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# A methodology for urban bike network design using floating car data: evidence from a medium-size city

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## ABSTRACT

Urban mobility plays a key-role in developing sustainable cities, prompting planners to promote alternatives to private cars. Among these, bikes offers significant potential. Therefore, this paper presents a methodology for designing bike networks using floating car data (FCD) and survey insights. FCD enables the estimation of origin-destination matrices, while surveys identify car trips that could shift to bikes. The approach is validated through a case study in Rovigo, a medium-size city in Northern Italy. Data from five working days, covering about 1,900 cars and 24,000 trips, allowed classification of travel patterns and demand analysis. Based on these findings, the proposed methodology achieved notable results, extending the existing bike network by approximately 28% in length. This study demonstrates the feasibility of leveraging FCD and behavioural data to support sustainable mobility planning and enhance cycling infrastructure.

## ARTICLE HISTORY

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## KEYWORDS

Bike network; demand forecasting; commuter trips; floating car data; network design; city sustainability; floating car data; modal share; state preference survey

## Introduction

In recent years, there has been a trend in many European cities to favor alternative modes of transport rather than cars. In fact, planners and city managers worked to increase services (e.g. bike sharing) and infrastructures (e.g. dedicated lanes for alternative transport modes, like bikes, e-bikes, e-scooters, and similar micromobility vehicles) in order to improve city livability (Comi and Polimeni 2024; Dong et al. 2025; Nigro et al. 2024; Weikl and Mayer 2023). Additionally, the World Health Organization (2018) suggests the use of transport modes that require muscle strength as a means of reducing sedentary habits. The bike is a mode of transport that meets both the needs to increase livability and use muscle strength for traveling. But despite the efforts, the bike network of many cities suffers the lack to be often incomplete, in the sense that not all destinations can be reached by following exclusively the bike network, forcing the bikers to travel on links with mixed flow (i.e. cars and bikes) with several safety issues that push users to prefer private cars. For example, in Rome the number of road accidents involving bikers is over 3%, although less than 1% of users travel by bike. Furthermore, when bikers are involved in road accidents, the consequences can be very severe (Comi, Hriekova, and Nigro 2024; Comi, Polimeni, and Balsamo 2022; RSM 2020). Therefore,

one of the main efforts is to make the bike network complete and safe, for example, by reducing conflict points at intersections with vehicles and increasing the links reserved for bikes. This could encourage users to adopt this means of transport (Aziz et al. 2018; Di Gangi et al. 2022). Studies in this field range from bike sharing to bike network design, from the demand analysis to the route choice/link cost function. The bike sharing can be dockless or not (Meng and Brown 2021): in the first case, the problem of locating the stations need to be solved (Frade and Ribeiro 2015; Park and Sohn 2017). The design of bike networks consists on adding links to an existing network or designing it from scratch (Mauttone et al. 2017; Ospina et al. 2022). Concerning the demand analysis, there are studies on the potential demand (Comi, Polimeni, and Nuzzolo 2022; Frade and Ribeiro 2014; Miah, Hyun, and Mattingly 2024) and studies on the attributes influencing the demand levels (Chibwe et al. 2021; Fitch-Polse, Mohiuddin, and Handy 2025; Rupi, Poliziani, and Schweizer 2020; Venkadavaran and Marisamynathan 2022). The estimation of link cost function for the bike and the consequent route choice is another topic explored in the literature; as an example see Schweizer, Rupi, and Poliziani (2020) and González, Melo-Riquelme, and de Grange (2016).

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The focus of this paper is to design the road bike network in order to provide users with a viable alternative to the car. To achieve this, a procedure is developed to design a bike road network. It takes into account the characteristics of potential demand, investigated through floating car data (FCD) and an ad hoc survey. In particular, the FCD provides the opportunity to infer about private car trips that could be replaced by bike trips, while the survey investigates the habits of users. By means of FCD, the origin-destination (O/D) matrix can be obtained without using advanced modeling framework (e.g. four step model; Cascetta 2009). Once the O/D matrix is available, it is possible to estimate the share of demand that can shift from car to bicycle. The bike network design has been developed with the aim of connecting zones within the study area where cycling is a feasible travel option. The problem is solved by assuming that the user is the owner of the bike. This implies that issues related to design, management, and control of shared services (e.g. location, fleet size, relocation) are out of scope of this research.

The design approach is flexible and can be applied to any study area, provided that the road sections where reserved bike lanes are allowed have been identified. This ensures that the specific characteristics and constraints of the city are considered. In this way, the circulation of other traffic components (e.g. cars) is not compromised, and the bike network is designed to maximize the use of dedicated lanes.

The paper is structured as follows. [Literature review](#) reports a brief literature review on the bike network design problem. [The proposed bike-network design procedure](#) reports the proposed methodology, while in [Results and discussion](#), an application to a real case study is discussed. Finally, in [Conclusions](#), the conclusions and the possible future development are drawn.

## Literature review

Active mobility (e.g. walking and cycling) is healthier and cleaner than driving, producing environmental, economic, and social benefits (Comi and Polimeni 2024; Kathait and Agarwal 2025). The literature on this topic is extensive and addresses various aspects, ranging from demand forecasting (Subramanian et al. 2023; Xu et al. 2025) to integration with other transport modes (Kapuku et al. 2021; Olafsson, Nielsen, and Carstensen 2016), as well as approaches that exploit trajectory data (Lopez et al. 2017; Wang et al. 2025; Zimmermann, Mai, and Frejinger 2017). Another topic tackled in the literature is the development of appropriate infrastructures (Aziz et al. 2018; Y. Li et al. 2025) that guarantee the safety of the trip (e.g. reserved lanes). Then, the design of a road

network for such transport modes is required. Focusing on the bike network, its design can be seen as a case of the more general *network design problem* (Cantarella and Vitetta 2006; Polimeni and Vitetta 2024). Doorley et al. (2020) proposed a network design problem to identify the layout of the bike network. The goal is to maximize the benefits of bike users and society, taking into account different factors (including air pollution, greenhouse gas emissions, and user surplus). Similarly, Duthie and Unnikrishnan (2014) proposed a formulation of the network design problem through the minimization of the total cost due to the improvement of road links and the junctions with the objective to obtain a defined level of service for cyclists.

The approach proposed by Lim et al. (2022) is aimed in improving the bike network tacking into account both the safety and the distance traveled. Zhu and Zhu (2020) formulated a *multi-objective problem* to design the bike network with the aim to minimize the number of conflicts with other traffic components, the construction costs, and the number of junctions, and to maximize the accessibility and the level of service. Putta and Furth (2021) proposed a methodology to improve the quality of the bike trip by eliminating one-way restrictions with the use of the contra-flow on some road links.

Gaspar et al. (2015) formulated a bi-level model: the upper level related with the bike network design, the lower level related with the transport system simulation considering the interactions among the different transport modes (car, bus, and bike). S. Liu, Siddiq, and Zhang (2024) formulated a procedure to estimate the impact of the bike lanes on the congestion (the presence of a bike lane can reduce the capacity of the infrastructure for the other modes), coupled with a mode choice model to simulate the choices of commuters.

Correa, Mauttone, and Robledo (2023) proposed a model to design the bike network with the aim to *maximize the demand shift* to bike, in relation to the level of technologies used in designing the network. Nigro et al. (2024) proposed a demand model to forecast the level of demand that shift from car to bike. The determinants considered in the choice are travel time, monetary costs, and safety. H. Liu, Szeto, and Long (2019) formulated a model to maximize route utility (i.e. minimizing the generalized route cost), simulating route choice with a path size model under budget constraints. Steinacker et al. (2022) proposed a general framework to generate the bike network taking into account the level of demand and the route choice.

Zagorskas and Turskis (2020) presented a ranking method to classify elements of the bike network for existing and proposed bike route segments. The

procedure considers different criteria, the goal is to minimize the investment costs by organizing a priority list of the elements to build. Similarly, Zuo and Wei (2019) developed a *multi criteria approach* to compare different bike network alternatives based on a set of evaluation criteria, such as the number of connected origin-destination pairs, the connection with public transport, the number of users served. Arellana et al. (2020) proposed a tool to assess and classify different layouts for the bike network, in order to allocate investments for road infrastructures. Similarly, Mauttone et al. (2017) proposed a formulation to minimize the bike users' cost considering budget constraints. In addition, the approach considers the discontinuities in the bike network (i.e. the cases where the bikers use non-reserved lanes). Ospina et al. (2022) proposed a network design problem aimed at maximizing the number of origin-destination pairs connected by the bike network (under budget constraints and considering the minimization of the travel costs related to the whole transport network).

Other approaches, often based on the *use of GPS data*, are possible in bike network design and in assessing the potential shift (Kapuku et al. 2022). As an example, Castiglione et al. (2022), starting from GPS data related to the route followed by e-scooters, proposed a clustering procedure to classify road links. The aim is to identify the potential bike network under the assumption that bike lanes can be used both by bikes and e-scooters and that bicyclists have the same behavior as e-scooter users. A bi-objective model (minimization of the travel cost and minimization of the network length) was proposed by Akbarzadeh, Mohri, and Yazdian (2018). GPS data from taxis are used to identify the origin and the destination of the trips within the city, and some of them are supposed to be the starting points to build the bike network.

Therefore, this brief literature review shows that some works have been developed for bike network design, however further effort should be made to build a more attractive and safer bike network that could attract trips currently undertaken by cars. In fact, many of the studies analyzed focus on network design procedures, but do not thoroughly analyze demand, particularly the level of demand that would utilize the bike network. To fill this gap, a procedure is presented that wants to contribute to this topic. In particular, the procedure takes advantage of the opportunity offered by FCD to contain investigation costs (Comi et al. 2021; Nigro et al. 2024) with the purpose of identifying the potential demand that could shift from car to bicycle and obtaining an overview of the routes typically followed by users.

## The proposed bike-network design procedure

In this section, a procedure to identify the lanes of the road network to assign to the bike network is discussed. The approach starts with the identification of the potential origin-destination flow (demand) that is supposed to be shifted from private cars to bikes. To achieve this purpose, a dataset of FCD is used to identify the potential car trips that could be made using the bike. This approach can be applied both to the design of a new bike network and to the extension or completion of an existing one. In fact, the infrastructures available in the study area are considered as input to the procedure; this means that, in terms of supply, the input is constituted by the existing bike network (if any) and all the road links where the use of a bike is permitted. Figure 1 reports on the adopted procedure. In particular, two parallel stages are proposed: the former focuses on land use and on supply network, while the latter investigates mobility through the FCD.

Therefore, the first stage consists of:

- *zoning*, the *study area* is partitioned into *traffic zones* (obtained by merging census areas; ISTAT 2024); for each traffic zone, a fictitious node (centroid) represents the origin/destination for all trips from/to the zone (Cascetta 2009);
- *supply analysis*, it consists of identifying the *existing bike network* (highlighting any discontinuity) and the *potential bike network*, namely a network constituted by links where it is possible to add lanes for bikes (i.e. links with geometric characteristics that allow the insertion of a dedicated bike lane without compromising vehicle flow).

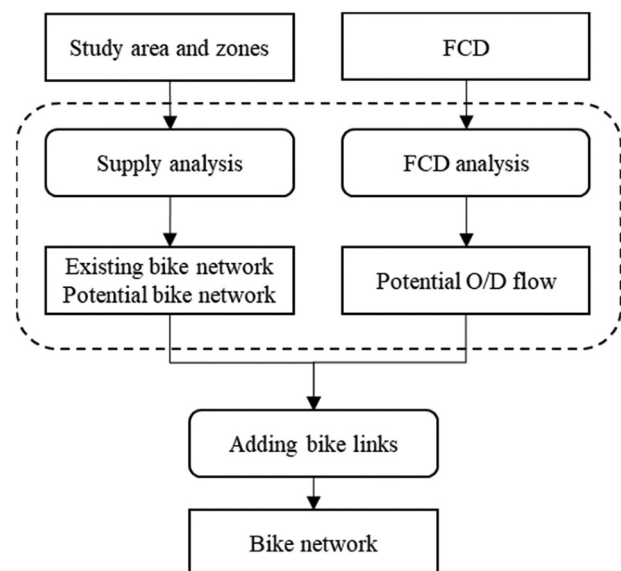


Figure 1. The whole procedure for bike network design.

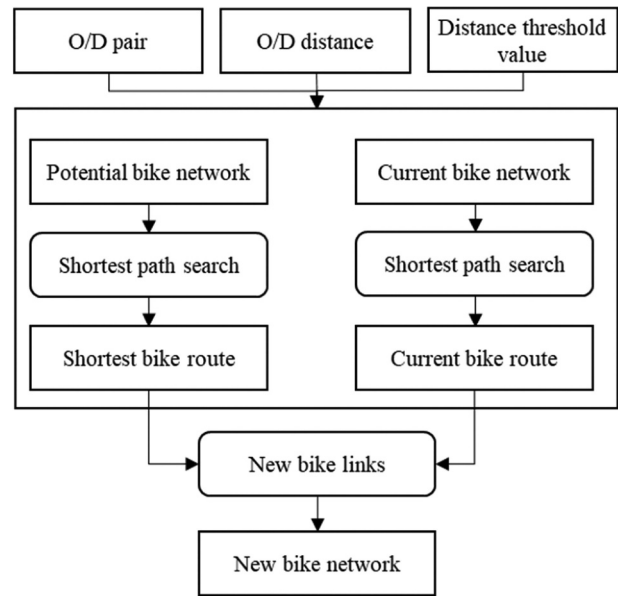
Note that in this phase, the current bike network may be an unconnected network, meaning that not all origin-destination pairs can be reached using exclusively a dedicated bike route (as emerged in some surveys carried out in Rome, bike users strongly point out safety issues and tend not to use unprotected routes; Nigro et al. 2024). However, the route could exist if other links, not exclusively dedicated to the bike, are used. This means that the approach prioritizes the creation of safe routes with dedicated bike lanes. When this is not possible, mixed-use links are inserted to preserve the connection of the bike network. In parallel, a database of FCDs is analyzed (*FCD analysis*) with two main objectives:

- to identify the current routes followed by road users;
- to identify the origin (*O*) and the destination (*D*) of each trip according to the zones in the study area.

The output of the *FCD analysis* is thus the *potential O/D flow* that could use the bike as transport mode. To identify this potential demand, some assumptions have been made about trips to shift from car to bike considering the results of the survey. The results of interviews with a sample of users, whose detailed results are presented in [Results and discussion](#) (see, for example, [Figure 7](#)), indicate that over 74% of respondents are willing to use bike for trips shorter than 5 km when a dedicated bike lane network is available. This finding aligns with evidence reported in the literature (e.g. McQueen, MacArthur, and Cherry 2020) and supports the adoption of 5 km as a reasonable threshold for classifying bike-eligible trips. Besides in order to capture the users' habits (that reflect the trip purpose), a method to identify the systematic nature of the trip (e.g. a home-work trip) is proposed. Since this information cannot be directly obtained by FCD, the proposed approach classifies the trips in relation to origin, destination, departure and arrival times, also considering when the vehicle remains stationary at its destination for more than two hours.

From these operations, a feasible first bike network emerges. In particular, the current routes followed by users give indications of the possible links to put in the bike network.

The final step consists of *adding bike links*: the potential supply is compared with the routes obtained from the potential O/D flow. This allows the supply to be completed by adding the missing links, obtaining a connected *bike network* that maximizes the overlap with the observed routes. This final step is detailed in



**Figure 2.** The procedure for adding links.

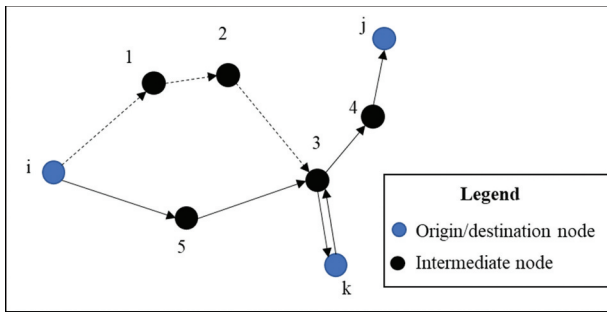
[Figure 2](#); note that the procedure reported in this figure should be repeated for each O/D pair. Given an *O/D pair*, the corresponding value of *O/D distance* is considered, and taking into account a *distance threshold value* (in general, the users use the bike for travels that do not exceed a certain travel length) a search procedure allows the links to add to the bike network to be obtained.

In this approach, a *potential bike network* and a *current bike network* are available: the first one contains all the links that could be used for the bike network, the latter contains the links already assigned to the bike network.

The potential network and the current network are the input of a *shortest path search* procedure (Dijkstra algorithm), obtaining, respectively, the *shortest bike route* and the *current bike route*. Being the current bike network a subset of the potential network, it can happen that:

- it does not exist; in this case, the links belonging to the shortest route between the origin and the destination are extracted from the potential network and inserted into the current network;
- it exists, but it is not certain that the obtainable routes are those of minimum cost.

[Figure 3](#) reports an example of link addition related to the second point discussed above. The objective is to add the links to the bike network from the origin *i* and destination *j*. In the represented case, it is supposed that, in previous iterations, the bike network links from *i* to *k* (*i-5-3-k*) and from *k* to *j*



**Figure 3.** Example of procedure for adding bike routes.

( $k-3-4-j$ ) were added. When considering only the links belonging to the bike network, route  $r_1$  between  $i$  and  $j$  is:  $i-5-3-4-j$ . When exploring the whole road network with links that could potentially be included in the bike network (i.e. they have features that allow them to be used by bikers safely), it emerges that the shortest route ( $r_2$ ) is  $i-1-2-3-4-j$ . In this situation, the links (dotted lines in Figure 3) to add to the network are ( $i-1$ ), ( $1-2$ ) and ( $2-3$ ).

## Results and discussion

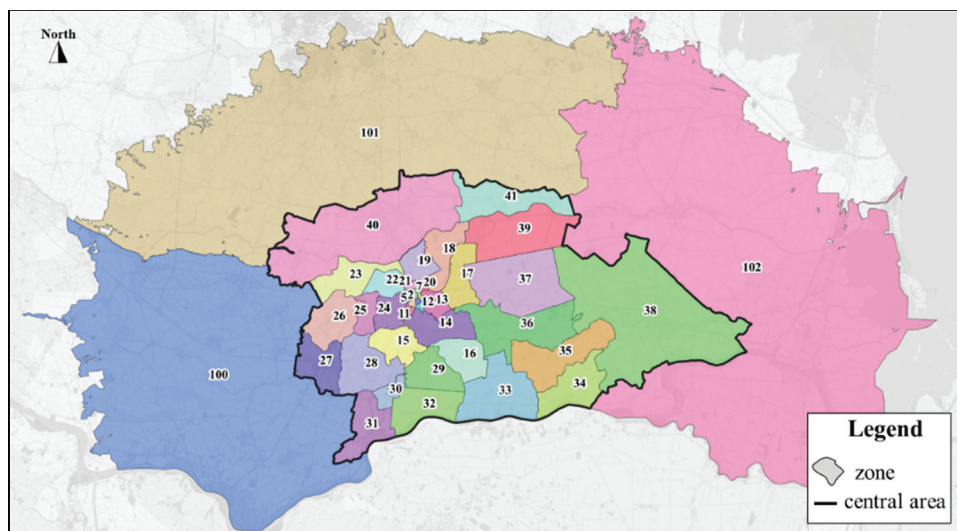
Once the procedure has been defined, the next step is its implementation in a real case study to assess its effectiveness and validate the results that can be obtained.

### Study area and data analysis

The procedure proposed in the previous section has been tested in a small town to avoid overlapping effects related to the size and complexity of demand. The study area is the city of Rovigo, an Italian town of about 50,000

inhabitants located in the Veneto region (North Italy). This area has been divided into 44 zones (Figure 4): the central area is composed of 41 zones, and the other zones (labeled from 101 to 103) are used to simulate interactions with the external environment. Table 1 reports some characteristics of the zones located in the central area. Zoning is obtained by aggregating census areas (ISTAT 2024), and following some criteria linked to the geographical and socio-economic attributes (Cascetta 2009). The dimensions of the zones affect the simulation of the system; in this application, a finer level of zoning detail is adopted to better capture spatial variations in travel patterns. In fact, the zones in the central area (from 1 to 12 and 20–21) are smallest than the others, in order to better capture travel behavior in the most densely populated part of the study area. Since the trips used for network design are those between different zones, the size of the zones affects the number of trips considered in designing the bike network. In fact, as the size of the zones decreases, intra-zonal trips are reduced, which in turn increases the number of inter-zonal trips used to define the bike network. Although the approach is general, the results depend on the level of zoning detail. This can be viewed both as a limitation (since varying zone sizes within the same study area may lead to different outcomes) and as an opportunity, as the method can be applied in any city regardless of the number of trips.

When analyzing the supply within the study area, it emerged that the current bike network (Figure 5) is 24.1 kilometers long (considering only paved roads). Figure 5 highlights that the bike network is piecewise continuous (a common event in the urban bike network, an element affecting the biker safety, as an example see



**Figure 4.** The study area.

**Table 1.** Zones in the central area.

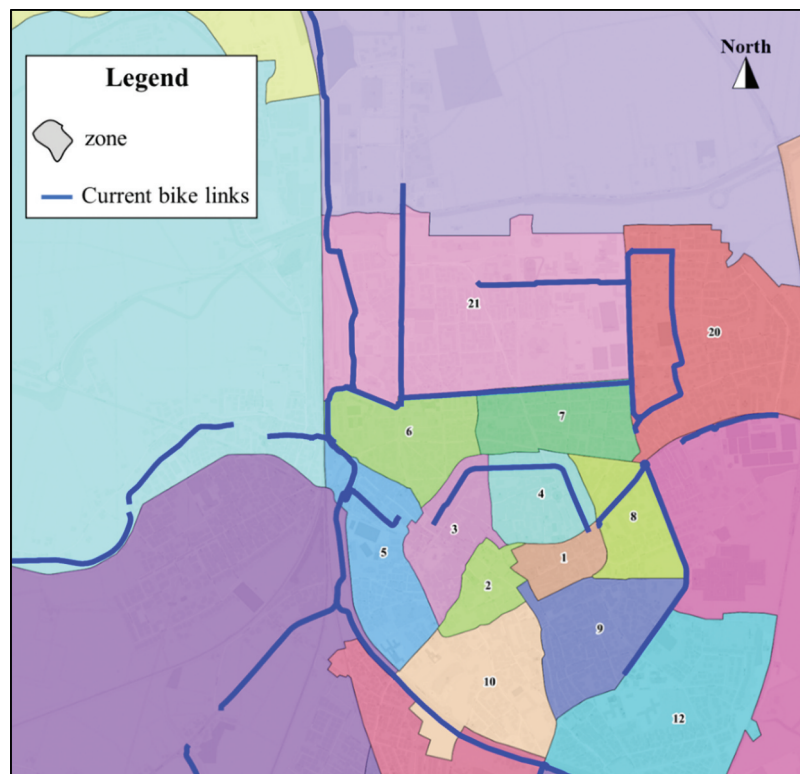
Zone id	Area [km <sup>2</sup> ]	Radius [km] <sup>(*)</sup>	Zone id	Area [km <sup>2</sup> ]	Radius [km] <sup>(*)</sup>
1	0.078	0.157	21	0.939	0.547
2	0.089	0.168	22	6.297	1.416
3	0.161	0.226	23	13.908	2.104
4	0.158	0.224	24	7.092	1.502
5	0.253	0.284	25	5.623	1.338
6	0.221	0.265	26	16.060	2.261
7	0.205	0.255	27	14.147	2.122
8	0.165	0.229	28	19.921	2.518
9	0.248	0.281	29	13.269	2.055
10	0.304	0.311	30	4.378	1.181
11	0.457	0.381	31	16.407	2.285
12	0.594	0.435	32	17.201	2.340
13	4.253	1.163	33	28.035	2.987
14	13.606	2.081	34	18.040	2.396
15	10.699	1.845	35	24.357	2.784
16	11.991	1.954	36	30.155	3.098
17	11.198	1.888	37	36.144	3.392
18	12.009	1.955	38	113.319	6.006
19	7.321	1.527	39	31.031	3.143
20	0.616	0.443	40	86.689	5.253
			41	21.655	2.625

<sup>(\*)</sup>Average value.

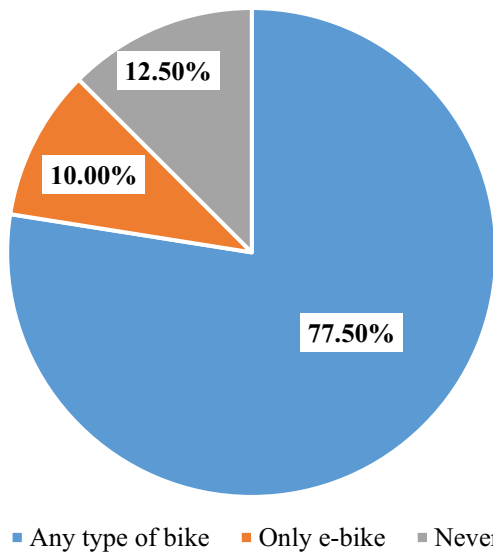
H. Li et al. 2024; Natera Orozco et al. 2020). The aim is to extend the bike network also trying, where possible, to join the various existing elements. This needs to be done not only at the infrastructure level but also taking into account the potential demand that can use it.

To support this study, a stated preference (SP) survey was carried out and 107 people answered. The questionnaire consists of 42 questions, and it is divided into

four sections. The first section collects information about the respondent's residence, whether they have a driving license, and the means of transportation available for their trips. The second section relies on systematic trips (e.g. home-work, home-school, home-university), while the third section is on non-systematic trips. The last section contains questions aimed at obtaining socio-economic information.



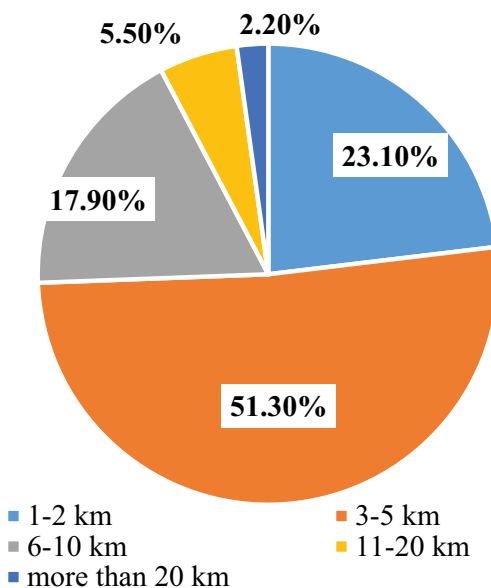
**Figure 5.** The current bike network: a zoom in the central area.



**Figure 6.** Willingness to use the bike in a protected network for systematic trips.

The survey analysis highlights that users, experiencing a systematic trip, would be willing to use the bike if the route is in a protected lane. In particular, as shown in Figure 6, at the question ‘Would you use a bike for systematic trips if there was a dedicated bike network?’, 77.50% of users responded to be available to use the protected network with any type of bike, while 10% of users would only do it if they owned an e-bike. Additionally, 12.50% of users are not willing to use the bike, even on a protected network, for systematic trips.

In relation to the length of the trip (Figure 7), it emerged that the users are willing to use the bike for



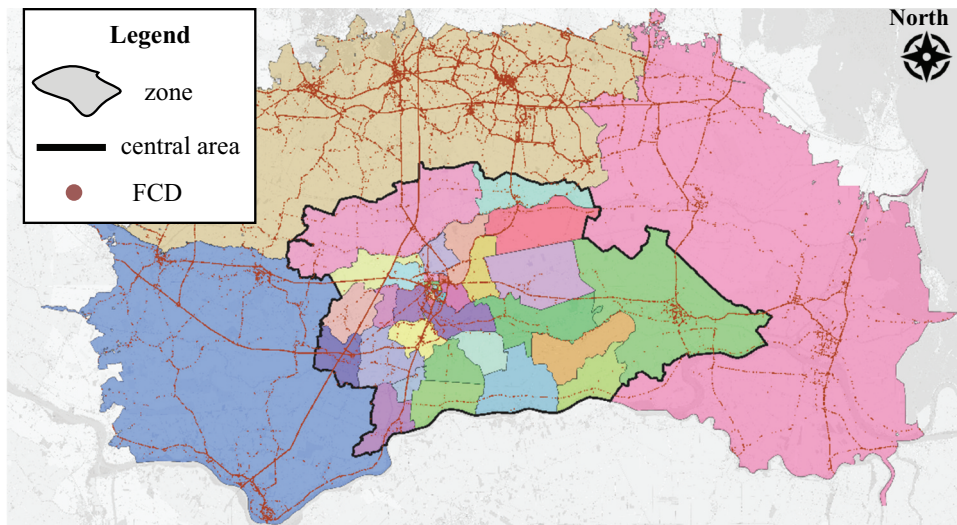
**Figure 7.** Trip length boundaries.

general short trips. In fact, 23.10% of users would use the bike for trips of less than 2 kilometers, 51.30% for trips between 3 and 5 kilometers. The 17.90% of users consider the bike as an available mode of transportation for trips from 6 to 10 kilometers, this value decreases to 5.50% for trips between 11 and 20 kilometers. Only 2.20% of users declared the willingness to use the bike for travels greater than 20 kilometers in length.

### Potential demand estimation

A first analysis of potential demand can be performed using the FCD. The available data are related to five working days of observations, involving 1912 cars, for a total of 205,595 GPS points and 23,846 trips (Figure 8). The data set contains data from cars that have used, on their trips, at least one link belonging to the study area during one of the days of observation. From the analysis of these data, it is possible to obtain the origin-destination matrix and, consequently, the potential users who could use the bike for traveling. The database is the same one used by the authors in another paper (Comi et al. 2021), in which, among others, it is shown that this data sample is sufficient to estimate the demand.

The first step to build the O/D matrix from FCD is to identify the origin and the destination of each trip according to the zones in the study area. In this application, the procedure proposed by Comi, Polimeni, and Nuzzolo (2022), briefly described below, was applied. The basic assumption is that the potential demand for micro-mobility consists of the user living in the study area who makes home-based systematic trips. The procedure takes as input a set of FCD and gives as output the systematic trips (home-based trip chains and home-based round trips) to put into the O/D matrix. Besides, only the trips by residents are considered, this raises the problem of their identification: this task is carried out by merging the FCD with vehicle registration data and adopting the rule that a user is a resident if the starting point of the first trip in the morning and the municipality where the vehicle is registered fall into the study area. Since the FCD are a sample of vehicles traveling in the road network, the O/D matrix obtained by analyzing the FCD is itself a sample that needs to be multiplied by an index to be expanded to the universe of investigation. This index has been defined as the ratio between the number of vehicles surveyed in a municipality and the total number of vehicles registered in such a municipality. Since the study area contains more than one municipality, there will be more than one expansion index (this means that the elements of the demand matrix are not all amplified equally). Finally, the value thus obtained was multiplied by the percentage of users willing to use the bike.



**Figure 8.** Zones and floating car data.

Naturally, not all of these trips can be made using a bike: either because there is no bike network between the origin and the destination or because the distance is too long. The procedure used to obtain potential trips that could be made by bike refers to the distance traveled.

Figure 9 reports a zoom-in on some trips generated in the study area in the case when a 5 km threshold is set as the maximum length of the trips. From this figure, it emerges that there are many zones for which the shift from car to bike for systematic trips is potentially possible.

### **Bike network design**

Applying the procedure reported in Figure 2, the bike network was updated by introducing some new links (Table 2 and Figure 10), for a total of 6.8 kilometers (an extension of 28.91% compared to the existing one). In terms of trips, the existing bike network could be used for 83% of the potential demand, while the designed network could meet 95% of the potential demand (Table 2). The evaluation of the covered demand was carried out by checking whether the connection between zones exists. Obviously, adding new connections (without hindering the mobility of cars) increases the level of demand that can be met.

### **Conclusions**

The paper tackles a design problem for bike networks. Two elements have been considered: demand potentially to be shift from private cars and the improvement of the existing bike network. The aim was to build a more attractive bike network for private car users

through the coverage of more origin–destination relationships in which, currently, users prefer to use a car, but bikes could be a valuable alternative.

For demand investigation, an approach based on FCD has been proposed. Starting from a set of data related to car mobility in the study area, the demand was evaluated, also with the support of a survey to understand the attitudes of the users. The data, related to different workdays, allow the origin–destination matrix and, consequently, the potential demand to be estimated.

For supply, the proposed approach has been implemented with the aim of identifying the discontinuities in the current bike network and solving them. In addition, the objective of the design procedure is to obtain a bike network that maximizes the covered demand.

The procedure has been tested in a small town (about 50,000 inhabitants) with an existing bike network of about 24 kilometers. A dataset of FCD and ad hoc survey allowed identifying the potential demand to shift from cars to bikes. The origin–destination matrix, built by analyzing the FCD, has been crossed with the results of the survey. This allowed filtering only the trips that users perceive as feasible by bike (trips with a length of less than five kilometers). In addition, it was discovered that users are inclined to choose the bike as transport mode only if the route is in a reserved lane. By applying the proposed procedure, the discontinuities in the current bike network have been solved, and the addition of new bike links has increased the covered demand by 14%.

This study is not without limitations. The main concern relates to the composition of the analyzed sample:

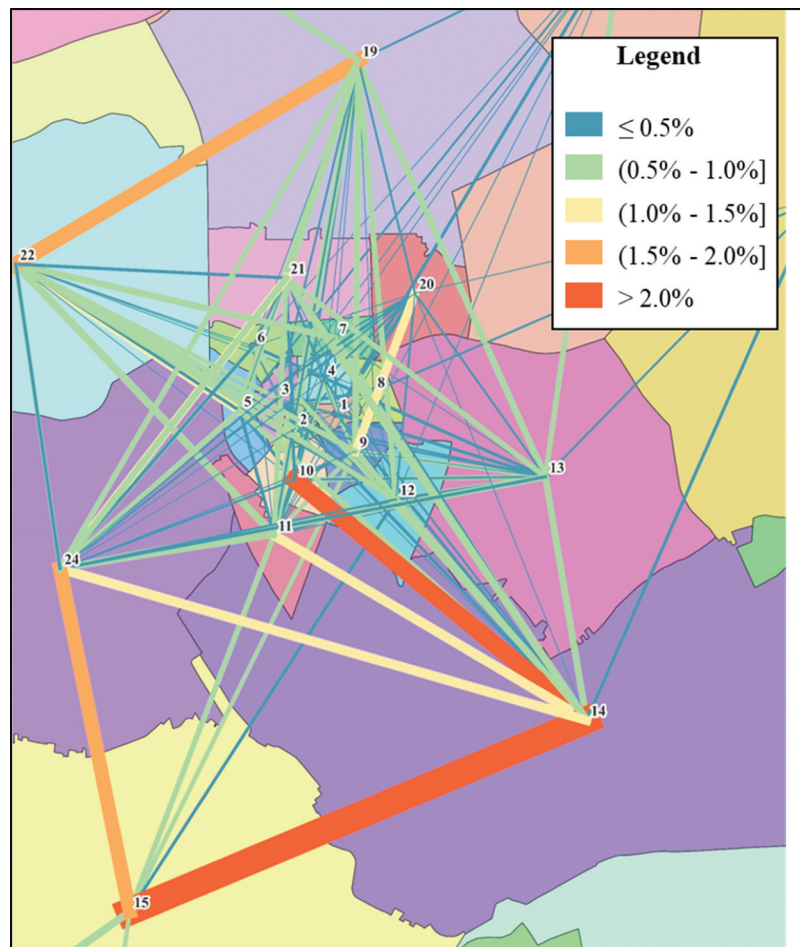


Figure 9. Example of trips among zones.

Table 2. Comparing scenarios.

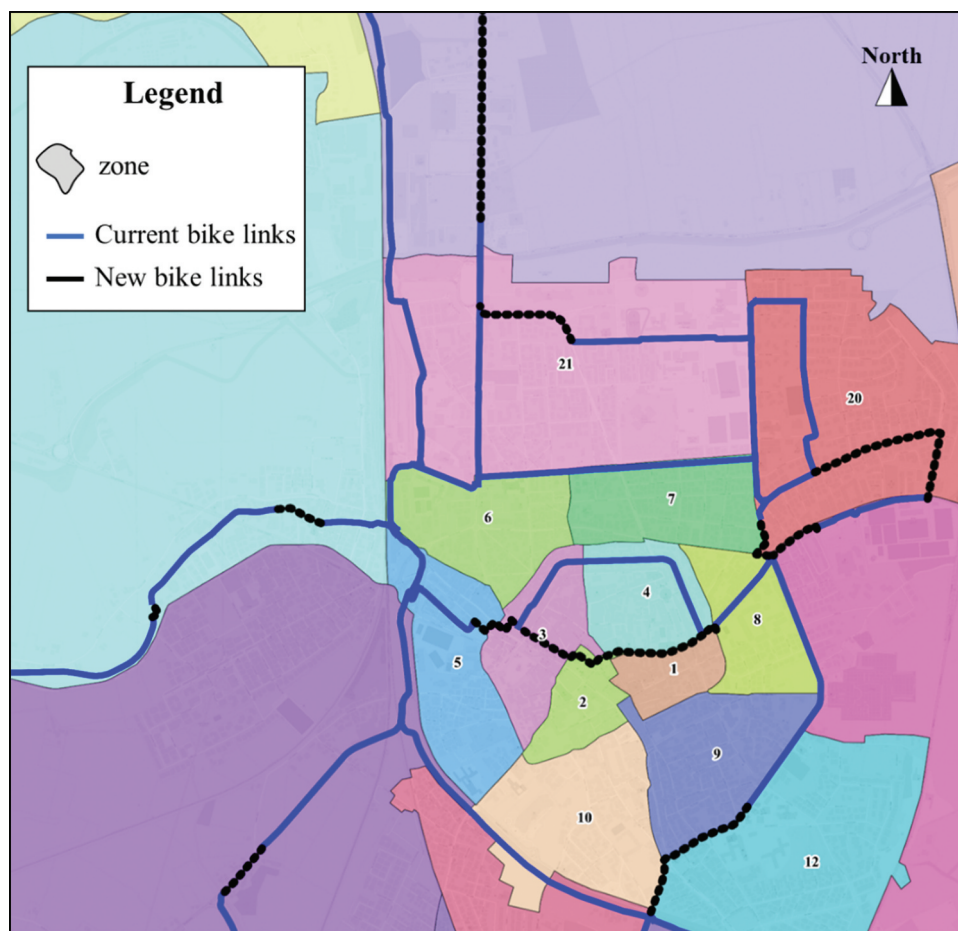
Parameters	Current scenario	Design scenario	Variation
Network length	24.1 km	30.9 km	+28.21%
Covered potential demand	83%	95%	+14.46%

66% of respondents are between 18 and 24 years of age, which may lead to an overestimation of cycling demand. Future research should address this issue by expanding the participant sample to achieve a more balanced representation. Nevertheless, this limitation does not compromise the validity of the proposed procedure, which remains applicable regardless of the overall demand level.

Future developments could be related to the analysis of the route choice by the bikers and the development of shared services including the investigation of issues related to the location of the sharing station along the bike network. Multimodal trips (e.g. a combination of micromobility and public transport) could be considered, for example, by assuming micromobility as a way of accessing (and/or exiting) public transport. Moreover, the role of trip chains warrants deeper

investigation, as the choice of transport mode in multi-stop journeys can differ substantially from patterns observed in single-trip travel. In such cases, factors such as time constraints, activity sequencing, and the need for flexibility could influence modal decisions, making them more complex than those associated with isolated trips.

Other aspects worthy of investigation refer to the improvement of modal share modeling (with a dedicated survey), as well as the development of methods to refine the obtained road bike network which take into consideration the attitude and preferences of the users, e.g. further improving the safety of bikers. Finally, the opportunity to take into account possible congestion effects could be assessed given that in the next future it is expected a significant increase of such users.



**Figure 10.** A zoom on zones: current bike network and an example of new (added) links.

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## References

- Akbarzadeh, M., S. S. Mohri, and E. Yazdian. 2018. "Designing Bike Networks Using the Concept of Network Clusters." *Applied Network Science* 3 (1): 12. <https://doi.org/10.1007/s41109-018-0069-0>.
- Arellana, J., M. Saltařın, A. M. Larrañaga, V. I. González, and C. A. Henao. 2020. "Developing an Urban Bikeability Index for Different Types of Cyclists as a Tool to Prioritise Bicycle Infrastructure Investments." *Transportation Research Part A: Policy and Practice* 139:310–334. <https://doi.org/10.1016/j.tra.2020.07.010>.
- Aziz, H. M. A., N. N. Nagle, A. M. Morton, M. R. Hilliard, D. A. White, and R. N. Stewart. 2018. "Exploring the Impact of Walk–Bike Infrastructure, Safety Perception, and Built–Environment on Active Transportation Mode Choice: A Random Parameter Model Using New York City Commuter Data." *Transportation* 45:1207–1229. <https://doi.org/10.1007/s11116-017-9760-8>.

- Cantarella, G. E., and A. Vitetta. 2006. "The Multi-Criteria Road Network Design Problem in an Urban Area." *Transportation* 33:567–588. <https://doi.org/10.1007/s11116-006-7908-z>.
- Cascetta, E. 2009. *Transportation Systems Analysis, Springer Optimization and Its Applications*. Boston, MA: Springer US. <https://doi.org/10.1007/978-0-387-75857-2>.
- Castiglione, M., R. D. Vincentis, M. Nigro, and V. Rega. 2022. "Bike Network Design: An Approach Based on Micro-Mobility Geo-Referenced Data." In *Transportation Research Procedia, 24th Euro Working Group on Transportation Meeting* 62, 51–58. Elsevier. <https://doi.org/10.1016/j.trpro.2022.02.007>.
- Chibwe, J., S. Heydari, A. Faghieh Imani, and A. Scurtu. 2021. "An Exploratory Analysis of the Trend in the Demand for the London Bike-Sharing System: From London Olympics to COVID-19 Pandemic." *Sustainable Cities and Society* 69:102871. <https://doi.org/10.1016/j.scs.2021.102871>.
- Comi, A., O. Hriekova, and M. Nigro. 2024. "Exploring Road Safety in the Era of Micro-Mobility: Evidence from Rome." *Transportation Research Procedia* 78:55–62. <https://doi.org/10.1016/j.trpro.2024.02.008>.
- Comi, A., and A. Polimeni. 2024. "Assessing Potential Sustainability Benefits of Micromobility: A New Data Driven Approach." *European Transport Research Review* 16 (1): 19. <https://doi.org/10.1186/s12544-024-00640-6>.
- Comi, A., A. Polimeni, and C. Balsamo. 2022. "Road Accident Analysis with Data Mining Approach: Evidence from Rome." *Transportation Research Procedia* 62:798–805. <https://doi.org/10.1016/j.trpro.2022.02.099>.
- Comi, A., A. Polimeni, and A. Nuzzolo. 2022. "An Innovative Methodology for Micro-Mobility Network Planning." *Transportation Research Procedia* 60:20–27. <https://doi.org/10.1016/j.trpro.2021.12.004>.
- Comi, A., A. Rossolov, A. Polimeni, and A. Nuzzolo. 2021. "Private Car O-D Flow Estimation Based on Automated Vehicle Monitoring Data: Theoretical Issues and Empirical Evidence." *Information* 12:493. <https://doi.org/10.3390/info12120493>.
- Correa, J., A. Mauttone, and F. Robledo. 2023. "Maximizing Modal Shift in Bicycle Network Design." In *Procedia Computer Science, the 14th International Conference on Ambient Systems, Networks and Technologies Networks (ANT) and the 6th International Conference on Emerging Data and Industry 4.0 (EDI40)* 220. *Procedia Computer Science* 220:226–234. Elsevier. <https://doi.org/10.1016/j.procs.2023.03.031>.
- Di Gangi, M., A. Comi, A. Polimeni, and O. M. Belcore. 2022. "E-Bike Use in Urban Commuting: Empirical Evidence from the Home-Work Plan." *Archives of Transport* 62 (2): 91–104. <https://doi.org/10.5604/01.3001.0015.9568>.
- Dong, S., A. Khattak, F. Chen, and J. Zhou. 2025. "Analyzing Severity of Vehicle–Bicycle Crashes: An Explainable Boosting Machine Strategy." *Transportation Letters*: 1–14. <https://doi.org/10.1080/19427867.2025.2500817>.
- Doorley, R., V. Pakrashi, W. Y. Szeto, and B. Ghosh. 2020. "Designing Cycle Networks to Maximize Health, Environmental, and Travel Time Impacts: An Optimization-Based Approach." *International Journal of Sustainable Transportation* 14:361–374. <https://doi.org/10.1080/15568318.2018.1559899>.
- Duthie, J., and A. Unnikrishnan. 2014. "Optimization Framework for Bicycle Network Design." *Journal of Transportation Engineering* 140:04014028. [https://doi.org/10.1061/\(ASCE\)TE.1943-5436.0000690](https://doi.org/10.1061/(ASCE)TE.1943-5436.0000690).
- Fitch-Polse, D. T., H. Mohiuddin, and S. L. Handy. 2025. "Can Bike-Share Change Attitudes? Evidence from the Sacramento, California Region." *Transportation Letters* 17:458–469. <https://doi.org/10.1080/19427867.2024.2360336>.
- Frade, I., and A. Ribeiro. 2014. "Bicycle Sharing Systems Demand. Procedia - Social and Behavioral Sciences, Transportation: Can We Do More with Less Resources?" In *16th Meeting of the Euro Working Group on Transportation – Porto 2013* 111, 518–527. Elsevier. <https://doi.org/10.1016/j.sbspro.2014.01.085>.
- Frade, I., and A. Ribeiro. 2015. "Bike-Sharing Stations: A Maximal Covering Location Approach." *Transportation Research Part A: Policy and Practice* 82:216–227. <https://doi.org/10.1016/j.tra.2015.09.014>.
- Gaspar, I., J. Benavente, M. Bordagaray, B. Alonso, J. L. Moura, and Á. Ibeas. 2015. "A Bilevel Mathematical Programming Model to Optimize the Design of Cycle Paths. Transportation Research Procedia, 18th Euro Working Group on Transportation, EWGT 2015, 14-16 July 2015, Delft, the Netherlands 10, 423–432." *Transportation Research Procedia* 10:423–432. <https://doi.org/10.1016/j.trpro.2015.09.092>.
- González, F., C. Melo-Riquelme, and L. de Grange. 2016. "A Combined Destination and Route Choice Model for a Bicycle Sharing System." *Transportation* 43:407–423. <https://doi.org/10.1007/s11116-015-9581-6>.
- ISTAT. 2024. "Basi Territoriali e Variabili Censuarie [WWW Document]." Istituto Nazionale di Statistica." Accessed September 7, 24. <https://www.istat.it/notizia/basi-territoriali-e-variabili-censuarie-test/>.
- Kapuku, C., S.-Y. Kho, D.-K. Kim, and S.-H. Cho. 2021. "Assessing and Predicting Mobility Improvement of Integrating Bike-Sharing into Multimodal Public Transport Systems." *Transportation Research Record: Journal of the Transportation Research Board* 2675 (11): 204–213. <https://doi.org/10.1177/03611981211045071>.
- Kapuku, C., S.-Y. Kho, D.-K. Kim, and S.-H. Cho. 2022. "Modeling the Competitiveness of a Bike-Sharing System Using Bicycle GPS and Transit Smartcard Data." *Transportation Letters* 14:347–351. <https://doi.org/10.1080/19427867.2020.1758389>.
- Kathait, N., and A. Agarwal. 2025. "User Intention to Adopt Public Bicycle Sharing System: A Priori Acceptance Approach." *Transportation Letters* 17:687–701. <https://doi.org/10.1080/19427867.2024.2375473>.
- Li, H., Z. Zhang, H. Lv, and G. Ren. 2024. "Investigating the Safety Impacts of Discontinuities in Cycle Network: A Case Study of London." *Journal of Transportation Safety & Security* 16:43–72. <https://doi.org/10.1080/19439962.2023.2180561>.
- Li, Y., Y. Zhang, Y. Long, K. Bhalla, and M. Ezzati. 2025. "Assessing Bicycle Safety Risks Using Emerging Mobile Sensing Data." *Travel Behaviour and Society* 38:100906. <https://doi.org/10.1016/j.tbs.2024.100906>.

- Lim, J., K. Dalmeijer, S. Guhathakurta, and P. Van Hentenryck. 2022. "The Bicycle Network Improvement Problem." *Journal of Transportation Engineering, Part A: Systems* 148:04022095. <https://doi.org/10.1061/JTEPBS.0000742>.
- Liu, H., W. Y. Szeto, and J. Long. 2019. "Bike Network Design Problem with a Path-Size Logit-Based Equilibrium Constraint: Formulation, Global Optimization, and Matheuristic." *Transportation Research Part E: Logistics and Transportation Review* 127:284–307. <https://doi.org/10.1016/j.tre.2019.05.010>.
- Liu, S., A. Siddiq, and J. Zhang. 2024. "Planning Bike Lanes With Data: Ridership, Congestion, and Path Selection." *Management Science* 71 (9): 7631–7654. <https://doi.org/10.1287/mnsc.2022.00775>.
- Lopez, A. J., P. Astegiano, S. Gautama, D. Ochoa, C. M. J. Tampère, and C. Beckx. 2017. "Unveiling E-Bike Potential for Commuting Trips from GPS Traces." *ISPRS International Journal of Geo-Information* 6:190. <https://doi.org/10.3390/ijgi6070190>.
- Mauttone, A., G. Mercadante, M. Rabaza, and F. Toledo. 2017. "Bicycle Network Design: Model and Solution Algorithm." In *Transportation Research Procedia, 20th EURO Working Group on Transportation Meeting, EWGT 2017*, Budapest, Hungary 27: 969–976. Elsevier. 4–6 September 2017. <https://doi.org/10.1016/j.trpro.2017.12.119>.
- McQueen, M., J. MacArthur, and C. Cherry. 2020. "The E-Bike Potential: Estimating Regional E-Bike Impacts on Greenhouse Gas Emissions." *Transportation Research Part D: Transport and Environment* 87:102482. <https://doi.org/10.1016/j.trd.2020.102482>.
- Meng, S., and A. Brown. 2021. "Docked vs. Dockless Equity: Comparing Three Micromobility Service Geographies." *Journal of Transport Geography* 96:103185. <https://doi.org/10.1016/j.jtrangeo.2021.103185>.
- Miah, M. M., K. K. Hyun, and S. P. Mattingly. 2024. "A Review of Bike Volume Prediction Studies." *Transportation Letters* 16:1406–1433. <https://doi.org/10.1080/19427867.2024.2310831>.
- Natera Orozco, L. G., F. Battiston, G. Iñiguez, and M. Szell. 2020. "Data-Driven Strategies for Optimal Bicycle Network Growth." *Royal Society Open Science* 7:201130. <https://doi.org/10.1098/rsos.201130>.
- Nigro, M., A. Comi, R. De Vincentis, and M. Castiglione. 2024. "A Mixed Behavioural and Data-Driven Method for Assessing the Shift Potential to Electric Micromobility: Evidence from Rome." *Front Future Transp* 5:1391100. <https://doi.org/10.3389/ffutr.2024.1391100>.
- Olafsson, A. S., T. S. Nielsen, and T. A. Carstensen. 2016. "Cycling in Multimodal Transport Behaviours: Exploring Modality Styles in the Danish Population." *Journal of Transport Geography* 52:123–130. <https://doi.org/10.1016/j.jtrangeo.2016.03.010>.
- Ospina, J. P., J. C. Duque, V. Botero-Fernández, and A. Montoya. 2022. "The Maximal Covering Bicycle Network Design Problem." *Transportation Research Part A: Policy and Practice* 159:222–236. <https://doi.org/10.1016/j.tra.2022.02.004>.
- Park, C., and S. Y. Sohn. 2017. "An Optimization Approach for the Placement of Bicycle-Sharing Stations to Reduce Short Car Trips: An Application to the City of Seoul." *Transportation Research Part A: Policy and Practice* 105:154–166. <https://doi.org/10.1016/j.tra.2017.08.019>.
- Polimeni, A., and A. Vitetta. 2024. "Network Design and Vehicle Routing Problems in Road Transport Systems: Integrating Models and Algorithms." *Transportation Engineering* 100247:100247. <https://doi.org/10.1016/j.treng.2024.100247>.
- Putta, T., and P. G. Furth. 2021. "Impact of One-Way Streets and Contraflow on Low-Stress Bicycle Network Connectivity." *Transportation Research Record* 2675 (10): 1174–1183. <https://doi.org/10.1177/03611981211014893>.
- RSM. 2020. *Rapporto Mobilità Roma - 2020*. Roma Servizi per la Mobilità. Rome, Italy, Roma.
- Rupi, F., C. Poliziani, and J. Schweizer. 2020. "Analysing the Dynamic Performances of a Bicycle Network with a Temporal Analysis of GPS Traces." *Case Studies on Transport Policy* 8:770–777. <https://doi.org/10.1016/j.cstp.2020.05.007>.
- Schweizer, J., F. Rupi, and C. Poliziani. 2020. "Estimation of Link-Cost Function for Cyclists Based on Stochastic Optimisation and GPS Traces." *IET Intelligent Transport Systems* 14:1810–1814. <https://doi.org/10.1049/iet-its.2019.0683>.
- Steinacker, C., D.-M. Storch, M. Timme, and M. Schröder. 2022. "Demand-Driven Design of Bicycle Infrastructure Networks for Improved Urban Bikeability." *Nature Computational Science* 2 (10): 655–664. <https://doi.org/10.1038/s43588-022-00318-w>.
- Subramanian, M., J. Cho, S. Veerappampalayam Easwaramoorthy, A. Murugesan, and R. Chinnasamy. 2023. "Enhancing Sustainable Transportation: AI-Driven Bike Demand Forecasting in Smart Cities." *Sustainability* 15:13840. <https://doi.org/10.3390/su151813840>.
- Venkadavarahan, M., and S. Marisamynathan. 2022. "Estimation of Rider's Shifting Intention for Electric Bike Adoption: An Integrated Choice and Latent Variable Approach." *Transportation Letters* 14:1151–1161. <https://doi.org/10.1080/19427867.2021.2000815>.
- Wang, P., H. Zhang, B. Zhang, S. Cheng, F. Lu, and T. Zhang. 2025. "Spatiotemporal Variations of Private E-Bike Trips with Explainable Data-Driven Technologies." *Cities* 158:105712. <https://doi.org/10.1016/j.cities.2025.105712>.
- Weikl, S., and P. Mayer. 2023. "Data-Driven Quality Assessment of Cycling Networks." *Frontiers in Future Transportation* 4:1127742. <https://doi.org/10.3389/ffutr.2023.1127742>.
- World Health Organization. 2018. *Global Action Plan on Physical Activity 2018–2030: More Active People for a Healthier World*. Geneva: World Health Organization.
- Xu, Y., Q. Ke, X. Zhang, and X. Zhao. 2025. "ICN: Interactive Convolutional Network for Forecasting Travel Demand of Shared Micromobility." *Geoinformatica* 29:175–200. <https://doi.org/10.1007/s10707-024-00525-9>.
- Zagorskas, J., and Z. Turskis. 2020. "Setting Priority List for Construction Works of Bicycle Path Segments Based on Eckenrode Rating and ARAS-F Decision Support Method Integrated in GIS." *Transport* 35:179–192. <https://doi.org/10.3846/transport.2020.12478>.

- Zhu, S., and F. Zhu. 2020. "Multi-Objective Bike-Way Network Design Problem with Space-Time Accessibility Constraint." *Transportation* 47:2479–2503. <https://doi.org/10.1007/s11116-019-10025-7>.
- Zimmermann, M., T. Mai, and E. Frejinger. 2017. "Bike Route Choice Modeling Using GPS Data without Choice Sets of Paths." *Transportation Research Part C: Emerging Technologies* 75:183–196. <https://doi.org/10.1016/j.trc.2016.12.009>.
- Zuo, T., and H. Wei. 2019. "Bikeway Prioritization to Increase Bicycle Network Connectivity and Bicycle-Transit Connection: A Multi-Criteria Decision Analysis Approach." *Transportation Research Part A: Policy and Practice* 129:52–71. <https://doi.org/10.1016/j.tra.2019.08.003>.

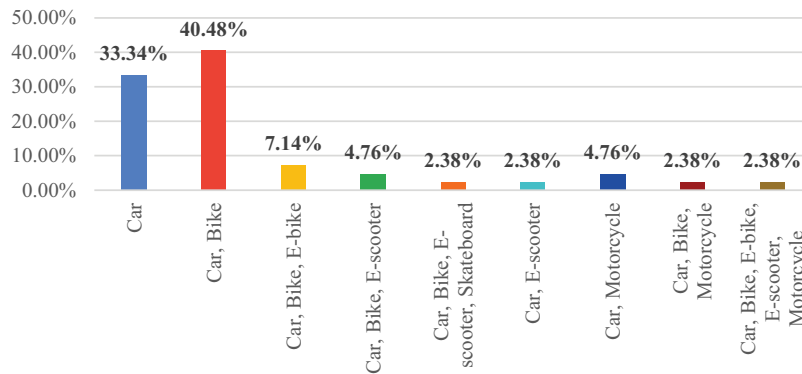
## Appendix

This appendix contains a summary of the SP survey. A total of 107 people answered the proposed questions. The questionnaire consists of 42 questions distributed in four sections:

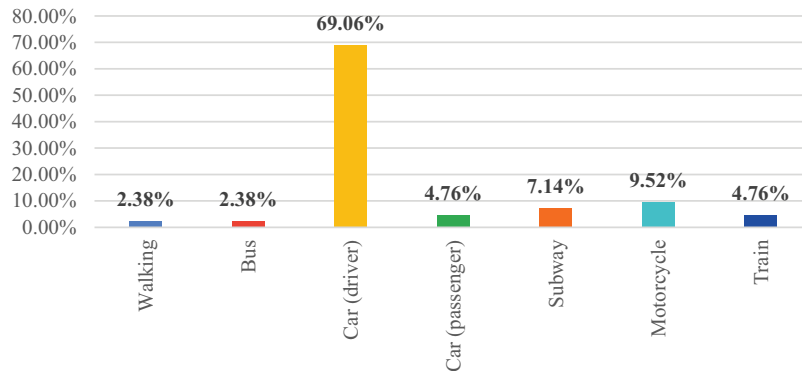
- the first section asks information regarding his/her residence, whether he/she has a driving license, and what means of transportation are available;
- the second section relies on systematic trips (e.g. home-work) while the third section is on non-systematic trips;
- the last section contains questions aimed at obtaining socio-demographic information.

In the sample, 95.24% of the respondents have a driving license and everyone has a car for traveling (as a driver or as a passenger). **Figure A1** shows the vehicles available to the respondents: about the 33% of them own only the car. In the other cases, respondents have more than one vehicle at their disposal (e.g., 40.48% own both a car and a bike, 7.14% own a car, a bike and an e-bike). **Figure A2** reports the transport mode used prevalently for systematic trips: 69.06% of the respondents declared the use of the car as driver for such type of trips, follows the use of the motorcycle (9.52%). Public transport (bus, subway and train) covers 14.28% of the trips.

**Table A1** reports the socio-demographic data of the sample. It emerged that about the 55% of the respondents are women, with a higher share (about 67%) of younger people (18–24 years old, those who could potentially be most interested in using micromobility). Only 2.38% of the sample is constituted by unemployed, there are 61.90% of employees, 21.43% of students and 14.29% of working students. The respondents belong to six income brackets, the bracket with the highest percentage of users is those with an income between twenty thousand and thirty thousand euros per year (21.43%).



**Figure A1.** Available vehicles.



**Figure A2.** Systematic trips: modal share.

**Table A1.** Survey findings: socio-demographic data.

Results	
Sex	
Woman	54.76%
Man	45.24%
<i>Total</i>	<i>100.00%</i>
Age interval	
18–24	66.68%
25–34	9.52%
35–44	4.76%
45–54	7.14%
55–65	11.90%
<i>Total</i>	<i>100.00%</i>
Employment condition	
Unemployed	2.38%
Employed	61.90%
Student	21.43%
Working student	14.29%
<i>Total</i>	<i>100.00%</i>
Income	
0–10000 €/year	19.05%
10001–20000 €/year	16.67%
20001–30000 €/year	21.43%
30001–40000 €/year	11.90%
40001–50000 €/year	16.66%
>50000 €/year	14.29%
<i>Total</i>	<i>100.00%</i>