Cyclable City: A Territorial Assessment Procedure for Disruptive Policy-Making on Urban Mobility

Giovanni Fortunato(✉), Francesco Scorza, and Beniamino Murgante

Laboratory of Urban and Regional Systems Engineering, School of Engineering, University of Basilicata, 10, Viale dell'Ateneo Lucano, 85100 Potenza, Italy
giovanni.fortunato88@libero.it,
{francesco.scorza, beniamino.murgante}@unibas.it

Abstract. Urban cycling is one of the main references for the development of sustainable mobility models [1]. Cycling is an active transport mode that is alternative to the use of public and private means of travel. At city scale it collects high levels of users satisfaction. Urban policies encouraging this transport mode are compared with modal split solutions that must take into account the morphological characteristics of the context as well as the organizational dimensions of urban transport. In this work, after highlighting good practices related to traffic moderation, the promotion of soft active mobility (Living street) and the widespread cycling in the urban context, we propose an intervention scenario for the development of an urban cycling infrastructure scheme that integrates current transport infrastructures (mechanized pedestrian mobility) according to a multimodal approach. The sample context is the city of Potenza (Basilicata - Italy). The focus on slow mobility is part of urban mobility strategies. The contribution described in this paper aims at the integration of mechanized pedestrian mobility and local public transport, by road and rail, with active cycle mobility. The aim is to demonstrate how the proposed scheme is feasible with respect to the steepness and integrates infrastructural solutions and reorganization of driveway mobility for widespread use of the bicycle (both traditional and the most innovative forms e-bike and pedelec).

Keywords: Cyclability · Sustainable transport · Sustainable urban development

1 Smart (Sustainable) Mobility and Urban Development

Urban mobility is at the center of national and international interest as it represents one of the sectors that can have a significant impact on sustainable development in the future. This is still true if we consider the fact that the world population residing in urban areas will reach 70% of the total in 2050 [2]. The transportation sector is energy-intensive as it has significant implications for energy consumption and polluting emissions. Urban mobility is responsible for 40% of the CO_2 emissions of the transportation sector which, as a whole, produces 25% of greenhouse gas emissions in the European Union's countries [3].

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A series of European Union initiatives [4–11] shows that the implementation of sustainable transport policies is at the heart of the European strategy aimed at promoting sustainable development. Faced with the current negative scenario whose data have been mentioned previously and the growing sustainability worries, smart mobility "could also be seen as a set of coordinated actions addressed at improving the efficiency, the effectiveness and the environmental sustainability of cities" [12].

Pinna et al. [13] state that: "mobility cannot be considered smart if it is not sustainable, the most substantial difference between sustainable mobility and smart mobility is that smart mobility is an integrated system comprised of several projects and actions all aimed at sustainability". This highlights that the paradigms of "smart" and "sustainable" are closely connected within the framework of sustainable urban development. Furthermore connectivity is the main element that characterizes smart mobility. This is also confirmed by Lyons [14] who, comparing his conceptual framework with many authors [15–17], provides the following definition of smart urban mobility: "*connectivity in towns and cities that is affordable, effective, attractive and sustainable*". Connectivity is not just about how people and goods move in urban areas but also "*the land use system, transport system and the telecommunications system*" [18].

Many studies show that the use of active travel modes (non-automobile modes such as bicycle ridership) increases when urban neighborhoods are characterized by land use diversity, proximity to retail stores, presence and distribution of transit stations [19–22]. A relevant example is the city of Berlin which has an urban poly-centric structure based on towns that have functional autonomy in the city [23–25].

Urban street design can help make sustainable modes of transport (walking and cycling) more attractive, thus increasing their use in urban travel and reducing the negative externalities on social environmental and economic basis [26–28]. Urban planning should promote compact urban patterns in order to make trips shorter. "*Ensuring enhanced permeability for pedestrians and cyclists can enrich the urban realm and influence how people connect in urban environments*" [14]. Furthermore, there is a connection between people's travel choices and urban form as demonstrated by the definition of 5 environment built variables in the field of urban planning: design, density, diversity, distance to the public transit and destination accessibility [29].

In light of this, the study presented aims to verify the possibility of integrating a system of cycle routes with related infrastructural interventions in the city of Potenza. Within the framework of sustainable mobility, the bicycle is a mean of transport that can contribute to urban sustainability thanks to its social, environmental and economic advantages. This study focuses on design measures aimed at promoting bicycle use, almost completely absent in the city of Potenza, and a consequent modal split from motor vehicles to cycling. In order to design a network of bicycle paths technical requirements for the bicycle facilities based on the review of state of the art manuals and national and international technical guidelines have been considered.

This paper proposes a GIS-based method to design bike facilities, to define the characteristics (such as provenance and distribution in urban area) of the demand of the daily commuters (workers and students) and to assess the bike accessibility to urban attractors.

2 The Global Framework Promoting Urban Cyclability and the Case Study

According to the European Parliament resolution of 27 September 2011 on European road safety 2011–2020 [1], there is a need to promote road safety in order to pursue the "Vision Zero" [30] in terms of accidents through regulatory and design measures which overcome the logic of the separation of road traffic flows between the different means of transport and encourage a shared use of the road as a public space, based on the type of road and the context. An International Transport Forum (ITF) research report shows that road crashes are the ninth main cause of death globally and the main cause of death worldwide for young people aged between 15 and 29 years [31]. Specifically vulnerable road users including pedestrians, cyclists represent 26% of all road traffic deaths [32]. From a safety point-of-view, a considerable lack of safe riding space that characterizes the cycling infrastructure discourages cycling as transport mode for urban trips.

So in the last decade road safety is considered a central issue by international community in the field of sustainable development, as demonstrated by the Decade of Action for Road Safety 2011–2020 [33]. The 2030 Agenda for Sustainable Development, which sets 17 Sustainable Development Goals (SDGs) and their 169 targets, includes 2 targets on the subject of Road Safety policy: one in Goal 3 (Health) and one in Goal 11 (Sustainable cities and communities) [34].

Goal target 3.6 calls for halving in the number of road traffic deaths by 2020 [34]. This is unlikely to be achieved. Sustainable Development Goal (SDG) target 11.2 highlights the importance on implementation of road safety measures in order to effectively create sustainable cities and communities: "*By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons*".

Many studies show how the installation of bicycle lanes promotes not only the use of the bicycle but also the increase in roadway safety, being in fact an effective and low-cost design street measure that allows the reduction of the risk of accidents for cyclists in a city (cfr. [34–38]). A study conducted by Kondo et al. [39] found that a significant reduction in the probability of bicycle accidents (more than 40%) occurred following the inclusion of bicycle lane in the streets. Jacobsen found that the probability of an accident between a weaker street user (pedestrian or cyclist) and a motor vehicle is inversely related to the pedestrian or bicycle traffic volume [40].

This is an opportunity to redefine the dimensions of mobility at urban level, encouraging a significant transition towards active forms of urban mobility. To achieve sustainable mobility, it is necessary to implement measures aimed at: reducing the need to travel, encouraging modal shift, reducing trip distances (through land-use policy measures) and increasing transport system efficiency [16]. In Europe there are examples of cities that, through their sustainable urban plans, are willing to return the roads intended as "public spaces" to the citizens: the Barcelona "Superblock" model [41, 42], the increase of 30 zones in Paris (at the end of 2017, 45% of the Parisian roads had a speed limit of 30 km/h [43] with the objective of reaching 85% in 2020 [44] and the

application of the speed limit of 30 km/h to 87% of the roads in Bilbao as established by its Plan de Movilidad Urbana Sostenible (PMUS) 2015-2030 (the remaining 13% will have a limit of 50 km/h) so that it can be defined as "30 City" [45, 46].

The case study, which is characterized by morphological limits to the diffusion of an extensive network of active mobility, required the experimentation of territorial analysis models in Geographic Information System (GIS) environment for the evaluation of the territory and the road network, the estimation of the journey times, the integration with mechanized transport infrastructures such as escalators, elevators. In a city with considerable slopes such as Potenza these mechanical means support walking, providing a great contribution to improving the quality of pedestrian mobility while reducing pedestrians' physical wear, travel times and discomfort. The city of Potenza can count on the presence of 4 escalators infrastructures.

In light of this, the research allowed to propose a new cycle infrastructure design to increase the use of the bicycle in combination with the public transport system and to increase the extent of the areas served (Buffer Zone) by urban mobility infrastructures [47]. Thus cycling can also be used for medium-long journeys: a part(s) of the trip travelled by bicycle and the rest with public transport. In this scenario, cycling could be used on trips to cover the first and last mile.

The present study assessing the feasibility of creating an urban cycle infrastructure within the city of Potenza is strongly coherent with the policy framework proposed by the Basilicata Region 2016–2026 Transport Plan which encourages forms of active and sustainable mobility both at regional and local level [48]. Moreover urban planning instruments and policy strategies developed in the context of the city of Potenza to promote active and sustainable transport mode have been taken into consideration: the Urban Plan of Potenza [49], the Urban Mobility Plan [50], the ITI Urban Development Program of the city of Potenza [51] and the Italian Highway Code [52].

The city of Potenza, with more than 67,000 inhabitants, has a value of 0 km/10,000 inhabitants of cycle paths, does not have a bike sharing service, but it is the fourth Italian city for "Index of car motorization" with 73,93 vehicles/100 inhabitants. However, Potenza is the Italian Regional County Seat with the largest number of green spaces per inhabitant of 371.6 mq/inh. compared to an average national value of 32.2 mq/inh [51].

Potenza is a city with high steepness: from the study of its orography it emerged that more than 80% of the urban territory has a terrain slope of more than 11%, about 45% of the urban area has a slope of more than 20%; just over 26% of the urban streets have a gradient less than 5% (Fig. 1).

References to national and European experiences allowed the construction of evaluation frameworks of the territorial context in the light of specific design solutions. The results can be transferred to other similar contexts for the construction of sustainable urban mobility projects and policies based on urban cycling.

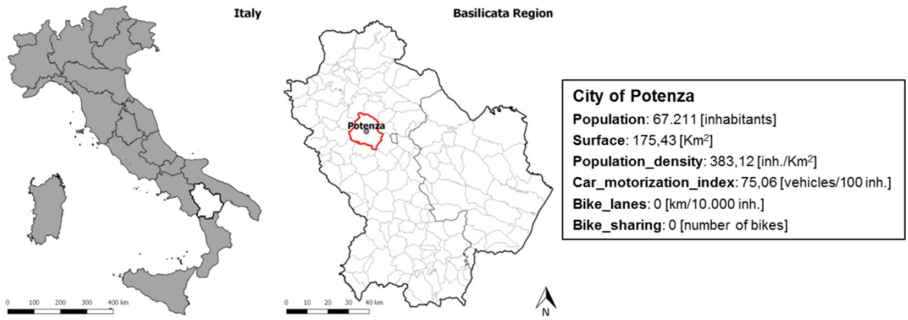

Fig. 1. Location of Basilicata Region in Italy on the left, location of the city of Potenza (red perimeter) in Basilicata Region on the center and data on the city of Potenza on the right. (Color figure online)

3 Cycling and Innovative Solutions for Smart Urban Mobility: The Case of Potenza

The first phase of the study began with the observation and collection of data relating to the urban context in order to verify the possibility of integrating a network of cycle infrastructures for daily journeys for study and work within urban area of the city of Potenza. In this study the indispensable knowledge of the urban cycling environment is obtained through the construction of a specific spatial data model, a territorial database built by GIS software.

In this paragraph, we discuss the approach to territorial analysis aimed at evaluating the city of Potenza's terrain and streets slope, in order to define a network of cycle routes in urban areas. The identification process of the main traffic generators/attractors (urban facilities such as public services and equipment) is described, the urban mobility infrastructures are represented, the demand analysis and the evaluation of the accessibility to public services and equipment are carried out through the realization of isochrones. In this work we followed the example of the Lisboa Horizontal project aimed at planning a network of cycle paths that involves roads with a slope of less than 4%. A group of developers in Lisbon designed an app that tells the cyclist the best routes to use. The Lisbon Horizontal app has also been used in other cities with different orographic profiles such as Madrid, Berlin, Brussels and Zurich [52]. We also followed "Bicipolitana" scheme in the city of Pesaro, whose scheme is created with reference to the model of the subway network.

Existing geographical data, available in the Geoportal of the Basilicata Region (RSDI Basilicata Region) and others resources freely accessible, such as Open Street Map, do not provide no geographical information concerning the morphological features of the land and the streets. The slope of each street segment, in addition to the width of the latter, is taken as a fundamental value for choosing a route more appropriate to accommodate a cycle infrastructure.

The first step consisted in the evaluation of the slope of the streets (length = 810.272 km) of the city of Potenza. From the geo-topographic regional database

(Regional Spatial Data Infrastructure (RSDI) Basilicata Region), vector layers on a municipal basis were downloaded, relating to the urban viability and administrative boundaries of the Municipality of Potenza and the Digital Terrain Model (DTM) blocks with a high resolution (cell size = 5 m) affecting the portion of the territory considered in order to perform a geomorphological analysis on the raster aimed at determining the urban territory and streets' slope expressed in percent terms (%).

Through the QGIS software tools it was possible to transfer the value of the slope to the vector layer of the road network. In this way each average slope value has been associated to the corresponding street segment and it was thus possible to select the arches of the road network by slope classes: less than 5% (12% of the entire road network of the city of Potenza); with a slope of less than 10% (35% of the road network). In the urban area more than 26% of the roads have a slope less than 5%, so these streets are absolutely suitable for cycling for urban trips. Slopes less than 5% are suitable for relatively low-stress cycling [53, 54]. Moreover the American Association of State Highway and Transportation Officials provides desirable uphill gradients for cyclists and respective acceptable lengths (for example, a max length of 240 m corresponds to a gradient of 5–6% while a max length of 60 m corresponds to a gradient of 9%.

As shown in Figs. 2 and 3 the roads with a slope less than 5% are located mostly in the inhabited center of the town and in the Southern part, along the Basento River Park.

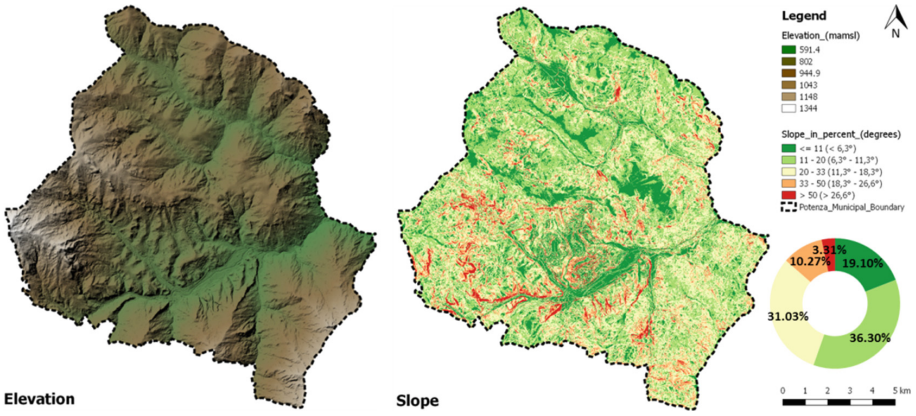

Fig. 2. City of Potenza: terrain elevation and slope

The next step consisted in determining the width of the road section. However these data are important for the purpose of a correct planning of an efficient urban cycle network, as this affects the opportunity to build cycle tracks or bike lanes or integrate traffic calming strategies in shared use paths and areas with other means of transport.

In particular 50% of the roads in the urban area of the city of Potenza has a width greater than 10 m. The width of the road section is considered as a primary design parameter for the realization of safe cycle facilities, especially in the presence of roads with legal speed limits and high operating speed values (Fig. 4).

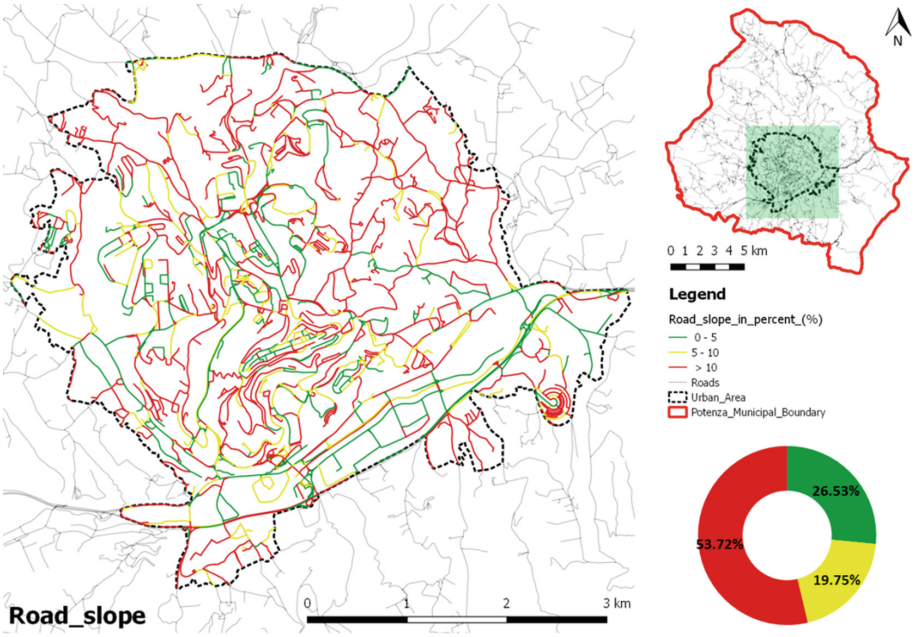

Fig. 3. City of Potenza: road slope in urban area

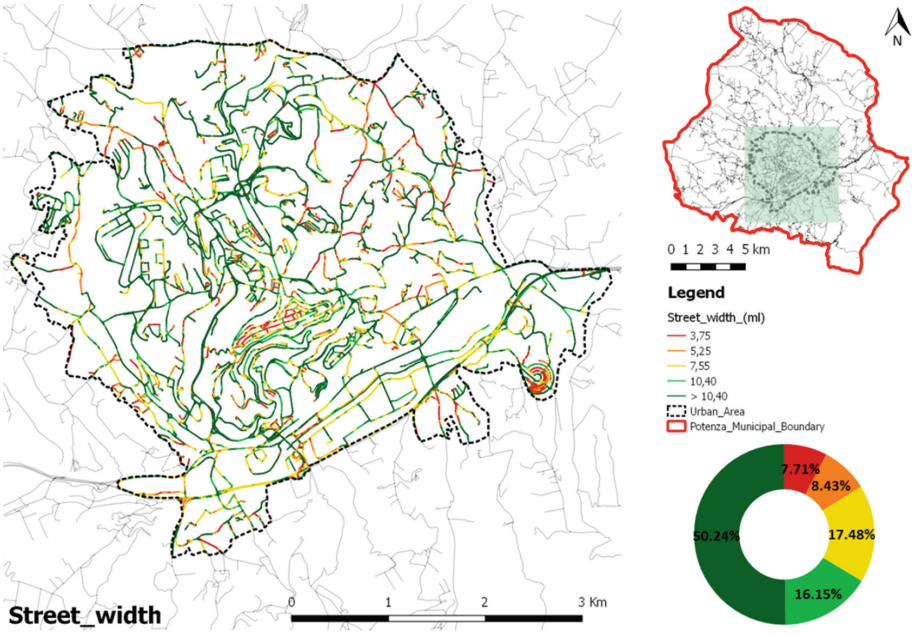

Fig. 4. City of Potenza: street width in the urban area

The next step consisted in identifying and georeferencing the strategic nodes generating road traffic flows and the sensitive receptors with the procedure defined by Las Casas et al. [54, 55]. It emerges, that the main urban traffic attractors in Potenza are the "San Carlo" Hospital, the headquarters of the University of Basilicata, the Historic Center and the Poggio Tre Galli district where the main educational institutions and the Basilicata Region Offices are located. Furthermore all sensitive receptors, urban facilities such as education and health services, have been mapped: schools, museums, theaters, sports fields, green urban parks, public offices, shopping activities. The identification of the main attractors of travel (residential, employment, retail, education, transport, health, tourist attractions, etc.) is an important stage in the development of a cycle routes' network within urban area [56] (Fig. 5).

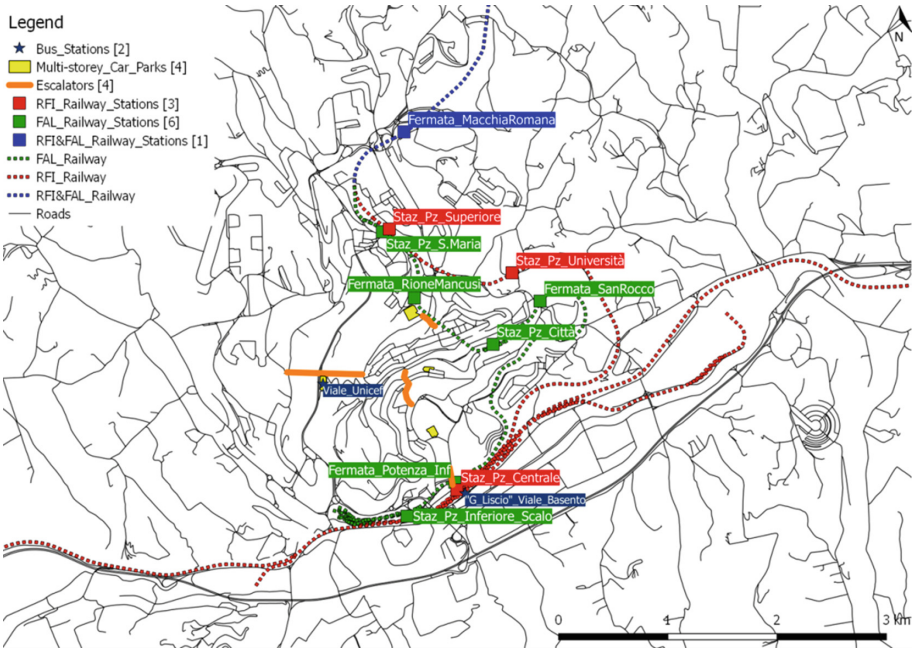

Fig. 5. City of Potenza: urban transport infrastructures

After identifying the main urban traffic attractors, we mapped the infrastructures for urban mobility (road, rail transport) and pedestrian mechanized systems (escalators and elevators): the single-track railway lines, Rete Ferroviaria Italiana (RFI) and Ferrovie Appulo Lucane (FAL), with the relative stations and stops, the four mechanized pedestrian mobility systems (escalator and lift integrated system), the bus stations serving urban and suburban public transport, the four multi-storey car parks, two of which are interchange mechanized connections ("via_Armellini" escalator, "Santa Lucia" escalator). The parking areas may encourage cycling, thus increasing the multimodal transportation.

To assess bicycle accessibility to public services and equipment, from mechanized pedestrian facilities and public transport railway and bus stations, the OpenRouteService website (ORS) was used. It is based on Open Standards and Open Geodata

(OpenStreetMap) and provides different Location Based Services, made by HeiGIT - Heidelberg Institute for Geoinformation Technology, including the "Isochrones Service". This service consists in the realization of isochrones, concentric curves that describe the place of the points having the same characteristics of time from a determined origin. The isochrones also allow to quantify the population and the extension of the land area affected by the curves. Specifically a period of 30 min and a range between the different curves of 5 min were considered (from 5 to 30 min, every 5 min). In order to assess the accessibility to urban facilities, the values are set in the hypothesis of travel by bicycle. Furthermore the accessibility map for urban facilities shows the amount of land area that is covered in 5, 10, 15, 20, 25, 30 min of cycle riding distance. It is also possible to determine the amount of population that can receive services in definite time distance values, mentioned above.

The origin of the isochrones has been placed in correspondence with the facilities of mechanized pedestrian mobility and the stop-stations of local public transport, by road and rail in order to encourage a multimodal and integrated approach to urban mobility. To gain users' availability for cycling the distance between multimodal nodes and the origins/destinations of trips should be small.

Specifically, it was considered:

- railway interchange point "Potenza Superiore Station" on the RFI network – "Potenza S. Maria Station" on the FAL network;
- escalators in "Via Tammone" – "Educational Centre" in Potenza (Poggio Tre Galli district);
- via Armellini, where there is a escalator-lift system, a multi-storey car park, the "Fermata Rione Mancusi" on the FAL network;
- "Potenza Centrale Station" on the RFI network, where you will find the "G. Liscio" bus station, escalators, the "Rione Mancusi Stop" on the FAL network (Fig. 6).

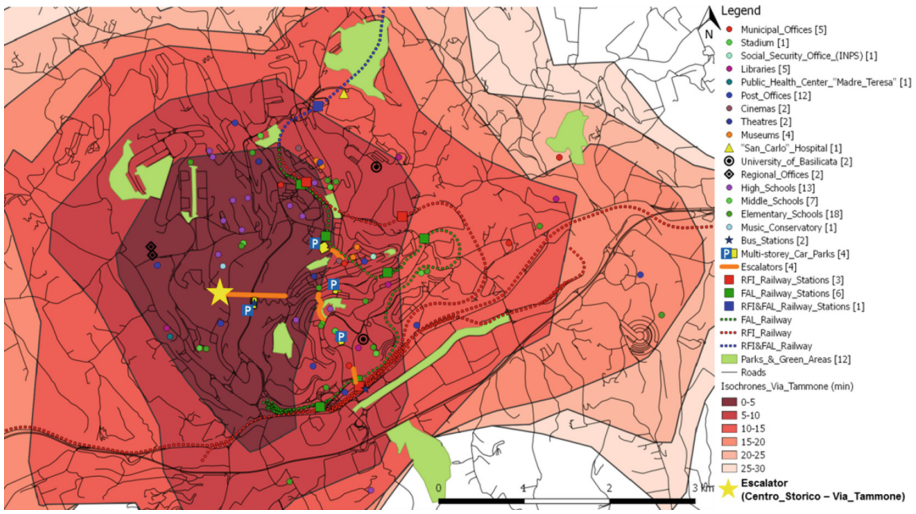

Fig. 6. City of Potenza: isochrones for travel by bicycle from escalator (Centro_Storico – Via_Tammone) to public services and schools in Poggio Tre Galli

4 Intervention Typologies and a Strategic Hypothesis for Potenza Cyclable Network

The Institute of Transport Engineers (ITE) defines Traffic Calming (TC) as "*the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized street users*" [57]. These strategies should ensure that non-motorized users are the first to benefit from street space. An important objective of these measures that affect urban street design is improving the street environment due to the reduction local air pollution and noise caused by motor vehicles and to the increase in the non-motorized users' (cyclists and pedestrians) safety. Traffic calming can be used in street design and it involves design and implementation of physical measures in order to control the speed and/or traffic volume of motor vehicles. Reducing vehicles' speed, cut-through traffic volume and accident frequency and severity in residential streets are the main goals of traffic calming [58].

The Traffic Calming philosophy was introduced at the end of the 60s in the Netherlands first and then in the other Northern European countries in contrast with the dominant principle of the 70s which included the separation of vehicular flows, motorized and not. However this principle required high economic investments and considerable land consumption to create new transport infrastructures [59].

According to Pardon et al. [60] an element that guarantees success in the designing and implementation of the measures is the stakeholders' participation.

In urban areas the traffic calming measures can be implemented to affect speed or volume of motorized vehicle or both. The main purpose of volume control devices (half and full street closures, forced turn islands) is to discourage/eliminate cut-through traffic. The main purpose of speed control measures (speed tables, raised intersections, realigned intersections, chicanes, centre island narrowings) is to physically slow traffic.

Taylor et al. [61] came to the conclusion that a reduction of speed (1.6 km per hour) can lead to a reduction in the number of road accidents by a rate of 5%. According to van Schagen [62] the percentage reduction of road accidents depends on the type of considered road, reaching the highest value for urban roads with low average speed (6%) and the minimum value (3%) for urban roads characterized by the highest speeds.

A measure that could encourage the diffusion of a widespread cycling in urban areas is the realization of contra-flow bike lanes. "*Contra-flow bicycle lanes are bicycle lanes designed to allow bicyclists to ride in the opposite direction of motor vehicle traffic. They convert a oneway traffic street into a two-way street: one direction for motor vehicles and bikes, and the other for bikes only*" [63].

Thanks to these street design strategies continuity and connectivity of cycle routes is guaranteed in a street context characterized by a high degree of safety for all users especially for cyclists. Looking at cyclist travel behaviour, a continuous path, without deviations, makes the bicycle not only a sustainable transport mode but also the most competitive for street users who generally make small-medium movements within 5-10 km distance [64]. In addition to the shortest routes eye contact when passing incoming traffic is an another advantage of counter-flows for cyclists [65] (Fig. 7).

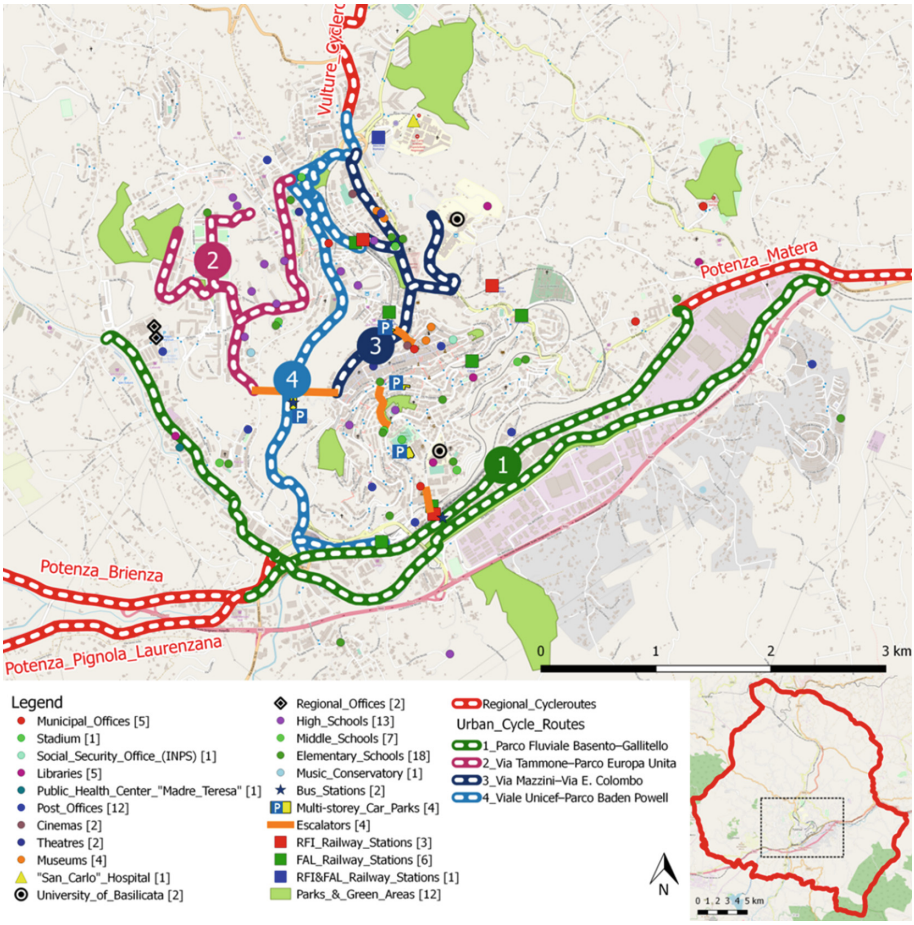

Fig. 7. Proposal for the development of urban cycling to integrate mechanized pedestrian mobility

The proposed intervention takes into account some Italian good practices. Among the main ones we report: 30 Zone in the "Piraghetto" district in Mestre [66], 30 Zone in the "Circoscrizione 2 Santa Rita - Mirafiori Nord" in Turin [67], urban redevelopment of "via E. Ospizio" in Reggio Emilia [68].

In this feasibility study, the construction of a bicycle route network requires the design of other incentive measures, such as restricted car use or traffic calming measures [69].

In the case of the city of Potenza it emerges that the four main routes to be nominated for an urban cycling project are:

- bicycle lane 1: Basento River Park – via del Gallitello (length = 10,288 m (of which Cycle Track: 4,657 m); average width = 956.38 m);

- bicycle lane 2: via Tammone – via Anzio – Parco Europa Unita (length = 3,792 m; average width = 1040.12 m);
- bicycle lane 3: via Mazzini – via Cavour – via E. Colombo (length = 3,049 m; average width = 1026.69 m);
- bicycle lane 4: viale dell'Unicef – via Roma – via Milano – viale Firenze – Parco Baden Powell (length = 5,043 m; average width = 1020.17 m).

5 Conclusions

This work highlights how it is possible to integrate cycling in a steep urban context like the city of Potenza, which can currently count on a consolidated infrastructure system for pedestrian/active mobility represented by escalators and elevators.

Such approach implies a radical shifting policy from cars oriented mobility toward more sustainable and active mobility schema at urban level, it means a shift towards a more sustainable urban management oriented on rational criteria [70, 71]. The proposed scheme, which should be deepened with a detailed analysis of the data on accidents, vehicular traffic and morphological characteristics of the roads involved, envisages a series of infrastructural and traffic calming measures. These measures are related to the cycle routes identified in urban areas in order to make them safe, linear, attractive, continuous, comfortable.

The aim is to make the bicycle a competitive means of transport as part of the modal split to the detriment of motorized vehicles (in particular private car). In order to encourage sustainable active mobility it is necessary to adopt a multimodal approach structured as an interconnection of pedestrian mechanized mobility system: a relevant public infrastructure whose use is currently marginal in Potenza.

In the perspective of widespread cycling, it is also necessary to improve the accessibility of the street user travelling by bike, focusing both on mobility infrastructures (such as escalators, elevators, railway stations) and on urban services. This approach passes from a careful evaluation and from the project of dimensioning urban planning standards in favor of the bicycle transportation mode and in particular favoring the distribution of bicycle racks in the areas where the planned cycle routes are located. Moreover, inclusive and participation approach has to be consider in order to accompany infrastructural investments with soft actions oriented to facilitate users' behavioral change [72, 73]. Potenza has a long tradition about that, especially in informal and bottom up participatory approach [74–76].

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