How to Ensure Walkable Pedestrian Paths? An Assessment in the Largo Felice Area of Cagliari (Italy)

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Abstract. Improve walkability, and therefore the capacity to provide safe and accessible walking opportunities, has emerged as a crucial topic especially for post-pandemic cities, seeking to create inclusive and liveable urban spaces. In this direction, a user-centred planning approach prioritises the creation of pleasant and accessible walking environments, which are essential for achieving a sustainable urban development. The physical features of the urban areas must be carefully designed and implemented to enhance the living standards, safety, and inclusiveness, also for vulnerable users. Based on the Geographic Information System (GIS) tools, this paper provides an analytical-assessment approach for evaluating walkability in urban settings, in order to identify the significant properties of urban infrastructures. The methodology is characterised by an integrated approach based on a survey process, including remote observations. The evaluation of pedestrian paths' performances considers the most influencing attributes (e.g., sidewalk width; visibility; crosswalk provision) which have been identified and evaluated for the case study of Largo Felice in Cagliari, Italy. To obtain an overall assessment in terms of safety, approachability, and enjoyment, each of these indicators has been analysed by aggregating and cross-referencing the detected attributes. The results highlight critical issues associated with the study area, that hinder the approachability and safety of pedestrian pathways, e.g., architectural barriers, discontinuities, poor visibility. Finally, the paper provides some recommendations for improving walkability in urban areas. Future research developments will include the assessment of further walkability attributes to perform a comprehensive analysis of an extended study area and in-field survey to validate the results.

Keywords: Urban planning · Walkability · Active Mobility · Pedestrian Paths · Sustainable Mobility · GIS · Cagliari (Italy)

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1 Introduction

Within the urban planning perspective, urban mobility represents one of the most important factors in ensuring a high quality of life in cities and walking is the primary transport mode at the neighbourhood level, offering access to services and amenities. The scientific literature is well established on the topic of active mobility, promoting the paradigm shift to reduce car dependency in favour of sustainable transport mobility alternatives, i.e., shared mobility [1–3], but even more active mobility [4–7], i.e., walking and cycling. Urban environments should support and encourage walking, which is the most important asset for communities, as most origin-destination pairs are within a range of distance suitable for walkability [8, 9]. The requirement for adequate pedestrian infrastructure is closely influenced by the morphological and functional organisation of urban activities and public services. In this regard, urban mobility is one of the main issues that must be extensively addressed to foster a broader democratisation of the city, promoting socialisation and an all-encompassing use of urban services. Many cities still continue to be characterised by low performance levels of pedestrian and bicycle infrastructure networks, especially for vulnerable users [10–13]. Thus, the creation of pedestrian-friendly environments constitutes a key research concept on how to correctly plan and design pedestrian pathways [14]. Moving towards a more sustainable framework focused of a and user-centred perspective, cities can achieve high infrastructural performance levels related to liveability, safety and inclusion [15–17]. Several studies on walkability provided appropriate criteria and tools for investigating, analysing and assessing the walkability of pedestrian network [18–22]. Nowadays, cities have become extremely complex entities and public administrations need effective tools to collect and evaluate several attributes related to the existing infrastructure in an effective way. Based on this premise, the paper proposes an analytical-assessment methodology of walkability applied to a real case study, coinciding with the area of Largo Felice in Cagliari (Italy), to identify a clear performance level of pedestrian paths. To provide a detailed assessment, attributes related to pedestrian approachability, safety and enjoyment, have been considered for pedestrian paths and crossings. The performed evaluation associates a qualitative assessment to each attribute, describing the characteristics of the infrastructure, and a quantitative value, based on the associated characteristics above mentioned. The analysis procedure is characterized by a series of research steps, including surveys with remote observations and mapping techniques, aiming at identifying weaknesses and critical points and providing a prioritization of interventions to ensure a more walkable pedestrian environment [23]. The results of the assessment showed that the Largo Felice area has several challenges hindering pedestrian paths, e.g., the presence of obstacles along the sidewalks, discontinuity, zebra crossings with excessive lengths. Therefore, the study provides valuable insights to improve the walkability of the Largo Felice area and offers useful methods to be replicated within other contexts. The paper is structured as follows: Sect. 2 presents the case study of Largo Felice in Cagliari; Sect. 3 focuses on the proposed methodology to assess walkability indicators within the analysed area; Sect. 4 describes the outcomes of the methodology application based on calculation of walkability composite indicators and their geographical representation through chromatic, and finally Sect. 5 provides conclusions and possible further developments of the research.

2 Case Study

The research area is located in southern Cagliari and encompasses a portion of Cagliari's historical centre (Fig. 1), with Largo Carlo Felice serving as its main street. This boulevard leads to the renowned Piazza Yenne. The selected area is characterised by a strategic location and high accessibility levels, close to both the seaport and the railway station, involving a high volume of activities. Furthermore, the extensive vehicular and pedestrian network characterising Largo Carlo Felice also played a key role in the selection of this area as case study. Specifically, it includes portions of three different neighbourhoods, namely Stampace, Marina and Castello. This area presents a significant impact due to vehicular traffic and hight motorisation rate. It is also characterised by different POIs (point of interests) such as cultural and historical elements, e.g., monuments, churches, theatres, and municipal buildings, as well as commercial activities, e.g., stores, restaurants and cafes as essential attraction for tourists visiting the city. These elements are situated along pedestrian links, including Corso Vittorio Emanuele II, newly pedestrianised road. Stampace and Marina are two neighbourhoods located respectively in the southwest and east of the historic centre of Cagliari, identified as the study area with the red border in Fig. 2.

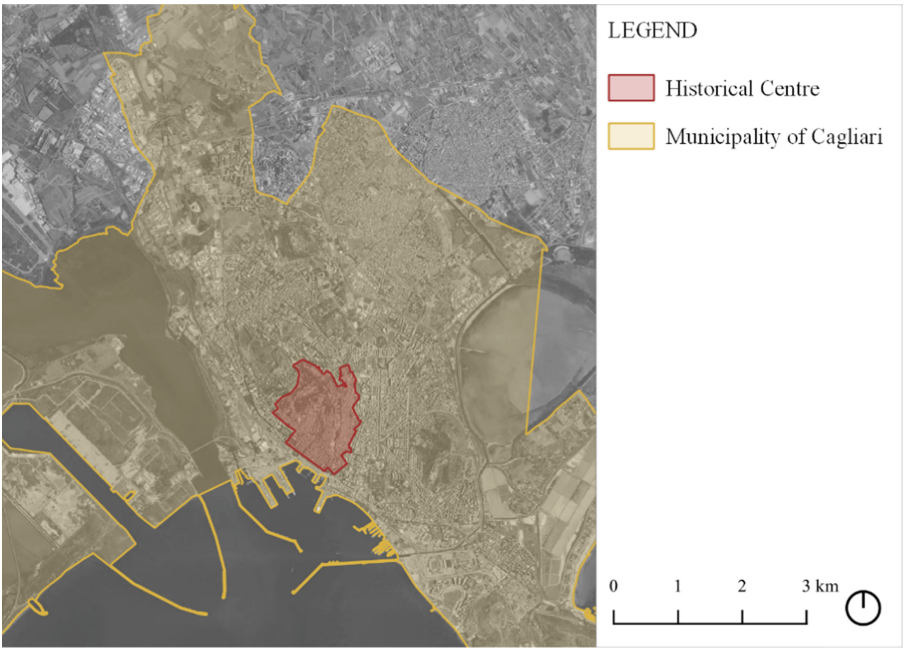

Fig. 1. Position of the historic center in relation to the Municipality of Cagliari. Source: Bing Aerial map processed in QGIS (authors elaboration).

The neighbourhoods are distinguished for the large number of artisans' and artists' boutiques, and are home to significant Baroque churches, e.g., San Michele and

Sant'Anna. The expansion of the Stampace district led to the gradual formation of modern districts in western Cagliari. Lastly, the Castello district is considered the main historical quarter of Cagliari. The neighbourhood has a high altitude compared to the rest of the city and it is characterised by cultural and architectural heritage. Castello currently hosts important institutions. Among the neighbourhoods, Stampace is one of the most densely populated in the municipality, considering approximately 7,200 inhabitants in 2021 [24], then Castello and Marina, respectively populated by approximately 1,300 and 2,600 inhabitants.

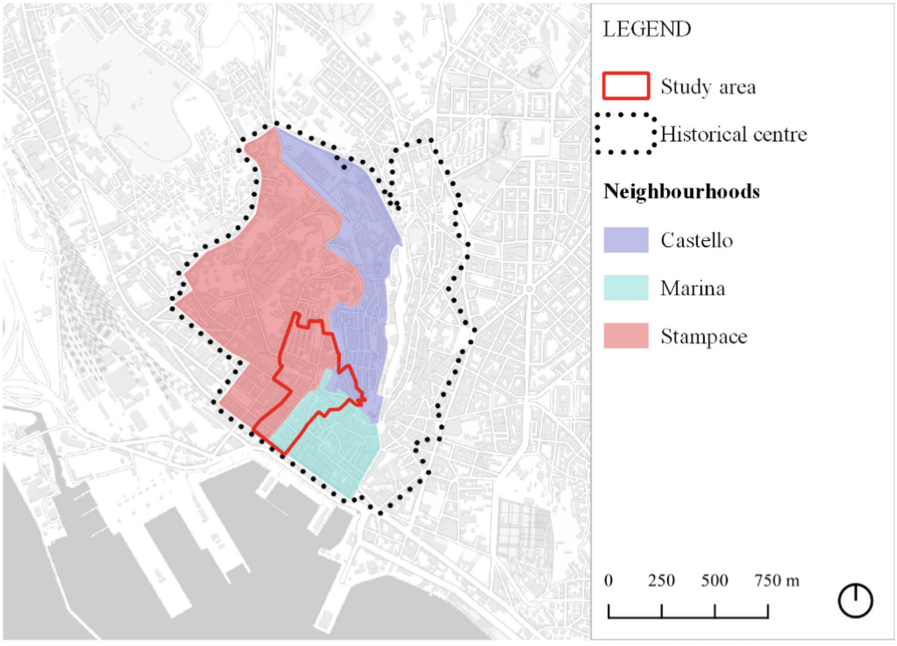

Fig. 2. Identification of the study area located in the historical center of Cagliari within the neighbourhoods of Castello, Marina and Stampace (authors elaboration).

3 Materials and Methods

This paper provides a methodology combining an integrated survey, mapping and well-encompassed evaluation approach of pedestrian networks. In the proposed research, pedestrian paths and crossings have been evaluated using an analytical-assessment model based on Geographical Information Systems (GIS). The model bases on a review of the existing literature, to identify and evaluate appropriate criteria for the acquisition and management of a large amounts of information on road infrastructures. Based on the objectives and guidelines identified in the pedestrian network survey, the main action is to specify the user group for planning purposes: the user group focuses on pedestrians also including vulnerable users [25]. In the GIS environment, the geometries used belongs

to two different information layers, corresponding to pedestrian paths in a linear geometry and to pedestrian crossings in point geometry. The survey phase involved searching for data from official sources and carrying on remote inspections. Data sources include Open Data portals, i.e., the Cagliari Municipality's Geoportal [26], with information layers and interactive WebGIS maps, to identify relevant areas and infrastructures for preserving pedestrian mobility, i.e., restricted traffic zones and 30 zones. Furthermore, remote observations were useful to comprehend infrastructures features, enabling the identification of vulnerabilities and peculiarities of paths at different scales, to achieve growingly desirable streets [27, 28]. Several applications and models exist to collect and manage attributes associated with pedestrian infrastructures [29–39]. In this research, the pedestrian network is assessed by considering the most influential attributes of walkability, which have emerged during a literature review and that are also consistent with the study area. These attributes contributed to the calculation of composite indicators, useful for analysing complex phenomena and making them more understandable. The topics that emerge most in the literature and provide a detailed assessment related to walkability correspond to the following indicators of approachability, safety and enjoyment, respectively (see Table 1).

Table 1. Literature review on walkability indicators

INDICATORS	DESCRIPTION	REF.
Approachability	Refer to how easily pedestrians can walk, ensuring equal and safe accessibility for all. It is also associated with intermodality, allowing the pedestrian's modal shift from walking to the bus in a connected and continuous path	[6, 40–46]
Safety	Related to pedestrian safety which is a set of preventive measures to avoid accidents and ensure a protected environment for footpaths and pedestrian crossings	[47–51]
Enjoyment	Create pleasant, attractive, and comfortable environments for pedestrians, using elements, e.g., vegetation, street lighting or benches	[34, 52–58]

3.1 Quantitative and Qualitative Attributes Evaluation

Data related to the pedestrian movement are associated to sidewalks and crossings with selected attributes, based on evaluation of the literature and urban context. Qualitative and quantitative values have been collected and assigned to each attribute. It is important to underline that an in-depth study has been performed, considering these attributes for both sides of the road. Criteria used for attribute selection differ depending on the type of the road the examined segment is on. Thus, the evaluation is characterised by values ranging from pedestrian space to high-speed road. The evaluated attributes for sidewalks and crossings for each infrastructure level are shown in Table 2 below.

Table 2. Attributes involved in the indicator calculation.

Indicators	Attributes	Criteria		
		Pedestrian Space	30 km/h	Above 50 km/h
Approachability	Sidewalk provision *(sidewalks)*		X	X
	Continuity *(sidewalks)*		X	X
	Surface quality and maintenance *(sidewalks)*	X	X	X
	Ramp provision *(crossings)*		X	X
	Access ramp provision *(sidewalks)*		X	X
	Width of sidewalk *(sidewalks)*		X	X
	Bottlenecks/obstacle *(sidewalks)*	X	X	X
	LPT stops *(sidewalks)*		X	X
Safety	Sidewalk provision *(sidewalks)*		X	X
	Bottlenecks/obstacle *(sidewalks)*	X	X	X
	Lighting *(sidewalks)*	X	X	X
	Illuminated crossings *(crossings)*		X	X
	Excessive length *(crossings)*		X	X
	Presence of crossing devices *(crossings)*		X	X
	Presence of tactile signage on the curb access ramp *(sidewalks)*	X	X	X
	Crossing visibility *(crossings)*		X	X
	Crossing type *(crossings)*		X	X
Enjoyment	Sidewalk provision *(sidewalks)*		X	X
	Seats *(sidewalks)*	X	X	
	Width of sidewalk *(sidewalks)*		X	X
	Greenery *(sidewalks)*	X	X	X

Tables 3 and 4 summarise the selected attributes to perform the indicators assessment, also reporting the qualitative and quantitative evaluation for each of them. The first set of attributes is associated with the sidewalks, e.g., pavement quality, continuity, sidewalk

provision and width, lighting, and tactile signage. The second set relates to pedestrian crossings, e.g., presence of access ramps, obstacles, visibility, and excessive length.

Table 3. Attributes involved for sidewalks assessment.

Attribute	Evaluation	Value
*Sidewalk provision	Both sides, only one side, Absent	2, 1, −1
*Continuity	Continuous paving along the sidewalk, Discontinuous paving along the sidewalk	1, −1
Surface quality and maintenance	Insufficient, Sufficient	−1, 1
*Width of sidewalk	<90 cm, 90 cm-150 cm, >150 cm	−1, 1, 2
*Access ramp provision	Present, Absent	1, −1
Bottlenecks/obstacle	Present, Absent	−1, 1
Lighting	Present, Absent	1, −1
**Seats	Present, Absent	2, 1
Presence of tactile signage on the curb access ramp	Present, Absent	1, −1
*LPT stops	Present, Absent	2, 1
Greenery	Present, Absent	2, 1
*Only Pedestrian link, ** Vehicular link		

Table 4. Attributes involved for crossings assessment.

Attribute	Evaluation	Value
*Crossing type	Pedestrian crossings with traffic lights, pedestrian crossings	−1, 1 (30 km/h) 1, −1 (50–70 km/h)
*Ramp provision	Present, Absent	1, −1
Bottlenecks/obstacle	Present, Absent	−1, 1
Illuminated crossings	Present, Absent	1, −1
*Excessive length	Present, Absent	−1, 1
*Presence of crossing devices	Present, Absent	1, −1
*Crossing visibility	Clear view with raised/coloured crossings, Sidewalk extension, Distance to parking spaces, Reduced visibility	2, 1.5, 1, −1
*Only Pedestrian link, ** Vehicular link		

3.2 Calculation of Composite Indicators

To perform a composite walkability assessment, the study proposes an analysis of the pedestrian network through an aggregate and cross-attribute evaluation. With the combination of different weighted attributes, specific values are calculated for the three indicators, as described in Table 1. They constitute key composite indicators of the pedestrian network performances, and their calculation is performed following the equations (Eq. 1–3):

$$I_V = a_{\substack{sidewalk \\ provision}} \cdot \left(1 + \frac{\sum_{i=1}^{n} a_n}{N}\right) \tag{1}$$

$$I_P = \sum_{i=1}^{n} a_n \tag{2}$$

$$I_C = \sum_{i=1}^{n} a_n \tag{3}$$

where:

- I_V = Indicator for vehicular links;
- I_P = Indicator for pedestrian links;
- I_C = Indicator for crossings;
- $a_{\substack{sidewalk \\ provision}}$ = value assigned to the attribute sidewalk provision (Table 2);
- $\sum_{i=1}^{n} a_n$ = Sum of the all-attribute values included in the evaluation of "Approachability", "Safety" and "Enjoyment" indicators (Table 1);
- n = number of considered attributes to calculate each of the three indicators;
- N = maximum value obtained by the sum of quantitative evaluation for the considered attributes.

The normalization of the obtained values for the indicators is achieved by following this formulation (Eq. 4), to obtain values between 0 and 1:

$$I^{Norm}_{V;P;C} = \frac{\left|I_{V;P;C} - I_{V;P;Cmin}\right|}{\left|I_{V;P;Cmax} - I_{V;P;Cmin}\right|} \tag{4}$$

4 Results and Discussion

The study conducted through data processing produced two types of results. First, thematic maps representing the most relevant individual attributes of the pedestrian network; second, the calculation of specific walkability indices, i.e., approachability, safety and enjoyment indicators.

The following thematic maps show the most significant individual attributes found in the preliminary analysis phase. Figure 3 considers the presence of continuous or discontinuous paving on sidewalks in vehicular links, as well as whether there is an access ramp at pedestrian crossings. From this map emerges a clear discontinuity above all in the northern part of the considered study area and specific criticalities in correspondence with some sidewalks. Figure 4 highlights the sidewalk provision (evaluated only for vehicular links) and how visible pedestrian crossings are from motor vehicles. In this case, there is a widespread reduced visibility at crossings and many road links without sidewalk provision or only on one side.

Figure 5 shows the presence of bottlenecks in the footpaths or obstacles along them, considering elements e.g., artificial lighting, rubbish bins and road signs. It is noticeable that there are obstacles along some pedestrian paths, which in some cases could be removed. Finally, Fig. 6 highlights attributes such as the presence of tactile signs and electronic crossing devices on pedestrian crossings, considered relevant to safety for the visually impaired. Tactile signs are present only along some sidewalks, while they are completely absent at crossing.

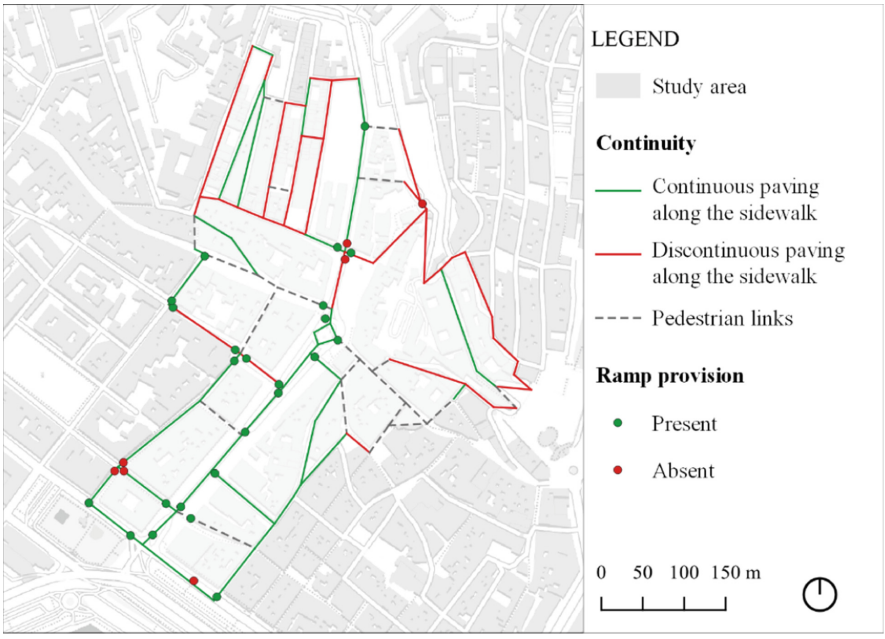

Fig. 3. Continuity and ramp provision attributes.

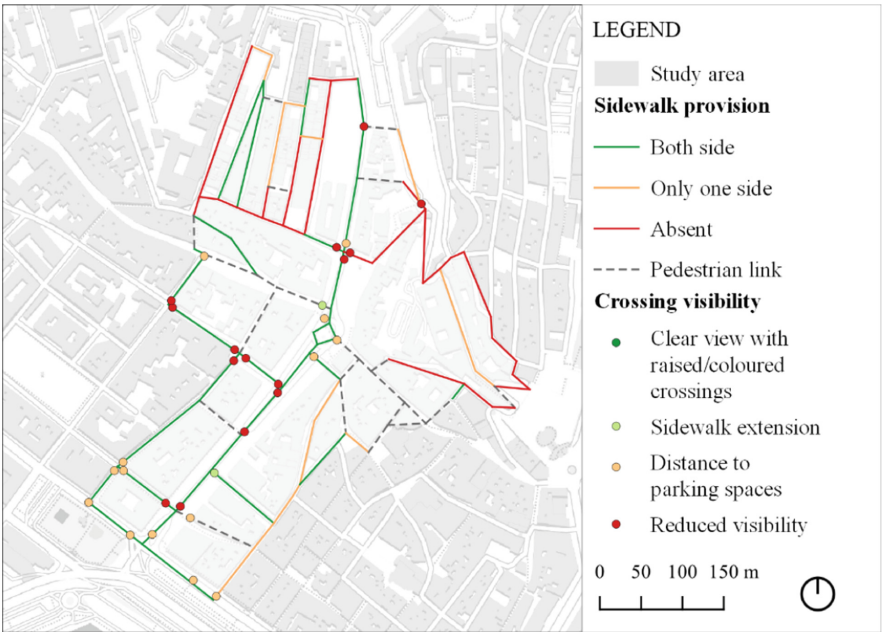

Fig. 4. Sidewalk provision and crossing visibility.

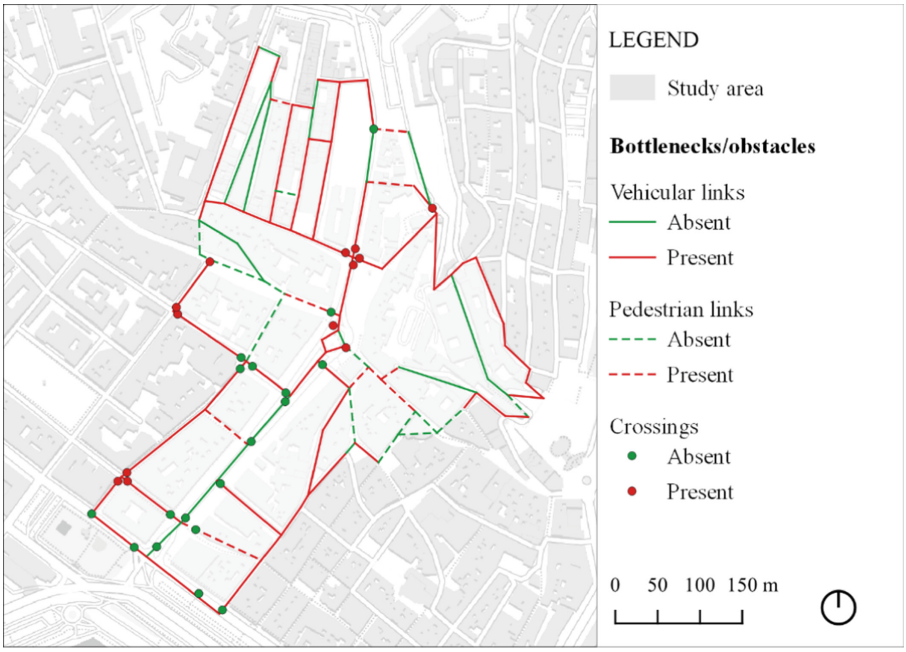

Fig. 5. Bottlenecks and obstacles

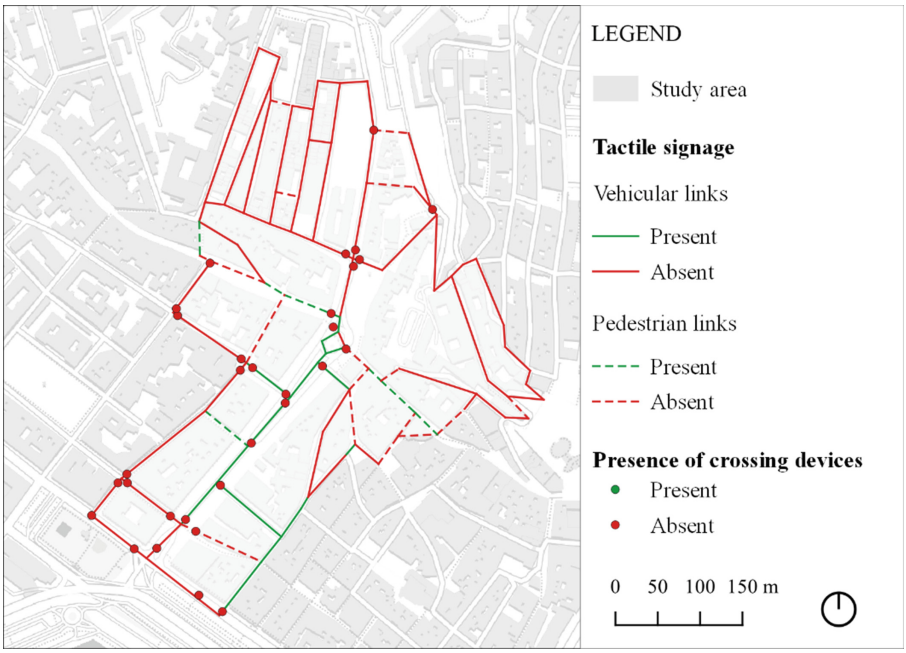

Fig. 6. Tactile signage and presence of crossing devices

According to the results of the performed analysis, the Largo Felice area presents some criticalities that affect the overall walkability level. Following the criteria provided in 2, the assessment has been considered more detailed and focused on issues of approachability, safety and enjoyment. Figures 7, 8 and 9 shows the maps derived from the calculation of each composite indicator.

The results demonstrate the close correspondence of the indicators to the actual physical configuration of the pedestrian paths, considering strengths and weaknesses. Links associated with low values of these indicators are generally characterized by pedestrian paths with poor functionality or not accessible for all users. Many of the critical links are related to the presence of obstacles and the reduced width of sidewalks, thus compromising approachability, especially in the northern part of the study area. Pedestrian paths are discontinuous due to pavement changes in level and steps, without ramp provision, also common in the southern part of the study area. The presence of numerous obstacles, e.g., lighting poles, garbage bins, and parking stalls close to crosswalks obstruct the pedestrian flow and reduce their visibility by drivers. Thus, pedestrians are often exposed to risks, also due to the excessive length of crossings and high vehicular traffic flows. As a result, it is advisable to limit vehicle speeds through traffic calming interventions and incentivize the implementation of pedestrian areas.

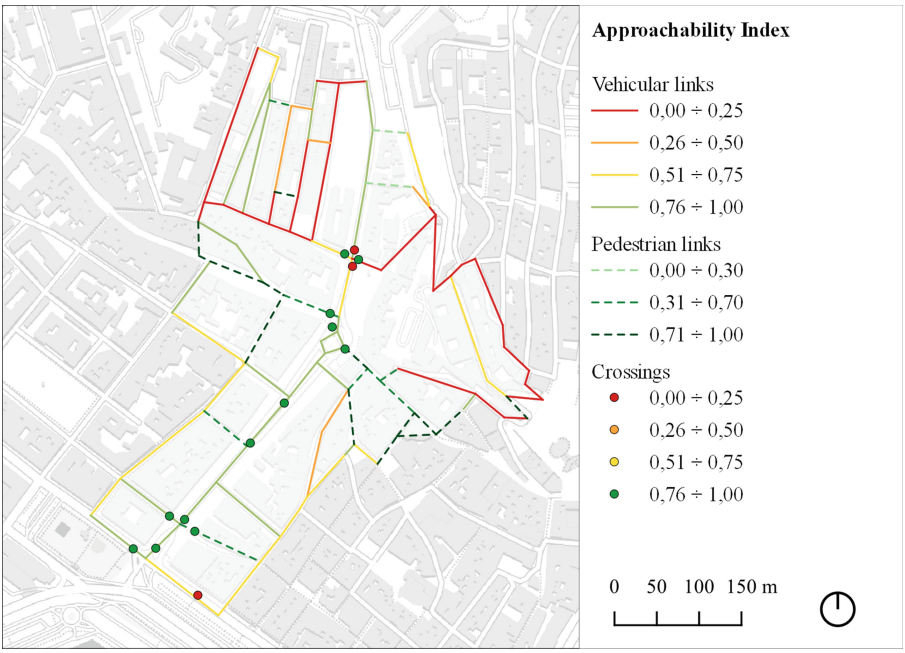

Fig. 7. Approachability index

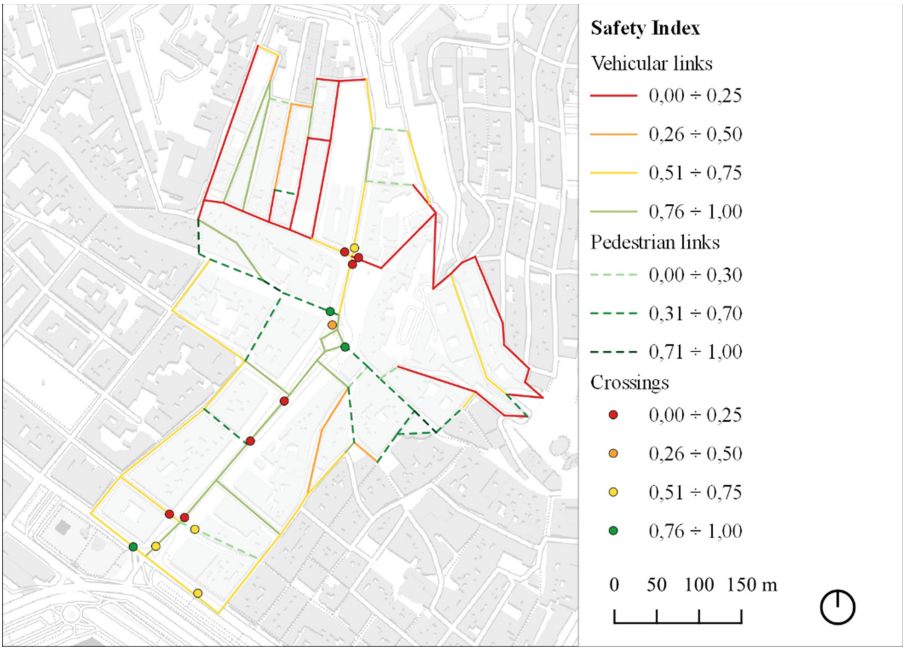

Fig. 8. Safety Index

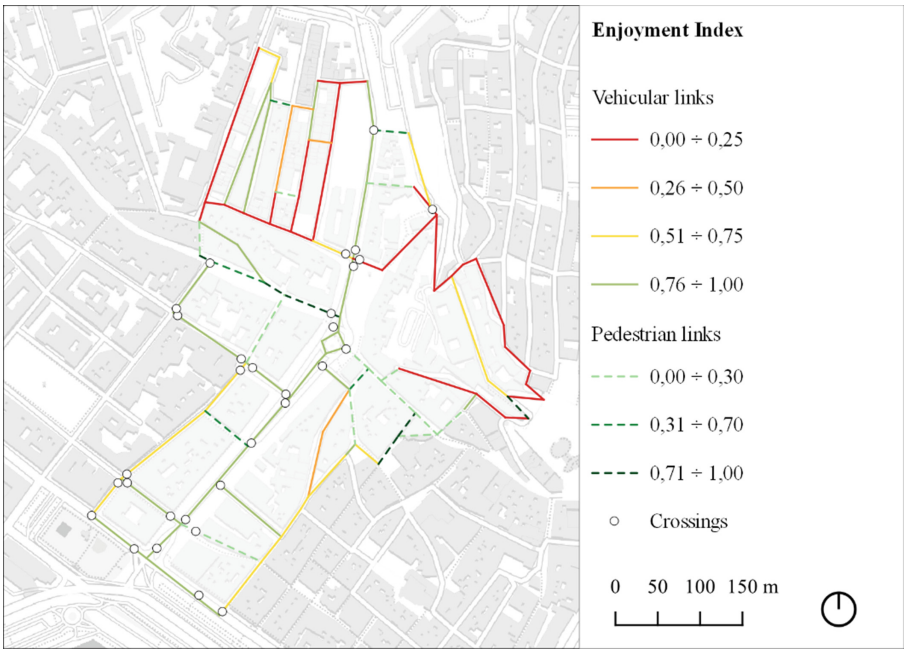

Fig. 9. Enjoyment Index

5 Conclusions

Nowadays, one of the main worldwide challenges within cities is to pursue a user-centred planning approach, that ensures a pleasant pedestrian experience, an opportunity of interaction with the urban environment and society, and thus promote sustainability.

In this direction, the current urban design paradigms require increasingly specific analyses. Furthermore, local authorities, must embrace an urban planning capable of guaranteeing approachability and safety of pedestrian paths for each user's category through priority, timely and rapid interventions. First of all, for the strengthening of pedestrian networks, urban spaces requalification interventions are needed. Simple analytical models are required to identify a priority of interventions and to incentivize active mobility in cities, thus the fundamental contribution of urban planning is to act through practical applications.

Within this context, the paper focused on the issue of walkability, evaluating the approachability, safety, and enjoyment of pedestrian paths in the area of Largo Felice in Cagliari and identifying potentialities and criticalities. With an extension of 15,52 hectares, the research area addressed in this work corresponds to an important central section of pedestrian flows in the historic centre. Through the calculation of composite indicators and the subsequent graphical processing of the obtained results, evident evaluations emerged. The choice of specific attributes for the calculation of these indicators has proved to be important for the research purposes, since the pedestrian network must provide adequate performance levels to meet of all user needs, even the vulnerable ones. The performed analysis can provide the public administration with a useful tool for

assessing the quality of pedestrian mobility within urban environment and identifying possible intervention priorities.

Future research can involve more detailed investigations based on the calculation of further composite indicators with additional walkability attributes. In this perspective, to enhance the adoption of pedestrian-friendly solutions in our cities, an extension of the mapping of pedestrian paths beyond the urban road network is envisaged.

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