Some Remarks on Soft Mobility: A New Engineered Approach to the Cycling Infrastructure Design

Mauro D'Apuzzo[1], Daniela Santilli[1](✉), Azzurra Evangelisti[1], and Vittorio Nicolosi[2]

[1] Department of Civil and Mechanical Engineering DICEM, University of Cassino and Southern Lazio, Cassino, Italy
{dapuzzo,daniela.santilli}@unicas.it

[2] Department of Enterprise Engineering "Mario Lucertini", University of Rome "Tor Vergata", Rome, Italy
nicolosi@uniroma2.it

Abstract. Worldwide, countries are working to reorganize transport networks by promoting a new form of mobility that is sustainable and healthy for citizens. The task assigned to the designers is to create interconnected, safe, attractive and comfortable routes so that users begin to change their habits by favoring modal shift to sustainable transport. In this paper, a preliminary procedure is defined for the design of the different types of cycling routes based on area's characteristics and, above all, cycling flows. An original estimation method for the cycling flow has been proposed that allows a refined safety-oriented cycling infrastructure design. Once that the design interventions have been defined, through a benefit-cost analysis and with the help of technical guides, it is possible to evaluate optimal cycling infrastructure layouts on the examined urban road network.

Keywords: Sustainable mobility · Cycling flow · Cycling networks

1 Introduction

Sustainable mobility, especially in recent years, is a key topic that has generated numerous debates in international and national context. In fact, governance increasingly needs to promote policies aimed at reducing the environmental impact deriving from the mobility of people and goods. An engaging discussion on sustainable mobility or rather on low environmental impact mobility aimed at maximizing the efficiency and speed of travel has been also undertaken in Italy since the 1990s. Indeed, according to the World Business Council for Sustainable Development [1], this mobility allows people to move freely, communicate and establish relationships without ever losing sight of the human and environmental aspects.

Thanks to a huge amount of research-driven evidences, European countries have now realized that by improving transport systems (focusing above all on public, shared and more eco-sustainable services) it is possible to make cities safe and livable by reducing

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negative externalities (noise pollution, smog, traffic congestion, accidents, greenhouse gas emissions or fine dust, etc.).

The growing demand for mobility of road transport, especially private, often makes circulation conditions in urban and extra-urban contexts very critical. Due to the unbalanced interaction between supply and demand, the decline in service levels and the increase in emissions of greenhouse gases, nitrogen oxides and fine particles are observed [2].

The spread of Covid-19 in 2020 and the consequent need to implement restrictive measures, as highlighted by National Geographic [3] and the ESA (European Space Agency) [4], emphasized that the reduction of vehicles in circulation and the reduction of the activity of factories have led to an improvement in air quality.

It is, therefore, necessary to change habits, choosing to share a new way of moving, this requires a multidisciplinary approach that involves citizens, car manufacturers, public administrations and politics.

It is, therefore, necessary to make cities smart by implementing strategies to optimize and innovate public services. This would allow for connected and automated multimodal mobility. This intelligent mobility, in addition to reducing congestion and pollution, is likely to improve traffic safety, inducing citizens to travel in a sustainable way [5, 6]. Moreover, developing smarter and more sustainable mobility will allow to:

- *Reduce air pollution*: Europe has set as a goal, by 2050, a 60% reduction in emissions from transport since transport sector consumes about one-third of total energy consumption and produces one-fifth of greenhouse gas emissions. To achieve the set goal, new technologies and the use of the most efficient systems must be encouraged (for example, hydrogen-powered trains, cars with electric motors, technological infrastructures, etc.).
- *Reduce noise pollution*: transport generates excessive noise levels and roads, railways and airports are certainly among the main sources of disturbance. This pollution has consequences on the health and well-being of people (sleep disturbances, increased blood pressure, cardiovascular diseases, etc.) and regulations at national level indicate the exposure thresholds and the measures to be undertaken.
- *Reduce vehicular congestion*: by encouraging the use of shared and public transport to the detriment of private ones, in order to reduce congestion and travel times and to make cities more accessible to vulnerable users.
- *Reduce land use*: due to the growth of transport systems often irrespective of the landscape issues, it is necessary to optimize the collective built-up spaces.
- *Reduce costs and transport efficiency*: by creating innovative, integrated, efficient and connected transport, both individual and collective costs and times are reduced.

To make cities innovative, connected but at the same time sustainable, technology can be used to control and save energy as well as to optimize mobility and safety solutions. To do this, it is essential to make the transport service efficient by focusing on multimodality. Multimodal transport allows using in a combined way different modes (at least two) of transport. So, tailor-made offers must be developed including various ways, such as public transport, shared cars and bicycles, electric scooters, taxis and more, such as Mobility-As-A-Service MAAS sytems that allow simple and safe access to the offers

of mobility providers through an app, which becomes visible and bookable; allowing to maximize resources and time by combining the different available means (Fig. 1).

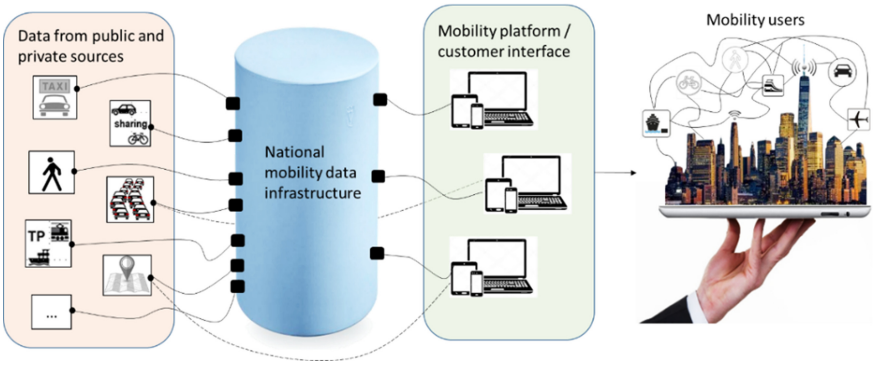


Fig. 1. Operation diagram of a multimodal service

Within this context, more and more often targeted interventions are implemented in the cities, such as:

- the re-design of public transport supply by means of the strengthening of the infrastructure and services both at local (urban) and and national/international level.
- the promotion of preferential lanes intended exclusively for public transport (buses, trams, taxis) or emergency vehicles; this allows to avoid traffic congestion giving an advantage to those who use public transport instead of private transport.
- the creation of cycling paths or pedestrian areas, therefore areas dedicated exclusively to bicycles and pedestrians; giving the feeling of greater safety and protection, which encourages people to walk or pedal for short trips instead of using a car or a motorbike;
- road pricing (urban toll) and park pricing to discourage or limit the access in urban areas to private vehicles (cars, motorcycles, scooters, etc.) in order to reduce traffic congestion, smog and encourage the use of public transport.
- traffic blocking i.e. a temporary and occasional public intervention to partially or totally limit vehicular traffic in urban areas;
- the use of limited traffic areas (ZTL in Italy) as a permanent blocking of traffic in the central or more congested areas of the city;
- car-sharing or bike-sharing i.e. forms of collective mobility based on the rental of a low environmental impact vehicle (electric car or bike) for a few hours or days, that are increasingly adopted in urban areas;
- car-pooling i.e. another form of collective mobility which consists in the use of a private car by several people, often colleagues or acquaintances, who travel the same journey from home to work at the same times.

Despite the idea of moving towards multimodal transport, most European countries and cities have devoted most of resources in the construction and management of infrastructure for motor vehicles, neglecting those for active modes, namely walking

and cycling. Among the many European projects implemented, the FLOW project [7] involving the implementation of strategies to promote walking and the use of bicycles, both in large and small cities, on short and medium distance journeys is one of most noticeable.

However, despite the success of EU programs, the roads are still not completely safe, in fact, a report [8] of the ETSC (European Transport Safety Council) highlights that in Europe from 2010 to 2018 the number of dead pedestrians was 21% of the total, 18% of cyclists and 8% of motorcyclists (bearing in mind that pedestrian deaths or injuries of vulnerable users are often not counted among road accidents because the police were not consulted). This suggests that in Europe there are on average more than 5180 deaths every year. Looking at the accident data, it seems that although there has been a slight reduction in fatal road accidents, there are no decreases in accidents involving vulnerable users.

Due to the intensity and speed of motorized traffic, cities are unsuitable for such users but especially for cyclists, since unlike pedestrians (for whom dedicated spaces have been built) they are often forgotten. It is, consequently, necessary to reorganize the road network to promote the use of bicycles as a daily mode of transport for various reasons (home-work/study, recreation, sport and free time).

To accomplish this task, it is necessary to establish rules to reduce the high risk of injury to which cyclists and pedestrians are exposed. This implies the reorganization of the streets which become multifunctional spaces shared equally among all users.

People choose the bicycle as a means of transport [9] based on subjective and objective factors. The former is linked to the sense of security, the feeling of comfort and social acceptance; while the latter ones are related to speed, topography, climate and safety (understood as the absence of obstacles).

Taking these factors into account, a cycle network can be designed, making it an integral part of urban mobility policies (Mobility plans and transport), which deal, among other aspects, to ensure that the journey takes place smoothly and therefore that the structure is:

- safe: the risk of injury due to interactions with other modes is reduced;
- direct: limiting the detours so that the travel time is reduced;
- continuous: so that the movements, between the different origins and destinations, do not have path interruptions (with good connections with other networks, mainly public transport stops and junctions);
- attractive or well integrated with the environment in which it is inserted;
- comfortable: allowing the cyclist to reduce physical effort and discomfort, so as to have a pleasant and relaxed travel experience.

In practice it is not always possible to meet all these requirements, so there is the need to find the right balance based on the environment in which the designer is operating.

2 Cycling Network Design

The design of a short-distance transport network depends on historical characteristics and land use evolution, thus knowledge of the land use layout, topography, climate and

lifestyle of the population is required. In addition, it is necessary to have traffic data (flow of motor vehicles, cyclists and pedestrians) and injury rates, highlight the presence of attractions (schools, universities, commercial or recreational activities, tourist areas, etc.) and existing structures with their respective geometric characteristics.

Known the land use characteristics, the different origins and destinations must be taken into consideration to identify the paths that users could choose to meet their needs.

This allows you to hierarchize the network in:

- *Main cycling paths*, for long distances, with city or rural connection function;
- *Secondary streets* that connect adjacent neighbourhoods;
- *Local routes*, for short distances, which allow movement within the neighbourhoods.

2.1 Types of Cycling Path Layouts

Before introducing the proposed methodology for the cycling infrastructure design based on given area characteristics and flows, the most common cycling path layouts are briefly presented.It is worth to be highlighted that this is not a exhaustive review, given the different legal definitions and terminologies used in EU countries.

Depending on whether or not cyclists share the infrastructure with other users, three situations can occur:

– *total sharing of road space* between the bicycle and vehicular traffic; this is usually a one-way lane, but there may be situations in where the bicycle can travel in the opposite direction (for example, zone 30) (Fig. 2).



Fig. 2. Total sharing of road space example

– *visual separation* with simple indication with horizontal signs on the sidewalk of the runway. The space intended for bicycles is an integral part of the carriageway, unidirectional, generally in the direction of the traffic flow (Fig. 3).



Fig. 3. Visual separation example

– *physical separation*: it is a lane, one or two-way, dedicated to bicycles (with the possibility of sharing with not motorized mode) separated by obstacles from the road network for other ways (Fig. 4).



Fig. 4. Physical separation example

By reviewing the different guidelines of European countries [10–18] albeit with different names, the cycle networks can be grouped as follows:

– *Greenway:* it is a "multipurpose" route reserved for non-motorized users, separated from traffic and independent from main roads, which passes trought open spaces, parks, gardens and woods and must respect the surrounding environment. Sharing the lane by different users can cause conflicts so it is recommended to physically separate the different parts intended for different users (Fig. 5).

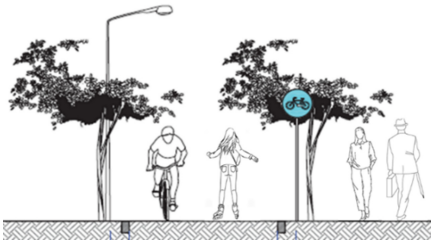


Fig. 5. Greenway example

– *Cycle lane* is an independent lane, separated from the carriageways, designed for the exclusive use of bicycles (Fig. 6).

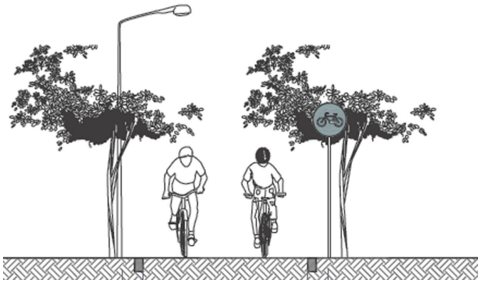


Fig. 6. Example of cycle lane

– *Protected cycle path* are protected lanes designed exclusively for bicycles with physical separation from motorized traffic. Usually, neither pedestrians nor skaters are allowed. This can be one-way (one lane on each side of the main road) or two-way (one lane with both directions on one side of the main road) usually near a road with high motorized traffic (Fig. 7).

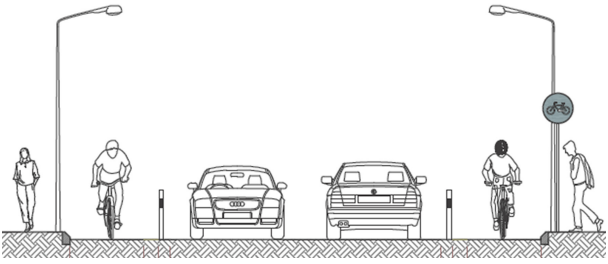


Fig. 7. Example of one-way protected cycle path

– *Cycle path* is reserved for bicycles and it is separated from the rest of the circulation by horizontal signs. It is designed for roads at low speed and with reduced transit of heavy vehicles (Fig. 8).

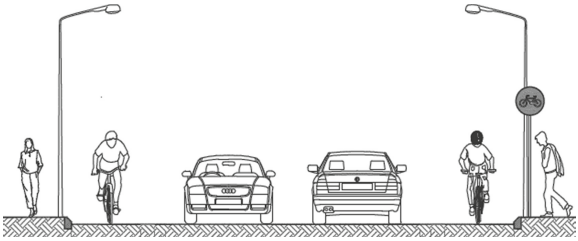


Fig. 8. Example of cycle path

– *Road of 30 km/h zone* where both bicycles and cars share the carriageway without any access restrictions (Fig. 9).

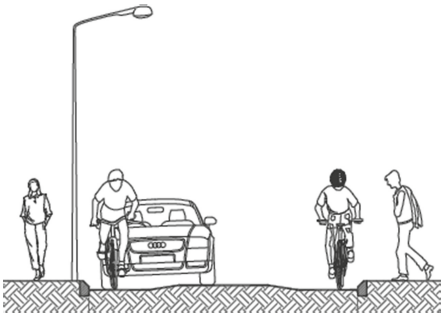


Fig. 9. Example of road of 30 km / h zone

– *Cycle track* in which pedestrians and cyclists share the sidewalk. The part intended for the bicycle must have the relative signs. As there is not always sufficient space, this usually takes place in pedestrian areas or in common routes where the speed limit for cyclists is of 20 km/h (Fig. 10).

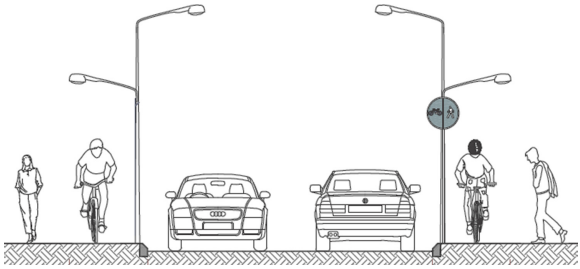


Fig. 10. Example of cycle track

– *Shared-use path* is shared between pedestrians and cars. These roads are also suitable for cycling, but with a speed limit of 20 km/h and with pedestrians always having priority (Fig. 11).



Fig. 11. Shared-use path example

2.2 Choice of the Specific Cycling Path Layout to Be Adopted

Since there is no absolute rule for the application of the different solutions for the choice of cycle path layouts, it is necessary to take into account the density or flow rate and speed of the vehicles (to define the type of protection on the cycle path), the expected number of cyclists (to define the width of the track), the existing space and the urban environment (to identify the type of cycle path and its characteristics).

The information that is hardly known is the density or the flow of cyclists traveling on the examined road network. To this purpose, an original prediction methodology has been developed and implemented in this work to estimate, at a preliminary level, the cycling demand at urban level.

Estimation of Cycling Flows

To evaluate the transport flows loading the network, several models and approaches have been proposed and employed, but while for the vehicular flow there is a solid knowledge, the same cannot be said for the cycling and pedestrian flow [19]. Therefore, a new methodology has been developed to preliminarly estimate the cycle flows, loading a urban road network starting from National commuter mobility data (15th ISTAT census, 2011).

Case Study

The proposed methodology was developed and calibrated in the central area of the Italian town of Cassino (Lazio, Frosinone) (Fig. 12).

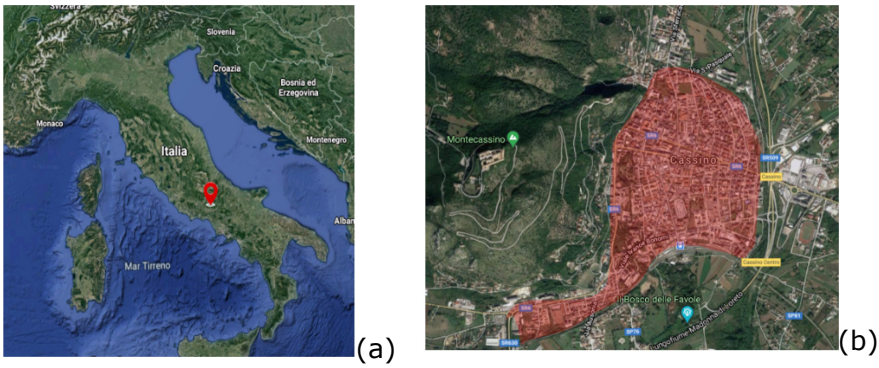


Fig. 12. Position of city of Cassino (a) detail of the study area (b)

The study area was discretized into census sections each represented by a corresponding centroid. Each of these defines an origin and/or destination (o-d) to which the total flow (given by the sum of the movements of students and workers) obtained from the ISTAT microdata has been assigned and an o-d matrix has thus been derived. Once the matrix was imported into QGIS using a plugin (*FlowerMapper*), the desire lines directly connecting each origin centroid with each destination centroid, were obtained (Fig. 13).

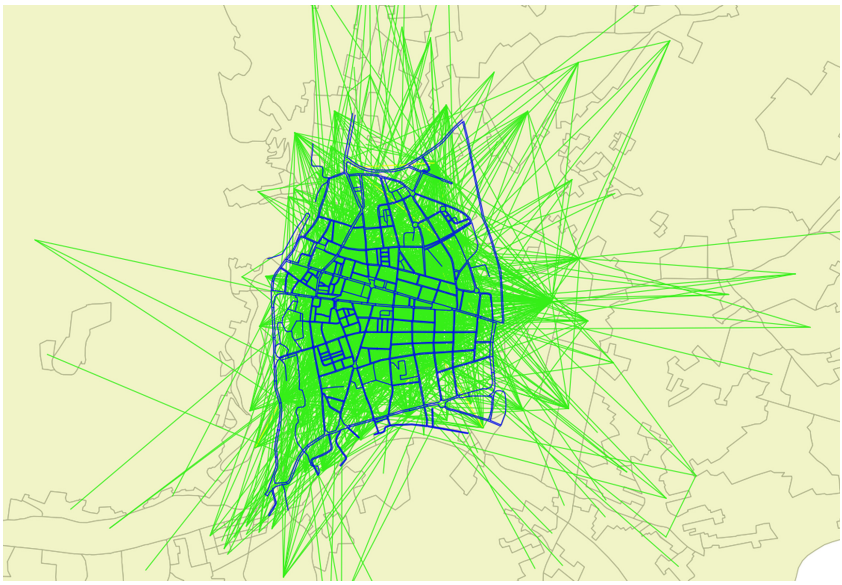


Fig. 13. Desire lines of the city of Cassino (in green) superimposed on the road network of the central area of the city (in blue) (Color figure online)

To apply the proximity function [19]. it was necessary to construct a distance matrix; this made it possible to obtain the real flows.

Once the distance between the different origins and destinations is known, it is possible to evaluate the cycling trip for a specific o-d pair by making use of an modal split impedance function derived from technical literature [20] able to estimate the attractiveness of the cycling mode for a commuter trip as a function of the traveled distance (see Fig. 14).

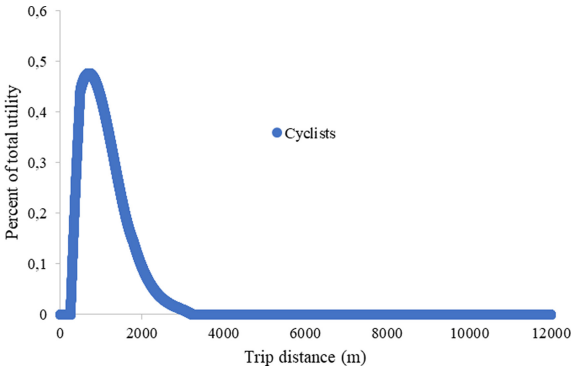


Fig. 14. Cycling impedance function

Therefore, by multiplying the commuting movements with the impedance coefficients, as a function of the distance, the actual flows that are likely to load the different link belonging to the Cassino road network are obtained.

Loading the Cycling Network

Once the road network model was developed and each road section (arc) was uniquely identified, As far as network loading is concerned, it is necessary to take into account that each arc can be affected by the contribution of different o-d pairs; shortest route connecting each o-d pair has been therefore evaluated by using QGIS geoprocessing tools according to a desire line buffer varying from 0 to 45 m (Fig. 15).



Fig. 15. Example of a superimposed buffer on the road network for a some o-d pairs

Buffer size calibration was carried out by a comparison with results provided by a common web-based route planning program. Then, once that the optimal route identification has been evaluated for each o-d pair, each route has been decomposed in its road sections and for each road arc belonging to the examined road network the contribution of all the relevant o-d pair cycling flow has been evaluated and summed (Fig. 16).

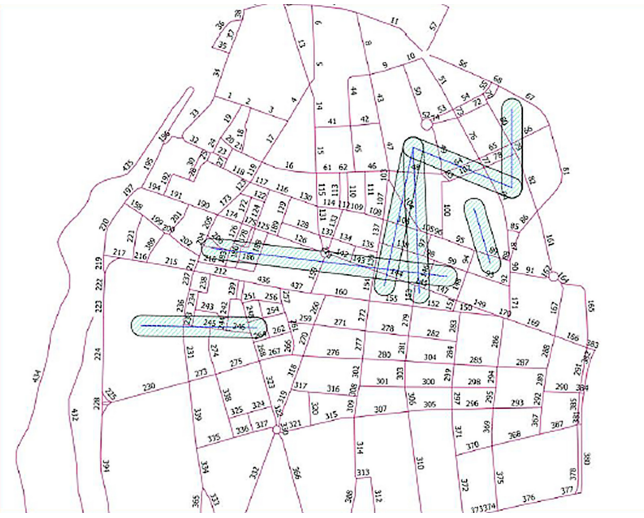


Fig. 16. Intersection of the road network with the buffer

Assigned cycling flows estimated with 0 and 45 m wide buffer approaches were conveniently averaged in order to derive a likely evaluation of cycling flow loading in the study area that is conveniently reported below (Fig. 17).

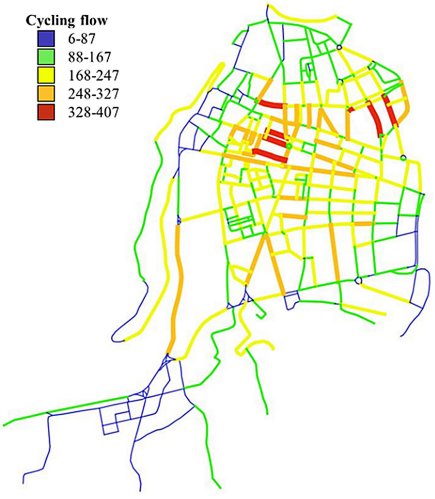


Fig. 17. Likely network loading with cycling flows

A Proposal for Use of Cycling Flows in Cycling Lane Layout Cost-Benefit Analysis
Once that cycling flows have been evaluated as described above, it is possible to use a cycling path layout decision matrix, such as the one shown below [21] derived from Dutch Standards and reported in the following table for sake of example, in order to evaluated optimal cycling path layout solution suitable for each specific road section (Table 1).

Table 1. Decision matrix for cycling path cross-sectional layout from Dutch Standards [20].

<table>
<tr><th colspan="3" rowspan="2"></th><th colspan="2" rowspan="2">Speed (Km/h)</th><th rowspan="2">Intensity (vehicles/day)</th><th colspan="3">Density of cyclists (bike/day)</th></tr>
<tr><th><750</th><th>500-2500</th><th>>2000</th></tr>
<tr><td colspan="3"></td><td colspan="2">Not applicable</td><td>0</td><td colspan="3">Greenway</td></tr>
<tr><td rowspan="4">Function traffic road</td><td rowspan="2">Local access road</td><td rowspan="3" colspan="2">Walking space or 30 Km/h</td><td>1-25000</td><td colspan="2" rowspan="2">Shared-use path</td><td rowspan="2">Cycle lane or cycle path</td></tr>
<tr><td>2000-5000</td></tr>
<tr><td rowspan="2">Distributor road</td><td>>4000</td><td colspan="2">Cycle lane or cycle track</td></tr>
<tr><td>50 Km/h</td><td>2x1 lanes
2x2 lanes</td><td rowspan="2">not applicable</td><td colspan="3" rowspan="2">Cycle track (adjacent or separated)</td></tr>
<tr><td colspan="2">70 Km/h</td></tr>
</table>

However, in order to choose the optimal solution it is necessary to take into account the characteristics of the road, the vehicular flows and speeds, the surrounding space, the hierarchy of the roads together with the available budget.

This means that planners and decision-makers must carry out cost-benefit analyzes that may represent an effective help to use the funds in a targeted way and to justify the investment on one choice rather than another. According to Elvik [19], the cost-benefit analysis of pedestrian and cycle infrastructures should use methodologies similar to those used for transport projects in general, keeping in mind that the costs associated with the design and construction of the cycling infrastructure improvements are relatively low compared to road projects of similar lengths.

Although apparently simple, it is not so straightforward to estimate the costs for the installation of cycle networks as these are often part of a larger maintenance or retrofitting project, such as the resurfacing of a road. So while it is quite simple to describe the cost of purchasing and installing the bike path equipment (vertical signs, paints, etc.), the other elements are grouped together in the larger project and are difficult to detail.

Each cycling path layout type has a series of possible variable costs, determined by the different measures implemented, which are related to the design and asset management. Therefore. the costs presented in this paper, relating to the design of cycle networks in Italy, are purely representative as they may greatly vary locally and even more nationally. Nevertheless they may represent a reference basis for a refined further engineered analysis.

It is intuitive to understand that optimizing the existing network by inserting a horizontal and vertical signaling system that delimits the route requires moderate financial resources (400 to 600 €/Km); such as, expanding an existing cycle network involves lower costs than new construction. Similarly, it is more convenient to create multi-purpose cycle paths than dedicated ones.

Many authors [23–27] have dealt with defining the costs of the different solutions, sometimes lacking details on the different components of the project. All the studies analyzed refer to specific manuals to define the costs according to the characteristics of the specific examined layout component (Table 2).

Table 2. Cost estimates for the design of the different solutions

	Type of separator	Cost (€/Km)	
		Unidirectional	Bidirectional
\Cycle path	Road markings	50000	40000
	Coloured bitumen	125000	100000
Protected cycle path	Curbstone	210000	120000
	Creasing	100000	60000
	Flower bed	210000	120000
	Parking stalls	260000	140000
Cycle track	Horizontal signs	170000	120000
	Sidewalk with staggered floors	165000	120000
	No separation on the sidewalk	40000	35000
Road of 30 km/h	No separation on the road	60000	
Cycle lane	Calcestre	\	330000
	Bitumen	\	195000

Once the costs have been defined, the benefits related to a specific cycling path layout must therefore be assessed in terms of reduction of accidents. However, in this connection, there is still a lack of knowledge for specific engineered safety performance functions based on national accident data. Moreover, multi-criteria methods can be effectively employed if the reduction of pollutant emissions, or the improvement of the quality of life and social profitability have to be also evaluated.

3 Conclusions

The use of bicycles as a way of moving on a daily basis is not equally widespread worldwide, although in recent years the idea that promoting cycling as a transport mode able to improve health conditions, support sustainability and facilitate access to different areas, has been increasingly spreading. It has been shown [28] that, by installing bicycle

infrastructures, users are able to perceive a greater level of comfort and safety which has encouraged them to use the bicycle as a preferential transport mode in urban areas.

In this paper, an original methodology was suggested able to evaluate cycling flows loading a urban road network that, in turn, may be critical for the design of the optimal cycling path cross-sectional layout within a specific study area. Designing a cycle network involves knowing the characteristics of the area (topographic, climatic, geometric, etc.) but, above all, motorized and non-motorized flows loading the road network. It is now fairly known how to estimate the vehicular flows but the same cannot be said for cycling ones, therefore a preliminary algorithm has been defined that takes into account area topology, commuter o-d matrix derived from National Census Database, based on a proximity criterion. Once that involved cycling flows have been evaluated, it is possible to choose the different cycling cross-sectional layout solutions within a benefits-cost (B-C) framework similarly to what is undertaken in other European Countries.

Hovewer, within the proposed methodological framework that is still in his preliminary stage, several future development need to be carried out detailed in the followings:

- the prediction methodology needs to be experimentally calibrated and subsequently validated on-site, by performing a suitable traffic data collection campaign; this will allow a finer tuning of the model parameters;
- the methodology needs to be applied to urban areas other than that specifically examined;
- a huge research effort should be carried out on safety of road vulnerable user with emphasis on cyclists in order to derive engineered National Safety Performance Functions that can help designer in selecting the most appropriate cycling path cross-sectional layout within a B-C analysis.

Nevertheless the proposed methological approach seems promising in helping designer in the development of Sustainable Urban Mobility Plans (SUMP) and it may represent a starting point for a wider design approach to be included in SUMP Guidelines for cycling infrastructures.

References

1. Council, World Business (2020). https://www.wbcsd.org/Programs/Cities-and-Mobility/Transforming-Mobility
2. Fioravanti, G., et al.: Gli indicatori del clima in Italia nel 2019-annoXV. s.l. : ISPRA – Istituto Superiore per la Protezione e la Ricerca Ambientale (2020)
3. Geographic, National. Coronavirus, le misure di contenimento hanno ridotto l'inquinamento (2020). https://www.nationalgeographic.it/ambiente/2020/04/coronavirus-le-misure-di-contenimento-hanno-ridotto-linquinamento-europa
4. Agency, European Space. La chiusura per fronteggiare il Coronavirus ha portato ad una riduzione dell'inquinamento in tutta Europa (2020). https://www.esa.int/Space_in_Member_States/Italy/La_chiusura_per_fronteggiare_il_Coronavirus_ha_portato_ad_una_riduzione_dell_inquinamento_in_tutta_Europa#:~:text=Agency-,La%20chiusura%20per%20fronteggiare%20il%20Coronavirus%20ha%20portato%20ad,dell'inqui

5. Garau, C., Masala, F. e Pinna, F.: Cagliari and smart urban mobility: Analysis and comparison. Cities **56**, 35–46 (2016)
6. Pinna, F., Masala, F. e Garau, C.: Urban policies and mobility trends in Italian smart cities. Sustainability (2017)
7. European Union, (UE). Flow (2020). http://h2020-flow.eu/
8. Council, European TRansport Safety. How safe is walking and cycling in Europe? (PIN Flash 38) (2020). https://etsc.eu/how-safe-is-walking-and-cycling-in-europe-pin-flash-38/
9. European Union, (UE). Cities for Bicicles, Cities of the Future (2009). https://www.ecf.com/sites/ecf.com/files/Future-cities-are-cycling-cities.pdf
10. Meschik, M.: Planungshandbuch radverkehr. Springer-verlag, Wien (2008)
11. Mobility, Brussels. Vademecum Velo en Region de Bruxelles-Capitale Brussels, Belgium : s.n (2006). https://mobilite-mobiliteit.brussels/en/node/265
12. Celis, Consult. Danish handbook for cycle traffic. s.l., Denmark : HÅNDBOG CYKEL-TRAFIK (2014)
13. Julien, A.: Cycling infrastructure design and urban public space- a comparison of cycling design manuals. Association Metropolis . s.l., France: PREDITMELT/DRAST (2000)
14. Ciclável, R.: Princípios de Planeamento e Desenho. COLECÇÃO DE BROCHURAS TÉCNICAS / TEMÁTICAS. s.l.: IMT (2011)
15. Government of Catalonia. Manual for the Design of Cyclepaths in Catalonia (2008)
16. Landsting, Trafikverket / Sveriges Kommuner och. Guideline on configuration, operation and maintenance of pedestrian, cycling and moped traffic. Handbok – Utformning, drift och underhåll med gång-, cykel- och mopedtrafik I fokus (2010)
17. Eidgenossenschaft, Schweizerische. Handbuch Wegweisung für Velos, Mountainbikes und fahrzeugähnliche Geräte (2010)
18. Officials, National Association of City Transportation. Urban Bikeway Design Guide (2014)
19. Gervasi, O., et al. (eds.): ICCSA 2020. LNCS, vol. 12251. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-58808-3
20. Kuzmyak, J.R.: J. W. NCHRP REPORT 770 - Estimating bicycling and walking for planning and project development: a guidebook (2014)
21. Dufour D.: Ligtermoet and the Netherlands Partners. PRESTO Cycling Policy Guide- Cycling Infrastructure (2010)
22. Elvik, R.: Which are the relevant costs and benefits of road safety measures designed for pedestrian and cyclist? Accident Anal. Prevent. **32**, 37–45 (2000)
23. Monsere, C., et al.: Evaluation of innovative bicycle facilities: SW Broadway Cycle Track & SW Stark/Oak Street Buffered Bike Lanes (2014)
24. NACTO: Urban bikeway design guide. New York: National Association of City Transportation Officials (2014)
25. Bushell, M.A., et al.: Costs for Pedestrian and bicyclist infrastructure improvements: a resource for researchers, engineers, planners, and the general public. s.l.: UNC Highway Safety Research Center (2013)
26. Benni, J., Macaraig, M. e Malmo-Laycock, J.: Costing of bicycle infrastructure and programs in Canada. s.l.: Mc Grill, (2019)
27. Nuno Lopez, F., et al.: Linee guida per la progettazione delle reti ciclabili (2006)
28. Weigand, L., McNeil, N. e Dill, J.: Cost Analysis of bicycle facilities: cases from cities in the Portland, OR region (2013)