Perceptions of Safety for Women in Urban Areas: A Spatial Regression Analysis in the City of Naples

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Abstract. One of the fundamental paradigms of contemporary urban design is "the inclusive and safe city": meaning the aim of developing spaces capable of meeting the needs of different population categories, promoting accessibility, equity, and a sense of belonging. Currently more than 4.5 billion people, or 55% of the world's population, live in urban areas, a percentage expected to rise to 68% by 2050. Such increasing urbanization generates opportunities, but also enormous challenges in achieving and maintaining environmental, economic and social sustainability. Although over half the global urban population is female, cities are often inadequately designed in terms of the needs and expectations specific to women. The current research deepens the knowledge of women's perceptions of safety as they move around the city, and evaluates which characteristics of the urban contexts, including physical, functional and socioeconomic elements, have significant impacts. In support of decision-makers, a tool is developed and proposed, based on GIS methodology, using open-source data on such contextual urban aspects. To these, the tool relates data on the safety perceived by women, derived from a mobile App (Wher) that collects women's own direct suggestions, comments and ratings on their perceptions of the safest walking routes. The GIS methodology proposed allows us to capture material and immaterial elements involved in the complex issues of perceived safety, and to focus on potentials for the relative improvements in urban landscapes. The methodology allows us to analyze the impact of the built environment on women's perceptions of walkability in different urban areas and at different times of day, identifying the relationships with various physical, functional, socioeconomic and environmental factors.

Keyword: Perception of safety · Women · Naples · Urban area

1 Introduction

One of the fundamental paradigms of contemporary urban design is "the inclusive and safe city", meaning the aim of developing spaces capable of meeting the needs of different population groups, promoting not only safety, but also accessibility, equity, and the sense

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of belonging. "Inclusion", then, means the creation of accessible urban environments for all citizens, regardless of their individual characteristics. Currently more than 4.5 billion people [1], or 55% of the world's population, live in urban areas, a percentage expected to rise to 68% by 2050 [2]. Such increasing urbanization generates cases of opportunity, but also enormous challenges in achieving and maintaining environmental, economic and social sustainability, which again relates to accessibility and inclusion. In this regard, despite the fact that more than half of the urban global population is female [3], cities are not designed to adequately address their specific needs and expectations. Urban and transport planning has long neglected the importance of the intersections between gender and mobility, and has therefore generated non-neutral urban environments, and often caused inequalities in accessibility to services and spaces for different user groups, among which women. The built environment has important effects on the quality of life experienced by women. Inadequacies can severely limit the ability of women to move within the city, to fully participate at the economic level, or to simply enjoy the spaces in which they live [4, 5]. Happily, recent experiences in urban planning and transport demonstrate a greater trend towards solutions of sustainable urban mobility, including a particular focus on walkability [6, 7]. The focus on this issue intensified significantly in 1988, with the adoption of the Charter of Pedestrian's Rights by the European Parliament, stressing the obligations of ensuring comfort and safety for pedestrians in urban areas. In 2006, the Walk21 Foundation, a British charity, introduced the International Walking Charter, outlining eight principles and thirty-two actions for improved urban walkability.

The General Theory of Walkability, proposed by Jeff Speck in 2013, offered a comprehensive framework for assessing the walkability of urban environments [8], since followed by other schemes. However, standardised methods for measuring walkability often fail to consider the needs of different populations, among which women. Approaches to measurement have traditionally focused on the spatial dimension, and it is only recently that recognition has been given to the demographics of populations and characteristics of individual users, which can concern travel purposes and mobility preferences [9, 10]. Although there are several factors that distinguish the walkability of women versus men, the safety factor is the most relevant, and is still much neglected in urban planning. Not only the objective degree of safety, but also its perception, is significant in the experience of mobility and has decisive influence on travel decisions [11, 12]. The constraints on mobility resulting from the sense of vulnerability and real and perceived risks of violence or other harms, especially at night, give rise to precautionary measures and avoidance behaviour by women, such as limiting or avoiding walking altogether. The overall effect is to significantly hinder the freedom of women in their use of public and private spaces [13–16].

Needs in mobility are not uniform among women, however. The concept of gender is complex and intersectional [17], and gender overlaps with the effects of social identities, such as race or class, making the shaping of women's experiences complex [18]. The intersectionality approach, introduced by Kimberlé Crenshaw (1989), has been used in addressing this multifactor experience.

Although urban policy-makers have devoted greater attention to gender discrimination, institutions have not invested in the collection of detailed information on women-specific safety, which would be fundamental to further action, and such indifference hinders the development of specifically dedicated tools. The understanding of the dynamics influencing urban safety remains limited, with only superficial knowledge of women's needs and expectations as pedestrians. Ultimately then, there are still few tools that could contribute to decision-making processes and facilitate interventions [19, 20].

This research aims to deepen knowledge on the issue of women's perceptions of safety during urban movement, and in particular to assess which characteristics of urban contexts, including physical, functional, socioeconomic and environmental elements, have the greatest impact [21]. The approach identifies gender as a key element influencing the experience of the urban environment, and in this regard, deals with the subjectivity of walkability criteria in relation to individual perceptions. Methodologically, the main objective is to develop a decision support tool based on GIS, capable of identifying the urban characteristics that most influence women's perceptions of walking the city. In pursuit of this objective, the work applies techniques of spatial analysis to data both on urban characteristics and on women's perceptions of safety, the latter derived from a mobile app (Wher) which suggests safer walking routes. The use of spatial statistical analysis makes it possible to study the impacts of the built environment on women's walkability in different urban areas and at different times of day, identifying relationships with different physical, functional, socio-economic and environmental factors. This identification of tangible and intangible elements, contributing to the complex matter of perceived safety, can facilitate decision-making for improvements in the urban environment and thereby promote greater accessibility and inclusion for women and others.

This research includes some theoretical outcomes of the know-how developed in the project "STEP-UP—Walkability for Women in Milan" (Grant No. 2022-1643), financed by Fondazione Cariplo under the call for proposals "Inequalities Research - Generating new knowledge to reduce inequalities."

2 Methodology

In the governance of urban transformations, policy-makers and administrators are called to take into account the issues of women's perceptions of safety. To do this, they would benefit from quantitative methodologies in support of their decision-making processes.

To define the list of proxy indicators, the study used the research outcomes of project "STEP UP—Walkability for Women in Milan". In particular, project proposes a subdivision in three main factors that influence the perception of safety for women in urban areas: (i) Spatial Features (space characteristics/morphological features); (ii) City Use (traces of behaviour and presence of other city users); and (iii) Hotspots (safe havens and no-go areas). The main factors are divided in nineteen different sub-factors as show in the Fig. 1.

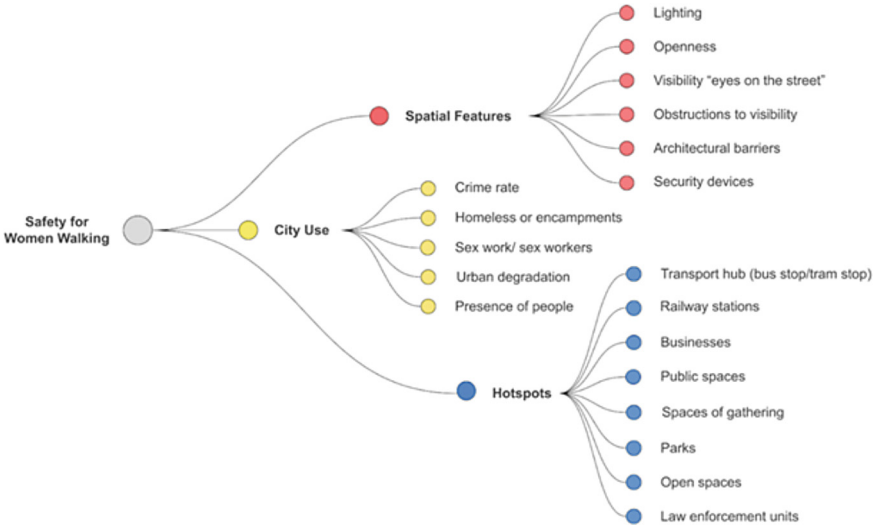

Fig. 1. Safety factors and sub-factors for women walking (STEP UP project elaboration)

On the base of STEP UP outcomes, this study proposes a selection of proxy indicators to cover the different Safety Factor categories. Table 1 shows the potential proxy indicators explanatory of women's perceptions of safety while walking at night, as proposed for the current methodology. The 18 indicators were advanced based on, in order of importance: i) their potential revelation of underlying safety factors, ii) availability of data in open format, iii) data in sufficient spatial detail (i.e., relatable to Italian census sections). Since the current study focuses specifically on women's perceptions of safety at night, the selection of indicators is balanced with this in mind.

On the other hand, the summary indicator of women's actually experienced perceptions of safety while walking at night is derived using a mobile app for grading of urban places, managed by the Walk21 Foundation. This App, called "Wher", allows women in cities such as Naples to rank georeferenced locations according to their perceived levels of safety while walking, as a cooperative device to assist other women in their mobility choices.

On further experimentation of the methodology, a decision was made to reduce the proxy indicators explanatory of women's perceptions from the proposed 18 to 11. This was done to ensure two criteria of effectiveness:

- Spatial consistency: the indicators are uniformly measurable in different parts of the city, limiting discrepancies caused by geographical variability and ensuring comparability;
- Temporality: the indicators are limited to those relevant to the night time period, i.e. from 8:00 PM to 6:00 AM (the most unsafe time interval of the day).

Table 1. Selected proxy indicators of safety for women walking at night

ID	Safety Factor		Indicator	Provider	Description
V1	Spatial Features	Openness	Ability to see and move in all directions	OSM	Layers describing vehicular, pedestrian and other public spaces
V2		Visibility "eyes on the street"	Night-time commercial activities	ISTAT	Number of pubs, restaurants, discos, coffee-shops, etc
V3			Residential buildings	ISTAT	City blocks of buildings with residences within first 2 floors
V4		Architectural barriers	Length of tunnels	DBSN	Locations of tunnels, by types
V5			Length of underpasses	DBSN	Locations of underpasses, by types
V6	City Use	Presence of people	Count of working population in selected roles	ISTAT ATECO	Density of working population in census tracts in 2021
V7			Count of resident female population	ISTAT	Density of resident population in census tracts in 2021
V8	Hot Spots	Transport hub	Count of public transport stops	OSM	Locations of bus and tram stops and train stations
V9		Public spaces	Surface of pedestrian spaces	OSM	Extension of pedestrian areas
V10			Surface of limited traffic zones	OSM	Extension of limited vehicular traffic areas
V11			Surface of urban green flowerbeds	DBSN	Extension s of urban green flowerbeds
V12		Spaces of gathering	Count of night-entertainment establishments	Google Earth	Locations of discos, night clubs, etc

(*continued*)

Table 1. (*continued*)

ID	Safety Factor		Indicator	Provider	Description
V13		Parks	Extension of urban parks	DBSN	Extension of wooded areas and parks
V14		Open spaces	Count of abandoned places	DBSN	Location of abandoned and degraded buildings
V15			Count of parking areas	OSM	Include parking areas greater than 250 square meters
V16			Count of industrial areas	OSM	Locations of Industrial agglomerations
V17			Count of industrial buildings	DBSN	Locations of industrial buildings
V18		Law enforcement units	Count of Enforcement presence	OSM	Locations of municipal and national police headquarters

OSM: OpenStreetMap
ISTAT: National Institute for Statistics
DBSN: National Synthesis Database
ATECO: National Classification of Economic Activities

After removal of the proposed indicators not meeting the above criteria, the ones remaining were: V1, V2, V3, V6, V7, V8 V9, V10, V12, V13 and V17. Subsequently, the data were collected for calculation of the 11 indicators over the minimum territorial reference unit, which in this case is the Italian census section.

The application of spatial statistical analysis typically offers important advantages in addressing large datasets, deriving explanatory and even predictive models of the relevant phenomena. The analytical procedures, however, can sometimes fail in providing sufficient precision concerning the spatial distribution of the analysed phenomena. The complexity of these techniques also requires a calibration phase in which the number of neighbouring elements or the distance with respect to which the values constituting the interpretative models to be defined are selected, on the basis of the phenomenon analysed. The different statistical techniques of spatial analysis useful for defining interpretative models of spatial phenomena are based on regression techniques. Although sharing commonalities, such techniques also have considerable differences. The classical Ordinary Least Squares (OLS) is a simple linear regression, but it does not consider the differences in spatial variables due to the non-stationarity of spatial locations. The Geographically Weighted Regression (GWR) provides a solution to non-smoothness in spatial coordinates, as its coefficients change with the variation of spatial coordinates [23]. The Multiscale Geographic Weighted Regression (MGWR) finds the optimal

bandwidth for each dependent variable, also showing the scale of action of the explanatory variables and further improving the model performance [24]. The objective of the current study, as stated, is to derive an explanatory model capable of individuating the critical factors influencing women's perceptions of safety while walking in urban areas. To achieve this objective, we propose a method using spatial statistic models, specifically GWR and MGWR, to determine the fit between the dependent variables (X_1, X_2, …, X_n) and the independent variable (Y). The application of GWR and MGWR requires a series of preliminary investigations, during which collinearity is eliminated using exploratory regressions. More specifically, the exploratory regressions individuate the set of statistical model variables with: adjusted R^2 greater than 0.3, p coefficient greater than 0.05, variance inflation factor (VIF) less than 5, and for which Jarque–Bera and spatial autocorrelation tests demonstrate the minimum acceptable value of 0.1. Naples is a considerable city with some of the highest population densities in Europe and a wide range of socio-economic and morphological complexities. These characteristics amplify the criticalities of urban planning and make the management of spatial phenomena particularly complex.

3 Case Study: The City of Naples

Naples is the third largest Italian city by population, within the second most populous metropolitan area. With 913,462 inhabitants, of which 474,264 female (ISTAT data, 2022), distributed over an area of 119.02 km^2, the average density is just over 7,600 persons per km^2. The city is divided into thirty districts for functional and physical characteristics and ten administrative municipalities. The historic centre of Naples, inscribed on the UNESCO World Heritage list in 1995, comprises the districts of Avvocata, Montecalvario, San Giuseppe, Porto, Pendino, Mercato, Chiaia, San Ferdinando, Stella, San Carlo all'Arena, San Lorenzo and Vicaria, as well as parts of the Vomero and Posillipo hills. Several of these districts are characterised by some of the highest population densities of Europe.

On the basis of their differing attributes, the thirty districts can be categorised as belonging to three fundamental types: Central, Semi-central and Peripheral (Fig. 2). The historic centre of Naples, rich in cultural attractions and economic services, is the most densely populated area. The districts of Chiaia and Posillipo, with some of the highest property values, are noted for premium residences, services and shops. Suburban districts such as Poggioreale and Ponticelli have lower population densities and lower property values, with intermixtures of residential, industrial, commercial and undeveloped areas.

The first phase of collecting data on the representative indicators was carried out using open access sources: the Urban Atlas of the European Environment Agency, the National Geoportal, OpenStreetMap, and ISTAT and City of Naples databases. The independent variable (perception of safety for women walking) was assessed using the data obtained via the Wher app. This indicator was calculated as the mean of the safety values reported on the app for evening (8:00–12:00 PM) and night (12:00 PM–6:00 AM), resulting in the definition of a single summary indicator of the level of perceived safety, from 8:00 PM to 6:00 AM.

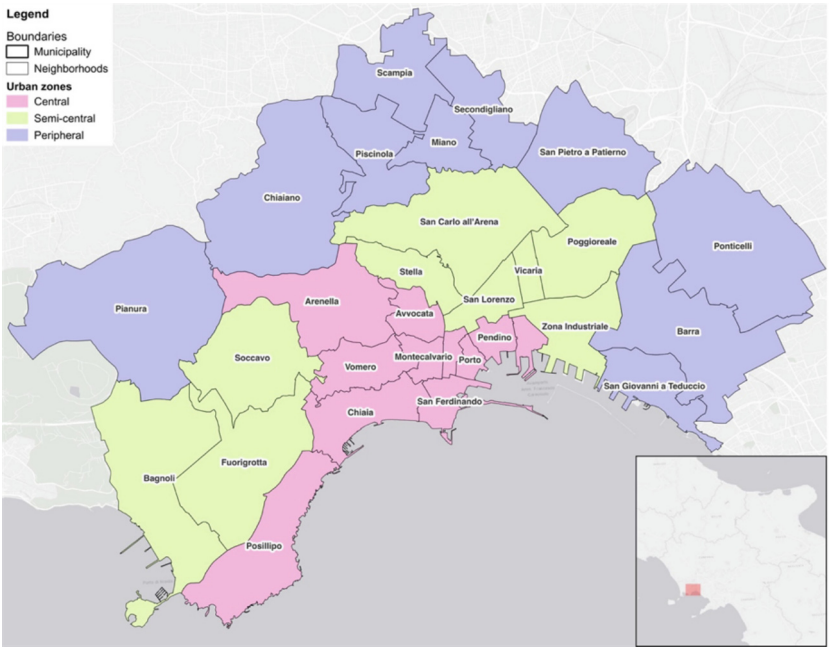

Fig. 2. The territory of city of Naples divided in the thirty districts (Municipality of Naples).

The mapping of perceived safety by district (Fig. 3) immediately reveals the low level of perceived safety for women walking at night in suburban districts, such as Barra, Chiaiano, Miano, Piscinola, Scampia and Secondigliano. The central districts and some semi-central residential areas, such as Arenella, Bagnoli and Fuorigrotta, show the highest values of perceived safety.

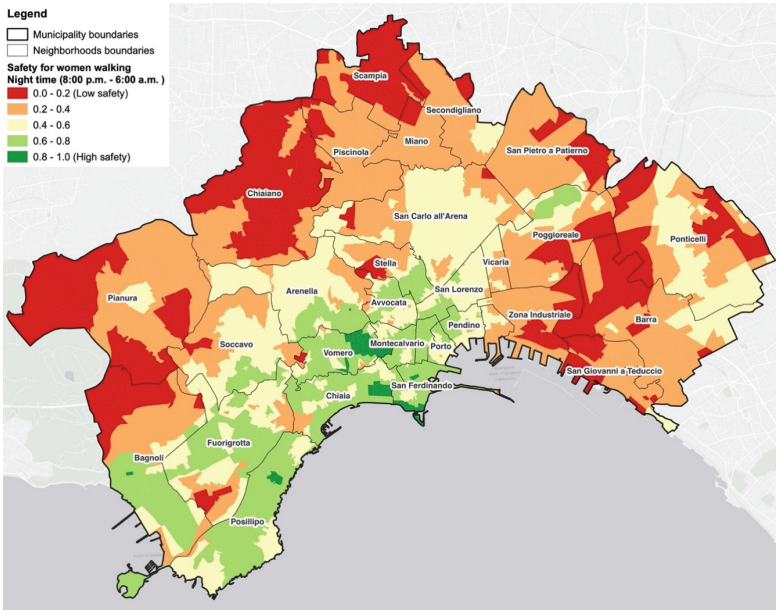

Fig. 3. Map of perception of safety for women walking at night (8:00 PM–6:00 AM).

Our next step is to evaluate all possible combinations of the candidate dependent variables, looking for OLS models that best explain the dependent variable within the context of user-specified criteria. The analysis was conducted considering all possible combinations of between three and eighteen dependent variables, applying the indispensable conditions: adjusted R^2 value of the variable greater than 0.3; p coefficient of significance greater than 0.05; variance inflation factor (VIF) less than 5; Jarque–Bera and spatial autocorrelation test values not less than 0.1. On this basis, the model developed included seven indicators of the original eighteen for which data were collected (V2, V3, V6, V7, V11, V13, V17) (Table 2).

Table 2. Comparing the fit of GWR and MGWR models

Model	Adj-R^2	AICc
GWR	0.360	10,300.94
MGWR	0.426	9,597.17

The results obtained show that the goodness of fit for the MGWR model is 0.426, significantly better than for the GWR model. The corrected Akaike Information Criteria (AICc) value for MGWR is also far lower than for GWR. We conclude that, for the city of Naples, MGWR is the better model of the relations between urban characteristics and women's perceptions of safety (Fig. 4).

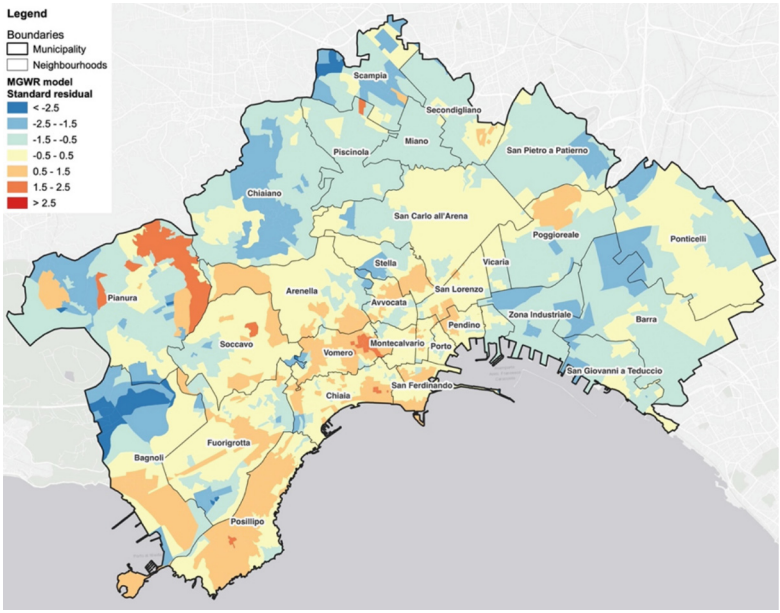

Fig. 4. Distribution of standardized residuals of MGWR model.

The representation of the standardized residuals detected nuclei that presented anomalies, with some exceeding the mean by more than 2.5 and less than −2.5 times the standard deviation. The neighborhoods with residuals greatly exceeding the mean were: Bagnoli, Chiaia, Chiaiano, Pianura, Posillipo, Vomero, Scampia and Soccavo.

The local R^2 indicates the level of performance for the applied local regression model. Results closer to 1 indicate a perfect fit to the local equation, while values below 0.3 indicate a lower fit. The results evidence 2,135 census tracts with a local R^2 value greater than 0.3, representing more than 60% of the total Neapolitan territory. The neighborhoods with highest local R^2 values are San Giovanni a Teduccio, Zona Industriale, San Carlo all'Arena, and Barra, all of which fall within Semi-central and Peripheral urban zones. The neighborhoods of the central urban zone evidence low values of local R^2, with reduced fit between the model local equation and variability of indicators (Fig. 5).

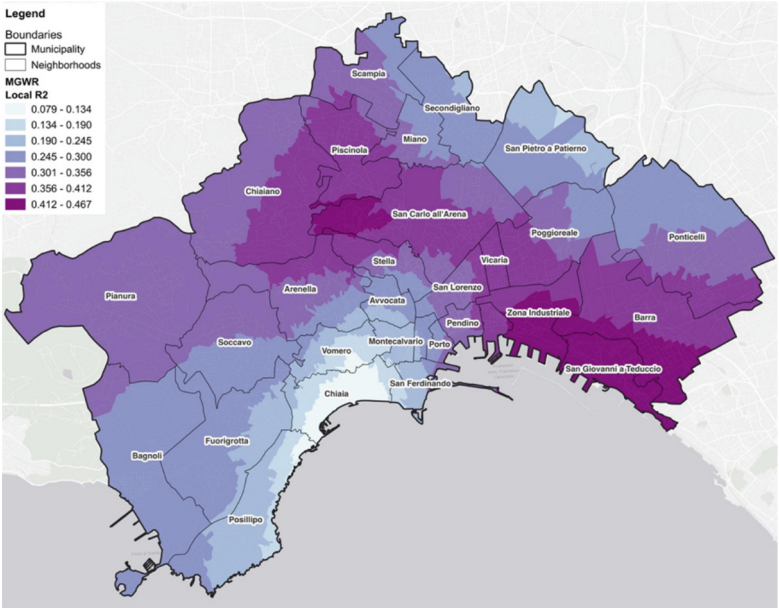

Fig. 5. Distribution of local R^2 of MGWR model.

From the observed variation of local R^2 values (Fig. 6), it appears that the obtained MGWR model fits with the variability of indicators in areas with a low level of safety. On the contrary, where women's perceptions of safety are higher at night, the model does not adapt to the variability of indicators.

These observations of results evidence that the use of spatial statistic techniques can be useful in understanding the relations between a spatial phenomenon, i.e. women's perception of safety, and certain urban characteristics. In interpreting the results, however, care must be taken to understand where and how the model is reliable in individuating the relations between the phenomenon of interest and the selected urban characteristics.

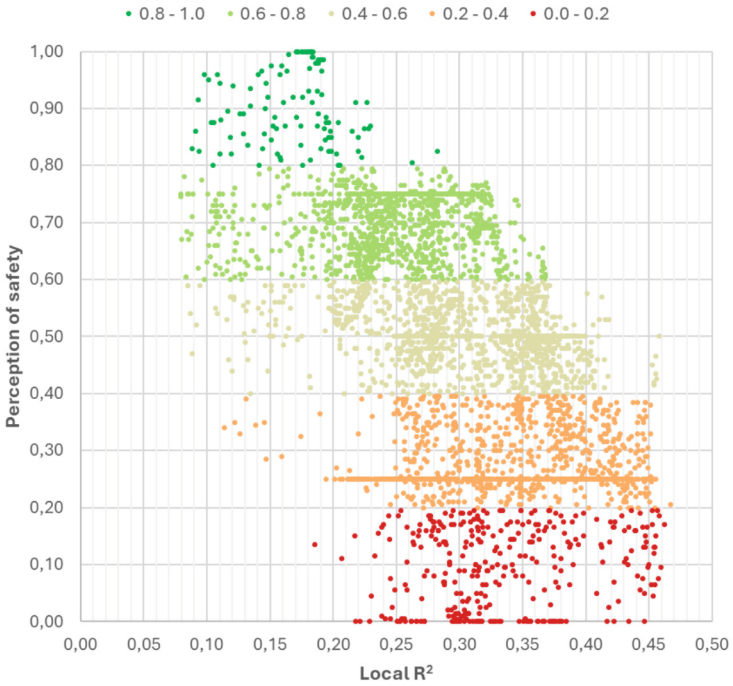

Fig. 6. Graph with the perception of safety for women walking during the night time (8:00 p.m.–6:00 a.m.) and the variation of local R^2.

4 Discussion and Conclusions

The UN Department of Economic and Social Affairs predicts that by 2050, 68% of the world's population will live in cities. Although more than half of the population is female, urban planning has generally failed to account for the particular needs of women. The generally low levels of urban liveability, in particular for females, result from concomitant causes. The complex phenomena are difficult to read and interpret, and the tasks are made still more difficult by the inadequacy of urban planning tools, which have long ignored the intersections between gender and the urban environment. In support of contemporary urban decision-makers, however, we do have the tools for identification and analysis of gender-related issues: by developing methodologies based on the collection of socio-economic, physical and functional data, and their processing through spatial statistical analysis.

Women's perceptions of safety are a particular concern, since these affect their mobility decisions in all aspects of urban life. The perception of safety does not adhere to objectively fixed rules, and is instead a complex function of physical, economic, cultural and traditional aspects of the different spatial contexts. The perception of urban space, and of safety, is therefore largely subjective in character, meaning that it can be particularly useful to develop methodologies of spatial statistical analysis on such perceptions in relation to socio-economic, physical and functional data collected on specific urban

environments. To this end, the current work has taken an integrated approach to understanding the relationships between the different urban aspects and women's perceptions of safety.

The contribution provides an initial research step in developing a tool to support decision-making processes aimed at improving women's perceptions of safety in the urban areas. The broader aim is to promote inclusive urban planning methodologies which account for gender-related needs, applicable to urban planning in general and transport planning in particular. The study, and its results, promote analytical methodologies that consider both tangible and intangible elements in perceptions of safety, improve understanding based on empirically collected data, and account for the specific needs and behaviours of women and gender minorities. Integrating information from women and under-represented groups into decision-making processes is in fact crucial, not only for increasing perceptions of safety, but for general improvements in the urban environment, appreciable and useful to all.

The main limitation of this study is the lack of useful data to calculate further proxy indicators representative of each safety factor category.

The proposed methodology provides the planning and administrative authorities of Naples with a tool for greater understanding of the urban context, based on quantitative and measurable data. The methodology could be further improved by incorporating additional data sources, such as on levels of crime or provision of street lighting. Our intention is to share the current research with local actors, hoping to verify the validity of the various results and associate them with practical recommendations.

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