A step towards walkable environments: spatial analysis of pedestrian compatibility in an urban context

Matteo Ignaccolo[1], Giuseppe Inturri[2], Nadia Giuffrida[1], Michela Le Pira[1], Vincenza Torrisi[1], Giovanni Calabrò[1]

[1]*Department of Civil Engineering and Architecture, University of Catania, Via Santa Sofia 64, Catania 95125, Italy*
[2]*Department of Electric, Electronic and Computer Engineering, University of Catania, Via Santa Sofia 64, Catania 95125, Italy*

Abstract

This paper presents a procedure based on a spatial analysis to assess the pedestrian compatibility of streets in an urban area. The aim is to provide decision-makers with a planning-support method that can aid them to decide the priority of investments, based on street pedestrian compatibility. The case study is Acireale, a small town of 50,000 inhabitants in Sicily (Italy), characterized by a high touristic vocation and a predominant use of private vehicles for daily urban trips. A set of evaluation criteria was chosen to assess the walking condition of each street, and an overall index of pedestrian compatibility was defined. Data were gathered and arranged in a spatial database, and different thematic maps produced, focusing on pedestrian compatibility, and on specific characteristics (e.g. presence and width of sidewalks, slope). First results reveal that some of the main streets crossing the historic centre have a good walkability, while other central streets suffer from car-space dominance. Besides, they also suggest paying more attention on improving pedestrian paths connecting the main facilities located outside the historic centre, being mostly experienced by vulnerable users (e.g. schools and hospitals). Accordingly, a case study regarding an educational centre is presented with different measures of intervention, in order to ensure continuity, safety and pleasantness of pedestrian paths. The developed GIS-based vector-model includes readily available data sources in an easily interpretable graphical format suitable for decision-makers to support the design of walkable environments.

Keywords: walkability; pedestrian mobility; GIS; sustainable mobility; street design

1. Introduction

Road transport accounts for 82% of all transport energy consumption, causes many negative externalities, including air and noise pollution, road traffic accidents, and is one of the main responsible of climate change (European Union, 2017; European Parliament, 2019). Under this respect, road traffic accidents in the Member States of the European Union claimed about 25,600 lives and left more than 1.4 million people injured in 2016 (European Commission, 2018).

This is particularly relevant in urban areas, with an increasing demand for mobility characterized by a huge number of short trips (Torrisi et al., 2018a), and a predominance of public spaces kept for motorized transport. Promoting the shift towards more sustainable transport modes (mainly walking and cycling) is one of the best ways for limiting the increase in motorization and climate change mitigation (Caprì et al., 2016; Ignaccolo et al., 2018). Besides, an effective way of reducing car dependency of our cities and the related energy consumption is to properly integrate land use and transport planning, e.g. by fostering smart growth principles and deploying of new intelligent technologies aimed at concentrating urban functions, thus limiting the length of trips and trying to optimize energy resources (Ignaccolo et al., 2016; Torrisi et al., 2018b; Volpe et al., 2017; Fichera et al., 2018).

Pedestrian mobility becomes a fundamental component of urban transport, although often underdeveloped in car-dependent cities (Tight et al., 2011). Under this respect, disperse automobile-based urban fabric and lack of adequate pedestrian infrastructures impede its spreading (Newman et al., 2016).

Walking in cities should be encouraged for systematic trips, as well as other trip purposes, via adequate planning and management of seamless pedestrian networks. However, in contexts characterized by limited resources, a priority of investments for developing walkable streets should be defined, paying careful attention to land use asset (e.g. points of interest). Appropriate decision-support tools based on sound data and analysis should be used to this purpose. In this respect, accessibility measures for non-motorized travels can provide a valuable support for planning and designing walkable spaces (see, e.g. Arranz-López et al., 2018). However, some problems can emerge, mainly linked to a general lack of reliable non-motorized travel data for a variety of trip purposes, as well as high-resolution land use data, inadequate zonal structure and travel networks, and the use of arbitrary impedance functions (Iacono et al., 2010).

Geo-localized data about both walking demand and supply allow performing spatial analysis using Geographic Information Systems (GIS) and help localizing the critical areas needing interventions via user-friendly maps (Giuffrida et al., 2017; Gonzalez-Urango et al., 2020). Under this respect, it is important to provide policy-makers with clearly understandable results.

The aim of this paper is to provide a simple GIS-based tool for spatial analysis aimed at evaluating street pedestrian compatibility. The GIS-based tool relies on detailed data acquisition on pedestrian network characteristics, and disaggregated and aggregated spatial analysis via thematic maps. This planning-support tool can assist policy-makers in deciding the priority of investments, by easily visualizing the conditions of the pedestrian network from multiple points of view. In this respect, it can be a valuable tool to bridge the gap between technical analysis and practical implementation of strategies aimed at improving walkability towards seamless walking networks.

The remainder is organized as follows. Section 2 will describe the main steps of the methodology, based on data acquisition (2.1) and analysis via the definition of an index (2.2), and spatial analysis via GIS (2.3). Section 3 will introduce the case study with the description of the analysed area, section 4 will show and discuss the main results, while section 5 will provide proposals of “critical” pedestrian paths’ requalification for a specific school site in the study area. Finally, section 6 will conclude by presenting future research steps.

2. Methodology

The methodology is based on five steps, i.e.: (1) building of the pedestrian network graph, (2) data acquisition via review of different characteristics of links and sidewalks, (3) creation of a spatial database, (4) evaluation of pedestrian compatibility, (5) spatial analysis.

In the following, the three main elements of innovation are described, i.e. review method, pedestrian compatibility index and spatial analysis.

2.1 Review method

The analysis of the links was carried out with reference to previous studies. In particular, the so called PERS - Pedestrian Environment Review System (Allen and Clark, 2007), a walking audit tool developed by TRL (Transport Research Laboratory), was taken as reference to assess the level of service and quality of different pedestrian environments, evaluating different characteristics of links, paths, pedestrian crossings, waiting areas for public transport, areas of modal interchange, public spaces.

Drawing inspiration from PERS, a simplified assessment procedure was defined, focusing on reviews of the following pedestrian environments:

- link, i.e. any street (both reserved to pedestrians and vehicle-allowed);
- pedestrian crossings, i.e. any designated or undesignated crossing where a pedestrian route intersects with a street.

Table 1 summarizes the parameters used for the evaluation (those with the asterisk are the only ones used for pedestrian links).

Table 1: Link/Crossing review with parameters and related evaluation (asterisks indicate the parameters used for pedestrian links)

REVIEW	*Parameters*	*Evaluation*	
Link review	Pedestrian/Vehicle-allowed*	Only Pedestrians allowed/ Vehicles allowed	P/V
	Sidewalk provision	Both side/No/Right side/Left side	2/-1/1/1
	Effective width of sidewalk (≥1.50 m)	Both side/No/Right side/Left side	2/-1/1/1
	Access ramps provision	Yes/No	1/-1
	Gradient*	High (>6%)/Low-No gradient	-1/1
	Obstructions*	Yes/No	-1/1
	Lighting*	Yes/No	1/-1
	Tactile information*	Yes/No	1/-1
	Surface quality and maintenance*	Insufficient/Sufficient	-1/1
	Continuity	Yes/No	1/-1
	Parking provision	Both side/No/Right side/Left side	2/-1/1/1
Crossing review	Crossing provision	Yes/No	1/-1
	Ramp provision	Yes/No	1/-1
	Maintenance	Insufficient/Sufficient	-1/1
	Excessive length	Yes/No	-1/1
	Obstructions	Yes/No	-1/1

Source or specifications.

2.2 Pedestrian compatibility index

A global compatibility index has been defined to account for multiple characteristics of the walking paths both for vehicle-allowed and pedestrian-only links, as follows:

$$PCI_V = \text{sidewalk} * (1 + \frac{\text{sidewalk}_{index}}{8}) + \text{crossing} * (1 + \frac{\text{crossing}_{index}}{4}) \quad (1)$$

$$PCI_P = \text{gradient+obstructions+lighting+tactile}_{\text{info}}\text{+surface}_{quality} \quad (2)$$

where the coefficient 8 and 4 correspond to the sum of the maximum values that can be assumed by the parameters respectively of the link and the crossing review, and:

$$\text{sidewalk}_{index}\text{=width+gradient+obstructions+lighting+tactile}_{\text{info}}\text{+surface}_{\text{quality}} + \text{continuity} \quad (3)$$

$$\text{crossing}_{index} = ramps + manteinance + length + obstructions \quad (4)$$

For each vehicle-allowed link i and pedestrian link j, PCI can be normalized to scale the data between 0 and 1 through a min-max algorithm in order to better appreciate the differences of results:

$$PCI_V^{i,norm} = \frac{|PCI_i - PCI_{\min}|}{|PCI_{\max} - PCI_{\min}|} \quad (5)$$

$$PCI_P^{i,norm} = \frac{|PCI_j - PCI_{\min}|}{|PCI_{\max} - PCI_{\min}|} \quad (6)$$

2.3 Spatial analysis

The creation of a spatial database and the spatial analysis is conducted by using QGIS, an open-source software for the analysis and manipulation of georeferenced data. The spatial database is constructed through an operation of join between a shapefile of the urban network model and the review database, through a common identification field for each element. In this way, all the elements are provided with a field for each evaluation parameter allowing the construction of the related thematic maps.

Next section will introduce the case study with a discussion of the review performed and the main results obtained, presented through maps.

3. Case study

3.1 Territorial framework

Acireale is a municipality of about 50,000 inhabitants and it is one of the most important urban centres of the Metropolitan Area of Catania; it lays on a lava-shaped terrace, "la Timpa", overhanging the Ionian Sea. In addition to the main urban centre, it includes numerous minor settlements linked to the flourishing agricultural and fishing activity. The main factors of economic development of the municipality are connected to tourism, commercial, agricultural and services sectors.

Pedestrian mobility is the most sustainable way to move around the city. Promoting walking not only helps to reduce the environmental impact of transport, but also contributes to make the city liveable and healthy. In Acireale's Urban Mobility Plan, (Piano Urbano della Mobilità – PUM), pedestrian mobility is described as not sufficiently widespread since citizens tend to use the car or the motorcycle even for short distances. The presence of inadequate sidewalks or their absence in some parts of the urban centre aggravate this situation, not favouring the development of a more "human scale" mobility. Moreover, from accident analysis it turns out that the percentage of pedestrian accidents is significant (13.6% and in urban areas it reaches 15.4%) and significantly higher than the regional average (8.8%), indicating the necessity of redevelopment of infrastructures that can be used by cyclists and pedestrians and the opportunity to carry out traffic calming interventions. Currently the approval and implementation process of the General Urban Traffic Plan, a short-term plan lasting two years, is ongoing; the review methodology presented in this study can be considered a valid contribution to such short-term planning tool, in order to identify the main criticalities of the urban area pedestrian network.

3.2 The context of analysis

The study area was identified starting from the existing activities and the main issues identified in the Urban Mobility Plan and can be divided as follows (Fig. 1):

- Old city centre (Area_1, Fig. 1), an area full of several activities (commercial, tourist, services) in which pedestrian mobility has an essential role;
- East district (Area_2, Fig. 1), an area of particular interest for the future development of public transport with the realization of a park-and-ride facility;
- West and north district (Area_3, Fig. 1), a more peripheral area with education facilities;
- Five seaside towns falling within the municipal territory of Acireale: Capo Mulini, Santa Maria la Scala, Santa Tecla, Stazzo and Pozzillo (Area_4, Fig. 1).

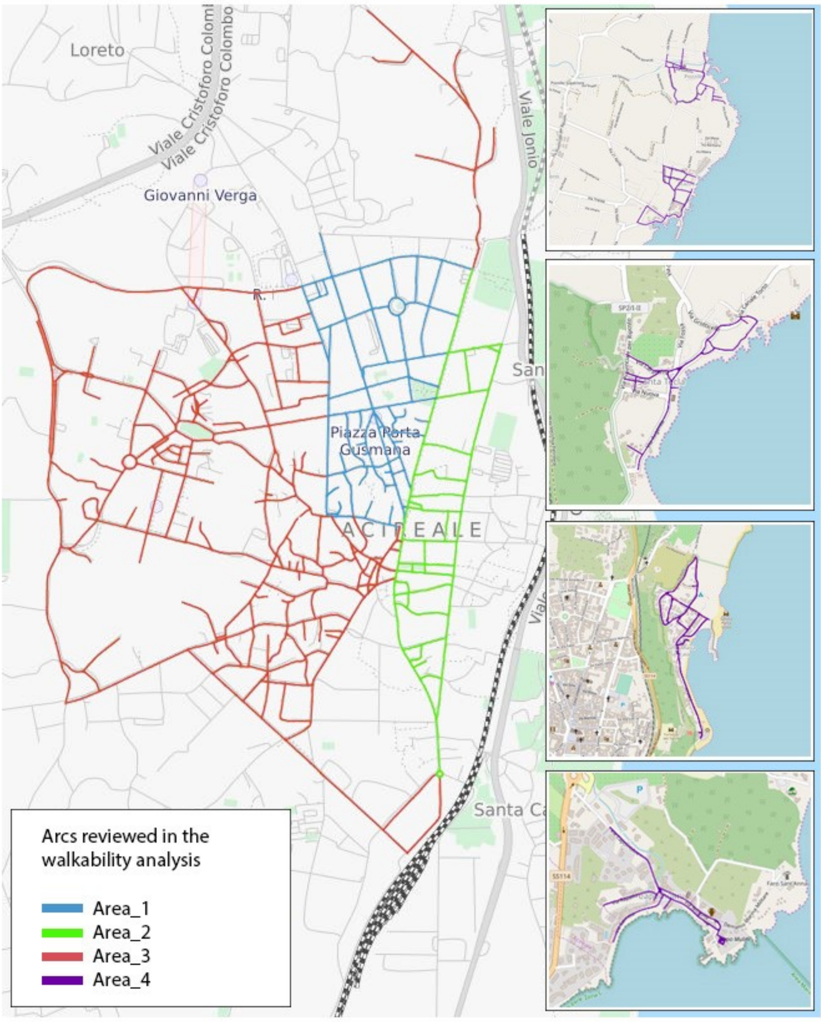

Figure 1: Links taken into account in walkability analysis in (a) Acireale, (b) Stazzo and Pozzillo, (c) Santa Tecla, (d) Santa Maria La Scala, (e) Capomulini
Source: own elaboration.

4. Results and discussion

The applied methodology to analyse the state of pedestrian network, as described in Section 2, has led to the generation of a database of 1123 links, each one characterized by the parameters of Table 1.

Starting from such information, five thematic maps related to the following geometric-functional characteristics have been created:

- sidewalk provision map;
- width of sidewalk map;
- continuity map;
- gradient map;
- PCI map.

With reference to the analysis of sidewalk provision, it was specified if (i) available on both sides, (ii) on one side or (iii) absent. From the survey, it emerged an overall sidewalk provision, generally absent in the peripheral area, corresponding to streets with central traffic island or with restricted road section; also, in the Eastern district, streets are characterized by discontinuity due to the absence of sidewalk. In summary, the overall outcome of this first analysis looks positive. However, the most critical issues emerge considering the effective width of sidewalk and its continuity.

Figure 2a shows the analysis related to the first parameter. It is possible to notice that a large number of links is characterized by an insufficient sidewalk width compared with minimum standards provided by current national regulations (more than 1.50 m), on one (yellow links) and both sides (red links). This forces the pedestrian to occupy the roadway in promiscuity with motorized traffic, without using a protected path. Moreover, in such streets, the sidewalk continuity is not always guaranteed (red links in Figure 2b). This is mainly due to the presence of obstructions along the sidewalk and the absence of vehicle access ramps provision in correspondence of driveways.

The analysis of gradients was conducted distinguishing links with an acceptable slope (<6%) and links with high gradient; this analysis can also be useful to plan investments for cycling mobility. Almost all the links presented an acceptable value of gradient, with the exception of some of the streets belonging to the historical centre and to the peripheral area.

Finally, to take into account the multiple analysed characteristics, PCI was calculated both for vehicle-allowed and pedestrian-only links; normalized values of PCI were associated with a colour scale consisting of four different colours from dark green to red (most critical situation), in order to obtain an immediate global assessment of each link with respect to emerging criticalities and consequently to a priority scale that identifies the areas of intervention (Figure 3). Results confirm that some of the main streets crossing the historic centre have a good walkability, while other central streets suffer from car-space dominance. Besides, they also suggest paying more attention on improving pedestrian paths connecting the main facilities located outside the historic centre, being mostly experienced by vulnerable users, especially educational services.

a. b.

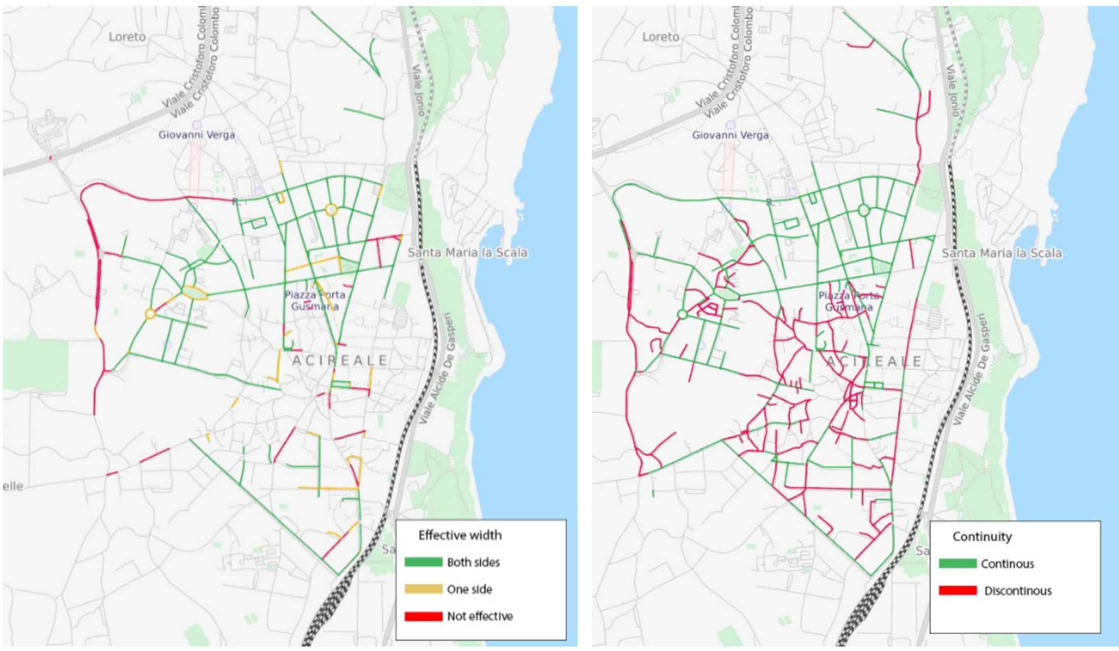

Figure 2: Thematic maps of (a) effective width and (b) continuity of the urban centre
Source: own elaboration.

This analysis was also conducted to the five seaside towns falling within the municipal territory of Acireale: Capo Mulini, Santa Maria la Scala, Santa Tecla, Stazzo and Pozzillo; this is important to understand how to improve pedestrian accessibility in such places, especially during summertime. All of them are characterized by the absence of sidewalk, or its provision only on one side. As far as Pozzillo is concerned, only a part of the town can be considered suitable for pedestrian mobility. A similar situation is found in Stazzo and Santa Tecla, which have sidewalks only along the waterfront. Santa Maria La Scala presents a recently built sidewalk on one side in the waterfront. However, a series of obstructions constituted by vegetation and street furniture are present. In the remaining areas of the town, similarly to the previous cases, sidewalk provision is inadequate. Finally, Capo Mulini is the only town that presents a sidewalk on both sides along its waterfront. Regarding the quality of such paths, the best runs along the waterfront in Santa Maria La Scala for about 500 m, and it is characterized by an effective width, although it is only on one side of the street; similarly, in Stazzo a good pedestrian path is recorded for about 300 m. As for the gradient, it appears to be acceptable in most cases, with the exception of some links located in Santa Maria la Scala, characterized by pedestrian paths with steps. The global assessment was obtained by evaluating the PCI for these five towns (Fig. 3). The obtained results show low values of this index for all the analysed areas in comparison with the urban centre of Acireale, and therefore interventions to improve pedestrian paths are needed.

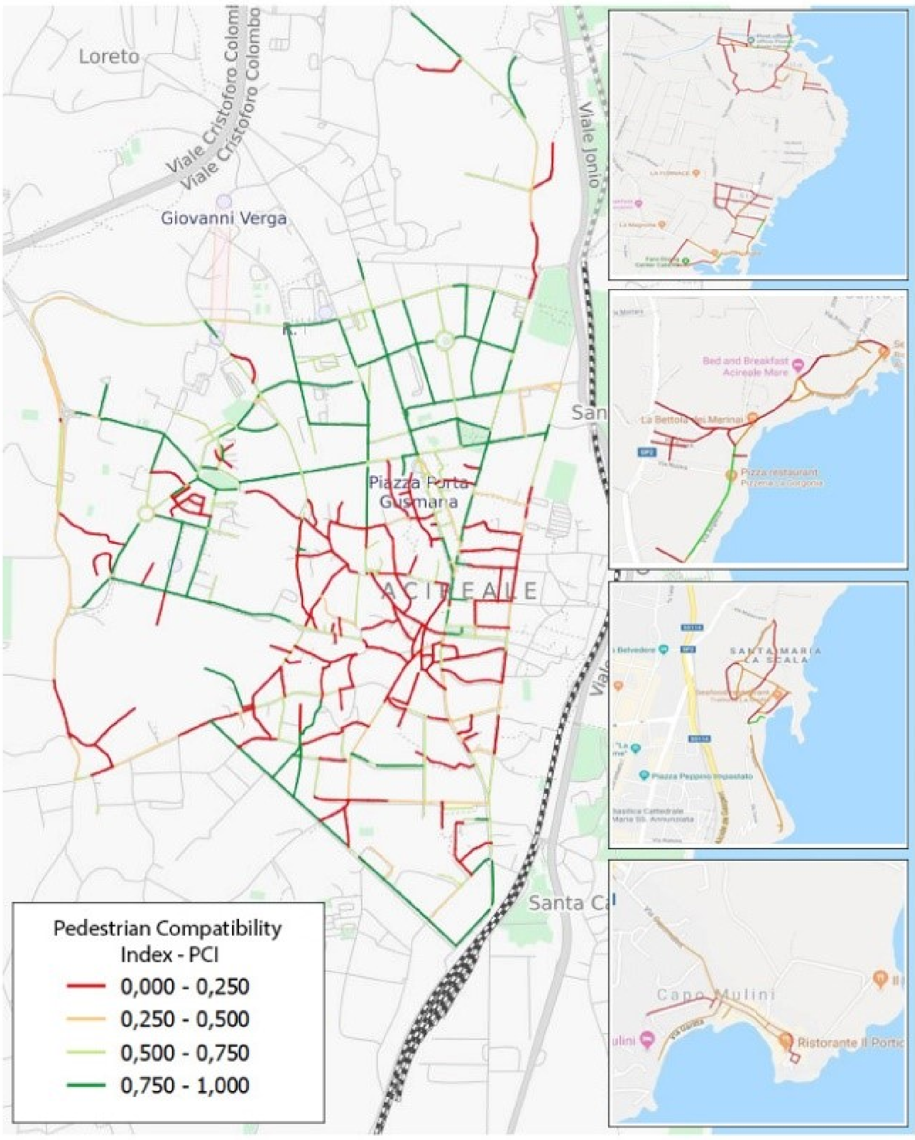

Figure 3: Thematic maps of PCI of the urban centre in (a) Acireale, (b) Stazzo and Pozzillo, (c) Santa Tecla, (d) Santa Maria La Scala, (e) Capomulini
Source: own elaboration.

5. Requalification proposals

This brief section presents a proposal of pedestrian paths' requalification around a school complex, which is located in the city centre. This site was chosen among the "critical" and priority ones, according to the average value of the PCI of the access streets to the schools. The design solutions consist of coordinated interventions, intended to improve safety, continuity and pleasantness of pedestrian paths to access the educational facilities. An on-site survey revealed different critical issues, such as the presence of several obstacles to pedestrian mobility (lighting poles, advertising boards, private vehicles parked illegally on the street and on public spaces) narrowing the pedestrian path on a sidewalk, whose width is inadequate in itself, or totally absent. Besides, the pedestrian crossings are not equipped with curb ramps, thus constituting an obstacle to wheelchair and vulnerable users in general.

The proposed interventions, shown in Figure 4 and 5, are described as follows:

- construction of a sidewalk (1.50 m wide) on the left side of the street (currently absent), with the insertion of parking bollards, avoiding illegal on-street parking and maintaining a one-way lane (3.50 m wide);
- creation of a raised pedestrian crossing as a traffic calming measure aimed both at reducing vehicle speeds near the entrance to the school and ensuring the continuity of the pedestrian path;
- curb extension at the intersection, with insertion of parking bollards, to improve visibility (and therefore safety) of users at pedestrian crossing;
- construction of curb ramps to suitably connect the sidewalk with the road pavement, ensuring the continuity of pedestrian paths;
- requalification of the square in front of the school entrance, through the resurfacing of the pavement, the insertion of urban furniture elements and removal of the illegal parking.

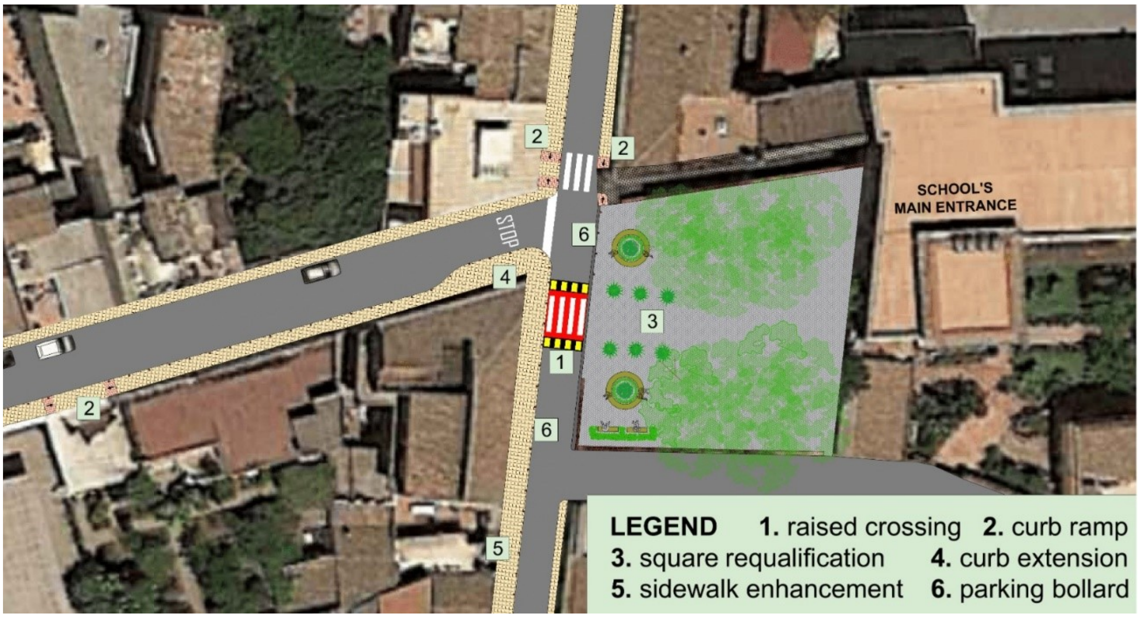

Figure 4: Layout of the school site subjected to requalification measures
Source: own elaboration.

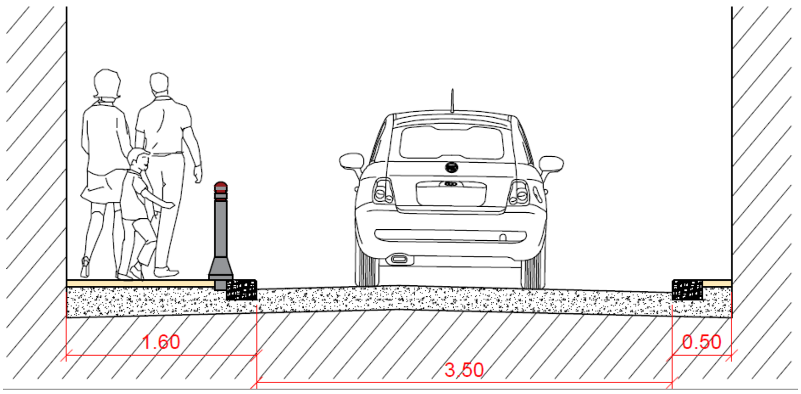

Figure 5: Layout of requalification measures of the school site: cross-section
Source: own elaboration

6. Conclusion

This paper presented a procedure based on a spatial analysis to assess the pedestrian compatibility of streets in an urban area. The aim is to provide decision-makers with a planning-support method that can aid them to decide the priority of investments, based on street centrality and pedestrian compatibility. The case study is Acireale, a small town of 50,000 inhabitants in Sicily (Italy), characterized by a high touristic vocation and a predominant use of private vehicles for daily urban trips. A set of evaluation criteria was chosen to assess the walking condition of each street, and an overall index of pedestrian compatibility was defined. Data were gathered and arranged in a spatial database, and different thematic maps produced, focusing on pedestrian compatibility, and on specific characteristics (e.g. presence and width of sidewalks, slope). First results reveal that some of the main streets crossing the historic centre have a good walkability, while other central streets suffer from car-space dominance. Besides, they also suggest paying more attention on improving pedestrian paths connecting the main facilities located outside the historic centre, being mostly experienced by vulnerable users (e.g. schools and hospitals). Future research would complement the proposed analysis by focusing on other characteristics, e.g. type of road, road width, road traffic, street vitality, which can be useful for priority intervention setting. Besides, it would be interesting to assign weights to the different walkability components, derivable e.g. from a multicriteria analysis or a stated/revealed preference survey. Finally, the link/crossing review based on the parameters of Table 1 could be replicated in other contexts, allowing benchmark analyses to be performed between different towns.

Such analysis is both important and needed especially for small towns where distances are usually limited and can be covered by non-motorized modes of transport. Pedestrian-based policies would allow a shift from car-oriented urban mobility to sustainable mobility, improving liveability and promoting human scale transport planning.

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Acknowledgements

This work has been partially financed by the University of Catania within the project “Piano della Ricerca Dipartimentale 2016-2018” of the Department of Civil Engineering and Architecture and the project “Piano per la Ricerca 2016-2018 - Linea di intervento 2” of the Department of Electric, Electronic and Computer Engineering.