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Identification of cycling service areas to promote the redevelopment of urban areas. A Multi-criteria GIS analysis to the City of Naples

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Abstract

Active mobility contributes to making urban areas more liveable and attractive, as well as offering numerous public health and environmental benefits. Cycling and walking routes play a significant role in the development of a sustainable and intermodal urban mobility system and are well suited for integration with digital mobility services such as MaaS. In this context, enhancing bicycle and pedestrian accessibility to urban destinations and services can serve as a catalyst for the broader revitalization and redevelopment of entire urban areas. From this perspective, the study aims to (i) identify suitable areas for improving cycling infrastructure and pedestrian access, and (ii) rank these areas based on their potential to host related services effectively. These two goals are oriented to support local policy makers in identifying the parts of a district that can be primarily and effectively destinated to host biking stations and that can promote the regeneration of the urban context. To this end, a methodology combining multi-criteria overlay analysis and the TOPSIS method within a GIS environment is developed and applied to the Fuorigrotta neighborhood in Naples, with a focus on the 11–18-year-old population group. The methodology, on the basis of Ad Hoc defined criteria, allows the definition and the classification of potential areas where cycling can be improved through cycling support services and which can be the driving force for the restoration of the urban context in which they are located. The study provides a support tool for decision-makers to improve accessibility to intermodal services and, at the same time, contributes to the triggering of broader redevelopment processes, with particular attention to peripheral areas adjacent to transport infrastructures, where the quality of public spaces is often inadequate. The study is part of the project 'National Centre for Sustainable Mobility' - Spoke 8, funded by the PNRR, aimed at implementing a new model of mobility, as a service, accessible and inclusive, for a more sustainable urban mobility system.

Keywords: Multi-Overlay Analysis, TOPSIS analysis, Urban Accessibility, MaaS, Active Mobility, Urban Planning.

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1. State of the art

The growing recognition of the multiple benefits associated with active mobility has placed the latter at the center of urban planning strategies aimed at transforming urban areas into more liveable, attractive, and sustainable contexts (Rinaldi et al., 2025).

Active mobility promotes public health by combating sedentary lifestyles and related diseases and protects the environment by reducing air pollution, noise, and greenhouse gas emissions caused by motorized traffic. In this scenario, infra-structures dedicated to soft mobility, such as cycling and pedestrian paths, emerge as key elements for the development of an urban mobility system that is both sustainable and intermodal, integrable with advanced digital mobility services, such as Mobility as a Service (MaaS) platform (Gran & Li, 2025).

An urban environment that favors active mobility tends to become more attractive for residents, visitors, and economic activities, stimulating social vitality, the use of public spaces, and the creation of a stronger sense of community. Targeted investments in the creation and enhancement of cycling and pedestrian infrastructure, together with urban redevelopment interventions that improve the quality of adjacent public spaces, can transform marginal or underused areas, triggering a virtuous circle of enhancement and redevelopment of entire urban areas.

In this context, the identification of strategic areas in which to intervene to improve cycling and redevelop the surrounding urban context takes on crucial importance for policymakers and urban planners.

Multi-criteria analysis (MCA) integrated into a Geographic Information System (GIS) environment is a powerful and effective tool for analyzing the complexity of the urban fabric by considering, in parallel, a plurality of interconnected criteria. The integration of multi-criteria evaluation in a GIS context brings significant added value to decision-making processes, especially when it comes to developing a decision support system (Bahadori et al., 2022; Aprigliano et al,. 2025).

In recent literature, numerous studies have successfully employed GIS and MCA approaches to analyze a wide range of territorial and environmental issues: land use optimization for identifying the most suitable areas for urban expansion (Rahman & Szabó, 2022; AlFanatseh, 2022) or for specific land use destinations (Hussain et al., 2024; Vitianingsih et al., 2024); risk management and vulnerability assessment of territories (Thirumurthy et al, 2022; Osman & Das, 2023); cycling infrastructure planning (Terh & Cao, 2018; Santos et al., 2022); identifying optimal locations for new infrastructure, such as electric vehicle charging stations (Zhao et al., 2023) or renewable energy plants (Şahin et al., 2024).

Overlay analysis is a component of spatial modelling that uses spatial multicriteria evaluation (Walke et al., 2012). This analysis technique has been explored several times to identify optimal locations for new transportation infrastructure or mobility services that encourage sustainable mobility choices. For example, Özkan et al. (2020) focuses on how to determine cycling routes in already developed urban contexts of densely populated cities, addressing a case study in the city of Izmir, Turkey. Overlay analysis and network analysis are used, not only at the city level but also at the neighborhood level, relating to multiple characteristics, mainly topography, land use, and population. Soltanian (2022) analyzes multi-layered spatial data of Kochy City Region, India, (including land use, population, transportation network, location of transit hubs, schools, recreational areas, existing cycling infrastructure, etc.), uses GIS overlay analysis tool to identify priority cycling areas in an already developed urban area.

Other studies have used overlay analysis to identify the optimal location of new micro-mobility support services (e.g., bike-sharing stations, e-scooter sharing stations). To facilitate the creation of an effective e-scooter sharing service system in Shah Alam city, Malaysia, Roslan & Naharudin (2023) use weighted overlay analysis to obtain a suitability map that examines the potential location of e-scooter sharing (ESS) stations, evaluating 8 criteria that took into account the location and distribution network of the main tourist destinations, public transport and the type of users. Chen et al. (2024) conducted a study to determine the appropriate locations for new bike-sharing stations in Nanjing, China. The study produced a demand-based overlay analysis suitability map and combined it with a service accessibility map to identify locations for building new stations to meet the highest potential demand. The results provide a useful tool for planners and policymakers to take appropriate measures to achieve a shared and sustainable mobility system.

These researches range from the analysis of existing and potential cycling connectivity to the evaluation of accessibility to urban services, up to the optimal location of infrastructures, evaluating, in addition to the physical and environmental aspects, also the specific needs of the population and potential users, such as young commuters. In particular, the analysis of cycling about the needs of the younger age group of the population is of specific importance. Young users, especially starting from middle and high school students (aged 11 to 18), who have increasing autonomy in their travel, constitute a significant portion of the urban population with specific daily mobility needs related to access to places of education, recreational activities and social contexts. Precisely for this reason, many studies that use overlay analysis include the distribution of schools and places of leisure among the evaluation criteria, to enhance cycling and the quality of life in urban environments. Young people who choose to travel actively and sustainably not only improve their lifestyle and independence but also contribute significantly to reducing dependence on the private car for daily travel to and from school and in their free time, with cascading benefits on traffic congestion and environmental pollution.

The present study is part of this research line, proposing and testing a methodology based on multi-criteria overlay analysis in a GIS environment specifically applied to the Fuorigrotta district of Naples, with a particular focus on the population age group between 11 and 18 years. The aim is to define potential areas where the improvement of cycling, through the implementation of dedicated support services, can act as a driving force for the redevelopment of the surrounding urban context. This approach aims to provide a concrete decision support tool to improve accessibility to existing and future intermodal services while contributing to the triggering of broader urban redevelopment processes, with a particular focus on peripheral areas adjacent to transport infrastructures, where the quality of public spaces is often lacking and the potential for improvement is significant. The study is part of the broader project 'National Center for Sustainable Mobility' - Spoke 8, funded by the PNRR, which aims to implement a new model of urban mobility as a service, accessible and inclusive, for a more sustainable urban mobility system at a national level.

2. Methods and study area

2.1 Aims and scope

The study aims to identify the most suitable areas in which to improve cycling and redevelop the urban context where bike-sharing stations can be located. The objectives of the study are:

- identify the most suitable areas for the installation of cycling support services (bike stations);
- classify these areas according to the attractiveness and the urban quality of their surroundings, to support the regeneration process of open spaces and related urban built environment and therefore to enhance inclusion and accessibility at the district scale.

The study extensively discusses the importance of cycling in urban areas and how its improvement can represent a driver for the redevelopment of the urban context.

To this end, the proposed methodology is based on Multi-Criteria Overlay analysis, first, and TOPSIS analysis, then, to determine and rank the most suitable areas where locating cycling services, to improve accessibility and contribute to the triggering of broader redevelopment processes (Figure 1). Both analyses are combined with the GIS and tested in the Fuorigrotta district of the Southern Italy city of Naples.

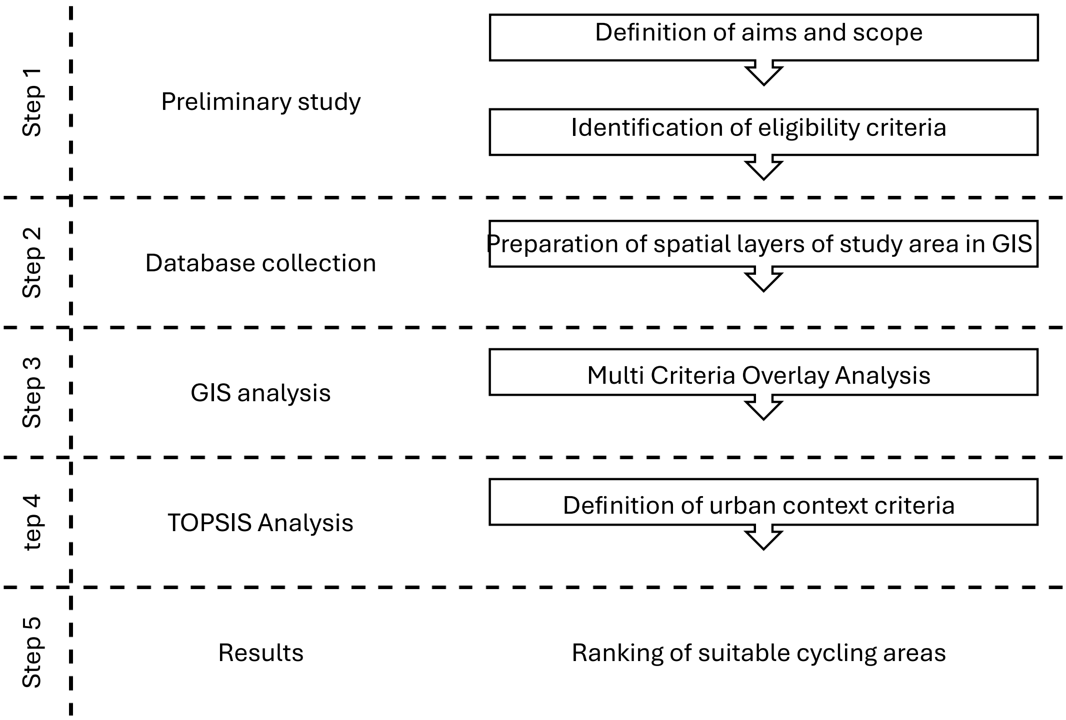

Figure 1: Methodology process.
Source: Elaboration of authors.

2.2 Eligibility criteria

In order to identify the most suitable areas in which to improve cycling with the integration of new cycling support services (cycling stations) this study used seven different suitability criteria divided into two categories: attraction criteria and detractor criteria. These seven factors under consideration (Table 1) are chosen through literature input and data availability. Attractor criteria include:

- Population density: this criterion considers the demographic trend that leads an area with a higher population density to potentially generate more cycling trips. For the analysis, the areas with the highest population density (n.ab/m² > 0.018) were considered by acquiring the data from the National Institute of Statistics (ISTAT, 2024).
- Cycle paths: the presence of dedicated cycle paths makes the use of the bicy-cle as a means of transport safer and more attractive. The location of the cycle paths was extracted from the OpenStreetMap (OSM) database.
- Schools: schools generate a high concentration of movements during entry and exit times, representing real mobility hubs with great potential, where improving cycling can encourage more children to use bicycles on their home-school journeys. The analysis took into account the position of secondary schools (Source: OSM) therefore considering students in the age group from 11 to 18, potentially more autonomous and/or interested in gaining independence in travel, more interested in traveling in groups and improving their social bonds, more sensitive to environmental issues and more inclined to use the bicycle for physical activity.
- Public transport stops and stations: in an integrated and sustainable mobility system, public transport stops and stations are intermodal nodes where the combined use of multiple means of transport is encouraged to reach the final destination, for example, the use of bicycles for short journeys such as the last mile. Bus, metro, and train stops and stations were included in the analysis by extracting their positions from the OSM database.

Detractor criteria include:

- Road slope: steep road gradients make cycling difficult and unsafe, especially for vulnerable people, such as children. This discourages the use of cycling as a means of transport, defeating the purpose of promoting cycling. For the analysis, the roads with the steepest gradient (greater than 20%) were identified starting from the digital elevation model (DEM) produced and managed by the National Institute of Geophysics and Volcanology (INGV).
- Main roads: proximity to major roads with heavy vehicle traffic is a strong deterrent to cycling. We used OSM data to determine the location of highways, major and minor roads, and their connections.
- Pre-existing cycle stations: to optimize the efficiency of a cycling mobility system and obtain an adequate distribution of the cycling service on the territory it is important to avoid excessive proximity between new and existing cycling stations. In conducting the analysis, we took into account the existing cycling stations (dedicated parking areas) provided by the bike-sharing services Bit and Voi, which operate in the area.

Table 1: Criteria and data source.

Criteria	*Description*	*Data source*
Attractor criteria		
C1 - Population density	proximity to areas with high population density	ISTAT
C2 - Cycle paths	proximity to bike lanes	OSM
C3 - Schools	proximity to secondary schools	OSM
C4 - Public transport stops and stations	proximity to local public transport stops or stations (bus, metro, train)	OSM
Detractor criteria		
C5 - Road slope	away from roads with steep slopes (> 20%)	INGV
C6 - Main roads	away from main roads (motorways, primary roads, secondary roads, and their connections)	OSM
C7 - Pre-existing cycle stations	away from existing cycle stations (dedicated parking provided by bike-sharing operators)	Bit App Voi App

2.3 Multi-Criteria Overlay Analysis

In this study, the overlay analysis in a GIS environment was applied. Overlay analysis involves combining multiple layers of geographic data to create a new layer that reflects the combination of these criteria. Spatial analysis was performed using Qgis, 3.40.5 software.

As mentioned in Section 2.2 "Eligibility Criteria", this study used seven different criteria (Population density, Cycle paths, Schools, Public transport stops and stations, Road slope, Main roads, Pre-existing cycle stations) to evaluate the optimal area for installing cycling support services. First, concerning the study area, all spatial data were collected using various sources (see Table 1) and for each criterion a different vector layer was created in GIS environment. The maps in the first column (Figure 2) show the input criteria before geoprocessing. Secondly, a conversion of the source vector data into appropriate rasters was performed. Working in raster space allows one to obtain a ranking of the suitability of the study area and to easily combine any number of input layers (Gandhi, 2019). Third, proximity rasters were obtained by performing proximity analysis using the Euclidean distance function (Qgis proximity algorithm).

Afterwards, each layer was reclassified (see second column of Figure 2) to give a higher score to pixels that are close to attractors (in the case of attractor criteria), and a lower score to pixels close to detractors (in the case of detractor criteria).

Each criterion was reclassified, by Boolean expressions, into three classes based on the suitability of pixels with respect to three distance bands: pixels up to 50 m, pixels from 50 m to 100 m, pixels over 100 m. Finally, the final multi-criteria overlay analysis is performed, summing all the reclassified rasters using the Qgis “raster calculator" tool. Once the processing is completed, the final raster will have variable pixel values where the lowest ones will be representative of less suitable areas and the highest values will indicate the most suitable areas for the placement of cycling support services.

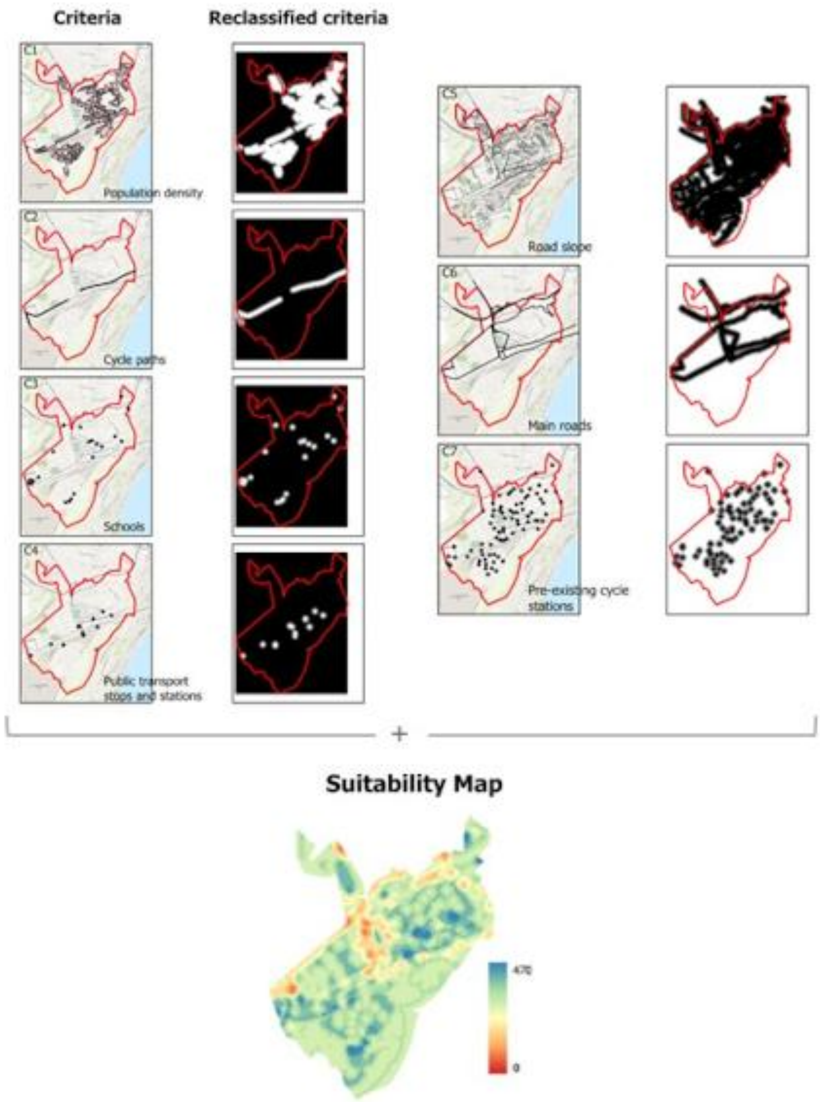

Figure 2: Thematic maps of overlay analysis in GIS.
Source: Elaboration of authors.

2.4 TOPSIS analysis

The technique for order preference by similarity to the ideal solution (TOPSIS) is a multi-objective method used for selecting the ideal choice by decision-makers. After obtaining the normalized matrix of the parameter values, the related weights are calculated by using entropy method, the positive (Ri+) and negative (Ri-) ideal alternatives are determined, with the related distances (Di+ and Di-) from the optimal solution and, finally, the nearness degree, is obtained as it de-fines the degree of proximity of each alternative (potential cycling area) and the optimal one. The larger the value is, the closer the urban public transport priority performance is to the optimal level. (Zhang et al., 2018; Önüt & Soner, 2008) are recommended for a detailed explanation.

In this work, the TOPSIS analysis is developed by considering further four criteria strictly related to the urban surroundings where the potential cycling areas are before identified, to consider the quality and attractiveness of the urban context: the proximity to commercial activity spots, the proximity to green areas, the presence of degradation and the total surface. The identification of potential locations for bike-sharing stations about the quality of the surrounding urban built environment is crucial for several interconnected reasons. The strategic placement of these stations within proximity to areas characterized by high commercial activity or green spaces significantly influences user accessibility and satisfaction.

Urban environments that integrate diverse land uses tend to attract higher volumes of potential users due to the functional benefits they offer, such as easy access to shopping, dining, and recreational opportunities. When bike stations are situated near commercial hubs, they serve not only as practical modes of transportation but also as facilitators of economic activity. Users are more likely to engage in cycling when they can easily access shops, cafes, and other amenities, thus enhancing the likelihood of increased ridership and promoting the habit of cycling as a viable mode of transport.

Moreover, the proximity of cycling suitable areas to green spaces reinforces the attractiveness of these facilities. Green areas are often associated with leisure and outdoor activities, which can inspire individuals to use bikes for recreation, commuting, or casual outings. The synergy between bike-sharing infrastructure and green urban spaces encourages an active lifestyle, further promoting sustainable mobility practices. The presence of parks and greenways not only provides a pleasant environment for cyclists but also contributes to the overall perception of the area as being more livable and environmentally friendly.

2.5 Study area

The study area is Fuorigrotta, a neighborhood located in the western part of the city of Naples, Italy, which extends over an area of about 6 km^2 (Figure 3). The neighborhood is bordered to the north by the Camaldoli hill, to the east by the Soccavo neighborhood, to the south by the Bagnoli neighborhood and to the west by the municipality of Pozzuoli. Its strategic position, a short distance from the historic center of Naples and well connected to the main communication routes, through the subway line, bus lines and the Campi Flegrei railway station, makes it a crucial hub for urban mobility. The study area stands out for being one of the neighborhoods with the highest number of residents (ISTAT, 2024), with a strong concentration of commercial activities, services and infrastructures, as well as the presence of important centers of attraction including the Diego Armando Maradona Stadium, the Mostra d'Oltremare and the university complex of Monte Sant'Angelo. These places, which attract thousands of people every day, generate significant traffic flows and pose complex challenges in terms of sustainable mobility.

Therefore, the analysis of cycling in this area takes on strategic importance to identify innovative and sustainable solutions and plan targeted and effective interventions that can improve the quality of life of residents and contribute to creating more liveable urban spaces, enhancing public spaces.

Figure 3: Fuorigrotta study area, municipality of Naples, Italy.
Source: Elaboration of authors.

3. Results and discussion

3.1 Multi-Overlay analysis

The pixel values of the final raster, the result of the overlay analysis, vary from 0 to 470, where 0 is the area considered the least optimal for the localization of new cycling support services while 470 is the one considered the most suitable. To better visualize the result of the analysis, the results were reported in a colour gradient scale from red to blue that allows to better represent the nuances that occur between the values 0 and 470 (see Suitability Map Figure 2).

After the suitability map was built, the next step consisted in identifying alternative areas for the creation of new cycling support services (new bike stations), as well as areas that could catalyze a reorganization and redevelopment of the surrounding public space. For these reasons, the suitability map is converted back into vector format through the Qgis “Polygonize” tool and reclassified based on the previously calculated scores, shown in Figure 4, into five levels of suitability.

Areas with low and low-medium suitability scores (maximum equal to 250) are excluded, while the ones with pixel values at least equal to 251 are taken into account (from medium suitability level). Figure 4a shows that more than 75% of Fuorigrotta district is not suitable to cycling stations and services, due to the slope and main road detractor criteria and to the concentration of Positive characteristics like the presence of schools and public transport nodes in some areas. This is the case of the area between the stadium and Piazzale Tecchio, the ones close to via Terracina and via Consalvo. On the contrary, areas near to via Lepanto, viale Augusto, via Cavalleggeri d’Aosta, and via Leopardi have suitability values equal to 470 thanks to the high functional mix and population density values characterizing them.

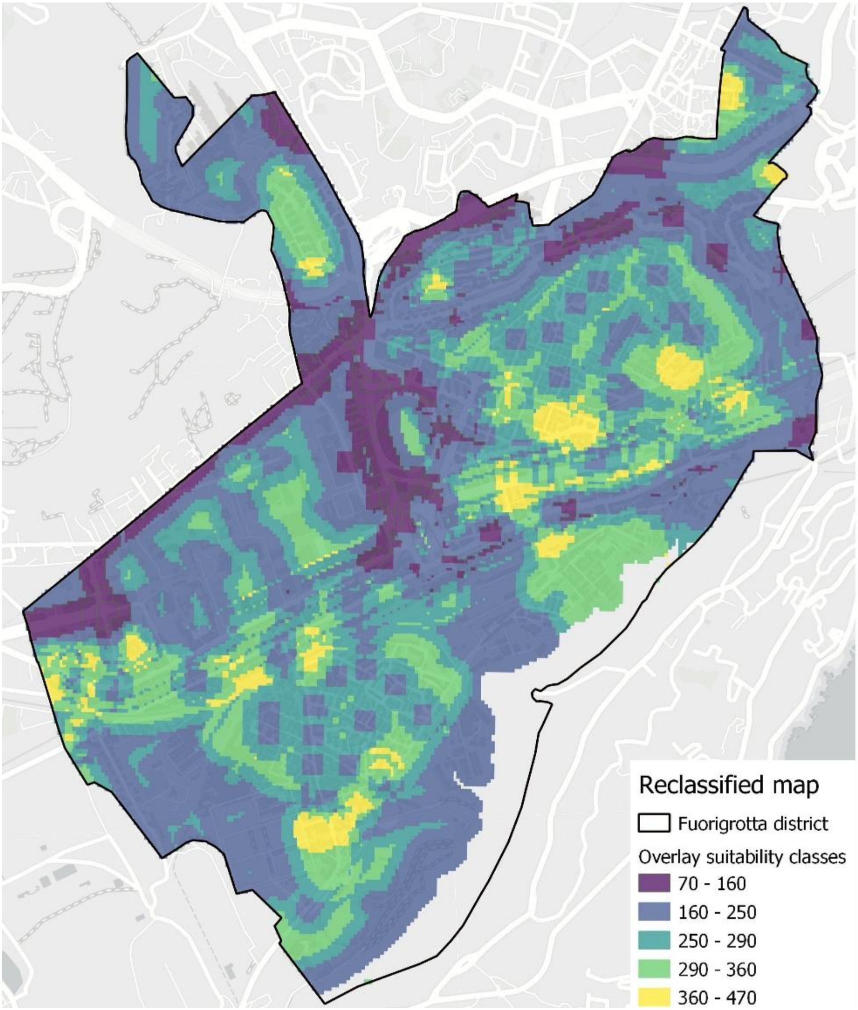

Figure 4: Reclassified map of suitability values.
Source: Elaboration of authors.

3.2 TOPSIS analysis

The regions identified through Multi-Overlay analysis, which exhibit a suitability value of 251 or higher, are selected for further evaluation using TOPSIS. This threshold has been established as the median value, thereby ensuring a balanced representation of suitability across the assessed areas, which enhances the robustness of the current analysis. Areas close to each other have been aggregated to not have redundancies in the definition of the related centroids useful to identify the individual portions of the territory to be classified based on the 4 criteria through which the quality of the urban surroundings is to be considered (sub-section 2.4).

Sixty-two potential places to locate cycling services are identified and ranked through TOPSIS analysis (Figure 5).

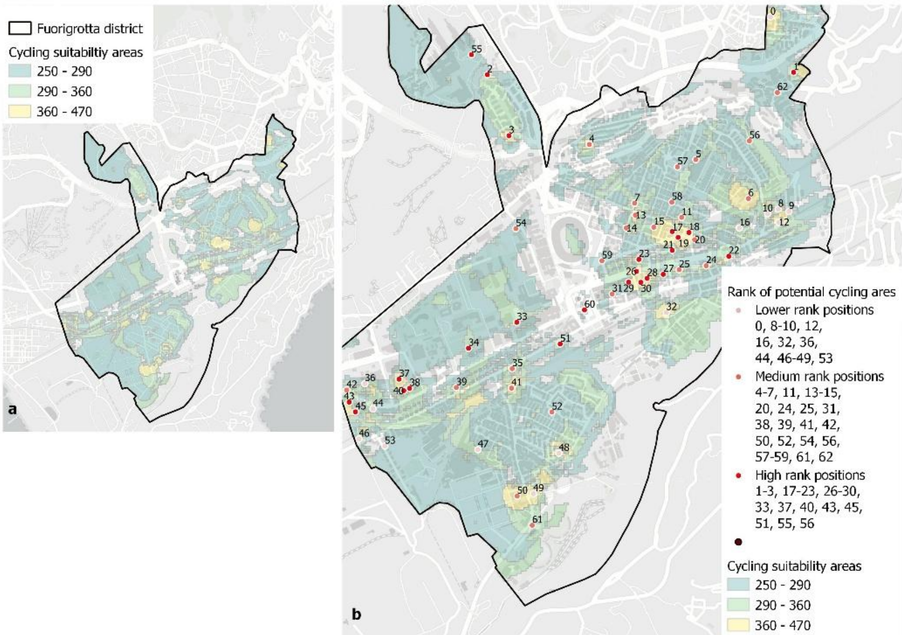

Figure 5: Medium-high suitability cycling areas (a) and related ranking (b).
Source: Elaboration of authors.

The cycling areas (13) that are at the bottom of the ranking are mainly distributed in the western and eastern parts of Fuorigrotta, at the border with the close Bagnoli district and close to via Carlo Duilio, respectively, and in the Cavalleggeri area. These lowest values can be due to the lack of both green areas and commercial activities, such as the low quality of the built environment as the related areas area characterized by the presence of near low-quality buildings and by a lack of maintenance of the open spaces.

The cycling areas (25) that are in the middle of the ranking are located in the most consolidated part of the district, between via Marino and via Leopardi, where there are a lot of services and activities of different kinds (food, recreational, administrative, …), such as the green areas.

The cycling areas (24) that are at the top of the ranking are near via Terracina, eastern part of the district, and near the main road axes of the consolidated part of Fuorigrotta, along viale Augusto, viale Giulio Cesare and via Lepanto. The latter are close the ones classified in the middle of the ranking, with simultaneous proximity to both services and green areas. This determines that such areas may be those where the installation of bicycle parking points, even in shared mode, and supporting services such as maintenance points, require more limited economic and time resources, due to the already adequate urban usability and attractiveness.

In these areas, open space enhancement processes aimed at increasing cycling can play a crucial role in triggering mechanisms of social inclusion and active participation in community life. The predisposition of the urban context, already oriented to accommodate sustainable forms of mobility, represents a unique opportunity to foster interaction among citizens. Thanks to their strategic proximity to essential services and green areas, such spaces not only foster accessibility but also promote an inviting environment for cycling.

On the contrary, the parts of Fuorigrotta that are lacking in terms of the quality of open spaces, proximity and supply of services, and urban attractiveness, are priority areas in which to locate nodes and even cycle networks to trigger processes of revitalization of the physical, functional and social fabric. Their presence can stimulate local business activities, creating a livelier and more attractive environment for citizens and visitors. This interaction between cycling mobility and commercial activities can stimulate a more dynamic local economy, supporting small entrepreneurs and promoting forms of socialisation among citizens.

Furthermore, the integration of cycling service points within the Cavalleggeri district, for instance, can facilitate better spatial planning, favouring the connection between different residential areas, educational institutions, and public services. The redefinition of street spaces can lead to a rethinking of the distribution of spaces, restoring previously neglected areas through urban green spaces and pedestrian areas. These elements not only smarten the neighbourhood but also promote a more functional use of urban space, making pre-existing socio-spatial inequalities misleading. bicycle mobility intervention also offers the opportunity to implement participatory processes, involving residents in the design and maintenance of the bicycle network. This approach not only strengthens the community's sense of ownership but also ensures that the solutions adopted adequately meet the real needs of users.

In summary, the installation of bicycle parking points and the definition of the bicycle network in the identified parts of Fuorigrotta district can be a synergetic action to promote positive and sustainable change, strengthening urban identity and improving the liveability of this city context.

4. Conclusion

This study is oriented to demonstrate the potential of targeted methodologies in identifying and classifying areas where cycling can be enhanced through the implementation of cycling support services (Carpentieri et al., 2023). By utilising customised criteria, we established a framework that aids decision-makers in not only enhancing accessibility to intermodal services but also in initiating broader urban redevelopment processes, particularly within peripheral areas adjacent to transport infrastructure, which often suffer from inadequate public space quality.

The strategic placement of cycling-suitable areas, including shared facilities, alongside essential maintenance services, catalyzes urban regeneration and the enhancement of open spaces. This is especially pertinent for neighborhoods located outside the central urban districts, where opportunities for fostering inclusion, boosting accessibility, promoting active mobility, and improving the urban built environment are crucial (Buettner & Zucaro, 2024; Carpentieri et al., 2024).

Our findings underscore the importance of GIS-based overlay and TOPSIS analyses in assisting local decision-makers in pinpointing areas that require urgent urban transformation interventions and also in integrating spatial and multi-criteria and statistical analysis that could be easily used by technicians of public administrations. Furthermore, this research contributes valuable insights into the integration of active mobility within MaaS systems, paving the way for sustainable and integrated urban mobility solutions. Overall, the study provides essential support in guiding the development of inclusive, accessible and vibrant urban spaces that prioritize active mobility and enhance the quality of life for citizens. Enlarging the set of criteria and variables used and implementing a sensitivity analysis to validate the results of the MCDA can represent the future developments of the work.

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