure and interaction with other road users, both reported by 34% of respondents. By contrast, economic cost and physical effort appear to play a less relevant role and are placed at the lower end of the ranking.

A complementary perspective emerges from the analysis of perceived incentives to cycle. As shown in Fig. 5, respondents clearly prioritize measures related to safer

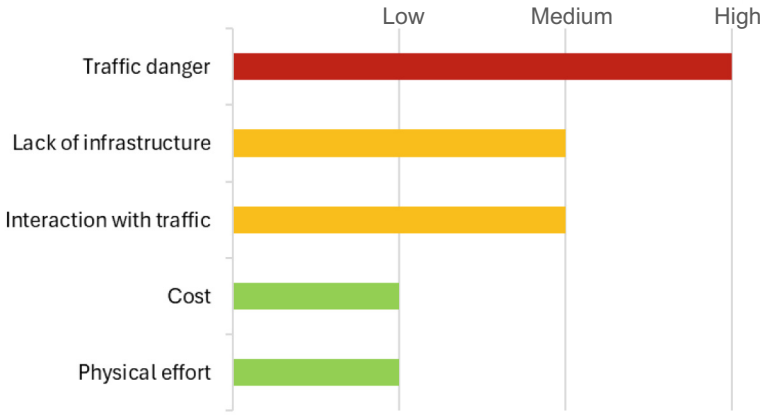

Fig. 4. Qualitative ranking of main perceived barriers to bicycle use

and better-quality cycling conditions. Road safety improvement is identified as the most relevant incentive, mentioned by 84.1% of respondents, followed by the improvement of cycling infrastructure, indicated by 65.9%. Secure parking facilities are also positively perceived, although with lower intensity, while financial incentives appear less important than infrastructural and safety-related measures.

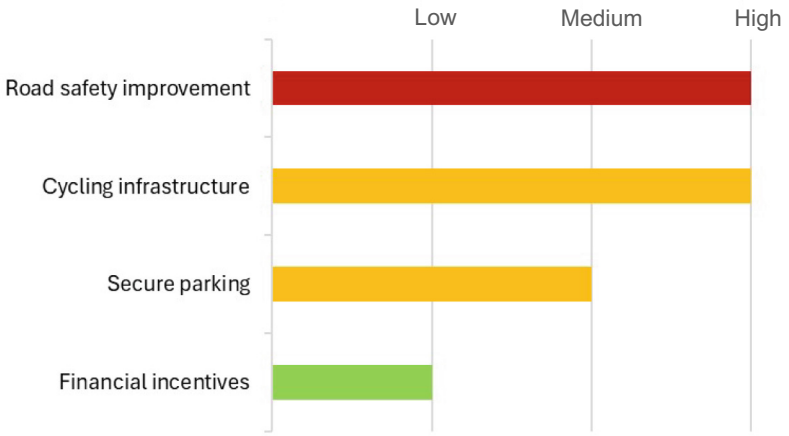

Fig. 5. Perceived incentives to increase bicycle use

Beyond the basic barriers and incentives, the survey also provides useful indications on attitudes toward technological innovation in cycling. Awareness of integrated bicycle technologies is split, with 50% of respondents declaring familiarity with such solutions and 50% reporting no prior knowledge. Among the proposed technologies, the most

appreciated are those directly associated with safety and trip support, especially collision-detection radar systems (75%) and GPS/navigation tools (60.7%).

However, this positive attitude does not automatically translate into a strong willingness to pay. Most respondents express interest in smart technologies only under conditions of economic affordability: 48.2% report being willing to spend up to €200 more for a bicycle equipped with such systems, while overall about 80% consider technological innovation a potential incentive only if associated costs remain accessible.

These findings indicate that the main constraints on cycling are associated more with infrastructural and safety conditions than with individual or purely economic factors. Additionally, the survey suggests that technological innovation may support cycling uptake, but only as a complementary factor within a broader context of safe, continuous and attractive cycling environments.

5 Discussion on Integrated Bikeability Assessment

The integrated assessment combines the spatial and perceptual dimensions discussed in the previous subsections in order to evaluate whether the current and planned cycling system in Catania corresponds to the conditions that users identify as necessary for bicycle use. Infrastructure, environmental context, and user perception are therefore interpreted jointly, so that bikeability can be examined as a composite urban condition rather than as a simple matter of route provision.

A first point concerns the relationship between the strategic vision outlined in the Biciplan and the cycling conditions currently observable in the study area. The plan proposes a broader and articulated cycling system, organized around hierarchical logic aimed at improving safety, connectivity and territorial coverage. This reflects an effort to move beyond isolated interventions and to frame cycling infrastructure as part of a wider metropolitan mobility strategy. However, the current spatial structure remains fragmented, with existing routes mainly concentrated in the central urban area and several segments disconnected.

Therefore, the transition from the current network to the planned one cannot be considered as a simple increase in route supply. Although the Biciplan expands territorial coverage, the practical value of the network depends on how continuity is achieved within the urban fabric, where daily trips are most likely to begin and end. The stronger emphasis on metropolitan and extra-urban continuity leaves some urban connections less clearly defined, even though these segments are pivotal for everyday cycling. In a context where bicycle use is still limited, local discontinuities may reduce the actual usability of the network even when the plan appears spatially more extensive.

A second point concerns the environmental dimension of bikeability. The spatial distribution of vegetated areas reveals a marked imbalance between the dense urban core and the more peripheral or peri-urban parts of the study area. Larger and more continuous vegetated surfaces are found mainly outside the urban fabric, whereas the central parts of the city show a more limited and fragmented presence of green areas. The sectors in which cycling demand is potentially higher do not coincide with city areas offering the most favorable environmental conditions. Even where cycling routes already exist, or are planned, the surrounding landscape may not provide a comfortable, attractive, or climatically favorable setting for daily cycling.

The survey evidence is coherent with this spatial reading. Cycling still plays a marginal role in daily mobility, while private motorized modes continue to dominate. Respondents identify traffic danger, lack of adequate cycling infrastructure and unsafe interaction with other road users as the main barriers to bicycle use. By contrast, improvements in road safety and cycling infrastructure are considered the most effective conditions for increasing bicycle uptake. Low bikeability level in Catania is therefore linked not only to the objective structure of the network, but also to safety, continuity, and comfort.

The comparison between spatial and perceptual evidence points to a clear mismatch. Planning documents describe a cycling system that is more connected, safer and more comprehensive than the existing one. The areas where cycling could be most relevant for daily mobility, however, are still characterized by fragmented infrastructure, limited environmental quality and low perceived safety. Bikeability cannot therefore be reduced either to the presence of cycling routes or to the planned extension of the network. It depends on the relationship between infrastructural continuity, environmental quality and how cycling conditions are perceived by users.

The case of Catania shows that improving bikeability in high-motorization urban contexts requires more than the network expansion. Infrastructure provision remains necessary, but its effectiveness depends on the creation of continuous and intelligible urban routes, on safer traffic conditions in the areas of greatest potential demand and on a better quality of the cycling environment. The integration of green infrastructure within cycling planning may represent an environmental enhancement measure, but also a relevant component of more attractive and user-oriented cycling policies.

A multidimensional reading of bikeability makes it possible to identify not only where cycling infrastructure could be embedded in conditions that can realistically support bicycle use. This point is especially relevant in cities where cycling is still underdeveloped and where the main challenge is not simply to build infrastructure, but to make cycling a realistic, safe and attractive mobility option.

6 Conclusions

This study proposed a multidimensional framework for assessing urban bikeability by integrating spatial evidence and user perception, with application to the case of Catania. The analysis combined three complementary dimensions: the configuration of the current and planned cycling network, the distribution of vegetated areas as a proxy for environmental quality and survey-based evidence on users' perceptions related to cycling conditions.

The main contribution of the study lies in the development of an integrated analytical framework able to combine heterogeneous sources of evidence in order to interpret bikeability as a multidimensional concept. Furthermore, its replicability to other case studies can allow to improve safety and sustainability of the sector. Rather than reducing bikeability to infrastructure provision alone, we consider the interaction between infrastructural, environmental, and perceptual dimensions. This makes the methodological approach particularly suitable for contexts where detailed georeferenced data are not fully available, but where planning documents, cartographic information, and user-based evidence can still be jointly interpreted.

From an empirical perspective, the case of Catania highlights a clear mismatch between the cycling system envisioned by planning strategies and the conditions currently experienced by users. From the spatial analysis emerged a fragmented and spatially concentrated existing cycling network, mainly located in central urban areas, while the Biciplan proposes a broader and more connected system at the metropolitan scale. In parallel, the analysis of vegetated areas showed an uneven environmental pattern, with more extensive and continuous green coverage in peripheral and peri-urban zones and a more limited presence in the dense urban core.

The perception-based findings further reinforced this interpretation. Survey results indicate that cycling is still marginal within daily mobility patterns and the main barriers to bicycle use are related to traffic danger, inadequate infrastructure and unsafe interaction with other road users. Conversely, respondents identify improvements in road safety and cycling infrastructure as the most effective conditions for increasing bicycle use. These findings suggest that bikeability in Catania is constrained by the limited continuity of the cycling network and by broader environmental and perceptual conditions.

These results have relevant policy implications for planning strategies. In high-motorization contexts such as Catania, expanding the cycling network is necessary but not sufficient. Planning strategies should also address the quality of the urban environment in which cycling takes place, improve safety conditions and reduce the gap between planned infrastructure and perceived usability. Thus, the integration of green infrastructure within cycling planning may represent an important opportunity to enhance the attractiveness, comfort and overall effectiveness of cycling routes.

Despite these contributions, the study also presents some limitations. The survey sample is relatively small, which can limit the generalizability of the perception-based findings. and the spatial analysis is based on a qualitative interpretation of the cycling network, due to the lack of a fully georeferenced analytical dataset suitable for advanced network processing.

In this regard, future research could extend the proposed framework by incorporating more detailed and fully georeferenced datasets in order to calculate quantitative GIS-based indicators of bikeability, such as connectivity measures, accessibility indices, and indicators of spatial proximity between cycling infrastructure and environmental resources. Moreover, comparative analyses across different urban contexts could provide further insights into how the interaction between infrastructure, environmental quality, and user perception varies across cities with different mobility patterns, planning traditions, and climatic conditions. Such developments would support a broader validation of the framework and strengthen its transferability to other high-motorization urban contexts.

Acknowledgments. The present study has been conducted within the framework of the project "SIA3 - Soluzioni InnovAtive e strategie di sostenibilità per città, territori e società - Innovative solutions and strategies for the sustainability of Cities, Land and Society", financed by University of Catania. This paper was also partially supported by the PNRR National Centre for HPC, Big Data and Quantum Computing, Mission 4 Component 2, Investment 1.4, CUP E63C22001000006. and project "Piano della Ricerca Dipartimentale" – "MOdelli di Pianificazione di Mobilità Sostenibile - MOPIMOS", University of Catania.

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