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A USER CENTERED ANALYSIS ON BICYCLE TRAIN INTEGRATION

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Abstract

Public transportation is the ultimate sustainable mode of transportation for the masses. It has the great potential to be combined with other means of transport to become more flexible allowing to reach the "last mile". For instance, railway stations have the potential to be mobility hubs, not only for private cars, but also for shared means of transport such as micro-mobility. The present research focuses on the combination of bicycle and train. To make the combined use of bike and train the first choice of a traveller, it is necessary that all the facilities and services that are needed to the bike user are guaranteed inside or close by the railway station. It is extremely important that the bike and the train are well integrated between each other as the train, being bound to a definite line offers better performances in time, but may not cover the whole desired trip. On the other side, the bicycle has more flexibility inside the city and can fulfil the ultimate destination. The two means of transport become complementary and construct together a healthier city. Not much research however develops into finding the drivers of bicycle train intermodality as a modal choice, specifically in Italy. This research aims to fill this gap and will move a step forward presenting a user centered tool useful, for public administrations and involved stakeholders, to implement accessibility to railway stations. This tool is made based on a general Italian sample survey and different national and regional guidelines. The steps of the research include first a draft of the survey, based on bibliographic review, then the spread of the survey and finally data analysis. Secondly a checklist on what makes a railway station accessible is made and weighted based on the survey results. The checklist has been in the end applied to 33 railway stations of the Emilia-Romagna region that took part of the PREPAIR project. Results of the survey show that people aged more than 44 years old, as well as people who do not feel safe while cycling, tend to use less the combination of bike and train as a modal trip. Students tend to use it more. Moreover, people aged between 18 and 35 who consider important the connection of the railway station with cycle paths are statistically leaner to adopt the bike train combination as a modal choice, while people aged between 34 and 45 who value bike sharing do not tend to use this modal choice. The application of the accessibility indicator (named AxI) shows that it is a valuable tool for the national application of it on railway stations, as results are not impacted by the number of passengers of the railway station.

A user centered analysis on bicycle train integration

Keywords

Accessibility

Bicycle train intermodality

Behaviour

Sustainable mobility

Simulation

1 Introduction

1.1 Research Motivation

1.1.1 Problem statement

Air pollution is a topic of primary importance due to the impact it can have on human health and the environment. Numerous clinical studies have shown the effect that air quality has in relation to diseases such as heart conditions, respiratory problems, and cancer [1] [2] [3] [4]. Pollution is the alteration of a medium such as air, soil, or water in a way that it becomes harmful to humans and nature. Moreover, today's transportation infrastructure supporting cities is likely to come under tremendous strain as a result of the population shift towards urban areas. The quality of life depends on access to basic resources and opportunities [5]. As prosperity spreads among the population, vehicle usage increases exponentially. In order to meet the needs of the ever-expanding urban population, governments across the world are constantly working on solutions to improve the efficiency of the urban transport networks [6]. A 2022 study conducted by the European Environment Agency revealed that transport alone is responsible for about 29% of Europe’s greenhouse gas emissions and its share is expected to increase further as the decarbonisation of the EU economy progresses faster in other sectors [7]. Since 2008, the European Union has enforced Directive 2008/50/EC, which requires member states to assess air quality and adopt appropriate measures in areas where atmospheric concentrations exceed the imposed limit values. The main objectives of the directive are: environmental protection, safeguarding human health, and evaluating the consequences caused by environmental pollution. To achieve these goals, it is essential to combat polluting sources by identifying and implementing effective measures to reduce their emissions. The key points of Directive 2008/50/EC are:

- Reduction of emissions of air quality pollutants;
- Assessment of air quality;
- Monitoring sites, measurement criteria, and standardized monitoring techniques across the EU;
- More information on pollutants and air quality to fight pollution and its harmful effects;
- Public access to information, greater transparency;
- Cooperation among member states in fighting pollution [8].

In Europe, four pollutants are strongly related to transport activities in urban areas: particular matter (PM10), ozone (O3), nitrogen dioxide (NO2) and benzene (C6H6) [9]. For these pollutants, the air quality limits imposed by the European directive are exceeded. Given that private cars are the dominant mode of passenger transport in Europe and that, in 2022, they accounted for 73% of passenger-kilometres travelled, a trend inversion is very challenging [10]. Reducing GHG emissions in cities can be achieved by adopting renewable energy, low-carbon or zero-carbon multimodal transport, sustainable land use, building construction and industrial processes, and models of production and consumption that are more sustainable, including behavioural and lifestyle changes [11]. Cities, governments and other multinational organisations have been working tirelessly on policies to address this issue. Mobility is a necessity, but given the variety of options available to consumers, it is unsurprising that sustainability rarely factors into picking a mode of transport. To discourage the ownership and use of private vehicles, the public must be provided with alternatives. Increasing the costs of car use is the most effective instrument. Another policy instrument in the transport policy plans of the Dutch government is the reduction of car use by improving alternative modes of transport such as public transport and the use of bicycles. A major obstacle in this policy is the quality of these alternatives in comparison with the use of a private car. For short distances the bicycle in many cases can serve as a good substitute for the car. For larger distances public transport is the only alternative for the use of a car. But public transport is evaluated as far more time consuming and more expensive than the use of the car (by users of car as well as public transport). Besides, travelling with the car is experienced as more comfortable, feeling more independent and having more status. So, the question arises how to improve the quality of travelling with public transport so that it can compete with the car [12]. In order to move towards bicycle train intermodality, governments need an objective method to efficiently allocate resources, concentrating on the priorities of cyclists and trying to understand the reasons that bring a person to the railway station with means other than the bicycle. To reduce car usage, optimal alternative solutions must be offered to users, capable of flexibly meeting their needs. A potential answer to the problem is passenger and freight multimodal transport. A multimodal (also said intermodal) trip is defined as reaching the destination using at least two different modes of transport [13]. One of the most critical points to promote intermodality are solutions aimed at facilitating the connection between different means of transport within a network and between different networks. The promotion requires the presence of specific infrastructure at interchange nodes and a comprehensive and efficient transport network [14].

1.1.2 Research objectives

In order to make bike-train intermodality the primary choice for users, there must be availability of elements that are useful for cyclists when travelling by train (whether they leave their bike at the station or take it with them). It is essential that these two modes of transport, bicycle and train, are highly integrated, since the train, being a fixed-route mode of transport that follows its own line, offers better performance in terms of journey times, but does not necessarily cover the entire desired route. On the other hand, bicycles offer greater flexibility within the city and allow cyclists to reach their desired destination directly. These two modes of transport are therefore complementary to contribute to a cleaner and more environmentally friendly city.

The extensive coverage of the national rail network, including mobility hubs, such as railway stations, passengers and loading points, is a key element in increasing the appeal and accessibility of the rail system, in combination with other modes of transport with a lower environmental and social impact. This integration contributes to the creation of a more sustainable and efficient mobility system. The general research objective is to explore what can have an impact on bicycle train intermodality. Hereafter, the specific research objectives (RO) that this thesis aims to fulfil are explained.

RO1 The scientific literature analysing the determinants of bicycle use is undoubtedly extensive. Multiple studies have explored sociodemographic variables, infrastructural, environmental and psychological variables affecting the engagement in bicycle use. However, the determinants impacting a multimodal trip involving the use of bike may differ. These factors have not been studied as much. The first RO is to analyse what impacts this modal choice. The methodology used to address this issue is made of a general population survey analysed with a General Stucture Equation Model (GSEM). Then a simulation has been done to address which infrastructural elements have an impact on the willingness to reach the railway station by bike.

RO2 There is not a standardized methodology to allocate resources to railway stations and cities to implement bicycle train intermodality. Even though the attention to sustainable mobility, in particular to multimodality, is very high nowadays, and is included in the documents concerning the urban management, there is a gap in a shared methodology useful to identify which railway stations, what urban areas and which infrastructures to prioritize to favour the exchange bicycle train. Currently economic resources are allocated based on availabilities, political influence or local initiatives. This approach risks to generate inefficiencies and territorial inequities. Moreover, impartial and transparent criteria are missing to understand the cost benefit relation for every intervention.

The objective of this study is to provide a detailed description of bicycle-train intermodality, identifying both the strengths and critical issues, particularly in some cities examined. The study involves monitoring the PAIR2020 railway stations, evaluating the presence of certain requirements considered essential to promote the train-bike exchange. The focus is especially on the presence and quality of bike paths at the railway hub, bike parking facilities, proper vertical and horizontal signage, and services dedicated to cyclists.

1.2 Scientific output

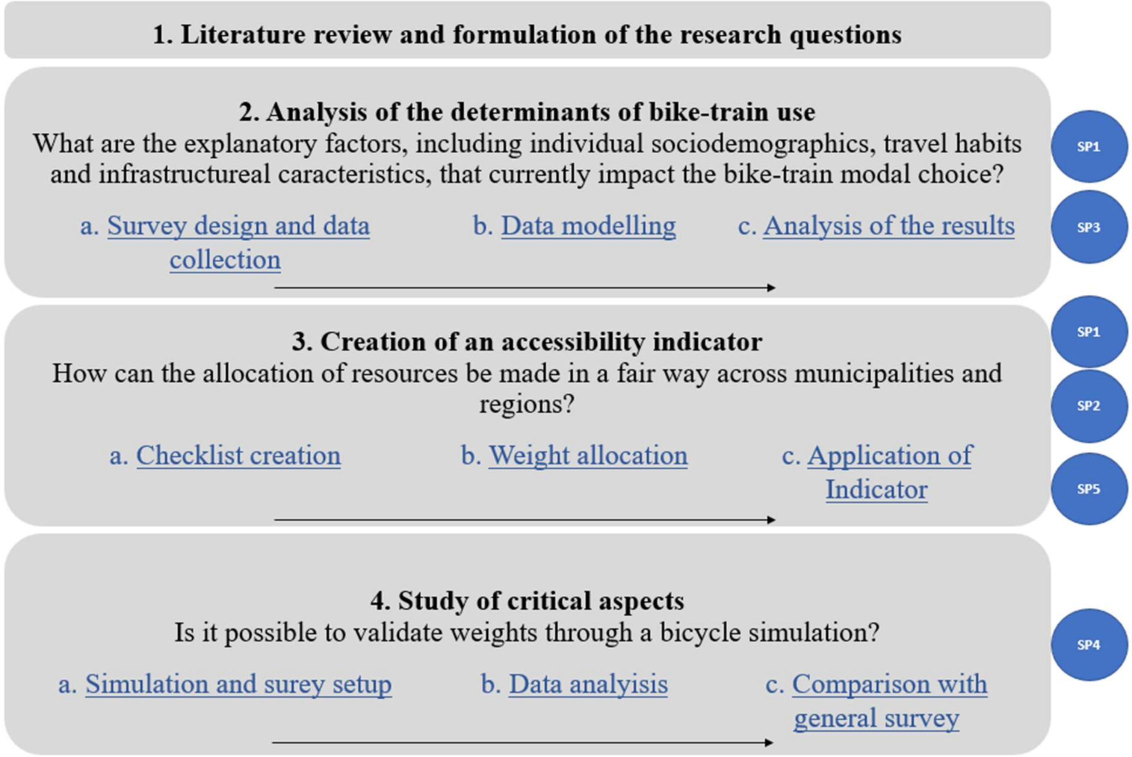
The main body of this thesis has resulted in the development of three Scientific Publications (SP), all of them already published in peer reviewed and indexed journals.

1. **SP1** Pazzini, M.; Lantieri, C.; Zoli, A.; Simone, A.; Imine, H. (2023) Evaluation of Railway Station Infrastructure to Facilitate Bike–Train Intermodality. *Sustainability*. doi: 10.3390/su15043525
2. **SP2** Zoli, A.; Pazzini, M; Vignali, V.; Imine, H.; Simone, A; Lantieri, C. (2025) Assessing Cyclists' Accessibility into Railway Stations Through a User-Centered Indicator. *Sustainability.* doi: 10.3390/su17020504
3. **SP3** Zoli, A.; Pazzini, M.; Lantieri, C.; Vignali, V.; Raffaeli, K; Gaspargo Moro, M.; Andrea, S. (2025) Users' preferences on bike-train intermodality: what can induce travelers to use this type of intermodal transport? Transportation Research Procedia, Volume 90, pp. 448-455. doi: 10.1016/j.trpro.2025.06.121.
4. **SP4** Zoli, A.; Sitohang, I; Adele, S.; Pazzini, M.; Imine, H.; Lantieri, C. (2026) Validation of survey data via bicycle simulation in a multimodal bicycle-train context Journal of Traffic and Transportation Engineering (English Edition), *Under review.*
5. **SP5** Zoli, A.; Lantieri, C.; Simone, A.; Vignali, V.; Pazzini, M. (2025) PREPAIR Report on information and recommendations on the planning of intermodal transport facilities and policies (bike+local public transport, with particular reference to the railway stations).

2 Research program

Figure 2.1 is a synoptic table representing the research framework based on a series of original research activities aimed to understand in-depth the development of a tool to promote bicycle-train intermodality and accessibility of railway stations. The dots on the side represent the relative Scientific Publications (SP) that resulted from each activity, as listed in chapter 1.2.

Figure 2.1 Overview of the steps of the thesis



1. Literature review and formulation of the research questions

2. Analysis of the determinants of bike-train use
What are the explanatory factors, including individual sociodemographics, travel habits and infrastructureal caracteristics, that currently impact the bike-train modal choice?

a. Survey design and data collection
b. Data modelling
c. Analysis of the results

3. Creation of an accessibility indicator
How can the allocation of resources be made in a fair way across municipalities and regions?

a. Checklist creation
b. Weight allocation
c. Application of Indicator

4. Study of critical aspects
Is it possible to validate weights through a bicycle simulation?

a. Simulation and surey setup
b. Data analyisis
c. Comparison with general survey

3 Activity 1: Policy background

The main purpose of personal mobility is access to goods, services and jobs, which is central to transport policy. Although it is rarely assessed directly, its presence in political discourse is growing. Policy and planning developed by national and local authorities increasingly mention accessibility as an objective. The provision of safe, affordable, accessible and sustainable transport systems for all is at the core of the United Nations (UN) Sustainable Development Goals and is a central commitment for the UN New Urban Agenda [15].

3.1 What is bicycle train integration?

A futureproof city focuses not only on cycling, but searches for synergies with other modalities such as public transport, walking, and the automobile. Intermodality is the opportunity to reach a destination without using the private car, and substituting it with public transport and reaching the last mile with the private bike or using the bike sharing service. Intermodality is very popular in the north of Europe, where travellers use both the bicycle, the private car, and the public transport to reach the place of work. There are mainly two options for intermodal travel combining bicycle and train.:

a. Cyclists may leave the bike at the station and then travel by train. In this case, stations should provide special parking facilities. Parking areas solve the transport problem, but to be effective, they must not only be located near the station, but also ensure security and surveillance to minimise the risk of theft and vandalism. One possible solution to this problem is bike sharing, a paid service that allows users to borrow bicycles from specific collection points for limited use during the day. This option is advantageous, but must be made available in sufficient quantities to meet demand.

b. Cyclists may take the bike with them. This form of integration mainly helps to boost rail transport, making it very accessible, and thus helps to eliminate the disadvantages and negative aspects associated with travelling by private motor vehicle. In this case, trains should allow these vehicles to be transported and therefore have special carriages.

Suraci [16] stated that there are four types of bicyclists to consider when planning the network implementation: “strong and fearless” who will ride regardless of roadway conditions and take a strong part of their identity from riding a bike; “enthused and confident” who prefer bikeways but are comfortable riding on a road, appreciate efforts to improve bikeway infrastructure;

“interested but concerned” are curious about bicycling and like to ride, but are afraid to do so, do not regularly ride and will not venture onto the arterials; lastly, the type “no way no how“ is not going to ride a bicycle, for reasons of topography, inability, or simply a complete and utter lack of interest. Bicycle-train integration should endeavour to reach all potential customers who bike, considering this spectrum and understanding what types of behaviour to expect from each group [17].

3.2 Strategies to improve bicycle train integration

There are many factors which may drive bicycle integration with transit in every community, including the desire to lower carbon emissions, lessen the demand for automobile parking, and reduce vehicle miles travelled. Proactive planning for creating bicycling opportunities for integration can drive increased transit ridership while minimizing conflicts and providing more connections [18]. Generally speaking, to make the bike train trip more competitive in respect to the car the journey by car has to be relatively more time consuming or inconvenient, for instance in urban areas where the traffic is high, the train will result faster. On the other hand, public transport has to be optimised to make the competition with private cars possible. One way to do this is to use a bicycle before and/or after the use of public transport in one trip. In this way, the journey-time from origin to destination can be shorter than only using a train and the use of public transport becomes more attractive [19]. Also, the "main" part of the trip (train, metro, express bus…) can be improved for instance with less stops, more direct connections, higher speeds, higher frequencies and more reliability. All modes could profit from an 'high quality' network: local public transport, train-taxi, shared taxi, transport for elderly and handicapped and private cars. All these modes could reach higher standards [12].

3.2.1 International best practices

United Kingdom

The UK National Cycle Network is made up of 12000 miles of cycling, walking and wheeling routes. This represents a significant civil engineering infrastructure asset that currently contributes to the provision of a sustainable transport mode option nationwide. It is a network that keeps high standards thanks to commuting and recreational cyclists, that often observe the hazardous conditions on these paths and report them. Different methods are in place to improve the network:

i. Establish clear governance to bring together land managers, funders, users and others to deliver recommendations in partnership;
ii. Introduce a process for designation of parts that cannot be improved, and a clear process for incorporating new routes that fill gaps or make new connections;
iii. Remove or redesign all barriers to make it accessible to everyone, with no barriers in place for continuous travel;
iv. Replace existing on-road sections with new traffic-free paths or by creating quiet-way sections so it is safer for everyone;
v. Ensure that on a quiet-way sections the speed limit is 20mph in built-up areas and 40mph in rural areas;
vi. Improve safety where the network crosses roads or railways;
vii. Adopt a new quality standard to ensure path widths and surfaces are suitable for everyone;
viii. Improve signage so everyone can use the paths without a map or smartphone;
ix. Deliver activation projects to demonstrate change.

Also, they have built a prioritisation checklist to help with the identification and prioritisation of the projects: (1) Does the project support the strategic aims of the Network in the region? (2) Does the improvement support access for all? (3) Does the project support the delivery of a traffic-free Network? (4) Does the project improve the safety of the section of the Network it deals with? (5) Does the project improve a section of the Network that has high current usage? (6) Is there good potential for increased usage in the future? (7) Is there land funding available for this project? (8) Is there landowner support for this project? (9) Is there community support for this project? [20]

European Union

According to the Transport and Environment report of 2021 the growth in transport emissions is mainly due to the increase in transport demand, combined with the dominant and slightly rising share of car transport among land transport modes. The climate impacts per passenger-kilometre travelled by car are substantially higher than those of public transport and active travel modes (walking and cycling) [21]. For this reason, one of the main ways to reduce the impact of transport on emissions is to shift towards modes that emit fewer greenhouse gases and towards non-motorised modes such as cycling and walking. In Italy, data suggest that mobility is predominantly a local, short-range phenomenon, since most traffic flows do not take place on long-distance networks but rather within limited spatial scales, covering short or even very short distances, and requiring relatively little time. The EU's ongoing legislative efforts reflect a clear strategy to position cycling and rail as complementary modes of transport, essential for achieving the goals outlined in the European Green Deal and the EU's broader sustainability agenda, and the strong commitment to promoting sustainable mobility, with a particular focus on integrating cycling with railway travel. These efforts do not only consist of guidelines but also of legally binding commitments that require member states to adapt their national railway networks to accommodate bicycles. The EU’s legislative framework pushes for greater multimodal connectivity by incentivizing railway operators to invest in infrastructure that supports the integration of bicycles on trains, making them a natural part of everyday travel. The regulations also address practical challenges, such as ensuring secure bike storage at train stations and creating policies that require adequate facilities for bicycles on both urban and long-distance trains.

The integration of bikes transportation within railway systems is becoming increasingly significant to address the growing challenges of congestion, and environmental sustainability. With the rise of multimodal transportation solutions, rail operators are recognizing the importance of providing options for cyclists, to improve the overall customer experience and reduce dependency on personal vehicles. This shift is driven by the need to cater to urban dwellers who seek flexible and eco-friendly travel options. The *European Declaration on Cycling* plays a crucial role in shaping policies that integrate cycling into broader transport strategies [22]. This declaration is a collaborative effort by the European Commission, the European Parliament, and the Council of the EU, and it aims to promote cycling as a sustainable and efficient mode of transport.

Regulation (EU) 2021/782 on Rail Passengers’ Rights and Obligations strengthens the rights of passengers traveling by train, including provisions for carrying bicycles on board. This regulation mandates that new and refurbished trains in the EU must have in principle a minimum of four dedicated spaces for bicycles, ensuring that cycling is a viable and accessible option for travellers throughout Europe. This requirement aims to standardize the accommodation of bicycles on trains across all EU member states, ensuring that passengers can more easily combine cycling with train travel, thereby promoting sustainable and multimodal transport options [23].

The EU’s TEN-T policy also indirectly supports the integration of cycling with rail transport by developing a comprehensive network of roads, railways, airports, and water infrastructure across Europe. The focus is on creating a seamless, sustainable, and efficient transport system that encourages the use of environmentally friendly modes of transport. TEN-T's development aims to facilitate easy connections between different modes of transport, including cycling and rail, promoting the reduction of carbon emissions and congestion in urban areas [24].

European Cyclists' Federation (ECF) advocates for the implementation of clear requirements regarding the number of dedicated bike spaces on trains, highlighting that such regulations are essential to accommodate the growing demand for bike-and train travel. The specific number of bike spaces required can vary depending on the train type and its intended service route. For example, regional and commuter trains, which serve areas where short-distance travel is common, typically need to allocate more spaces for bikes than long-distance or high-speed trains [25].

#ChallengeMyCity is an EIT Urban Mobility (EITUM) program that assists European cities in testing innovative and sustainable solutions to solve specific mobility-related problems in their urban environment. These solutions focus on the needs of the cities, complementing their planned political and financial commitments [26]. The #ChallengeMyCity project involves identifying mobility-related issues through public engagement workshops, which are conducted in conjunction with the cities to make sure it fits within their strategic agenda. This is followed by inviting start-ups or other businesses to develop solutions to address these specific challenges that are identified through the workshops. Once the solutions are in place, a pilot launch event with public participation is done to introduce the initiative to the public and persuade them to try the solutions. The solutions are tested throughout the pilot phase, which can last anywhere between 6 and 12 months. Finally, the data from the pilot phase is collected and the efficacy of the solution is evaluated in terms of its impact. Analysing the impact is necessary for the cities to understand if the solution is feasible, scalable or can be replicated in other areas [27].

The Netherlands, Denmark and Germany have integrated the bicycle into public transport, recognising the important role of the bicycle as feeder mode. The Netherlands stands out as a leading example in the integration of bikes and trains, achieving an ideal ecosystem that many other countries strive to replicate [28]. A strong argument in favour of combining modalities can be found in the success of the bicycle policies of the Netherlands Railway (NS). Key elements in this strategy, other than long and continuous cycle paths, include the public transport bike (OV-fiets) and the extensive parking facilities at Dutch railway stations. Dutch railway stations offer unparalleled bike parking infrastructure, with over 510,000 spaces available nationwide, and an ambitious goal to increase this to 600,000 by 2027. Low access train design and well-placed bike compartments ensure easy boarding and deboarding for cyclists. These features are complemented by strategic placement of bike parking close to station entrances, enhancing the overall accessibility for multimodal travellers. These strategies benefit both the cyclists (proper facilities) and NS, as close to 50 percent of all train commuters arrive by bicycle. By facilitating these cyclists, NS largely increases its customer base [29]. In the Netherlands, the bicycle is a very important mode for accessing train stations; it has a 38% share in the modal split for those people who live up to 3 km from a train station [30]. In Germany and the UK, 40% of bicycle users only cycle up to 2 km to a train station [31].

Italy

In general, in Italy, the gradual expansion of infrastructure dedicated to cycling mobility in provincial capital cities continues. In 2022, there were 27.9 km of cycle paths for every 100 km² of land area (compared to 21.1 km in 2015). However, there are significant disparities between cities in the North (66 km per 100 km²) and those in the Centre (18.3 km), and especially compared to those in the South (only 6.5 km, ten times less). Regarding policies to mitigate car traffic, pedestrian areas and Limited Traffic Zones (ZTLs) are now present in almost all provincial capitals (with a few exceptions in Central and Southern Italy). As for 30 km/h zones, their presence ranges from 100% in Northern and metropolitan cities to 50% in Southern capitals. During 2022, most cities maintained the situation of the previous year, some expanded these areas, and almost none reduced them [32].

RFI (Rete Ferroviaria Italiana), in Italy, introduced specific regional trains that not only comply with European accessibility standards, but they have also been optimized to meet the needs of major associations representing people with reduced mobility. They have been designed to offer greater comfort to those who wish to transport a bicycle on trains. One type of train is equipped with specially designed horizontal racks, which makes it easier for anyone transporting a bicycle by train, as the bike can be placed horizontally without the need to lift it. A potential issue could arise from the fact that only the bicycle's wheel can be secured, and not the frame. A second type of train is equipped with vertical racks, which require the bicycle to be lifted and placed in an upright position. One of the challenges associated with this system is that it does not allow the bicycle to be locked, making it potentially vulnerable to theft. Additionally, this type of train also offers the possibility to charge electric bicycles through dedicated charging stations.

The Regional Integrated Air Plan (PAIR2020), approved with Legislative Assembly Resolution No. 115 of 2017 in implementation of Legislative Decree 155/2010 (which implements Directive 2008/50/EC on ambient air quality and cleaner air in Europe), sets specific goals for reducing traffic flows through the implementation of measures aimed at increasing the modal share of cycling, walking, and public transport [33]. The PREPAIR project (Po Regions Engaged to Policies of AIR), an integrated LIFE project coordinated by the Emilia-Romagna Region, which involves the regions of the Po Valley basin in implementing measures to support regional air quality plans is also involved in ameliorating intermodality. The Prepair includes initiatives that facilitate the transport of bicycles on trains, with around 630 trains suitable for carrying bicycles operating solely in the Emilia-Romagna region. The existence of dedicated areas for parking and storing bicycles at railway stations, metro stops, and bus terminals encourages users to integrate bicycle use with public transportation for longer journeys. Part of the project focuses on monitoring the infrastructure of the main railway stations in the Emilia-Romagna Region to promote intermodality between people and urban transport, specifically bike train combination. The investigation is especially focused on train-bicycle intermodality in 33 cities of Emilia-Romagna. The decision to promote the intermodality of transport modes is based on the goal of achieving environmental and quality of life objectives, significantly reducing the use of private cars in favour of public transport or non-polluting means such as the bicycle. The cycling paths located within an urban area include several types:

- Cycling lanes in their own dedicated right-of-way, minimizing the risks of intrusion by motor vehicles;
- Shared pedestrian and cycling lanes;
- Shared cycling and vehicular lanes.

Within this general framework, the Sustainable Urban Mobility Plan (PUMS), through the interventions defined in the Metropolitan Biciplan, identifies the strategic cycling network for daily mobility as well as the cycle-tourism network, for which it defines the technical and performance standards, and the design criteria (Annex 3: Guidelines for the Design of the Cycling City, developed and approved by the Emilia-Romagna Region). These guidelines also outline a wide and structured range of services to support cycling mobility and its long-term consolidation, such as bike sharing, parking and storage, e-bikes, urban cycle logistics, bicycles for social mobility, cycle-tourism services, apps and communication tools, as well as guidance for managing the development of electric micromobility. For each type of route or intervention identified in the Biciplan (strategic cycling network, cycleways, cycle-tourism itineraries, etc.), it will be appropriate, where possible, to plan effective connections to Mobility Hubs and railway stations. The Plan also foresees improvements and extensions to bicycle infrastructures and services near these hubs, increasing the availability of bike parking spaces [34].

Veneto Region has become a leading region for cycling in Italy, offering a quarter of all bicycle spaces on Trenitalia rail carriages and integrating cycling with rail travel. The region's commitment to cycling is also evident through its robust network of cycle lanes and dedicated infrastructure. The introduction of the 'Tutto Bici' supplement for train travellers has boosted this trend significantly, with sales increasing by 45% within a year. The 'Tutto Bici' service caters for the Bologna–Verona–Trento–Bolzano–Brennero line, passing through scenic, cyclist-friendly areas. Veneto alone provides 6,240 bicycle spaces daily, 896 of which are specifically for this route. Data revealed that up to 9,000 cyclists used the service at weekends in summer 2023, highlighting the region's popularity with cycling tourists. Despite previous challenges in integrating bicycles with rail travel the "Tutto Bici" initiative in Veneto stands out as a successful model. It complements major national cycling routes such as the Alta Italia and Ciclovia del Sole, establishing the region as a key destination for cycling tourism in Italy [35].

3.2.2 Determinants of bicycle use

The determinants of bicycle ownership and use among the population has been investigated in multiple settings. The main factors that impact a person’s decision to use a bicycle are:

- Objective: climate, topography land use and infrastructure; for instance, infrastructure includes bicycle lanes, bicycle parking, and support facilities as well as the infrastructure provided for other modes. The level of connectivity of a cycle lane may also affect cycling rates.
- Subjective: perceived safety, personal habits and attitudes, as well as social context.
- Demographic: physical condition, family circumstances, income, age, race/ethnicity, immigration status and sex.

Factors such as climate and terrain, land use, and infrastructure play an important role in influencing cycling behavior [36]. Infrastructure includes not only dedicated cycling facilities like bike lanes, paths, and shared roads but also amenities such as bike parking, workplace showers, and bike racks on public transport [37]. It also considers the infrastructure available for alternative modes of transport that compete with cycling. Numerous studies suggest that improving cycling infrastructure can encourage more people to ride bikes [38] [39] [40] [41]. Some research shows that cyclists often prefer using designated bike facilities, even if it means taking a slightly longer route [42]. Most of this research relies on broad datasets, self-reported preferences, or specific subpopulations. For instance, a study examining major U.S. cities found a correlation between higher bike commuting rates and greater availability of bike lanes [43]. The use of aggregate census data limits the ability to directly assess how infrastructure influences individual cycling behavior. However, through a large literature review it was found that preferences for cycle infrastructure vary by gender and age, and that differences in preferences are quantitative rather than qualitative, meaning that for instance preferences for separated infrastructure are stronger for some groups than in others, but no group prefers integration with motor traffic [44]. In many regions lacking extensive bike lanes, cyclists rely on the street network for everyday travel [45]. The structure and connectivity of streets can significantly influence cycling rates, especially for functional, everyday trips. Travel behavior theory suggests that people seek to minimize travel time; for cyclists, this means having a direct and efficient route. Grid-like street patterns tend to offer more direct paths and route options, which can support cycling. Some studies using travel data show a positive relationship between street connectivity and non-car travel [46]. Observations indicate that the type and width of cycling facilities affect how closely cyclists travel alongside cars [47]. Other factors influencing cyclist comfort include pavement quality, traffic speed and volume, and lane width [48]. Yet, these studies do not conclusively show whether such factors lead people to choose cycling more often. Land use influences the positioning of trip origins and destinations, which, combined with infrastructure, shapes the realistic distance of potential bike trips. However, research directly connecting land use and cycling is even more limited than that related to infrastructure, partly due to the low number of cyclists in urban travel surveys. These surveys often only span a single day and may not capture infrequent bike trips. A study in the San Francisco Bay Area found that having a diverse mix of land uses at the starting point of a trip increased the likelihood of biking. Design features that support cycling, such as a well-connected street layout, also had a positive effect [46]. On the contrary, in Seattle, the presence of convenience stores (often paired with gas stations or located along busy roads) was associated with reduced cycling. The study also found that subjective perceptions, like how bike-friendly a neighborhood felt, had a strong influence on cycling. People who perceived bike lanes and trails in their area were more likely to cycle, while those near schools and stores were less likely to ride [49].

Environmental factors like weather and topography also affect cycling decisions and performances [50] [51]. Cold and rainy conditions generally discourage bike use. For example, a study found that the number of rainy days negatively impacted bike commuting [52]. However, the Netherands still maintain high cycling rates despite rain [53]. The effect of terrain is less definitive. Some research shows a weak link between hilly terrain and lower cycling rates [54]. A stated preference survey found that cyclists favored flat or moderately hilly routes over steep ones [55]. Yet, this survey involved a self-selected group of frequent cyclists, which may have skewed the results. Another study found that while steep slopes discouraged biking, rain had less of an impact [46]. Although climate and topography are outside the control of city planners, understanding their impact can help in designing better policies. Some cities may underestimate the potential for cycling by placing too much weight on these environmental barriers. Improved cycling infrastructure might reduce the influence of hills and rain. For example, integrating bikes with public transport could offer cyclists an alternative during bad weather or when traveling uphill.

Subjective factors influencing bicycle use include perceived safety, convenience, cost, time sensitivity, health or fitness benefits, personal habits, attitudes and values, and social acceptance [56]. The National Bicycling and Walking Study also identifies distance as a subjective element, since individuals vary in how far they’re willing to ride [57]. Importantly, a person's perception of their environment and infrastructure may differ from objective measurements, and these perceptions can significantly shape their travel decisions. These subjective influences often differ depending on the purpose of the trip and the demographic characteristics of the individual. Concerns about safety are not unfounded: in 2001, U.S. cyclists faced a fatality rate 12 times higher per mile traveled than car occupants [58]. Many studies have explored how different infrastructure designs affect cyclists’ route selection and their sense of safety, using both observed behaviors and self-reported preferences. However, these studies typically focus on experienced or frequent cyclists. For example, findings show a general preference for marked bike lanes over wide road shoulders. While these insights are valuable for infrastructure planning, they don’t necessarily explain how to encourage occasional or non-cyclists to start cycling. In a 2002 survey, adults who hadn’t ridden a bike in the past month expressed lower satisfaction with how their comminity accommodated bicycle safety. The most common suggestion for improvement was to expand bicycle infrastructure [59]. However, the study didn’t include objective data about the existing infrastructure in respondents’ areas, which limits the interpretation of these responses. Additionally, fears about neighborhood crime may further discourage cycling. Attitudinal and psychological factors also play a role in shaping travel behavior and engagement in physical activity. A study conducted in Trondheim Norway found that people with pro-urban or pro-environmental attitudes were more likely to adopt alternative travel behaviors like cycling. For instance, promotion of active modes of transport among university students would probably lead to more stable environmental outcomes in the coming decades. Furthermore, university students represent a convenient and easily accessible population as they tend to use a wide variety of transport modes [60]. Moreover, psychosocial elements, such as having social support, a strong sense of self-efficacy, and a positive mindset toward physical activity, are key predictors of whether someone chooses to bike. These internal factors may also interact with external environmental conditions in influencing cycling behavior.

Demographic characteristics that may influence cycling behavior include factors such as an individual's physical health, family responsibilities, income level, age, race or ethnicity, immigration background, and gender [61]. A study specific on shared-use-paths (SUP) found that higher levels of education influence the likelihood of SUP utilization, while the higher frequency of SUP usage is influenced by the secondary modes of transportation. On the other hand, as the age increases, the likelihood and frequency of SUP usage decreases. Further, households with higher income are associated with a higher likelihood of SUP utilization, male residents are likely to use the SUPs more frequently compared to their female counterparts [62]. Depending on the cultural context there is a difference in frequency of cycling between men and women. For instance, in the Netheralnds, Germany, and Denmark men and women bicycle at relatively equal rates, however, in the United States, men’s total bicycle trips surpass women’s by a ratio of at least 2:1 [63]. Research has produced mixed results regarding the relationship between income and cycling activity. A study conducted in Seattle by Moudon et al. observed that cycling was more common among white, middle-aged men, especially those who worked fewer hours and had more than one vehicle available per adult in the household [49]. Another study found that people in lower-income household cycle less for transport, particularly for commuting, than people in higher-income households [64]. Regarding age differences, individuals aged 25 to 45 are more likely to cycle than those aged 18 to 21. Among young people the use of the bike often changes over time to become less utilitarian and more recreational and occasional. The main determinants explaining cycling practices among young people are socialization (the parents’ cycling practices and level of education), gender, and the spaces of everyday life (place of residence and school) [65].

3.2.3 Drivers of bicycle-train integration use

A number of different factors influences the success or failure of the initiatives to encourage the use of bike and public transport. The study of these factors contributed to **SP1**. Attitudes towards station environment and perception of connectivity and perceived quality of bicycle facilities are important factors in the choice of cycling to the railway station. Regarding perception of connectivity and bicycle facilities, one of the most important factors is the quality of unguarded bicycle parking. Similarly, bicycle facilities at the station are best perceived by a good quality of bicycle access roads. From the user's point of view, the connectivity of departure station mostly manifests itself in two elements of service level: punctuality and frequency of train service. Regarding the attitude towards the station environment, one of the most relevant elements is the quality of bicycle parking, having a positive influence on cycling to the station. The higher the valuation of the station environment, the higher the probability of cycling to the station. Low quality of lighting in station surroundings discourages train users from accessing the station by bicycle. The availability of high-speed trains at the station also discourages cycling to the station. Regarding the perceived quality of bicycle facilities, the assessment of unguarded bicycle is more important than the assessment of unguarded bicycle parking. A discount for train use would make the train more attractive, and this is also associated with more bicycle use. However, a student card, which is an indicator of occupation, is negatively associated with bicycle use because it reduces public transport cost, making public transport more attractive than cycling to the station. Other deterrents include longer travel time of the main journey, car availability, access distances greater than 3.6 km [66]. Other research states that the use of bicycle for the first or last mile of the trip is encouraged if the distance ridden is between .5 to 4 kilometers to and from a bus stop or station. The use of bike and public transport can only be a realistic alternative to car use if the public transport link has very high standards in: travel time, reliability and frequency. For the use of bicycle and public transport a total travel distance of at least 10 to15 kin. is appropriate. Cycling to the station is more frequent in areas with lower residential density, thus the effect of residential density is negative. A research from Bristol found that the main motivators for bike train intermodality are saving time and saving money, and getting exercise [67]. The decision about parking the bikes overnight (at the destination station), and parking the bike only during the day is influenced by the security of bicycle parking, the perceived security of parking, the ease or difficulty of taking a bicycle on the train, the distance at either end of the rail journey and the journey frequency.

A key requirement for successfully combining cycling with public transportation is ensuring high-quality service on the main leg of the journey, which is typically the public transit component. This combination can only present a viable alternative to private car use, if public transport offers fast, frequent, and reliable service, with a minimum frequency based on the needs. The bike-transit combination is most suitable for total travel distances ranging between 10 to 15 kilometers, with the cycling portion ideally covering 0.5 to 4 kilometers on either end, connecting the user to and from a transit stop or station. Using a bicycle for these initial or final segments can significantly reduce wait times and enhance the overall reliability of the trip. In theory, a high-quality public transport network serving distances of at least 10 kilometers is achievable, especially in densely populated urban regions. In such areas, complementary modes, including bikes, local transit, cars, taxis, shared rides, and services for specific groups such as the elderly or disabled, can serve as feeders. Using these feeder options would allow for a larger-scale, faster, and more efficient public transport system, with fewer stops, higher speeds, better reliability, and improved service frequency. As the network expands, feeder services can also be enhanced. In practice, when networks are restructured to cover larger areas, some former users of the denser network discontinue their use, while others begin cycling to access bus stops. Moreover, new users were attracted to the system. This raises an important question: what network structure and scale are most effective in replacing car use within specific regions? Another important aspect is bike storage availability at transit stops and stations. Enhancing bike parking at express bus stops, for example, has led not only to an increase in cycling to these stops but also to a broader rise in overall bus usage. Improvements in bike parking facilities have also enhanced both the perceived quality and image of bus stops. In addition, station and stop design can significantly affect passengers' travel time and comfort, influenced by elements like walking distances, stairways, and the quality of storage options. Infrastructure for cyclists is also a critical component. Providing safe, fast routes to public transit in urban, suburban, and even rural areas is essential. Giving priority to cycling infrastructure in road planning and traffic management can elevate the status of cycling and other car alternatives. At either end of the journey, whether at home or at the destination (work, school, shopping, or recreational areas), there must be secure bike parking. In the Netherlands, safe bike storage has proven to be a major factor in encouraging cycling. Additionally, bike availability plays a role. Bicycles should ideally be accessible at both ends of the trip. For commuters, employers might provide bikes or subsidies, just as they do for car or transit users. To promote the bike-transit combination, employers may need to cover the costs of public transport and bicycle-related expenses such as storage or maintenance. However, current long-term agreements between employers and employee organizations often favor car or public transit use alone, rather than the integrated bike-transit approach. Public transport providers could help encourage this integration by offering incentives like discounts for bringing bikes on board during off-peak hours. The use of public transport and cycling can also be influenced by how easy it is to book and pay for the entire journey. Fragmented payment systems for each segment of the trip do not align with modern marketing strategies that treat the entire journey as a single, seamless service with consistent quality and pricing. The way this combined travel option is presented to employees plays a significant role in its adoption. Many employers are skeptical, often perceiving disadvantages without recognizing the benefits. Their choices tend to be shaped by existing travel habits. Interestingly, trials where employees were encouraged to switch from cars to bike-transit commutes, on a voluntary basis and without additional costs, showed that many participants reported positive experiences. Ultimately, people will always compare the overall quality of the bike-transit journey to that of other travel options. For example, car parking availability at the workplace remains a critical factor influencing whether individuals consider alternative modes like cycling and transit. [68].

3.3 Methodology

After a review of scientific literature on the determinants of bike use and bike combined with train use, some existing gaps that still need to be filled are identified and formulate the research questions of this thesis. This step aims to gain deeper understanding of the drivers of bike train intermodality use. The modelling framework chosen to analyse this dataset was a Path Analysis combined with a Multilevel model. The former allowed to disentangle the correlations between the potential direct and indirect impact of socio-economic characteristics and travel habits of the individual on bike train intermodality use. The latter was implemented to account the possible heterogeneity that could exist between different bike train intermodality frequency users.

3.3.1 Survey campaign

The data employed for this thesis are primarily derived from a survey conducted in Italy, of which preliminary results have been published in **SP3**. A sample survey was conducted among the Italian population, without applying restrictions based on age, gender, ethnicity, disability, income, or other socio-demographic variables. The questionnaire was distributed online through both email and LinkedIn, and it received a total of 1,125 responses. The survey remained available for one month, and the average completion time was approximately 10 minutes. Prior to the full rollout, a pre-test involving 20 interviews was carried out to detect any questions that could be misinterpreted or misunderstood by respondents [69]. The final survey included 21 questions, divided into several formats: 9 multiple-choice questions, 1 true/false question, 5 open-ended questions, and 6 items using a 5-point Likert scale to get as much information as possible in the shortest amount of time. These questions were organized into four key sections: Section 1 gathered socio-economic data such as gender, age, place of residence, education level, and employment status. Section 2 focused on the respondents' current travel habits to work or school, along with the motivations behind their chosen modes of transportation. Section 3 explored participants' willingness to engage in bike-train intermodal travel, and their overall interest in adopting cycling as a regular means of transportation. Section 4 addressed the specific preferences and priorities of users when planning or considering a bike-train intermodal trip. Within the third section, respondents were categorized based on their current cycling behaviour. For non-regular cyclists, a 5 points Likert scale was used to determine which factors might encourage them to begin cycling (1 indicating no influence, and 5 indicating strong influence). Conversely, for those who do cycle but do not feel safe, a different Likert scale assessed which features would enhance their sense of safety while riding (again using a 1 to 5 scale). An overview of the operational characteristics of the survey campaign and the specific variables captured is displayed in Table 3.1.

Table 3.1 Summary of the variables included in the survey

	Variable included in the survey	**Variable choices**
Part 1	Socio-economic characteristics	Gender Age Place of residence Level of education Employment type
	Usual mean of transport	Private car Car sharing Train Bus More means of transport including train More mean of transport excluding train Private car shared Scooter/moped Bicycle Depends on the wheather

	Regular mean to reach the RS	Bicycle Electric bicycle Folding bicycle Bike sharing/escooter sharing Foot Private car Car sharing Scooter/moped E scooter Bus
	Frequency of use of bicycle train intermodal trips	
	Frequency of use of bicycle	
	Perceived safety riding	
	Elements that would provide increased perceived safety	Cycle paths protected by unsurpassable limitations Cycle paths fast and direct (even if using cycle lane) Parking spots Lighting of the cycle path Signs on the cycle path Bicycle deposits Steepness of terrain Vehicles interference Raised above level cycle paths
	Elements that would increase engagement in using bicycle	Cycle paths protected by unsurpassable limitations Cycle paths fast and direct (even if using cycle lane) Parking spots Bike sharing Signs on the cycle path Bicycle deposits Vehicles interference Appropriate outfit

		Bicycle parking spots Showers and locker rooms at destination Lighting of the cycle path Steepness of terrain Closeness to points of interests Risk of bike theft Owning a low cost bike Physical fatigue Air pollution Wheather conditions Raised above level cycle paths
Part 2	Cycle path related elements that would increase engagement in bike train intermodality	Closeness to the RS Direction Punctual obstacles Pedestrian interference Vehicles interference Maintainance Colour of the pavement One way rather than two ways Parked cars on the side of the cycle path Lateral interference due to driveways Signs indicating point of interests

	Cyclist’s related services close to the RS	Lighting of the RS square Pedestrians’ interference close to the RS Vehicles’ interference close to the RS Bike sharing Dockless bike sharing Maintainance column Direction for cyclists to lifts and platforms Ramps and access lifts Visibility of bike racks Bike racks High bike racks Bike deposit distance/cost/services/opening hours/access method

The responses of the survey are spread all over Italy, with a majority in the north as shown in figure 3.1

Figure 3.1- Spread of responses through the Italian territory

The respondents of the survey are mainly people travelling with their bike (43.06%) and on a smaller share, people travelling with motorized vehicles (18.15%). The mean age of the respondents is around 51 years old and mainly males (table 3.2).

Table 3.2. Main transport mode of interviewed people

Travel Mode	% of Sample	Mean Age (M)	SD	Sex
Bicycle	43.06	55.34	13.72	37.63 females; 0.65 other
Train only	4.72	48.90	14.94	41.18 females
By foot (pedestrians)	7.5	53.09	16.04	37.04 females
Train combined with other transport modes (Other transport mode is bike)	13.43 (73.10)	50.15 (48.38)	15.44 (15.01)	30.34 females; 0.69 other
Multiple transport modes excluding train	2.59	58.82	12.43	28.57 females
Bus	2.22	39.75	15.79	37.50 females
Motorized vehicles (scooter, private car, car sharing)	18.15	54.16	12.38	43.00 females
The mode of transport variates based on weather conditions	8.3	54.4	12.28	41.11 females; 3.33 other

3.3.2 Modelling techniques

Given the research questions and the characteristics of the data, a series of modelling frameworks have been designed and implemented to fulfil the research objectives. Path analysis (PA) is a widely used statistical technique in behavioural sciences. PA can be considered as an extension of traditional regression models in which several sub-models are jointly estimated, reproducing the variance-covariance matrix between all variables included in the model. It takes as given the structure of relations between all the different variables and the succession of regressions. Consequently, this structure should be established by the modeller based on previous evidence and a sound hypothesis regarding the decision processes faced by the individual. Therefore, the variables can be classified as exogenous, if they do not have a casual relationship with other variables in the model or endogenous if they are assumed to be explained by one or several variables included in the model. PA is particularly useful when a variable that can be explained by series of explanatory factor is in turn an explanatory factor of subsequent variables. Subjective attitudes and lifestyle preferences play a key role in travel choices in regard to the adoption of bike train intermodality and the frequency of use. However, these attitudes are not directly observable, so measure scales that allow to quantify them should be derived from observed behaviours or choices. For this reason, some latent variables are built. This process is done through Factor Analysis. Initially, various tests are conducted to verify that the data gathered in the survey processes match the assumptions needed for a robust implementation of Factor Analysis. In particular, the KMO measure of sampling and the Barlett's test of sphericity are employed to ensure the suitability of the data. An explanatory Factor Analysis is conducted following a Common Factor Analysis methodology and a Promax rotation, to determine the optimal number of factors that could be derived from the dataset, as well as to identify the most suitable indicators that compose each of those factors. The Explanatory Factor Analysis phase allows to define preliminary hypotheses regarding which indicators could be grouped together to build reliable measurement scales for the latent constructs that are intended to be captured. This reliability is evaluated through the Cronbach's alpha, which measures the level of correlation between the indicators that make up a factor [70]. A Confirmatory Factor Analysis is made to estimate the final model to measure the latent constructs and analyse the model's goodness-of-fit and estimate the weights of each indicator on the correspondent factor. The impact of these latent constructs can be included in the modelling framework, together with the socio-economic variables and the declared travel behaviour. The model's specification includes four latent variables capturing the level of importance attached by individuals to specific aspects of the bike-rail infrastructure integration. These dimensions include the availability of safe places to park the bike when leaving it at the station (*personal bike security*), the easiness of access to the station when using the bike (*easiness of access*), the connectivity between the cycling infrastructure and the railway station (*connection to cycle path*) and the availability of bike sharing services (*BS availability*). The latent variables are only considered to impact the adoption and frequency of rail-bike intermodal trips, since they are related to the level of integration between the modes. Structural Equation Model has a more specific nature and is aimed at understanding the impact of infrastructural and dynamic road aspects on the use of bike train intermodality among cyclists. It brings together different statistical techniques, namely factor analysis, generalised linear regression models and path analysis. Structural Equation Models allow to combine latent variables that capture subjective attitudes and preferences. The possibility of building a more complex model where different kinds of variables are introduced is very relevant in this context. At the same time, preferences and beliefs are in turn directly influenced by socioeconomic attributes and both subjective and objective attributes have an effect on mid-term decisions. This second approach allowed to understand in more depth how different infrastructural and dynamic elements may affect the level of use of bike train intermodality. The methodology for this step involved the creation of a GSEM (Generalized Structural Equation Model) to simultaneously study the influence of socioeconomic characteristics, latent constructs, and mobility habits on individuals' frequency of use of bike train intermodality, as well as the impact on these elements on the adoption of bike train intermodality. The GSEM allows the introduction of different types of link function between exogenous and endogenous variables. As a result, this makes it possible to model dependent variables other than those of a continuous nature such as ordinal, nominal or binary responses.

3.4 Analysis of the results to determine key findings

From the analysis of the survey it was possible to state which elements where the most relevant for every type of user, while reaching the railway station by bike and to be encouraged to reach the railway station by bike. Regarding the four latent variables it is found that (1) age negatively impacts the use of *bike sharing*, and that females are more lean to use this service rather than men. (2) *connection to cycle paths* is more important to the people who feel safe cycling and to the ones living in bigger municipalities. (3) the people who feel safe while cycling value less the *easiness of access* (for instance the interaction with pedestrians or vehicles along the way) rather than the people who do not or not always feel safe cycling. (4) people living in municipalities with population included between 19999 inhabitants and 75000 inhabitants value as less important *personal bike security*, compared to municipalities higher in size.

The analysis made considering only the people who use bike train intermodality compared to the ones who never use it, without taking into account the frequency of use, found that the people aged between 18 and 35 who value the connection of the railway station to cycle paths adopt bike train intermodality, while the ones who value bike sharing services are more lean to not use bike train intermodality. In general, older people, as well as females and the people who do not feel safe while cycling, tend to not use bike train intermodality as a modal choice. In contrast, the people who most frequently use the bike, the people who live in municipalities with more than 199999 inhabitants, and the people who own a university degree adopt more bike train intermodal trips.

In case the respondent uses the bike at least once a month to reach the railway station it was found that students and the people who, in general, use the bike will use bike train intermodality as a modal choice more frequently. However, older people and the people who do not feel safe cycling will adopt this kind of solution less frequently. The people who use the bike almost every day and who value the connection of the cycle path to the railway station use bike train intermodality less frequently as well as females who value the importance of bike sharing services.

4 Activity 2: Improving bike-train intermodality and investment through the use of an accessibility indicator

The action C.9.3 of the PREPAIR project, named *Survey on bike infrastructures availability in railway stations* states: *Survey on the necessity of bike infrastructures (parking, ramp, lift access system to the rail line, road sign, electric recharging point, etc.) in the main railways stations of the participating Regions and in the urban area of the Municipality of Bologna, in order to direct funding opportunities to improve intermodal mobility systems (bike + train + local public transport) and bikes parking infrastructures. Analysis of the data obtained from the survey (Piedmont Region) in order to identify the needs of new infrastructures; the results will be integrated in Regional Mobility Plan.* [71], is at the core of activity 2 and contributed to the publication of **SP1, SP2 and SP5.**

To fulfil the aim of action C.9.3, a methodology was built to be able to survey every railway station equally, and allocate resources in a fair way among different municipalities.
The project focuses on the main railway stations of the Region Emilia - Romagna to favour the combination of bike and train. To this purpose, 30 railway stations have been taken as case study. Based on the findings reported in activity 1 and 2, a checklist was created to determine the elements that are likely to increase bike train intermodality.

4.1 What is an accessibility indicator?

Accessibility measures the ease of independently reaching amenities and opportunities (e.g. housing, work, education, recreation, essential services, and social contacts) primarily through land use and the transport system [72] [73]. Improving accessibility, improves social and economic opportunities [74]. Accessibility refers also to the use of products such as consumer electronics, ticketing and vending machines, websites and mobile acts, available for all [75]. Even among the transportation field, the accessibility issue can be treated based on different aspects. One of which includes unevenly distributed transportation in space, meaning that different areas have different mobility levels [76]. Limited accessibility and mobility can result in decreased quality of life and well-being, as well as social exclusion [77]. Accessibility is considered a driving factor of territorial development and a key performance indicator of transport and cohesion policies [78]. Inclusive mobility is part of a set of political priorities defined by several European countries to refer to the social dimension of transport or daily mobility policies. More in general, “inclusiveness” refers to social cohesion, which has been one of the declared objectives of the European Union since the beginning of the 2000s. As a way to facilitate access to opportunities, individual mobility is currently considered as a necessary prerequisite for people’s participation in social activities [79].

An accessibility indicator is a measure used to assess how people, including those with disabilities or limitations, can access and use a service, space, or resource. It evaluates factors such as physical access, digital usability, affordability, and availability of information and services. Indicators are used to identify barriers that prevent equitable participation in society. Governments, organizations, and designers use them to ensure inclusivity in public policies and infrastructures and promote fairness and equal opportunity by highlighting where improvements are needed. The development of accessibility indicators are the building blocks for accessibility-based decision-making frameworks to:

- Establish accessibility as a criterion for decision making;
- Provide a common language for the integration of planning and decision-making between transport and other policy areas towards the common goal of enhancing accessibility;
- Monitor progress in achieving accessibility goals;
- Compare territories according to the access to opportunities or points of interests they offer and thus contributing to making accessibility a central criterion for a policy success [5].

How well the European transport systems perform in providing connections and interactions within the European territory is described by accessibility indicators. For instance, a study from the European Union showed that the average accessibility levels can increase with the increase of population doing road network improvements [80].

4.2 The formation of the accessibility indicator for bike train intermodality (AxI)

The creation of the AxI consists of mainly three steps: the checklist, the weighting of each indicator of the checklist and the application of the AxI to the 30 railway stations. The detailed explanation on how to use the AxI and how each element contributes to this KPI is well detailed in **SP5.**

4.2.1 Checklist

The checklist is made of five categories that include: the quality of the cycle track infrastructure, the visibility of the area outside the railway station and signs to direct the cyclists inside the railway station, the services for cyclists near the railway node, the bike deposit and bike sharing. The five categories make up 109 indicators in total, 76 of which come from the first category (quality of the cycle track infrastructure) as it is measured in the four main cardinal directions (North, East, South, Weast).

The cycling routes connected to a railway station should cover its area of influence and meet the following requirements as much as possible:

- Encourage access to the hub by bicycle for trips under 5 km;
- Create an integrated network of interconnected routes for widespread cycling;
- Prioritize the elimination of problematic nodes within the cycling traffic network;
- Where cycling traffic is mixed with motor traffic, include measures to enhance cyclist visibility (horizontal and vertical signage), ensure safe lane sharing, and reduce vehicle speed;
- Extend areas with speed restrictions (20–30 km/h zones);
- Encourage intermodality between cycling and public transport by improving bike access to the hub and allowing bikes to be carried on public transport;
- Increase the number of secure bicycle parking facilities.

In particular, it is advisable to provide adequately paved and possibly covered parking spaces for bicycles, with clearly marked and visible access points, charging stations for e-bikes, and preferably automated entry systems with user authentication (numeric code via keypad, QR Code, chip on paper, BIP smart card, or app) to improve theft prevention.

Access to cycling routes must be ensured through comfortable, user-friendly lanes with flat, draining, and well-lit surfaces, directional markings, adequately sized traffic islands, or traffic lights that protect cyclists while also ensuring the safety of pedestrians and people with reduced or visual mobility. To make cycling trips to and from the railway station more appealing, it is necessary to guarantee routes that are accessible and comfortable for users of all ages and abilities [81]. In addition to the guiding principles adopted by the PUMS for defining the metropolitan network (attractiveness, continuity, recognizability/readability, directness), the following additional attributes are proposed: (1) coherence: a network capable of connecting all potential origins and destinations, with clear and recognizable routes, consistent safety standards, and key points equipped with rest areas and bike parking; (2) directness: a network based on optimized routes that avoid delays and detours, offering real time savings compared to other transport modes; (3) safety: a network that is both safe and perceived as safe, minimizing conflicts with other forms of transport (motorized or pedestrian) and designed with adequate curvature radii and intelligent drainage systems; (4) comfort: a network free of bumps, dips, or slippery surfaces, kept in good condition, and of adequate width depending on location, flow, and user speed. It should also avoid excessive slopes, allow manoeuvring, minimize nuisances from road traffic (noise, splashes), and guarantee alternative routes during works or detours; (5) attractiveness: a network integrated with its surroundings and landscape, contributing positively to urban design, safe, and well maintained.

In light of these five key characteristics, the main factors to be considered in designing cycling routes include the average cyclist speed, approximately 12 km/h, the minimum width required, taking into account cyclists' dynamic movement, the visibility of crossings, junctions, and fixed elements, the interference from other traffic components (cyclists or vehicles), the need for effective signage and protective elements to guide and encourage bicycle use. When sizing cycling paths, it is also important to consider increasingly common vehicles such as e-bikes, which have higher average speeds. Therefore, optimal dimensions should be adopted whenever possible.

The development of supervised bike stations should be promoted, offering not only parking but also support services such as repair workshops, information points, and bike rental. Alternatively, secure, access-controlled parking facilities should be promoted. Automated access systems with user authentication should be implemented to increase security. The demand for bicycle parking (on-street or structured) may vary significantly depending on each railway station and its relationship with the surrounding area. The choice of parking type depends on pricing, interaction with other transport modes, offered services (e.g., supervised parking), and ancillary services (for bikes and cyclists). Particular attention should be paid to the design of supervised bike stations, which, besides providing secure parking, also offer support services (repair workshop, info point, bike rental, etc.). These are a key element for ensuring bike–public transport intermodality. Where passenger flows are insufficient, or as an interim measure before creating a supervised bike station, it is advisable to develop unsupervised veloparks where users can safely store their bikes. This is a cost-effective solution that can accommodate even a few dozen bicycles.

4.2.2 Weighting of the indicators

The weight was assigned to each indicator based on the survey presented in activity 1. The respondents rated the importance of each characteristic on a scale from 1 (minimum) to 5 (maximum) when asked: "How important is this feature to you when imagining a multimodal journey involving the use of both bicycle and train?". The survey results were normalized on a scale from 0 to 1 and a weighted average was made. The questionnaire used to assign the weights was divided into two sections. The first section concerned general information about the respondent, such as their tendency or attitude toward bicycle use. The second section focused on the preferences of travellers undertaking an intermodal journey. Passenger flows were used to properly size the services of the railway station. In particular: the number of bicycle spaces within a storage facility is considered sufficient when it equals 4% of the station's daily passenger flow. The number of bicycle parking spaces is considered sufficient when there is one space for every 10 passengers using the railway station. Passenger flow data provide objective information on the level of use of the cycling network, the railway station, and the services offered within it. Moreover, they allow for a more accurate estimation of the minimum required capacity of bicycle racks and storage facilities. This is essential to ensure that the infrastructures are adequate to actual demand and can support an integrated transport system that promotes the combined use of bicycles and trains. The values required for applying the indicator refer to: the number of passengers boarding trains daily; the number of passengers boarding trains during peak hours.

4.2.3 Application of the AxI

The use of the AxI indicator has been explained in detail in the *"Report on information and recommendations on the planning of intermodal transport facilities and policies (bike + local public"* **(SP5)**. After the application on 33 railway stations of the region Emilia-Romagna, the main criticalities have been identified. Based on the score each station receives in each category, it is possible to determine where to prioritize interventions. Although each node requires a dedicated case-by-case analysis some general recommendations could be made to achieve a station that best promotes intermodality between train and bicycle.

One of the aspects requiring particular attention is the clear definition of any existing or planned cycle path, ensured through appropriate and orderly vertical and horizontal signage. The external cycle path leading to the station should be clearly signposted from within the railway station itself, guiding users all the way to its access point.

Where a cycle path is present (either one-way or two-way), it should preferably be raised above road level or physically separated from motor vehicle traffic by elements that cannot be crossed and that occupy a width of at least 1 meter.

Special attention should be paid to potential conflicts between pedestrians and vehicles, by properly adjusting the spaces dedicated to pedestrians and cyclists, while taking into account the maintenance and long-term sustainability of the project in relation to growth and increasing passenger flows. It is also important that bicycle parking racks are clearly visible from the entrance or exit of the railway station. Often, bicycle parking areas are not properly indicated by directional signage and are located away from the most direct path to the station. The number of racks must be properly dimensioned. To do this, it is necessary to know the daily passenger flows of the railway station in question. If such data cannot be obtained from the relevant authorities, an on-site survey can be carried out during peak hours (typically between 1:00–2:59 p.m. and 5:00–7:59 p.m.) to assess service availability. Bicycle racks should preferably be covered by canopies. To meet all user needs, bike repair stations are usually installed in many railway stations, although these often require maintenance. Urgent maintenance is recommended for any non-functioning elevators, and where ramps are not available, these should be replaced with elevators of adequate dimensions for bicycle transport (minimum size: 1.4 m x 1.10 m). Bike stations are essential facilities to ensure the safety of cyclists undertaking intermodal journeys, but certain conditions are required to make them usable by as many users as possible. For example, the ideal bike station should be accessible 24/7, free of charge, video-monitored, and located within 150 meters of the railway station. The presence of more than one bike station would allow for the provision of competitive services. The final important feature that defines an intermodal station with respect to cycling is the availability of a bike-sharing service. In particular, this service should be dockless and accessible via a mobile app.

5 Activity 3: Simulating a bike trip to reach the railway station

5.1 Introduction

Bicycle simulators are very popular for studying the cyclist's behaviour and to evaluate cycling safety, in order to avoid the danger from real environments. Simulators are used to find cyclists' behaviour in different contexts with controlled variables and the interaction with other vehicles. In fact, the fear of road accidents is one of the main reasons that discourage people from riding a bike. For the purpose of this research the bicycle simulator has been used to build a comparison with the results of activity 1. This means that the priorities identified through the survey while doing a bicycle train intermodal trip, where compared with the ones identified after the use of the bicycle simulator. In fact, the participants to the experiment were told that they were reaching the railway station by bicycle.

5.2 Methodology

5.2.1 Bicycle simulator experiment

The PICS-L bicycle simulator, developed by the French Institute of Science and Technology for Transport, Development, and Networks (IFSTTAR), was built by mounting a real bicycle on a platform with a single degree of freedom, the steering angle. The simulator is equipped with two friction feedback devices: one provides haptic feedback to the handlebars, and the other is dedicated to the rear wheel. The rear wheel speed and the handlebar angular position are measured and recorded. The perception of friction is generated at the rear wheel by a motor connected to a cylinder in contact with it. To provide more realistic conditions, the simulator is composed of several components, as illustrated in Figure 5.1 and described below.

Figure 5.1 Bicycle simulator at University Gustave Eiffel.

The simulator is made of the following elements:

1. A fan, placed in front of the bicycle, which reproduces the airflow experienced by cyclists in real-life situations. The fan speed is proportional to the speed of the rear wheel.
2. An incremental encoder, connected to the fork, which allows the cyclist to interact with the virtual environment and provides realistic haptic feedback on the handlebars, while measuring the steering angle and speed.
3. A passive mechanical lateral suspension system, which allows participants to slightly tilt the bicycle when turning left or right.
4. A flywheel, connected to the rear wheel, simulates an inertia equivalent to 60 kg of mass in real cycling. The simulator is also equipped with a motor capable of increasing the inertia up to 85 kg, as in real cycling.
5. An incremental encoder connected to the rear wheel, used to calculate the bicycle's speed for use as input in the virtual reality system to determine the cyclist's position and trajectory.
6. Five visual screens installed in front of and beside the bicycle, forming a cave-like virtual environment that provides simulated conditions similar to real life. The displays

offer a 225-degree horizontal and 55-degree vertical field of view to enhance immersion in virtual reality. An additional display device is positioned behind the cyclist's left shoulder to provide a rear view of the road.

In the PICS-L bicycle simulator, the single-track model was used to build a more accurate simulation, aimed at studying the following environmental determinants of cyclists' behavior:

1. The environmental elements to which cyclists adapt their behavior (speed, safety distance, steering, etc.);
2. How cyclists adjust their riding practices when interacting with other road users;
3. How cyclists anticipate risks in hazardous riding situations and what strategies, equipment, or behaviors they adopt to cope with such risks. The mathematical model that controls the simulator was developed by the engineers of the Simulator Team (SimTeam) of the PICS-L laboratory at Gustave Eiffel University (the SimTeam is a group of engineers and technicians at Gustave Eiffel University responsible for the operation, maintenance, and development of the university's driving simulators).

The purpose of this model is to ensure that the simulator operates efficiently in coordination with the virtual environment, rather than focusing on the dynamic parameters of the bicycle itself.

All participants wore the Tobii Pro II Eye Tracker. The Tobii Pro II is an eye-tracking system that enables the study of human cognitive abilities and behavior when interacting with systems, devices, vehicles, and objects or events in the surrounding environment. The eye tracker is used to examine a person's situational awareness and ability to respond effectively to potential hazards.

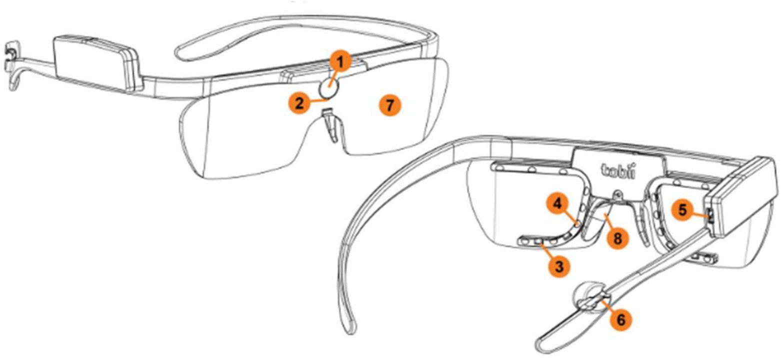
The Tobii Pro II consists of 16 illuminators and four eye cameras integrated into scratch-resistant lenses. It is equipped with a scene camera with a 106° field of view. The main unit of the Tobii Pro II must be mounted on the test participant's head (like a standard pair of glasses). The system must then be calibrated individually for each participant. During the calibration process, the participant is asked to look at a calibration card for a few seconds.

The device is composed of the parts shown in Figure 5.2:

1. High-definition scene camera: captures a Full HD video of what is in front of the participant.
2. Microphone: records sounds from the participant and the surrounding environment.
3. Eye-tracking sensors: record the orientation of the eyes, such as gaze direction.
4. IR illuminators: illuminate the eyes to support the eye-tracking sensors.

5. Micro connector: connects to the recording unit via the supplied main unit cable.
6. Cable guide: routes the main unit cable toward the participant's back.
7. Protective lens: provided in both clear and tinted versions.
8. Nose stand: adaptable for different sizes.

Figure 5.2. Eye tracker device elements



As the simulator represents the movement of the user on the road, it was possible to evaluate not all the elements that were evaluated in the general survey, and then clustered in latent variables, but only the ones from *easiness of access* and *connection to cycle paths*. Referring to the checklist of activity 4, the indicators studied were the ones from *the quality of cycle track in access of the railway station*. The elements evaluated are: the existence of the bicycle lane; the distance of the bicycle lane from the railway station; the type of bicycle lane (at street level or elevated); the absence of fixed obstacles on the cycle path, the absence of conflict with pedestrian traffic, the absence of conflict with vehicular traffic, the horizontal signage, the vertical signage. In addition, the presence of a bicycle lane in the desired direction and the presence of cars parked along the bicycle lane were also evaluated. The list of elements reproduced in the simulation is shown and divided by scenario in order of appearance in Table 5.1.

Table 5.1. Description of scenarios ridden by the participants

Scenario	Characteristic
1	No bicycle lane; cars parked on the right side of the road; three pedestrians; traffic light
2	Dedicated bicycle lane; cars parked on the right side of the bicycle lane; moving vehicles to the left of the participant; traffic light; three pedestrians
3	Dedicated bicycle lane; raised pedestrian path; three pedestrians; traffic light.

4	Bicycle lane on the left side of the roadway, in the opposite direction of the cars (and the participant); parked cars on the roadway; traffic light; lane reserved for buses and bicycles; no bicycle lane; three pedestrians walking on the adjacent raised path.
5	Separate bicycle path; sign "route for bicycles only"; separate bicycle path with parked cars on the left and a raised pedestrian path on the right; trash bin placed on the bicycle path; pedestrian walking on the bicycle path; sign "end of dedicated bicycle path."
6	Two-way bicycle lane; vehicles moving on the participant's left side, toward the participant.
7	No bicycle lane; parked cars on the roadway; truck at the traffic ligh
8	Sign "path reserved for bicycles and pedestrians"; raised path reserved for bicycles and pedestrians; three pedestrians

A total of 33 people participated in the experiment. Twenty participants wore the eye tracker device, as they did not need to use corrective glasses. The experimental procedure included several phases:

6 Bicycle simulator setup: Before the participants arrived, the bicycle simulator equipment was configured and calibrated to ensure accurate simulation. This involved checking and adjusting the bicycle's saddle height and handlebar position. Once the participants were ready, the virtual scene was launched on the simulator screens.

7 Orientation session: Participants were welcomed and informed about the objectives and procedures of the study. They were advised of their right to withdraw from participation at any time, with assurance that doing so would not result in any disadvantage. Before starting the experiment, all participants agreed to take part and confirmed their understanding of the data privacy protocols.

8 Training ride: Participants underwent a detailed introduction that included a familiarization ride to learn how to use the simulator. The purpose of this trial ride was to help them get accustomed to handling, steering, pedaling, and braking the bicycle in a virtual environment. The training scenario included traffic, intersections, and curves, ensuring that participants became comfortable with the simulator's functions and had full control. Participants were allowed to extend the familiarization ride until they felt completely at ease.

9 Main driving experiment: Participants then rode through realistic driving scenarios for approximately 20 minutes. They encountered various access points and interactions with other road users, as described in the previous section. The simulator recorded all bicycle movements, including steering, speed, and distance.

10 Post-simulation questionnaires: After completing the simulator ride, participants filled out a discomfort assessment questionnaire and a specific questionnaire regarding the simulation experience. The discomfort questionnaire is designed to evaluate any symptoms potentially caused by the simulator

The post-simulation questionnaire aims to gather participants' perceptions of the infrastructural elements encountered along the route, in relation to the impact these elements have on their willingness to reach the railway station by bicycle. The questions were designed using a Likert scale format, allowing participants to rate the infrastructural features on a 5-point scale, where 1 indicates a "negative influence" and 5 a "positive influence". The questionnaire is divided into an initial section that identifies the participant's socio-economic characteristics, followed by sections assessing the participant's perceived safety in each scenario, the influence of each infrastructural or behavioral element (from other road users) on the willingness to reach the railway station by bike, and the level of enjoyment experienced while riding through each scenario.

5.2.2 Data analysis

A non-parametric analysis was chosen as the most suitable methodology for this research, since the data did not follow normal distributions. The distribution was verified using the Shapiro-Wilk test (p-value < 0.05) and the Kolmogorov-Smirnov test (p-value < 0.05), both of which produced significant results. All eight simulated scenarios were compared based on perceived safety using Friedman and Wilcoxon post-hoc tests. Under the null hypothesis (H0), it is assumed that the independent variable, the scenario, has no effect on the dependent variable, perceived safety; the eight sets of scores come from the same population. Symbolically, this can be expressed as H0: R1 = R2 = R3 = R4 = R5 = R6 = R7 = R8. If this hypothesis were true, the sums of the ranks Rj would be similar. Alternatively, if the scenario affected perceived safety, the Rj values would differ. The calculation formula for the Friedman test is given by equation (1):

$$Q = \frac{12}{Nk(k+1)}\left(\sum_{j=1}^{k} R_j^2\right) - 3N(k+1) \tag{1}$$

Where k is the number of observations, N is the number of participating subjects, and Rj is the rank of the safety scores for each scenario. Since the Friedman test was significant, the Wilcoxon post-hoc test was conducted to examine differences in perceived safety between two scenarios. The Mann-Whitney U test compares elements in the general questionnaire with elements in the post-simulation questionnaire. The purpose of the Mann-Whitney U test is to test the null hypothesis that $P(X < Y) = 0.5$, where X and Y are random samples from the two populations of interest, in order to assess statistical significance. Then, the fixation duration (D_F) on a given element is correlated with the propensity to reach the railway station using Spearman's correlation. Fixations are the most common eye movement, and can be used to make inferences about cognitive processes and attention. During a fixation, eyes stop scanning the scene and hold the foveal area of our field of vision in one place. This allows the visual system to take in detailed information on what is being looked at. In reality, even though our eyes seem to be stationary during a fixation, there are always minute eye movements. However, these do not move our focus away from what is being focused, and are therefore considered to belong to the same fixation. Some facts about fixations:

- Last between 50 to 600 ms.
- Their frequency is <3 Hz.
- Visual information is mainly acquired through fixations.
- Usually analyzed by their location (i.e., what is being fixated) and by computing their frequency and duration on an area of interest (e.g., Fixation Count and Fixation Duration metrics in Tobii Pro Lab).
- The duration of a fixation reflects the effort required to process visual information [82].

The Spearman rank correlation coefficient is a non-parametric statistic (independent of the distribution), proposed by Charles Spearman, as a measure of the strength of association between two variables. This method is used when the data distribution makes the Pearson correlation coefficient undesirable or misleading [83].

5.3 Outcomes

Results show differences for the importance of horizontal signs, the absence of vehicle interference and the absence of parked vehicles on the side of the cycle path. Significant differences were observed for only four elements: the presence of a bicycle lane, the presence of an unsurpassable barrier, the absence of interference with vehicles, and the presence of horizontal signage. In these four cases, the results of the general survey showed a higher willingness to travel to the railway station by bicycle compared to the post-simulation survey results, with highly significant p-values ($p < 0.02$). The presence of an unsurpassable line showed the largest difference ($|\Delta M| = 0.47$), followed by horizontal signage ($|\Delta M| = 0.41$) and the absence of vehicle interference ($|\Delta M| = 0.38$). The smallest difference between the two respondent groups was for the existence of a bicycle lane ($|\Delta M| = 0.22$). This suggests a potential overestimation of the importance of these elements in the general survey, which may lack the realism provided by the simulated experience. No significant differences were found for other elements, including the existence of an elevated bicycle lane, the absence of fixed obstacles, and the absence of interference from pedestrians, indicating comparable evaluations between the two data collection methods. The existence of a bicycle lane opposite to the traffic flow showed the highest average willingness in the simulation-related questionnaire ($|\Delta M| = 0.56$), although this difference did not reach statistical significance ($p = 0.17$). Regarding the fixation duration data (D_F), these were correlated, using Spearman's correlation, with the impact of each element on the willingness to reach the station by bicycle as reported in the post-simulation questionnaire. The presence of cars parked along the side of the bicycle lane showed a significant negative correlation with %D_F (rho = -0.3696, p = 0.0140), suggesting that this factor is associated with a reduced willingness to reach the railway station by bicycle. Similarly, interaction with pedestrians is negatively correlated with %D_F (rho = -0.2134, p = 0.0254), indicating a potential impact on cyclists' willingness to reach the railway station. Other variables, including passable barriers, interactions with vehicles, point obstacles, and signage (horizontal and vertical), did not show statistically significant correlations. The scenarios in which both pedestrians and parked cars along the roadway are present are scenarios 1, 2, 4, and 8. A Mann-Whitney test comparing the fixation percentages of the two elements within each scenario revealed a significant difference (p-value < 0.00001) in scenario 2, showing that participants paid more attention to the cars parked on the right than to the pedestrians (sum of ranks = 736.5; 253.5).

6 General conclusions

This doctoral thesis has provided a user-centred investigation into the determinants, infrastructural conditions, and behavioral aspects that impact bicycle–train intermodality. By integrating social, infrastructural, and perceptual factors, the research has contributed both methodologically and empirically to sustainable mobility systems. Its novelty lies in combining survey-based statistical modelling, accessibility-indicator development, and simulated behavioural experiments into a single framework designed to inform equitable resource allocation and policy prioritization for railway-station planning. The objective was to identify mechanisms that can support data-driven decisions in the development of multimodal transport networks focusing on cycling and rail travel. In doing so, the research addressed the lack of a unified and objective methodology to allocate investments in cycling and intermodal infrastructure across territories. This represents an important step forward from traditional, politically driven or ad-hoc decision-making processes that often lead to inefficiencies and territorial inequities.

The research is developed in three sections: (1) a nationwide survey analysed through a PA and a (GSEM);(2) the formulation and application of an Accessibility Indicator (AxI) to 33 railway stations in Emilia-Romagna; (3) a bicycle-simulator experiment to validate attitudinal survey data with observed behaviour.

Across these stages, consistent findings emerged regarding the socio-demographic and perceptual drivers of intermodality. Age and perceived safety are powerful predictors of behaviour. Older respondents and those who feel unsafe while cycling are less likely to adopt bike–train combinations. Gender differences persist: while women show higher appreciation for bike-sharing services, they display lower frequency of combined bike–train use, reflecting safety and comfort concerns. Also, urban context matters: individuals living in medium-to-large municipalities (> 75 000 inhabitants) exhibit higher rates of intermodal behaviour, suggesting that density and infrastructure integration strongly affect modal choice. Education and habitual cycling positively influence the likelihood of multimodal travel, implying that both cultural capital and habitual exposure to cycling environments shape sustainable behaviour.

Regarding infrastructure, the connection of cycle paths to railway stations consistently emerged as a high-impact determinant of intermodality. The presence of secure bike parking, clear signage, and integrated bike-sharing systems increase willingness to reach stations by bicycle. This means that intermodality cannot rely only on behavioural aspects but requires visible, high-quality, and spatially continuous infrastructure.

The Accessibility Indicator (AxI) represents the thesis's most significant methodological output. Designed as a replicable and scalable assessment tool, AxI integrates both quantitative and qualitative parameters, from cycle tracks in access to the railway station and station facilities to the sizing of bicycle parking. The weighting of each indicator of the checklist ensures that evaluations of infrastructure quality reflect the lived experience of travellers rather than only technical criteria. The AxI application across Emilia-Romagna revealed disparities in bicycle train integration. Some stations demonstrated adequate parking provision and good signage but lacked safe connecting routes, while others showed the opposite pattern. This confirmed the need for context-sensitive, evidence-based investment strategies. The indicator's independence from the number of trains or commercial activities present in the railway station makes it particularly suitable for national-level resource allocation, ensuring that smaller or peripheral municipalities are not underestimated.

In policy terms, the study highlights that intermodality initiatives should be the core of Sustainable Urban Mobility Plans (SUMPs) and regional accessibility strategies. National or regional governments could use the AxI tool to prioritise funding for interventions that deliver the highest marginal gains in accessibility.

The introduction of virtual bicycle-simulation experiments at Université Gustave Eiffel provided an innovative validation methodology. By comparing survey-based self-reported attitudes with real-time eye-tracking and behavioural data, the study confirmed both convergences and discrepancies. For instance, participants tended to overestimate the positive impact of certain infrastructural elements (such as horizontal signage or separation barriers) in the general survey compared to after simulation. Elements like parked vehicles and pedestrian interference were found to significantly reduce perceived safety and willingness to complete the trip correlations verified through Spearman's non-parametric tests. These insights reinforce the methodological importance of combining stated-preference and revealed-preference techniques. Simulation and immersive technologies can complement traditional surveys by providing a more realistic assessment of cyclists' risk perception and attention distribution. Future research could integrate biometric or physiological data (e.g., stress indicators) to refine understanding of comfort and safety thresholds in multimodal contexts.

The data obtained that includes user experience, perceived safety, and equitable access, aligns with the United Nations' Sustainable Development Goals (especially SDG 11: Sustainable Cities and Communities) and the EU's Green Deal objectives.

The study found that promoting bike-train integration is not only an infrastructural challenge but a social transition requiring coordinated action among municipalities, railway operators, and the society. Education campaigns, data-driven design, and participatory planning processes are essential complements to physical investments.

The gap of the research, which will have to be of interest for future research is to dive deep into what impacts the use of train rather than only concentrating on cyclability in combination with the train. Much research has focused on the increase in train ridership and the underlying reasons. The access of the railway station, the level of service offered are just some of the factors that impact the propensity to travel by rail [84]. For instance, access and egress times are a function of access and egress modes and trip orientation rather than of socioeconomic caracteristics [85]. All those factors should be included in the analysis of bike and rail integration. In this research the cyclability part is preponderant compared to other factors that could have been taken into account concerning the behaviour related to train use. The dominance of cycling variables leaves room to investigate train-related determinants that could influence the intermodal uptake [86]. Future work should thus aim to balance the "cyclability" perspective with a more detailed rail behaviour analysis. Additionally, extending the methodology to different national contexts would allow for cross-cultural validation of the AxI. Differences in governance, culture, and urban form could reveal how transferable the Italian findings are to other European or global regions.

In conclusion, this research advances the understanding and practical implementation of bike - train intermodality. It proposes a robust, evidence-based methodology for identifying, prioritising, and validating interventions that enhance the integration of cycling and rail transport. The work offers a concrete operational framework for public administrations, metropolitan planners, and transport operators aiming to achieve cleaner, fairer, and more efficient mobility systems. The link between behavioural modelling, accessibility measurement, and experimental validation, demonstrates that successful multimodality depends on aligning infrastructure with human perception and behaviour. The research reaffirms that fostering a symbiotic relationship between bicycles and trains can transform urban and regional mobility, contributing to a more inclusive, resilient, and low-carbon future.

References

[1] World Health Organization, “Air quality, energy and health,” 2025. [Online]. Available: https://www.who.int/teams/environment-climate-change-and-health/air-quality-energy-and-health/health-impacts. [Accessed 22 Oct 2025].

[2] National Institute of Environmental Health Sciences, “Your environment. Your health,” April 2025. [Online]. Available: https://www.niehs.nih.gov/health/topics/agents/air-pollution. [Accessed 22 Oct 2025].

[3] JL Ish, CJ Chang, DB Bookwalter, RR Jones, KM O'Brien, JD Kaufman, DP Sandler, AJ White. “Outdoor air pollution exposure and ovarian cancer incidence in a United States-wide prospective cohort study,” Environmental health perspect, vol. 132, no. 10:107701, 2024.

[4] S. Yang, L. Zhang, K. Khan, J. Travers, R. Huang, V. Jovanovic, R. Veeramachaneni, S. Sakamuru, C. Tristan, E. Davis, C. Klumpp-Thomas, K. Witt, A. Simeonov, N. Shaw and M. Xia, “Identification of Environmental Compounds That May Trigger Early Female Puberty by Activating Human GnRHR and KISS1R,” Endocrinology, vol. 165, no. 10:bqae103, Aug. 2024.

[5] ITF, “Improving transport planning and investment through the use of accesibility indicators,” International transport forum policy papers, no. No. 66, 2019.

[6] M. Elassy, M. Al-Hattab, M. Takruri and S. Badawi, “Intelligent transportation systems for sustainable smart cities,” Transportation engineering, vol. 16, June 2024.

[7] European Environment Agency, “Transport and mobility,” 10 Feb 2025. [Online]. Available: https://www.eea.europa.eu/en/topics/in-depth/transport-and-mobility?activeTab=fa515f0c-9ab0-493c-b4cd-58a32dfaae0a. [Accessed 30 Sept. 2025].

[8] European Parliament, “Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe,” 2008, pp. 1-44.

[9] R. Danielis, “Air pollution and road transport in Europe. A cluster and a regression analysis among countries and cities,” [Online]. Available: http://www.sietitalia.org/siet8/papers/Danielis.pdf.

[10] European Environmnet Agency, “Transport in Europe: some signs of progress but difficult journey ahead to sustainability,” 10 Oct 2024.

[11] UN-Habitat, 2024. [Online]. Available: https://unhabitat.org/sites/default/files/2024/11/wcr_2024_-_chapter_1.pdf. [Accessed 30 Sept 2025].

[12] J. van der Loop, “Intermodality: successs by integrating public transport modes and cycling,” Transport Research Centre, Ministry of transport and public works, 01 Dec 2011.

[13] S. Groth and T. Kuhnimhof, “Multimodality in transportation,” International encyclopedia of transportation, pp. 118-126, 2021.

[14] I. Kosmidis, D.M. Muller-Eie. “The synergy of bicycles and public transport: a systematic literature review,” Transp. Rev., pp. 34-68, 2024.

[15] U. Nations, “New Urban Agenda HIII,” 2017.

[16] D. Suraci, “Bicycle and transit integration: a practival transit agency guide to bicycle integration and equitable mobility,” APTA standards development program, 2018.

[17] Apta standards development program, “Bicycle and transit integration - a practical guide to bicycle integration and equitable mobility,” 2018.

[18] H. Makahleh, M. Taamneh and D. Dissanayake, “Promoting Sustainable Transport: A Systematic Review of Walking and Cycling Adoption Using the COM-B Model,” Future Transp., vol. 5, no. 3, p. 79, 2025.

[19] M. Bauer and P. Kisielewski, “The Influence of the Duration of Journey Stages on Transport Mode Choice: A Case Study in the City of Tarnow,” Sustainability, vol. 13, no. 11, p. 5922, 2021.

[20] Sustrans report- join the movement, “Paths for everyone 3 years on| 2018-2021 progress update,” UK, 2021.

[21] European Environment Agency, “Transport and environment report 2021,” 01 Jun 2022. [Online]. Available: https://www.eea.europa.eu/en/analysis/publications/transport-and-environment-report-2021.

[22] European Commission, “European declaration on cycling,” 2022.

[23] European Parliament, “Regulation (EU) 2021/782,” 2021.

[24] European Parliament, “Regulation (EU) 2024/1679,” 2024.

[25] UIC, “Optimizing Bikes and luggage transportation in railway systems,” Paris, 2024.

[26] European Institute of innovation & technology, “EIT Urban Mobility #ChallangeMyCity call for proposals,” 2022. [Online]. Available: https://www.eit.europa.eu/our-activities/opportunities/eit-urban-mobility-challengemycity-call-proposals.

[27] N. M. Mohamed, “Station as mobility hubs: impact of transforming public spaces on the adoption of sustainable modes of transoprtation and promotion of intermodality,” Barcelona, 2022.

[28] S. Gričar, U. Longar, T. Longar and V. Sugar, “Cycling into Sustainability: Lessons from the Netherlands for Slovenia’s E-Bike Adoption,” Sustainability, vol. 16, no. 22, p. 9987, 2024.

[29] Dutch cycling embassy, “Cycling & Intermodality,” 29 Jun 2021. [Online]. Available: https://dutchcycling.nl/expertises/cycling-intermodality/. [Accessed 01 Oct. 2025].

[30] M. Givoni and P. Rietveld, “The access journey to the railway station and its role in passengers’ satisfaction with rail travel,” Transport Policy, vol. 14, no. 5, pp. 357-365, 2007.

[31] K. Martens, “Promoting bike-and-ride: The Dutch experience,” Transportation research part A: policy and practices, vol. 41, no. 4, pp. 326-338, May 2007.

[32] ISFORT, “21° Rapporto sulla mobilità degli italiani,” 2024.

[33] Presidenza del consiglio dei ministri, “DECRETO LEGISLATIVO 13 agosto 2010, n. 155,” 2010.

[34] Comune di Bologna, “Biciplan,” 2019.

[35] EU Mobility Observatory, “Successful integration of cycling and rail travel in Veneto,” 17 July 2024. [Online]. Available: https://urban-mobility-observatory.transport.ec.europa.eu/news-events/news/successful-integration-cycling-and-rail-travel-veneto-2024-07-17_en. [Accessed 22 10 2025].

[36] X. Wang, E. Valenzuela, C. You, V. V. Nguyen, L. Sun and L. Miranda-Moreno, “The future of urban cycling: A predictive framework for climate change,” Transportation research part D: transport and environment, vol. 143, p. 104722, June 2025.

[37] “A rising need for end-of-trip facilities,” 2023. [Online]. Available: https://classic-arch.com/articles/end-of-trip-facilities/#what_are_end-of-trip_facilities. [Accessed 27 Oct 2025].

[38] J. Hong, D. McArthur and J. Stewart, “Can providing safe cycling infrastructure encourage people to cycle more when it rains? The use of crowdsourced cycling data (Strava),” Transportation research part A: policy and practice, vol. 133, pp. 109-121, March 2020.

[39] R. Mitra, A. Khachatryan and P. Hess, “Do new urban and suburban cycling facilities encourage more bicycling?,” Transportation research part D: trasnport and environment, vol. 97, p. 102915, August 2021.

[40] C. Rissel, S. Greaves, L.M. Wen, M. Crane, C. Standen. “Use of and short-term impacts of new cycling infrastructure in inner-Sydney, Australia: a quasi-experimental design,” Int. J. Behav. Nutr. Phys. Activity, vol. 12, no. 129, 2015.

[41] K.M. Parker, J. Gustat, J.C. Rice. “Installation of Bicycle Lanes and Increased Ridership in an Urban, Mixed-Income Setting in New Orleans, Louisiana,” J. Phys. Activity Health, vol. 8, pp. S98-S102, 2011.

[42] L.M. de Freitas, K.W. Axhausen. “What influences cycling infrastructure preferences? A stated-preference survey.,” Transportation, April 2025.

[43] J. Dill and T. Carr, “Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them.,” Transportation Research Record Journal of the Transportation Research Board, vol. 1828, pp. 116-123, 2003.

[44] R. Aldred, B. Elliott, J. Woodcock and A. Goodman, “Cycling provision separated from motor traffic: a systematic review exploring whether stated preferences vary by gender and age,” Transp. Rev., vol. 37, no. 1, pp. 29-55, Jan 2017.

[45] W. E. Moritz, “Survey of North American Bicycle Commuters: Design and Aggregate,” Transportation research record, vol. 1578, pp. 91-101, 1998.

[46] R. Cervero, M. Duncan, “Walking, Bicycling, and Urban Landscapes: Evidence from San Francisco bay area,” American Journal of Public Health, vol. 93, no. 9, pp. 1478-1483, 2003.

[47] P. Schepers, E. Theuwissen, P. Velasco, M. Niaki, O. van Boggelen, W. Daamen and M. Hagenzieker, “The relationship between cycle track width and the lateral position of cyclists, and implications for the required cycle track width,” Journal of Safety Research, vol. 87, Dec. 2023.

[48] D. T. Fitch, J. Carlen and S. Handy, “What makes bicyclists comfortable? Insights from a visual preference survey of casual and prospective bicyclists,” Transportation research part A: polocy and practice, vol. 155, pp. 434-449, Jan. 2022.

[49] A. Moudon, C. Lee, A.D. Cheadle, C.W. Collier, D. Johnson, T.L. Schmid, R.D. Weather. “Cycling and the built environment, a US perspective.,” Transportation, vol. 10, no. 3, pp. 245-261, 2005.

[50] A. Giordano, H. Matthews, P. Baptista, P. Fischbeck, “Impacts of topography and weather barriers on commercial cargo bicycle energy using urban delivery crowdsourced cycling data,” Sustainable cities and society, vol. 76, p. 103326, Jan. 2022.

[51] N. Falah, N. Falah and J. Solis-Guzman, “Weather-Driven Cycling: Developing a Predictive Model for Urban Bicycle Usage Based on Five Key Weather Factors,” Urban science, vol. 9, no. 2, p. 41, 2025.

[52] M. Nankervis, “The effect of weather and climate on bicycle commuting,” Transportation research part A: policy and practice, vol. 33, no. 6, pp. 417-431, Aug 1999.

[53] “Cycling in the Rain: Dutch Resilience in Utrecht’s Downpour,” 17 Jan 2024. [Online]. Available: https://bicycledutch.wordpress.com/2024/01/17/cycling-in-the-rain-dutch-resilience-in-utrechts-downpour/. [Accessed 28 Oct 2025].

[54] Y. Yang, X. WU, P. Zhou, Z. Gou, Y.Lu. “Towards a cycling-friendly city: an updated review of the associations between built environment and cycling behaviors (2007–2017),” J. Transport Health, vol. 14, p. 100613, 2019.

[55] M. Stinson, C. Bhat, “Commuter Bicyclist Route Choice: Analysis using a Stated,” Transportation Research Record, pp. 107-115, 2003.

[56] S. Useche, L. Montoro, J. Sanmartin, F. Alonso, “Healthy but risky: A descriptive study on cyclists’ encouraging and discouraging factors for using bicycles, habits and safety outcomes,” Transportation research part F: traffic psychology and behaviour, vol. 62, pp. 587-598, Apr. 2019.

[57] “National Bicycling and Walking Study,” 2004.

[58] J. Pucher, L. Dijkstra, “Promoting Safe Walking and Cycling to Improve Public,” American Journal of Public Health, vol. 93, no. 9, pp. 1509-1516, 2003.

[59] National Highway Traffic Safety Administration, & Bureau of Transportation Statistics, “National Survey of Pedestrian and Bicyclist Attitudes and Behaviors: Highlights Report,” Washington, DC: U.S. Department of Transportation. , 2003.

[60] M. Zavareh, M. Mehdizadeh and Nordfjærn, “Active travel as a pro-environmental behaviour: An integrated framework,” Transportation research part D: transport and environment, vol. 84, 2020.

[61] I.M. Martin Lopez, O. Garcia-Taibo, A. Aguilò and P. Antoni Borràs, “Understanding Factors Influencing Cycling Behaviour Among University Students and Staff: A Cross-Sectional Study,” Social Sciences, vol. 14, no. 5, p. 261, 2025.

[62] B. Kutela, F. Ngeni, N. Novat, H. Shita, M. Ngotonie, J. Mwekh'iga, N. Langa, S. Das, “Understanding socio-demographic factors associated with shared-use-paths (SUPs) utilization,” JOurnal of cycling and micromobility research, vol. 2, 2024.

[63] C. Emond, W. Tang, S. Handy, “Explaining Gender Difference in Bicycling Behavior,” TRB 2009 Annual Meeting CD-ROM, 2009.

[64] E. Tortosa, R. Lovelace, E. Heinen, R. Mann, “Cycling behaviour and socioeconomic disadvantage: An investigation based on the English National Travel Survey,” vol. 152, pp. 173-185, 2021.

[65] A. Schmassmann, D. Baehler, P. Rérat, “The contrasted evolution of cycling during youth. Determinants of bicycle ownership and use,” International Journal of sustainable transportation, vol. 18, no. 2, pp. 103-114, 2024.

[66] L. La Paix Puello and K. Geurs, “Modelling observed and unobserved factors in cycling to railway stations: application to transit-oriented-developments in the Netherlands,” EJTIR, vol. 15, no. 1, pp. 27-50, 2015.

[67] Centre for Transport & Society University of the West of England, “BIKE-RAIL INTEGRATION AS ONE SUSTAINABLE TRANSPORT SOLUTION TO REDUCE CAR DEPENDENCE,” 2010.

[68] I. Kosmidis, D. Muller-Eie, “The synergy of bicycle and public transport: a systematic literature review,” Transport reviews, vol. 44, no. 1, pp. 34-68, 2024.

[69] D. Collins, “Pretesting survey instruments: An overview of cognitive methods,” Qual Life Res, vol. 12, pp. 229-238, 2003.

[70] L. J. Cronbach, “Coefficient alpha and the internal structure of tests,” Psychometrika, vol. 16, no. 3, pp. 297-334, 1951.

[71] LIFE, “LIFE INTEGRATED PROJECTS 2015; Stage 2- FULL PROPOSAL; Technical application forms; Part A- administrative information,” 2015.

[72] N. Cass, E. Shove, J. Urry, “Social exclusion, mobility and access 1,” The sociological review, vol. 53, no. 3, pp. 539-555, 2005.

[73] K. Geurs, B. van Wee, “Accessibility evaluation of land-use and trasnport strategies: review and reserach directions,” Journal of transport geography, vol. 12, pp. 127-140, 2004.

[74] D. Halden, “Using accessibility measures to intefrate land use and transport policy in Edinburgh and the Lothins,” Transportation Policy, vol. 9, no. 4, pp. 313-324, 2022.

[75] European Commission, “The EAA comes into effect in June 2025. Are you ready?,” 2025.

[76] P. Jones, K. Lucas, “The social consequences of transport decision-making: clarifying concepts, synthesising knowledge and assessing implications,” Journal of transport geography, vol. 21, pp. 4-16, 2012.

[77] V. Pyrialakou, K. Gkritza, J. Fricker, “Accessibility, mobility, and realized travel behaviour: assessing trasnport disadvantage from a policy perspective,” Journal of transport geography, vol. 51, pp. 252-269, February 2016.

[78] European Commission, “Transport and accesibility,” 17 July 2018. [Online]. Available: https://knowledge4policy.ec.europa.eu/territorial/transport-accessibility_en. [Accessed 21 Oct. 21].

[79] C. Gallez, B. Motte-Baumvol, “Inclusive mobility or inclusive accessibility? A European perspective,” Cuadernos Europeos de Deusto, April 2017.

[80] C. Jacobs-Crisioni, F. Batista e Silva, C. Lavalle, C. Baranzelli, A. Barbosa, C. Perpiña Castillo, “Accessibility and territorial cohesion in a case of transport infrastructure improvements with changing population distributions,” European transportation res. Rev., vol. 8, no. 9, 2016.

[81] Comune di Bologna, Citta metropolitana di Bologna, “Piano urbano della mobilità sostenibile,” 2019.

[82] Tobii, “Types of eye movements,” 30 Oct 2024. [Online]. Available: https://connect.tobii.com/s/article/types-of-eye-movements?language=en_US. [Accessed 28 Oct 2025].

[83] J. de Winter, P. Bazilinsky, D. Wesdorp, V. de Vlam, B. Hopmans and Visscher, “How do pedestrians distribute their visual attention when walking through a parking garage? An eye tracking study,” Ergonomics, vol. 64, no. 6, pp. 793-805, 2021.

[84] Brons, M.; Givoni, M.; Rietveld, P. Access to railway stations and its potential in increasing rail use. Transp. Res. Part A, vol. 43, no. 2, 2009.

[85] Krygsman, S.; Dijst, M.; Arentze, T. Multimodal public transport: an analysis of travel time elements and the interconnectivity ratio. Transport Policy, vol. 11, no.3, pp.265-275, 2004.

[86] C. van Goeverden, “Explaining factors dor train use in european long-distance travel,” Tourism and Hospitality Planning & Development, vol. 6, no. 1, pp. 21-37, 2009.

[87] American Public Transportation Associacion, “Bicycle and transit integration- practical transit agency guide to bicycle integration and equitable mobility,” 2018.

List of Annexes

1. **SP1** Pazzini, M.; Lantieri, C.; Zoli, A.; Simone, A.; Imine, H. (2023) Evaluation of Railway Station Infrastructure to Facilitate Bike–Train Intermodality. *Sustainability*. doi: 10.3390/su15043525
2. **SP2** Zoli, A.; Pazzini, M; Vignali, V.; Imine, H.; Simone, A; Lantieri, C. (2025) Assessing Cyclists' Accessibility into Railway Stations Through a User-Centered Indicator. *Sustainability.* doi: 10.3390/su17020504
3. **SP3** Zoli, A.; Pazzini, M.; Lantieri, C.; Vignali, V.; Raffaeli, K; Gaspargo Moro, M.; Andrea, S. (2025) Users' preferences on bike-train intermodality: what can induce travelers to use this type of intermodal transport? Transportation Research Procedia, Volume 90, pp. 448-455. doi: 10.1016/j.trpro.2025.06.121.
4. **SP4** Zoli, A.; Sitohang, I; Adele, S.; Pazzini, M.; Imine, H.; Lantieri, C. (2026) Validation of survey data via bicycle simulation in a multimodal bicycle-train context Journal of Traffic and Transportation Engineering (English Edition), *Under review.*
5. **SP5** Zoli, A.; Lantieri, C.; Simone, A.; Vignali, V.; Pazzini, M. (2025) PREPAIR Report on information and recommendations on the planning of intermodal transport facilities and policies (bike+local public transport, with particular reference to the railway stations).

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Article

Evaluation of Railway Station Infrastructure to Facilitate Bike–Train Intermodality

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Abstract: In recent years, emissions into the atmosphere have been brought to the attention of the authorities and some action has been taken to try to solve the problem. One is the application of EU legislation 2008/50/EC, which requires states adhering to this law to constantly monitor air quality and subsequently find solutions to reduce the impact of emissions. The data show that 20% of emissions come from transport, 70% of which come from private vehicles. Sustainable mobility can be a possible solution to reduce pollution and traffic congestion. The promotion of cycling, as part of sustainable mobility, is a required action to achieve the objectives pursued. This research aims to define the quality of infrastructure and accessibility of railway stations to the use of bicycles. The approach used was to define a technical checklist to estimate the criticalities of the structure in a quantitative way. An example is the case study developed in the Emilia-Romagna region (Italy) within the PREPAIR project where 33 railway stations were classified and analyzed. In the end, the checklist was effective in defining the necessary interventions and the required activities and can be used in similar cases during the decision-making processes.

Keywords: intermodality; accessibility; cycle paths; railway stations; sustainable mobility

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1. Introduction

Reducing CO_2 emissions into the air is a global issue that major authorities have been considering for years. As to this purpose, the International Energy Agency has committed 30 member countries to achieve zero emissions by 2050 [1]. Moreover, it should be stressed that an important part of emissions comes from the transport sector. In fact, the 2019 figures show that CO_2 emissions from transport account for 25.2% of total emissions, 17.5% of which come from road transport [2], and significantly, about 70% from passenger cars [3]. In Italy, daily travelers amount to 30,214,401, 50.7% of the total number of citizens. In particular, 67.9% travel for work and 32.1% for educational reasons. A total of 57.5% of these people travel within their municipality, while 42.5% move outside of it [4]. The data concerning commuters are extremely important as they indicate the large number of people who rely on the mobility infrastructure every day [5]. A survey from the University of Trieste shows that 70.1% of all commuters use their private car to reach their destination (17.5% use only private cars, 52.6% use their car combined with a public transport) [6,7]. To improve this situation, a possible solution could be to replace 20% of private cars, thus reducing air emissions by 12% (CO_2 equivalent). Of course, to achieve this purpose and significantly reduce pollution, private car users should rely on an efficient network of multiple and shared means of transport, including bicycles [7–9] with mobility hubs allowing for easy and safe access to different modes of transport [10–12]. Relying on an intermodal transport means that the destination is reached using at least two different modes of transport, while providing economical and technical advantages, improving efficiency and reducing energy consumption and greenhouse gas emissions [13–15]. To this extent, not only do mobility hubs help in decreasing emissions, but they also provide a healthier lifestyle by reducing accidents and facilitating connections [15]. Moreover, it was demonstrated that favoring intermodality improves the attractiveness and efficiency of a journey [16]. Mobility hubs and real global hubs should be located in strategic areas, such as railway stations; the infrastructures should be grouped together, thus allowing for users to reach public and shared transport as well as the city centers [9,17,18].

Non-motorized transport modes, such as bikes and kick scooters, which actively involve pedestrians and cyclists, are among the most important means of transport to be found at mobility hubs. In fact, they are cheap, noise-free, environmentally friendly and can be parked in small places [19,20]. It should be noted that the European Decree 2008/50/EC itself defines bicycles as a sustainable means of transport [21]. Moreover, the Sustainable Urban Mobility Plan (SUMP), a European strategic plan based on the infrastructure planning of the mobility of goods and people to increase the quality of life in and around cities, also defines bicycles as non-polluting means of transport. The grouping of bicycles, public transport and walks results in the description of perfect sustainable mobility, but it only counts for less than 40% of all daily trips [18]. The opportunities created by the development of bicycle accessibility to reach railway stations and the facilities provided are therefore of great importance [22].

Encouraging travelers to combine the use of bicycles with the use of trains is a challenge that involves also the infrastructure around the railway station. It has been proven that a better quality of cycling infrastructure has a positive impact on the utilization of this means of transport, thus increasing the number of users [23]. As for the use of bicycles, in addition to the quality of dedicated infrastructure, speed limits of less than 30 km/h, traffic-calming devices, the safe use of common ground, proximity to suitable trails, and adequate slopes [24,25] should be guaranteed to further attract cyclists [26]. In addition, the volume of traffic, the risk of accidents, the distance to the central business district, the high-density housing areas, the type and quantity of cycling facilities, road connectivity, population density and the perception of infrastructure availability are important factors to consider [27–30]. Maria Konstantinidou et al. [31], through a preference questionnaire survey, found that the propensity to cycle depends on the presence of cycle paths, parking areas, bike-sharing facilities and on the quality of air breathed while cycling. Moreover, Maciorowski et al. [32,33] consider bicycle paths, crossing options, lighting and signaling, afforestation and shading as part of the infrastructure that users of non-motorized vehicles consider while travelling. Krizek and Stonebraker [33], through a survey using the Analytic Hierarchy Process (AHP) multicriteria decision-making tool, found that cyclists attach great importance to bicycle parking security, while Egan et al. [34] found that bicycle parking types defined as “Any”, “Accessible” and “Secure” are preferred, placing emphasis on locked or guarded bicycle parking facilities. Finally, Arbis et al. [35] found that the favorite spot to park a bicycle depends on the frequency of the railway service. When the train service is poor, the chances of theft are greater and bicycle users prefer to park their bicycles into locked spots. Given the vulnerability of accidents, cyclists’ safety is one of the most important parameters to consider when analyzing the use of this means of transport [36–38]. Many studies have analyzed the number of accidents related to infrastructure or to mixed traffic of cars and non-motorized vehicles. For example, Osama and Sayed noted that the number of cyclist–motorist crashes has no linear relationship with the increase in vehicles and transit traffic or with socio-economic variables, as well as variables related to the built environment. However, it has been shown that the decrease in cyclist–motorist crashes is related with the increase in the proportion of local roads and off-street bike links, as well as an increase in recreational and residential density [39]. Besides cyclist–motorist crashes, there are also single-bicycle crashes (SBC), which count for 85% of all crashes involving bicycles. By diving deep into the causes of SBC, it was found that 44% is due to road maintenance deficiencies, 16% to bicycle–cyclist interaction, 15% to road design, 14% to cyclist behavior and 10% is due to the interaction with other road users (e.g., evasive actions to avoid collision) [40]. The above data again indicate the importance on acting on the quality of the infrastructure.

Different methods define in the literature the quality of the cycling infrastructure. Tran et al. defined the accessibility and performance metrics of mobility hubs based on different weightings to reflect different policy priorities. The output is infrastructure investment, servicing and maintenance.

As for Italy, actions have been taken to reduce emissions through the application of the Legislative Decree of 16 June 2022, n. 68, which provides founds to improve road safety, including cycle paths [41]. The "PREPAIR" project—Po Regions Engaged to Policies of AIR—was founded by the Life European program in 2016 with the aim of implementing the measures provided by the Air Quality Plans and to achieve the "Bacino Padano" (Po Basin) Agreements on a larger scale [22]. The objective of this article is to define a methodology to give priority to infrastructure needs and interventions to facilitate the accessibility of bicycles in railway stations. Cyclist parameters are considered to be important both in the literature and in the Italian decree of 11 January 2018 n.2, and have been taken into consideration. A case study applied in the Emilia-Romagna region, Italy, for the accessibility of bicycles inside 33 railway stations, was carried on in order to develop intermodality between bicycles and trains. The methodology will provide a ranking of results to demonstrate the most performing and, above all, the least efficient railway station. It will also show in which area train stations are less effective and how to implement it. Figure 1 shows the different steps followed to obtain the monitoring table definition and the main critical issues of the bike–train intermodality infrastructure.

Figure 1. Steps to obtain the monitoring table definition to determine the critical issues in the bike–train intermodality.

2. Case Study and Railways Classification

This project is driven by the necessity to define the quality and interventions necessary for the accessibility of bicycles inside mobility hubs in order to increase intermodality between bicycles and trains. This aim is part of PREPAIR, which is a project involving Italy and Slovenia based on achieving the objectives of the Air Directive by implementing the Air

Quality Plans (Directive 2008/50/EC) [21]. One of the main objectives of this plan concerns "actions to promote cycling mobility" with the intention of reducing vehicle congestion and air pollution in urban areas. This part includes the section "survey on bike infrastructures availability in railway stations", stating the importance to have good bike infrastructures in the main railway stations of the study area and to understand the amount of investment that should be made to reach satisfying levels of efficiency. To achieve this goal, bicycle–train intermodality needs to be analyzed to detect the actual deficiencies and eliminate them. The measures proposed by PREPAIR are taken by municipalities with more than 30,000 people, that is, by those who are obliged to adopt the Urban Traffic Plans. In Italy, this task is led by the Emilia-Romagna region, where the applied case study is based.

2.1. Case Study

The Emilia-Romagna region is located in the northern part of Italy with a population of 4,459,866 in 2021 [42]. The region borders Lombardy, Veneto, Piedmont, Liguria, Tuscany, Marche and the Republic of San Marino, while the eastern side overlooks the Adriatic Sea. Due to its geographical and historical features, the region is a tourist attraction and offers a multitude of job opportunities. In 2021, the Emilia-Romagna region hosted more than 30 million tourists, some of them travelling within the cities, attracted by business trips or spa facilities [43]. The presence of the Apennines and of the hills attracts tourists for outdoor activities as well. Moreover, the Emilia-Romagna region, characterized by the coast of the Adriatic Sea, reaches the highest share of tourists in this area during the summer thanks to equipped beaches and activities involving different age groups. These data show the importance of movements between different localities inside the region, which also depend on the season of the year. The Po Valley is also part of the Emilia-Romagna region. Crossed by the river Po, the main Italian river, this is historically one of the most important industrial areas of northern Italy. This leads to a substantial movement of commuters who need to move exclusively for work reasons to areas far from their households. The railway station infrastructure, as a mobility hub, is therefore of great importance and must include all the facilities necessary to reach the place of interest in the easiest and most sustainable way possible, without excluding bicycles. To give priority to interventions, the following method has been developed.

2.2. Classification of Railway Stations

The project starts with the classification of the railway stations by RFI—The Italian Railway Network—which divides each railway station into three categories: gold, silver and bronze. These categories are important to define which features and services should be included in a railway station in relation to the number of passengers attending it, the level of services offered to the travelers, the presence of areas opened to non-travelers and the intermodality present in the node. Figure 2 shows the categories defined.

- GOLD: These railway stations have an average of 10,000 visitors per day and offer services to travel for long and short distances. Inside the railway station, there are also services and facilities for non-travelers and sometimes for the city. The number of gold railway stations present in the study area is 10.
- SILVER: These railway stations have an average daily attendance ranging from 2500 to 4000 people and may offer services to travel for long and short distances or only regional and metropolitan services. The number of silver railway stations present in the study area is 8.
- BRONZE: These are the smallest railway stations. They have 500 visitors per day and are only provided with regional and urban services. The number of bronze railway stations present in the study area is 15.

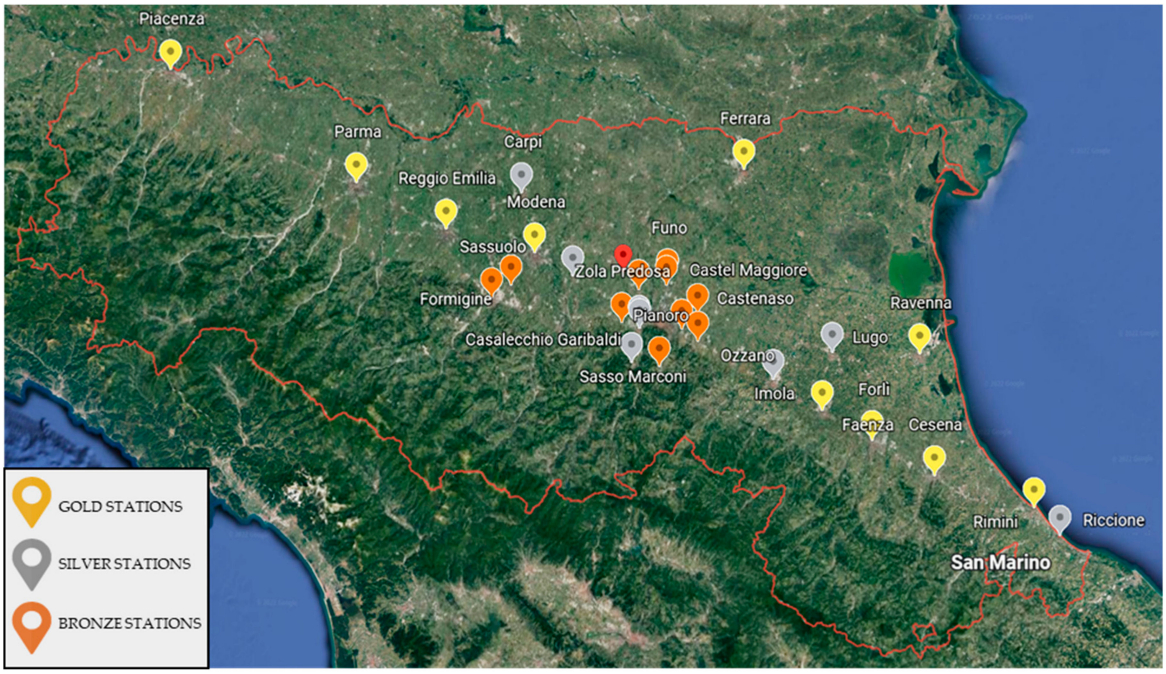

Figure 2. The 33 railway stations of the Emilia-Romagna region analyzed (© Google Earth).

The parameters used to create this classification were:

- Daily attendance: this is given by the number of passengers who daily pass through the station to get on or off a train and by the number of people who, although not using the passenger transport service, still frequent the facility (for purchases, interchange with other types of transport, tourism, simple transit, etc.);
- Level of passenger service: this considers the importance of the system exclusively in terms of the commercial offer of transport, counting the number and type of trains (AV-high-speed train, long-/medium-distance train, regional or metropolitan train);
- Areas open to the public: this criterion considers the total area of services open to the public; commercial areas such as shops and exhibition areas; transit areas; underpasses; transit tunnels; so-called "operational" areas, that is, those areas that from outside the station lead passengers to the train (platforms, main entrances, track header, ticket offices);
- Intermodality: this considers the simultaneous presence or absence—within the station or in the immediate vicinity—of metro stops; bus terminals for urban/extra-urban buses; tram stops; taxi lanes; connections to airports; car, motorcycle and bike parking lots.

Figure 2 shows the 33 mobility hubs of the 30 municipalities of the Emilia-Romagna region that took part in PREPAIR.

3. Methods

A checklist was created to understand the facilities at each railway station. The checklist was integrated with the elements included in the regional guidelines and in The Highway Code. The use of the checklist allows for each railway station to be compared with the most performing, ideal one—namely, the one that obtains the highest score in all the sections of the checklist—as well as to compare stations among them. The inspection in the checklist begins by analyzing the cycle path that ends near the railway station. If there are no bike paths, the speed limit of 30 km/h is checked. In fact, a speed limit of 30 km/h or less indicates that bicycles and cars can safely proceed together on the same road. In order to assess the safety of a cycle path, the presence of both vertical and horizontal signs indicating a possible cycle path should be analyzed. In addition, the visibility of such signs must be assessed as well. Another important feature to analyze is the type of cycle path, if promiscuous or separated from pedestrians. The inspection then assesses the services provided to cyclists, such as a safe storage for bicycles or a bike-sharing service. Each of these attributes is divided into detailed sections to dive deep into the characteristics of the accessibility of bicycles in the proximity of the railway station and inside it.

Appendix A contains the checklist used to carry out the analysis on the accessibility of cycling infrastructure within railway stations that considered the D.M. of the 30 November 1999, n.557 (regulation with the rules for defining the technical characteristics to build cycle tracks) [44], the "New highway code" [45] and the regional guidelines [46].

The monitoring tables are divided into five main groups that are: the quality of the cycle path infrastructure regarding access to the railway station, the sign and lighting, the services provided to the cyclist, the bicycle safekeeping service and the bike-sharing service.

3.1. Cycle Path Infrastructure Regarding Access to the Railway Station

The section regarding "cycle path infrastructure in access to the railway station" includes the following points:

- The presence of a cycle path and its distance from the railway station. These characteristics refer to Art.2 of the Regional Law of the 5 June 2017, n.10, which promotes cycling through interventions and actions aimed at improving the quality of daily trips [47]. The cycle path close to the railway station is a great way to promote active mobility.
- Assessment of the type and quality of pavement that together ensure the safety of users. In particular, the adherence of the pavement and the presence of plant roots, or anything else consuming the pavement should be detected. Rate "2" is given to an "excellent" pavement, "1" to a "good" pavement and "0" to a "bad" one.
- Attachment 3 of the Regional Guidelines states that, in urban areas, two-way cycle paths are not allowed since safety would not be guaranteed. This is the reason why rate "0" is assigned to two-way cycle paths and "1" is given to the one-way kind. Moreover, rate "2" is given to paths reserved for bicycles only, "1" to streets with a speed limit 30 km/h and "0" is given in case the type of cycle path is unclear.
- Geometrical standards defined by the law and guidelines [48]. They include the width of the path, which should be 1.5 m only in the case of a one-way path; the minimum width of 1.25 m for each side of the path just in case of more than one cycle path; if the cycle path width is reduced to 1 m, it has to be indicated.
- The slope of the cycle path. This is an important factor to engage bike users and should be less than 5% to limit speed and to enable riding uphill for less agile users.
- One-off obstacle warning. They can reduce the width of the bike path and careful attention should be paid not to reduce safety for users.
- The presence of pedestrians, vehicles or lateral entrances. In particular, conflicts between bicycles and pedestrians are evaluated, as well as possible users from side streets, shops or garage doors that could interfere with the safety of the cyclist.
- Visibility of the access to the cycle path on exit from the railway station. If the paths are not visible, cyclists could reduce their safety by using another option, such as a different road or a different means of transport.

3.2. Signs and Lighting

The "signs and lighting" section is defined by the following technical legislation: "Technical instructions for the design of cycle networks—Draft n.3 of the 17 April 2014", the "Paper of the interministerial decree of the 31 March 1993—n.432" and the "New highway code". The signs are also divided into horizontal and vertical signs, and the elements on which the method focuses on are:

- Horizontal signs on the cycle path. These must be clearly distinguishable from other road signs using a visible color. The brightness of the signals is evaluated by assigning the number "2" in case of good color, "1" to a medium color and "0" to no color. The edges of the cycle path must also be visible and ensure safety for users.

- Vertical signs near the railway node and along the cycle path. Such signs should be present to provide users with important information. The New Highway Code requires the presence of “the cycle lane sign contiguous to the sidewalk”. It must be installed at the beginning (and at the end) of the cycle path. A sign indicating the pedestrian and cycle path should be set at the beginning (and end) of a promiscuous cycle path. Signs within the railway station to direct cyclists inside are also evaluated.
- Lighting is analyzed and its source is checked. Rate “2” is given in case the lighting is dedicated only to the cycle path, rate “1” in case the lighting is on the general road, and rate “0” in case it comes from advertising or no lightning is provided.
- Signs indicating the points of interest of the city must provide users with all the “necessary information for a proper and safe circulation, as well as easy identification of routes, locations and services” (Art. 124 C.1 RA) (Art. 124 (Art. 39 Cod. Str.). Rate “2” is assigned if the signs are present and complete, “1” in case they are incomplete and “0” in case there are none.

3.3. Services Provided to the Cyclist

The third section includes the “services provided to the cyclist”. The points in this part mainly refer to the “Regional guidelines for cyclability” [46]. It is extremely important that a railway node is furnished with bicycle racks, located at a short distance from the station. Besides securing a bicycle wheel, they should also fix the bicycle frame. The parameters used to define this section are:

- The bike racks covered by shelters are evaluated based on the number of bicycles they can hold.
- The bike racks not covered with shelters are evaluated depending on the portion of bicycle they can secure. If they can secure the body and the wheel, they are marked with number “1”; if they can only secure the wheel of the bicycle, they are marked with number ”0”.
- Accessibility: the presence of elevators or ramps is evaluated, allowing users to carry a bicycle and reach the platforms comfortably, or on the contrary, they can only use stairs.
- Toilets inside the railway station are important to guarantee comfort. Toilets inside commercial activities have not been considered.

3.4. Bicycles Safekeeping Service

The safekeeping places for bicycles are large areas closed to the public that offer the possibility to leave a bicycle safe from all weather conditions and theft, since they are often guarded by personnel. Moreover, most of the time, they are paid services and are accessible using a key or magnetic card.

The following parameters are especially evaluated:

- Proximity to the train station. In this case only, the presence of a safekeeping service for bicycles is considered useful, otherwise it loses attraction to the user.
- The availability of the spots for bicycles inside the safekeeping area is also rated based on the needs.
- Any additional services, such as toilets and vending machines, provided to the user within the safekeeping place.

3.5. Bike-Sharing Service

The section regarding bike sharing is evaluated considering its presence, the distance from the railway node and the availability compared to the needs. Moreover, the possibility to leave the bicycle in a spot different from the point of collection is evaluated with the number “1”, while number “0” is given to its opposite.

3.6. Checklist Score Calculation

At this stage, the checklist created only provides a qualitative result. In order to transform it into a quantitative evaluation, the road network safety ratings [49] and the checklist proposed by the Agency for the Control and Quality of Public Services in the area of Rome [50] were examined. In the study from Rome, the checklist is implemented by assigning a number to each characteristic based on the criticalities that the on-site inspection identified, contributing to the creation of a monitoring table; here, the inspection focuses on the quality of cycle paths in Rome. The road network safety rating is used to monitor the safety quality of a road network and to act on the inadequate ones. Both methods use a checklist where a number is assigned to each topic. In the checklist elaborated for the inspection of intermodality between bicycles and trains, the numerical evaluation of each section is given using an algorithm that provides the following results:

- Every main section is rated between 0 and 100;
- The positive answers provide 1 point, the negative ones provide 0 points;
- The multiple-answer responses provide a fractional rate between 0 and 3;
- The values obtained are, at the end, given in a percentage by multiplying the total number of questions in the single section by the values obtained in the single question in relation to the maximum achievable value.

  The calculation is carried on:

$$\%\ section\ score = \frac{100}{n_{tot}}\left(\frac{x_1}{x_{1tot}} + \cdots + \frac{x_j}{x_{jtot}}\right) \quad (1)$$

- n_{tot} = the number of questions in the single section;
- x_1 = the score of the first question;
- x_{1tot} = the maximum score of the first question;
- x_j = the score of j question;
- x_{jtot} = the maximum score of j question.

- The monitoring tables, one for each type of railway station, are divided into five main groups that consider the above-mentioned characteristics.

The checklist is completed during the inspection while the results are calculated in a second phase, providing a result for each section of each station in the form of a percentage.

4. Results

The results obtained for each section of the checklists are represented in Figure 3 by comparing the three different station categories.

“Sec.IV”, concerning the quality of the bicycle safekeeping service, has the worst results in all three station categories. This service is not present in any of the bronze stations and exists only in a single silver station; even in the gold stations, it does not achieve satisfactory results, as it is estimated at only about 40%.

“Sec.V”, concerning bike sharing, is present in only one bronze station, while it is present in two silver railway stations where the quality of the service is valued at 75%.

When comparing the quality of each gold station, it turns out that bicycle safekeeping services are those that need the most improvements, both inside and around the train station. In fact, this service is missing in three of the railway stations defined as gold and, where present, it does not reach a quality percentage above 86%. The presence of a greater amount of bike-sharing reduces the problem related to bicycle safekeeping. Signs and lighting (“Sec.II”) in proximity to the railway station node represent the second category to be improved in the gold railway stations. Here, only one railway station scores more than 80%, while 4 railway stations out of 11 score less than 50% of quality. The remaining three sections, “Sec.I”, “Sec.III” and “Sec.V” for gold stations are rated between 70% and 80%. “Sec.III” must be stressed as having two railway stations that reach only 50%.

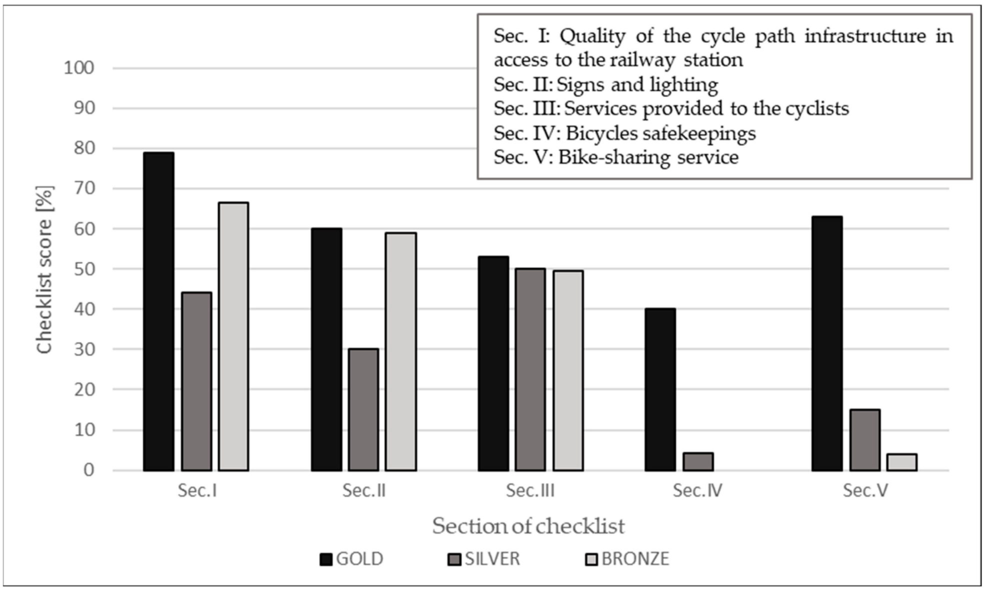

Figure 3. The average results for every section of each station category.

Compared to the other categories, the silver and bronze railway stations are mostly lacking in bicycle safekeeping services (“Sec.IV”). The mostly unfinished category, and therefore, to be implemented for bronze and silver railway stations, is “Sec.V”, which shows the rare presence and low quality of the bike-sharing service. The most performing section in silver railway stations includes services provided to the cyclists. However, they reach only 70%. “Sec.I” and “Sec.II” are rated below 50% in silver train stations. On the contrary, “Sec.I” and “Sec.III” are the most performing sections in bronze railway stations, with a small difference between the two of 66% and 63%, respectively. Finally, Figure 4 shows that the score of “Sec.III” does not differ much among the three gold, silver and bronze categories, respectively, 71%, 66% and 63%.

In the next phase of the study, the results obtained for the three categories of stations in each of the check list applications were compared. Figure 4 shows the results obtained in percentage terms in the five sections analyzed. For the three categories of stations, the trend obtained in each graph is similar because the highest percentages and most critical issues are in the same points.

In Sec.I, concerning the quality of the cycle path, gold stations achieved the highest results in most of the questionnaire items, obtaining 100% in four questions. Question 5, regarding the type of cycle path (Appendix A), obtained the lowest value for all the three categories of stations because the cycle path—if present—is of bidirectional type. Another problem faced for all three types of stations is the conflict with pedestrian traffic (question 12) due to the presence of promiscuous cycle paths. The quality of cycle path is generally worse for silver stations, which never obtain average values above 50%. Basically, this is because only four out of eight stations belonging to this category have a cycle path. The score obtained by each single silver station with a cycling infrastructure ranged from 80% to 90%.

In Sec.II, concerning the visibility and signage of the cycle path, the low values obtained are due to the coloring of the bike path pavement, especially in gold and silver stations. In fact, where a cycle path is present, it is not visible near the railway stations because it is poorly marked. Even vertical driving signs for cyclists are inadequate at most stations. In fact, the signage reaches only 40% for gold stations, while for bronze and silver stations just 20%. On the contrary, gold stations have good night lighting, although this does not always come only from the bike path but also from street lighting.

Sec.III, relating to services for cyclists near the railway node, shows similar values for all three categories of stations. In fact, parking spaces for bicycles outside the station are inadequate for all the stations analyzed. In the bronze stations only, there are shelters equipped with photovoltaic panels and repair kits for bicycles, while no gold and silver stations offer this service. Railway stations are easily accessible for bikes, reaching values above 90% in all three categories. Toilets inside the station are present only in a bronze station, while they are outside the structure in all the other stations.

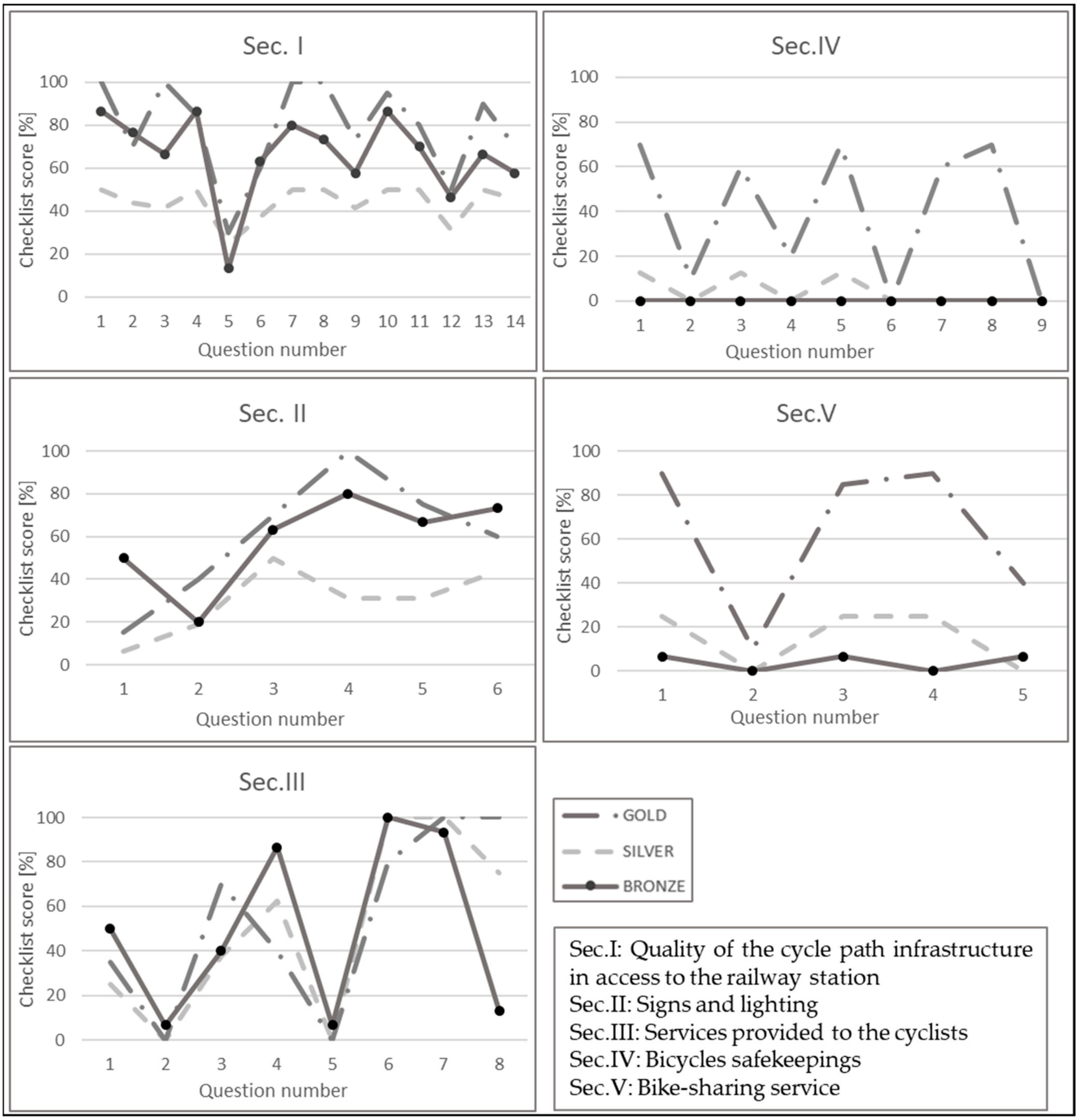

Figure 4. Average results for every question of each section of the checklist (see the number of questions in Appendix A).

Sec.IV, relative to the presence of bicycle storage or velostations, obtains a score equal to 0 in all bronze stations since they are absent in all the fifteen stations analyzed. At silver stations, bike storage services are only outside the station, over 50 m away. Gold stations have more deposits, even more than one per station, but all for a fee.

Bike-sharing services, Sec.V, are present in most gold stations but only one of these also offers other micromobility services. At silver and bronze stations, these services are definitely absent. However, the service does not meet the needs of cyclists at all stations and the bicycle must be brought back to a specific hub without the possibility of leaving it where it is most convenient for users.

5. Discussion and Conclusions

The main objective of this study is to enhance bike–train intermodality in order to improve air quality and reduce traffic pollution sources. To achieve this goal, the characteristics of the stations are analyzed and classified in gold, silver and bronze according to the RFI classification of the Emilia-Romagna region adhering to PAIR 2020, thus highlighting strengths and weaknesses. The monitoring checklist provided in this study allows for an accurate assessment of the strengths and weaknesses of each mobility hub, identifying aspects to be improved with respect to the city that, following the analysis, presents the most efficient infrastructure.

Gold stations have the best overall quality compared to silver and bronze stations. In fact, they obtain the highest scores in all five categories. Perhaps this is because gold railway stations have the highest number of passengers and must ensure a high standard of services accordingly. In addition, gold stations have the important feature of being located in strategic areas relative to city centers and are part of an intermodal system for travelers living in the area. Considering that in the studied region, commuters are over half of the total population (55.4%) (ISTAT commuter data), it is clear why the most powerful railway stations are located in the most populated areas. Eight out of ten railway stations classified as gold have more than 100,000 inhabitants. In total, the average population of gold stations is approximately 145,000 inhabitants, while the average population of silver stations is approximately 41,000 inhabitants and the average population of bronze stations is approximately 23,000 inhabitants. Silver stations have a lower overall quality than bronze ones, although their population is higher. Considering their proximity to important industrial areas, they should guarantee a better standard of service. However, it should be pointed out that in silver stations, the average population is only 18,000 inhabitants higher than in bronze stations, while they have 104,000 fewer citizens than in gold railway stations.

Analyzing the gap between the two stations, silver railway stations do not reach the rates of the bronze stations in "Sec.I" and "Sec.II". This is because half of the railway stations classified as silver have no infrastructure to facilitate the cyclist to reach them. In the four silver railway stations considered, there are no cycle paths, signs, lighting or speed limits of 30 km/h or less that facilitate access to the railway stations for cyclists. As for the bronze railway stations, only two out of fifteen railway stations have no accessible infrastructure outside the railway stations.

"Sec.V" shows that in bronze stations, bike-sharing services are absent in almost all stations. These stations are located in rural areas where citizens use more private vehicles to move because of the distance from urban centers. A study carried out in rural municipalities in Germany has shown that users living in these areas are interested in shared mobility solutions, but it is up to the local authorities to motivate them with educational work by advertising the service offered and how to use it [51].

Providing bike-sharing services close to railway stations is one of the possible solutions to encourage the use of sustainable means of transport for intermodal travel. Jamber et al. have shown that in areas with numerous public transport stops, there is also a significantly higher number of bike-sharing trips. In addition, the combined use of bike-sharing and train seems to be preferred over bike-sharing and bus [52].

To encourage the use of bike-sharing, adequate infrastructure is needed to reach the railway stations. A study carried out in Maryland has shown that the presence of a well-structured network of cycle paths connected to the main nodes would facilitate the use of bicycles to reach very busy places [53]. It has also been shown that increasing bike racks and other services for users, such as lockers inside or near the railway station, increases the number of cyclists using intermodality between bicycle and train as a means of transport [54]. Additionally, Cervero et al. have shown that the improvement of facilities dedicated to cyclists in or near a railway station is directly linked to the increase in the number of bicycles arriving at the railway station [55]. Bicycle parking should be implemented as well. It has been studied that limited bicycle parking racks near railway stations reduce the number of bicycle users [56].

Finally, gold stations, with a total rate of 67%, should be improved, starting from signs and lighting outside and inside the railway station; for example, by redoing the boundaries of the cycle path, painting it and scheduling regular maintenance. In fact, poor lighting results in a negative perception by users of safety, security and comfort [57]. Moreover, the presence of safe and free parking spaces where cyclists can leave their bikes and sharing services (bikes and e-scooters) outside the station increases comfort and services for cyclists [58].

If two railway stations obtain the same score, the subsections of the checklist will be compared quantitatively according to the number of services. This will result in the railway station with the lowest score in the subsections, namely, the one that needs to be given priority regarding implementing interventions. This method helps to define the most urgent interventions among different railway stations. However, it does not help to establish a threshold of complete satisfaction by users of bicycles as a means of transport, while a 100% threshold would be ideal for each station. To overcome this challenge, future developments of the research foresee the involvement of the main stakeholders through questionnaires and round tables to know their needs and the major criticalities they find daily in the railway stations analyzed. In addition to technical aspects, during the decision-making process, social, economic and environmental aspects should also be considered to define the priority actions for the proposal of the project [59,60]. Moreover, future studies will also include the analysis and comparison of the data on bike–train users with the results of the checklists.

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Appendix A. The Checklist Used to Evaluate Bike–Train Intermodality and Accessibility

Table A1. Checklist of bike-train intermodality and accessibility.

Section	Characteristic			Rate
QUALITY OF THE CYCLE PATH INFRASTRUCTURE IN ACCESS TO THE RAILWAY STATION (Sec.I)	1	The cycle track close to the MH is	present or the speed limit is 30 km/h	2
			planned	1
			missing	0
	2	The cycle track is located	close to the station	2
			at least 50 m by the railway station	1
			more than 50 m from the railway station	0
	3	The main pavement is	asphalt or similar	3
			self-locking bricks or similar	2
			macadam or similar	1
			natural soil	0
	4	The quality of pavement is	excellent	2
			good	1
			bad	0
	5	The type of cycle track, if present, is	one way or 30 km/h each way	1
			two-ways	0
	6	The cycle track is	reserved to bicycles or adjoining to sidewalk	2
			combined with pedestrians or with 30 km/h	1
			not defined	0
	7	Are geometrical standards respected when combined with sidewalk?	yes	1
			no	0
	8	Is the slope of the of the cycle track below 5%?	yes	1
			no	0
	9	The sides of the cycleway have	a 20 cm edge beam or dedicated lane	3
			white and yellow stripes or more in general a yellow preferential lane	2
			white lame/30 km/h speed limit lane	1
			missing	0
	10	One-off obstacles, reduction in standards are	missing	2
			almost missing	1
			frequent	0
	11	Lateral conflict due to the presence of shops, household entrances or vehicle entrances are	missing	2
			soft	1
			very frequent	0
	12	Conflict with pedestrian traffic	missing	2
			soft	1
			very frequent	0
	13	Conflict with vehicles traffic	missing	2
			soft	1
			very frequent	0
	14	Accessibility: visible and in good state accesses of cycle path	excellent	3
			good	2
			poor	1
			bad	0
TOTAL				

Table A1. *Cont.*

Section	Characteristic			Rate
SIGNS AND LIGHTING (Sec.II)	1	The cycle path is painted (or has colored tiles) characterized with	good color	2
			average color	1
			no color	0
	2	Street signs indicating the correct behavior cyclists must follow	existing/makes sense	2
			existing	1
			missing	0
	3	Horizontal street signage: the limits of the cycle path are	very visible	2
			averagely visible	1
			not sufficient	0
	4	The cycle path is provided with	great lighting	2
			normal lighting	1
			poor lighting	0
	5	The type of lighting is	inside the cycle path	2
			on the public street	1
			private, from advertising	0
	6	Does the vertical signage exist in the node?	yes, visible and close to the cycle path	2
			yes, not clearly visible	1
			no	0
TOTAL				
SERVICES PROVIDED TO THE CYCLIST (Sec.III)	1	The bicycles parking slots are protected with overhead shelter	with great coverage, 2 or more lanes of bicycles	2
			average coverage, one lane of bicycles	1
			missing	0
	2	If present, are the shelters covered with fotovoltaic panels?	yes	1
			no	0
	3	In case of no shelters, the bike racks are	both types	2
			high, the tire and body of the bicycle can be secured	1
			low, only the tire can be secured	0
	4	Is the number of bike racks enough compared to the needs?	yes	1
			no	0
	5	Is there a bike repair kit?	yes	1
			no	0
	6	Are there locations for leaving the bike?	yes	1
			no	0
	7	Is there a ramp or a lift to descend?	yes	1
			no, only stairs	0
	8	Are there toilets inside the railway station?	yes	1
			no	0
TOTAL				

Table A1. *Cont.*

Section		Characteristic		Rate
BICYCLES SAFEKEEPINGS (Sec.IV)	1	Is there a deposit for bicycles?	yes	2
			in plan	1
			no	0
	2	The safekeeping is	inside a covered building	1
			in the open air	0
	3	If present, is the safekeeping within 50 m from the railway station?	yes	1
			no	0
	4	Is there more than one safekeeping?	yes	1
			no	0
	5	Inside the safekeeping, the racks are disposed in	two lanes with central access	1
			one lane with lateral access	0
	6	The safekeeping is	for free	1
			for payment	0
	7	The safekeeping	has services for users	1
			does not have any service	0
	8	The safekeeping	has services for bike repair/bike rent	1
			does not have services for bike repair/bike rent	0
	9	Is the number of available spots shown from the outside?	yes	1
			no	0
TOTAL				
BIKE SHARING SERVICE (Sec.V)	1	Is there bike sharing?	yes	1
			no	0
	2	Are there other micromobility services?	yes	1
			no	0
	3	Bike-sharing service is located	less than 50 m from the railway station	2
			between 50–500 m from railway station	1
			more than 500 m from railway station	0
	4	Is the bike-sharing service adequate compared to the needs?	yes	1
			no	0
	5	Can the shared bike be left in a place other than the collection place?	yes	1
			no	0
TOTAL				

References

1. International Energy Agency. Net Zero by 2050—A Roadmap for the Global Energy Sector. 2050. Available online: www.iea.org/t&c/ (accessed on 4 November 2022).
2. ISPRA. Emissioni di Gas a Effetto Serra da Trasporti. 2019. Available online: https://annuario.isprambiente.it/pon/basic/11 (accessed on 5 December 2022).
3. Zheng, X.; Lu, S.; Yang, L.; Yan, M.; Xu, G.; Wu, X.; Fu, L.; Wu, Y. Real-World fuel consumption of light-duty passenger vehicles using on-board diagnostic (OBD) systems. *Front. Environ. Sci. Eng.* **2020**, *14*, 33. [CrossRef]
4. ISPRA. Istituto Superiore per la Protezione e la Ricerca Ambientale. Available online: https://www.isprambiente.gov.it/it/servizi/mobilita-sostenibile/strumenti (accessed on 8 November 2022).
5. Battistini, R.; Passarini, F.; Marrollo, R.; Lantieri, C.; Simone, A.; Vignali, V. How to Assess the Carbon Footprint of a Large University? The Case Study of University of Bologna's Multicampus Organization. *Energies* **2022**, *16*, 166. [CrossRef]
6. Daniels, R. La Decarbonizzazione dei Trasporti: È un Obiettivo Possibile? Available online: http://eut.units.it (accessed on 4 November 2022).

7. International Transport Forum. *Shared Mobility Simulations for Lyon*; International Transport Forum Policy Papers, No. 74; OECD Publishing: Paris, France, 2020. [CrossRef]
8. Eren, E.; Uz, V.E. A review on bike-sharing: The factors affecting bike-sharing demand. *Sustain. Cities Soc.* **2019**, *54*, 101882. [CrossRef]
9. Aydin, N.; Seker, S.; Özkan, B. Planning Location of Mobility Hub for Sustainable Urban Mobility. *Sustain. Cities Soc.* **2022**, *81*, 103843. [CrossRef]
10. Arseneault, D. UCLA Capstone Projects. In *Mobility Hubs: Lessons Learned from Early Adopters*; UCLA Institute of Transportation Studies: Los Angeles, CA, USA, 2022. [CrossRef]
11. Bell, D. Intermodal Mobility Hubs and User Needs. *Soc. Sci.* **2019**, *8*, 65. [CrossRef]
12. Tran, M.; Draeger, C. A data-driven complex network approach for planning sustainable and inclusive urban mobility hubs and services. *Environ. Plan. B Urban Anal. City Sci.* **2021**, *48*, 2726–2742. [CrossRef]
13. Litman, T. Introduction to Multi-Modal Transportation Planning—Principles and Practices. 2022. Available online: https://vtpi.org/multimodal_planning.pdf (accessed on 8 November 2022).
14. Dacko, S.G.; Spalteholz, C. Upgrading the city: Enabling intermodal travel behaviour. *Technol. Forecast. Soc. Change* **2013**, *89*, 222–235. [CrossRef]
15. Heddebaut, O. Creating Sustainable and Efficient Transport Interchanges: Some Findings of the City-HUB Project. *Adv. Civ. Eng. Technol.* **2018**, *1*, 1–3. [CrossRef]
16. Pazzini, M.; Lantieri, C.; Vignali, V.; Simone, A.; Dondi, G.; Luppino, G.; Grasso, D. Comparison between different territorial policies to support intermodality of public transport. *Transp. Res. Procedia* **2022**, *60*, 68–75. [CrossRef]
17. Weliwitiya, H.; Rose, G.; Johnson, M. Bicycle train intermodality: Effects of demography, station characteristics and the built environment. *J. Transp. Geogr.* **2019**, *74*, 395–404. [CrossRef]
18. Gołębiowski, P.; Gołda, I.J.; Izdebski, M.; Kłodawski, M.; Jachimowski, R.; Szczepański, E. The evaluation of the sustainable transport system development with the scenario analyses procedure. *J. Vibroeng.* **2017**, *19*, 5627–5638. [CrossRef]
19. Akgün, N.; Daniels, S.; Bell, M.C.; Nuyttens, N.; Thorpe, N.; Dissanayake, D. Exploring regional differences in cyclist safety at roundabouts: A comparative study between the UK (based on Northumbria data) and Belgium. *Accid. Anal. Prev.* **2020**, *150*, 105902. [CrossRef] [PubMed]
20. Rietveld, P. Non-motorised modes in transport systems: A multimodal chain perspective for The Netherlands. *Transp. Res. Part D Transp. Environ.* **2000**, *5*, 31–36. [CrossRef]
21. Parlamento Europeo. Direttiva 2008/50/ce del Parlamento Europeo e del Consiglio. 2008. Available online: https://eur-lex.europa.eu/legal-content/IT/LSU/?uri=CELEX:32008L0050 (accessed on 16 November 2022).
22. Metropolitan City of Bologna. SUMP—Sustainable Urban Mobility Plan. 2019. Available online: https://www.cittametropolitana.bo.it/pianificazione/Strumenti_di_pianificazione/Piano_Urbano_della_Mobilita_Sostenibile_-_PUMS_metrobo (accessed on 16 November 2022).
23. Dill, J.; Voros, K. Factors Affecting Bicycling Demand. *Transp. Res. Rec. J. Transp. Res. Board* **2007**, *2031*, 9–17. [CrossRef]
24. Rietveld, P.; Daniel, V. Determinants of bicycle use: Do municipal policies matter? *Transp. Res. Part A Policy Pract.* **2004**, *38*, 531–550. [CrossRef]
25. Parkin, J.; Wardman, M.; Page, M. Estimation of the determinants of bicycle mode share for the journey to work using census data. *Transportation* **2008**, *35*, 93–109. [CrossRef]
26. Mateo-Babiano, I.; Bean, R.; Corcoran, J.; Pojani, D. How does our natural and built environment affect the use of bicycle sharing. *Transp. Res. Part A Policy Pract.* **2016**, *94*, 295–307. [CrossRef]
27. Mertens, L.; Compernolle, S.; Deforche, B.; Mackenbach, J.D.; Lakerveld, J.; Brug, J.; Roda, C.; Feuillet, T.; Oppert, J.-M.; Glonti, K.; et al. Built environmental correlates of cycling for transport across Europe. *Health Place* **2017**, *44*, 35–42. [CrossRef]
28. Moudon, A.V.; Lee, C.; Cheadle, A.D.; Collier, C.W.; Johnson, D.; Schmid, T.L.; Weather, R.D. Cycling and the built environment, a US perspective. *Transp. Res. Part D Transp. Environ.* **2005**, *10*, 245–261. [CrossRef]
29. Aertsens, J.; de Geus, B.; Vandenbulcke, G.; Degraeuwe, B.; Broekx, S.; De Nocker, L.; Liekens, I.; Mayeres, I.; Meeusen, R.; Thomas, I.; et al. Commuting by bike in Belgium, the costs of minor accidents. *Accid. Anal. Prev.* **2010**, *42*, 2149–2157. [CrossRef]
30. Heesch, K.C.; Giles-Corti, B.; Turrell, G. Cycling for transport and recreation: Associations with the socio-economic, natural and built environment. *Health Place* **2015**, *36*, 152–161. [CrossRef]
31. Konstantinidou, M.; Spyropoulou, I. Factors affecting the propensity to cycle—The case of Thessaloniki. *Transp. Res. Procedia* **2017**, *24*, 123–130. [CrossRef]
32. Maciorowski, M.M.; Souza, J.C. Urban Roads and Non-Motorized Transport: The Barrier Effect and Challenges in the Search for Sustainable Urban Mobility. *Transp. Res. Procedia* **2018**, *33*, 123–130. [CrossRef]
33. Krizek, K.J.; Stonebraker, E.W. Assessing Options to Enhance Bicycle and Transit Integration. *Transp. Res. Rec. J. Transp. Res. Board* **2011**, *2217*, 162–167. [CrossRef]
34. Egan, R.; Dowling, C.M.; Caulfield, B. Planning for Diverse Cycling Practices: A Cycle-Parking Type Preference Typology. *Case Stud. Transp. Policy* **2022**, *10*, 1930–1944. [CrossRef]

35. Arbis, D.; Rashidi, T.H.; Dixit, V.; Vandebona, U. Analysis and planning of bicycle parking for public transport stations. *Int. J. Sustain. Transp.* **2015**, *10*, 495–504. [CrossRef]
36. Garrard, J.; Rose, G.; Lo, S.K. Promoting transportation cycling for women: The role of bicycle infrastructure. *Prev. Med.* **2008**, *46*, 55–59. [CrossRef]
37. Johnson, M.; Charlton, J.; Oxley, J.; Newstead, S. Naturalistic cycling study: Identifying risk factors for on-road commuter cyclists. *Ann. Adv. Automot Med.* **2010**, *54*, 275–283.
38. Campisi, T.; Akgün, N.; Ticali, D.; Tesoriere, G. Exploring Public Opinion on Personal Mobility Vehicle Use: A Case Study in Palermo, Italy. *Sustainability* **2020**, *12*, 5460. [CrossRef]
39. Osama, A.; Sayed, T. Evaluating the Impact of Socioeconomics, Land Use, Built Environment, and Road Facility on Cyclist Safety. *Transp. Res. Rec. J. Transp. Res. Board* **2017**, *2659*, 33–42. [CrossRef]
40. Eriksson, J.; Niska, A.; Forsman, Å. Injured cyclists with focus on single-bicycle crashes and differences in injury severity in Sweden. *Accid. Anal. Prev.* **2021**, *165*, 106510. [CrossRef] [PubMed]
41. President of the Republic. Law Decree n.68. 16 June 2022. Available online: https://www.infoparlamento.it/tematiche/disegni-di-legge/ac-3702-governo-dl-682022-trasporti (accessed on 17 November 2022).
42. Emilia Romagna Region. Resident Population in Emilia Romagna. 2021. Available online: https://statistica.regione.emilia-romagna.it/notizie/2021/popolazione-residente-emilia-romagna-2021#:~:text=Al%20primo%20gennaio%202021%20risultano,del%20%2D0%2C32%25 (accessed on 17 November 2022).
43. Emilia Romagna Region. Tourism in Emilia-Romagna in the First Two Years of Pandemic Crisis. 7 July 2022. Available online: https://statistica.regione.emilia-romagna.it/notizie/2022/turismo-emilia-romagna-primi-due-anni-di-pandemia-2019-2021#:~:text=Nel%20corso%20del%202021%20le,inferiori%20del%2023%2C6%25 (accessed on 17 November 2022).
44. Minister for Public Works. Regulation Defining the Technical Characteristics of Cycle Paths. 30 April 1999. Available online: https://www.gazzettaufficiale.it/eli/id/2000/09/26/000G0315/sg (accessed on 17 November 2022).
45. President of Republic. New Highway Code. 30 March 1992. Available online: https://www.gazzettaufficiale.it/eli/id/1994/03/22/093A6158/sg (accessed on 17 November 2022).
46. Emilia Romagna Region. Linee Guida per il Sistema Regionale Della Ciclabilità (L.r. n. 10/2017)—In Coordinamento con il Progetto Life Integrato PREPAIR. May 2019. Available online: https://mobilita.regione.emilia-romagna.it/allegati/convegni_presentazioni/2019/mag2019_lineeguidaciclabilita/lineeguidaciclabilita_allegato1.pdf/@@download/file/lineeguidaciclabilita_allegato1.pdf (accessed on 17 November 2022).
47. Emilia Romagna Region. Legge Regionale 5 Giugno 2017, n.10. 2017. Available online: https://demetra.regione.emilia-romagna.it/al/articolo?urn=urn:nir:regione.emilia.romagna:legge:2017-12-27;25&dl=LR/10/2017/LR_2017_25_s1/LR_2017_25_s1_v1.xml&dl_db=y&dl_t=text/xml&dl_a=y&dl_id=10&pr=idx,0;artic,0;articparziale,1&anc=cap4 (accessed on 17 November 2022).
48. Federal Highway Administration. Separated Bike Lane Planning and Design Guide. 2015. Available online: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/separated_bikelane_pdg/separatedbikelane_pdg.pdf (accessed on 3 February 2023).
49. European Commission. Mobility & Transport—Road Safety. Available online: https://road-safety.transport.ec.europa.eu/statistics-and-analysis/statistics-and-analysis-archive/safety-ratings/road-network-safety-ratings_en (accessed on 17 November 2022).
50. Municipality of Rome. Agenzia per il Controllo e la Qualità dei Servizi Pubblici del Comune di Roma. 2010. Available online: https://www.agenzia.roma.it/documenti/schede/430.pdf (accessed on 17 November 2022).
51. Schaefer, C.; Stelter, A.; Holl-Supra, S.; Weber, S.; Niehaves, B. The Acceptance and Use Behavior of Shared Mobility Services in a Rural Municipality. *Smart Cities* **2022**, *5*, 1229–1240. [CrossRef]
52. Jaber, A.; Abu Baker, L.; Csonka, B. The Influence of Public Transportation Stops on Bike-Sharing Destination Trips: Spatial Analysis of Budapest City. *Future Transp.* **2022**, *2*, 688–697. [CrossRef]
53. BART Bicycle Plan: Modeling Bicycle Access to Transit. July 2012. Available online: https://www.bart.gov/sites/default/files/docs/BART_Bike_Plan_Final_083012.pdf (accessed on 1 February 2023).
54. Akar, G.; Clifton, K.J. Influence of Individual Perceptions and Bicycle Infrastructure on Decision to Bike. *Transp. Res. Rec. J. Transp. Res. Board* **2009**, *2140*, 165–172. [CrossRef]
55. Cervero, R.; Caldwell, B.; Cuellar, J. Bike-and-Ride: Build It and They Will Come Bike-and-Ride: Build It and They Will Come The Case for Bike-and-Ride. *J. Public Transp.* **2013**, *16*, 83–105. [CrossRef]
56. Cervero, R.; Round, A.; Goldman, T.; Org, E. UC Berkeley Earlier Faculty Research Title Rail Access Modes and Catchment Areas for the BART System Publication Date. 1995. Available online: https://escholarship.org/uc/item/07k76097 (accessed on 3 February 2023).
57. Ferreira, M.C.; Costa, P.D.; Abrantes, D.; Hora, J.; Felício, S.; Coimbra, M.; Dias, T.G. Identifying the determinants and understanding their effect on the perception of safety, security, and comfort by pedestrians and cyclists: A systematic review. *Transp. Res. Part F Traffic Psychol. Behav.* **2022**, *91*, 136–163. [CrossRef]
58. Simons, D.; Clarys, P.; De Bourdeaudhuij, I.; de Geus, B.; Vandelanotte, C.; Deforche, B. Why do young adults choose different transport modes? A focus group study. *Transp. Policy* **2014**, *36*, 151–159. [CrossRef]

59. Corticelli, R.; Pazzini, M.; Mazzoli, C.; Lantieri, C.; Ferrante, A.; Vignali, V. Urban Regeneration and Soft Mobility: The Case Study of the Rimini Canal Port in Italy. *Sustainability* **2022**, *14*, 14529. [CrossRef]
60. Pazzini, M.; Lantieri, C.; Vignali, V.; Simone, A.; Dondi, G.; Luppino, G.; Grasso, D. Case Studies in the Emilia Romagna Region in Support of Intermodality and Accessibility of Public Transport. In *Advances in Mobility-as-a-Service Systems*; Springer: Berlin/Heidelberg, Germany, 2021; Volume 1278, pp. 65–74.

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Assessing Cyclists' Accessibility into Railway Stations Through a User-Centered Indicator

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Abstract: Nowadays, there is a growing interest in integrated sustainable transportation. Bike–train intermodality is one of the sustainable modes of transport, combining long-distance service and reaching the last mile. However, bike–train intermodality development both presents challenges for transport service providers and has its drawbacks for users who prefer connections that do not require changing between transport modes. The challenge consists of providing a better transition during changes between transport modes. This can be accomplished through understanding the needs of travelers followed by the implementation of infrastructural changes and the expansion of targeted services that increase the accessibility of the nodal points. Cost-effectiveness analysis, cost–benefit analysis, and a multicriteria decision process are some of the methods that can be used to allocate resources that could improve bike–train intermodality. This research extended the concept of resource allocation to a new multilevel weighted indicator (AxI) that measured the level of accessibility of bikes into railway stations to identify the criticalities and define the priority of interventions. The proposed method was applied in thirty-three Italian railway stations of different sizes. The results showed that the proposed indicator was a valid tool for railway station infrastructure managers and all stakeholders involved for prioritizing interventions related to the advancement of bike–train intermodality. The AxI indicator is a lean methodology to identify the exigencies and communicate them to the parties involved in the management and actualization. The AxI lays the groundwork for a straightforward discussion on resource distribution priorities.

Keywords: bike–train intermodality; prioritization; accessibility

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1. Introduction

In the 2021 "Transport and Environment Report", the European Environment Agency reported that unlike other sectors, greenhouse gas emissions from the transport sector have increased by 33.5% in the last three decades, and in 2019, transport was responsible for about a quarter of EU greenhouse gas emissions. According to available data, 72% of transport emissions come from roads. In this scenario, cars play a predominant role, contributing 60.6% of total emissions, followed by heavy trucks and buses, which together account for 27.1% of emissions. The climate impacts of a passenger-kilometer transported by car are substantially higher than those of public transport and active modes of travel (on foot and by bicycle). One of the means to reduce the influence of transport on emissions is to switch to modes of transport that emit fewer greenhouse gases and to non-motorized modes such as cycling and walking. In 2018, only 0.4% of the EU's total greenhouse gas emissions came from the rail sector [1]. There are multiple benefits in the use of rail transport compared with other modes [2]. Baum-Snow et al. found that commuter travel times were significantly shorter in areas that had developed a strong rail system compared with similar places with no rail system [3]. On the environmental side, Shang et al. demonstrated that implementing an urban rail transit would drastically reduce emissions [4]. One of the rail transport issues is reaching the "last mile" [5]. Previous studies recommend that making the railway station more accessible to modes that could fulfil the last mile (bicycles, ride-hailing, or on-demand services) would encourage the use of the train as the main means of transport [6]. In the Netherlands, UK, and Germany, users would cycle up to 5 km to reach the railway station [7].

In recent decades, there has been a growing interest in the use of bicycles, for its low cost, the little experience required for the user, and the environmental impact. The promotion of cycling is one of the objectives that aligns with those of the European Community outlined in the 2030 Agenda. In Italy, the Ministry of Sustainable Infrastructure and Mobility published the "General plan of cycling mobility 2022–2024", which aims at improving a long-term plan on the cycling mobility system [8]. The two-year plan aims to strengthen the execution of the National Cycling Mobility System to build an integrated, multimodal, and sustainable mobility model, with cyclability as the focus [9]. The sustainable urban mobility plan contains actions to encourage cycling and adopt sustainable policies through understanding and sharing of good practices and providing adequate funding [3]. At a microscale, several cities have embraced initiatives to encourage micromobility as a viable mode of transportation [10]. Data show that in Italy, the use of dockless bike-sharing between 2021 and 2022 had an increase of 95% [11]. The Municipality of Bologna provided an urban plan to improve sustainable mobility through, among other actions, the improvement of the use of bicycles to reduce by 40% the emissions provided by motorized vehicles by 2023 [12]. In addition, Bologna has invested in cycle paths and services connecting the city, as well as providing guidelines and standard models for creating mobility hubs. The project aims to provide a safe network for cyclists, in order to involve more people in using the bicycle for commuting [13].

Mobility hubs are an urban infrastructure designed to provide a variety of shared transport modes (at least two) in the same place, where integration with public transport is highly recommended [14]. Mobility hubs emerge as central elements for the promotion of intermodality. In fact, these places act as points of convergence between different modes of transport, facilitating the integration of medium- and long-haul, suburban and urban travel. As indicated in the 20th Report on the Mobility of Italians, intermodality is crucial to promote a sustainable alternative to the private car.

The foundations of an intermodal and sustainable mobility system are made up of rail transport, local public transport, "soft" mobility (such as walking, cycling, and electric micromobility), and sharing mobility, especially when connected to public transport [15]. Specifically, bike–train intermodality is a significant opportunity to promote integrated travel modes that respect the environment. Railway stations are the nodal points of this interconnection, acting as an interface between rail and two-wheeled transport. The attractiveness of the bike-and-ride mode of transport is strictly connected to the accessibility of railway stations [7]. Arthur et al. demonstrated that there is a positive correlation between cycling and the number of facilities dedicated to it, especially for commuters [16]. Numerous studies have identified the relationships between rates of bicycling and provision on infrastructure [17]. Handy et al. found that a short distance to work, safe streets for cycling, and high monthly parking costs are associated with bicycle commuting [18]. Moreover, the presence of traffic lights, a low traffic volume, and congestion, as well as bicycle ownership and frequency of use, increase the propensity to cycle as they are factors that increase a positive perception of the surroundings [19]. A study also showed that infrastructure, communication, incentive, and regulative measures are also of importance for making intermodal transportation a viable option for commuters [20].

Despite the many advantages and investments made to encourage sustainable mobility, and especially bike–train intermodal trips, there is currently no method for allocating resources efficiently. There is a need for an effective way to improve services and infrastructure in order to increase the number of passengers and commuters using intermodal travel. Past research has studied methodologies used for resource allocation. Cost–benefit analysis is a quantitative method that compares the total expected costs against the total expected benefits of one or more actions, to choose the most profitable option [21]. It is highly concentrated on economic aspects as it states how prepared an individual is to pay for a reduced risk or improvement of a service [22]. Browne et al. studied and compared the use of the cost–benefit analysis and the cost-effectiveness analysis on the transportation sector and found out that the two methods did not provide complete results and that they should be associated with the multicriteria decision analysis [23]. The multicriteria decision analysis is a decision-making framework that evaluates multiple conflicting criteria in decision making. In this case, each criterion is assigned a different weight [24]. The analytical hierarchy process (AHP), among others, is one of the many methodologies developed to define each weight, specifically the modification to the fuzzy AHP method [25].

Research was carried out in the past on specific applications of these methodologies at railway stations. Coppola et al. implemented a multicriteria decision-making tool to prioritize investments in railway stations using a multidimensional cost-effectiveness analysis. The methodology focused on a series of successive phases, proposing several interventions to achieve strategic objectives that acted to reduce costs while maintaining high standards [26]. Another tool used to prioritize interventions related to railway stations is the condition-based monitoring method; however, it is used to detect faults in the rail system and focuses only on the maintenance of existing facilities [27]. To prioritize the importance of services, Geetika et al. carried out a passenger survey of 16 items at an Indian railway station platform and then applied principal component analysis [28]. Gupta et al. developed a methodology to prioritize interventions related to services inside Indian railway stations [29]. Here, the use of Likert scale data is substituted with the law of categorical judgment. Although many methods have been studied to prioritize interventions, the specific improvements in the accessibility of bicycles inside a railway station from the user and potential user have not yet been studied. The accessibility level has been widely used as an indicator of equity. For instance, parks accessibility is studied through an OD cost model based on the minimum cost analysis of travel time between residents and parks [30]. Many methodologies show how the executions on infrastructure and services can be economically quantified and prioritized. However, each methodology is either too complex and non-cost-effective or non-specific to bike–train intermodality.

In this research, a specific method is proposed to explore and identify a multidimension of key performance indicators for prioritizing interventions. This paper builds upon the above methodologies introducing some innovative aspects. In particular, it takes advantage of a sample of more than 1000 people, allowing us to obtain a robust user-centered tool. The methodology is divided into three main steps:

1. Identification of elements defining bike accessibility and bike–train intermodality;
2. Connection of each element with a weight since not all items have the same importance;

3. Setup of an equation as the final AxI value calculation.

2. Materials and Methods

The model defined for this research followed the sequential structure represented in Figure 1 and included three main parts. The first part consisted of the definition of the categories and their indicators. A category defined the set that contained the indicators. The indicator was the specific characteristic of a category that was being evaluated. The categories that were identified were as follows:

- A—Quality of cycle track infrastructure direction north;
- A—Quality of cycle track infrastructure direction south;
- A—Quality of cycle track infrastructure direction east;
- A—Quality of cycle track infrastructure direction west;
- B—Visibility of the area outside the railway station and signs to direct cyclists inside the railway station;
- C—Services for cyclists near the railway node;
- D—Bike deposit;
- E—Bike sharing.

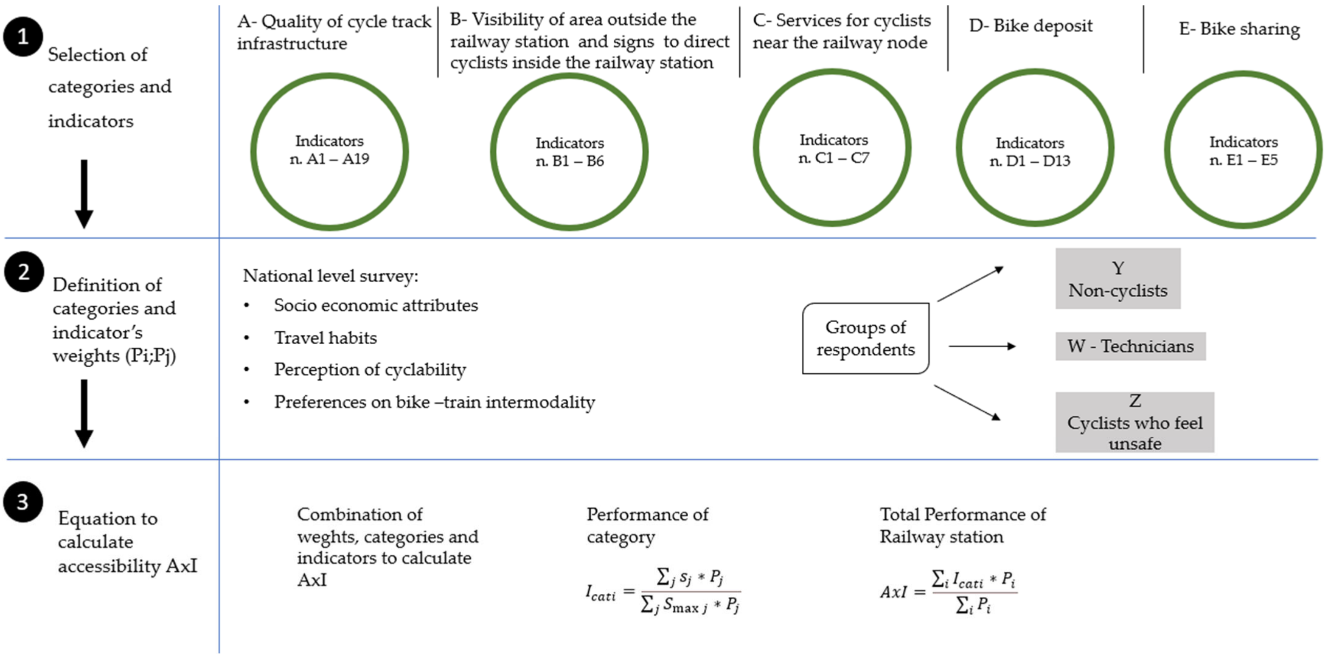

Figure 1. Path diagram of the proposed model to obtain the AxI.

Each of the above categories had a specific number of indicators, based on the elements evaluated inside the railway station.

The second part of the sequential structure was the weighting and normalization of indicators. The weighting process was based on a survey conducted on the Italian population. Here, the respondents were divided into three groups. The main identified groups of respondents were non-cyclists, regular cyclists who did not feel safe while riding, and technicians. Each survey response could be directed to a specific category and indicator. Finally, in the third part of the methodology, the final calculation of the accessibility indicator to measure bike–train intermodality (AxI) was defined through the combination of the weights, indicators, and categories.

2.1. Selection of Categories and Indicators

The accessibility indicator to measure bike–train intermodality was developed through understanding of the needs of cyclists who reached the railway station. The Highway Code, the Regional Guidelines on Cyclability, and the International Manuals on Cyclability define the qualities required to create an accessible environment for cyclists [31–33]. These qualities could be classified into infrastructural elements and services. The infrastructural characteristics included cycle tracks that allow access to the railway station. The presence of bike sharing, of a bike deposit, or of bike racks were some of the evaluated services.

2.1.1. A—Quality of Cycle Track Infrastructure

Category A defines the quality of cycle track in access to the railway station. To provide the most effective results, category A is repeated for the four main cardinal axes. The aim is to understand if the railway station is accessible from every direction. The indicators from category A are listed in Table A1 of Appendix A.

2.1.2. B—Visibility of the Area Outside the Railway Station and Signs to Direct Cyclists Inside the Railway Station

The evaluation of signs inside the railway station and lighting outside the railway station addresses the presence of vertical signs inside and on the immediate external area of the railway station, with a focus on ensuring clear communication and visibility for cyclists. The indicators evaluated are listed in Table A2 of Appendix A.

2.1.3. C—Services for Cyclists near the Railway Node

Specific services for cyclists should be available near the railway station to improve the attractiveness of the trip. Services include bike parking spots, a bike repair kit, lifts or ramps to access platforms, and the ticket office. The indicators from category C are listed in Table A3 of Appendix A.

2.1.4. D—Bike Deposit

Theft risk is one of the factors included in the cyclist mobility costs that affect the choice of taking this means of transport [34]. A bike deposit is a good solution to prevent bicycle thefts as it is a protected facility, usually separated by free parking racks and accessible through specific modalities. The elements evaluated within the bike deposit are listed in Table A4 of Appendix A.

2.1.5. E—Bike Sharing

A bike sharing service is a fast-growing transport mode that allows people to rent bicycles for short-distance trips and last-mile connections [35]. The choice of a user to engage in the use of bike sharing depends on many factors. One of these includes the dockless bike share, which has a broader use, especially when integrated with transit [36]. The indicators included in category E are listed and described in Table A5 of Appendix A.

2.2. Definition of Categories and Indicators' Weights

Each category and indicator was assigned to a weight in a multilevel weighting system, to allow a rewarding macrodecision and to also be able to prioritize interventions on a microlevel scale [26]. The weight associated with each category and indicator was defined by a population survey where cyclability and bike–train intermodality elements were requested to be rated [37]. The survey collected information concerning the following:

- The socioeconomic attributes of the respondents, which include the sex, age, occupation, level of education, and residence;
- The mobility habits, the use of bike, and the use of bike combined with the train;

- The preferences regarding cycling and the combination of biking and riding on the train: 52 indicators were included according to a five-point structure on the Likert scale. The indicators were intended to capture the attitudes or psychological traits of the quality-of-service demand behavior.

Figure 2 shows how the respondents to the survey were divided into groups. First, respondents were divided into regular cyclists and non-cyclists. In case they were non-cyclists (15.69%) (group Y), they were asked what elements would drive them to the opposite trend. If they already used their bike frequently (at least once a week) (84.31%), they were asked what elements affected their perception of safety while riding. Among frequent bike users, 84.83% (35.80% females; 1.22% others) stated that they did not always feel safe (group Z), and 15.17% (44% females) stated that they always felt safe. In case the respondent did not feel safe, questions were asked about what affected their perception of safety. All respondents (non-cyclists and regular cyclists) were then asked specific questions on bike–train intermodality. Finally, group W, which included technicians, had to respond to a specific set of technical questions on bike–train intermodality.

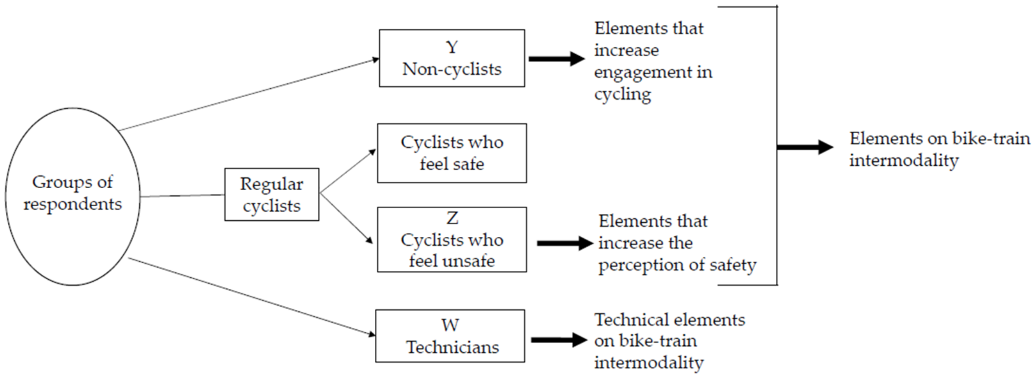

Figure 2. Identification of groups of respondents.

This methodology allowed for a more heterogenous sample and more precise results, including all types of travelers and all different perceptions regarding cyclability.

The elements evaluated by groups Y, Z, and W separately and by regular cyclists and non-cyclists are listed in Table 1, associated with the indicator they refer to.

Table 1. Elements evaluated by the different participants of the survey, each related to an indicator from the AxI (see Appendix A for the definition of each indicator).

Element Evaluated	Regular Cyclists and Non-Cyclists	W	Y	Z	Category	Indicator Number
	Intermodality Specific		Bike Specific			
Direct and fast cycle paths even if they mean the use of a cycle lane			✓	✓	A	1
Closeness to points of interest	✓		✓		A	2
The type of road paving		✓			A	3
The quality of the road paving		✓			A	4
Cycle paths at raised level			✓	✓	A	6
Cycle paths protected with curb			✓	✓	A	7
The presence of a one-lane cycle path rather than two lanes in a two-way cycle path	✓				A	8

Table 1. *Cont.*

Element Evaluated	Regular Cyclists and Non-Cyclists	W	Y	Z	Category	Indicator Number
	Intermodality Specific		**Bike Specific**			
The respect of the geometric standards		✓			A	
Lower slope of the street			✓	✓	A	9
The absence of fixed obstacles	✓				A	10
The absence of lateral conflict due to driveways	✓				A	11
The absence of interference with pedestrians	✓				A	12
Low conflict with vehicular traffic	✓		✓	✓	A	13
The coloring of the cycle path compared with the external asphalt	✓				A	14
The presence of signs dedicated to the points of interest	✓				A	17
A good cycle path lighting			✓	✓	A	18
The source of lighting of the cycle path		✓			A	19
Good signs dedicated to cyclists			✓	✓	A	15–16
Direction of the cycle path					A	
The maintenance of the cycle path	✓				A	
The absence of vehicles parked by the cycle path	✓				A	
The lighting at the entrance of the railway station	✓				B	2
The visibility of bike racks entering/exiting the railway station	✓				B	4
A sign to distinguish the bike parking		✓			B	5
Signs direct to lifts/ramps/cycle paths	✓				B	1_3
The presence of bike racks	✓				C	1
The possibility to tie up the bike frame and the wheel	✓				C	2
The number of bike parking slots		✓			C	3
The presence of a pumping column	✓				C	4
The presence of ramps/lifts to reach platforms	✓				C	5
The accessibility of bikes to the ticket box		✓			C	6
The presence of toilets inside the railway stations		✓			C	7
The possibility to bring the bike on the bus		✓			C	8

Table 1. *Cont.*

Element Evaluated	Regular Cyclists and Non-Cyclists	W	Y	Z	Category	Indicator Number
	Intermodality Specific		**Bike Specific**			
Bike parking spots not overcrowded			✓		C	
Lower probability of theft			✓		C	
Presence of bike deposits			✓	✓	D	1
The presence of a deposit inside the railway station		✓			D	2
The distance of the bike deposit from the railway station	✓				D	3
The presence of more than one bike deposit		✓			D	4
The number of bike spots inside the bike deposit		✓			D	5
Safe, free parking spots	✓		✓	✓	D	6
The level of occupancy of the bike deposit		✓			D	9
The presence of video surveillance inside the deposit		✓			D	10
The possibility to book in advance a slot inside the bike deposit	✓				D	11
The opening hours of the bike deposit	✓				D	12
The method to access the bike deposit	✓				D	13
The presence of services for the cyclist inside the bike deposit	✓				D	7_8
Bike sharing availability	✓		✓		E	1
The presence of micromobility services other than bike sharing		✓			E	2
The distance of the bike sharing from the railway station		✓			E	3
The number of bikes of the bike sharing service		✓			E	4
The presence of bike sharing without obligation to return in specific areas	✓				E	5

The seventh column of Table 1 shows that some questions were not assigned to an indicator but only to a category (e.g., “Bike parking spots not overcrowded”, category C). The elements associated with a category and not a specific indicator were used to calculate the weight of the category.

The survey was diffused online to the Italian population via LinkedIn and the regional company. The map (Figure 3) shows a heat map of the distribution of responses in the country; the heat map indicates that the majority of responses came from the northern half of the peninsula.

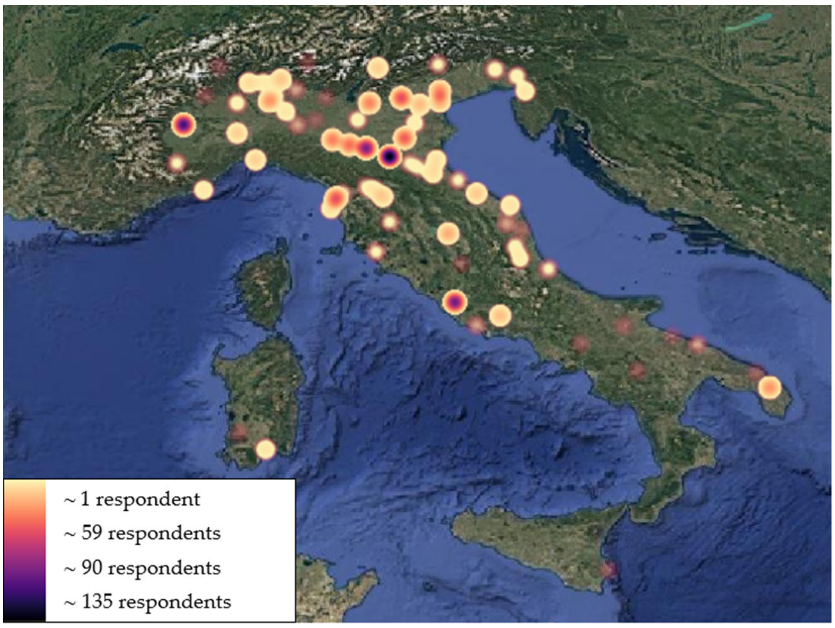

Figure 3. Distribution of respondents in Italy. Our own elaboration.

The total number of respondents to the survey was 1125, but only 1080 (96%) specified the regular transportation mode. The main transportation modes of the survey respondents are summarized in Table 2. The sample of respondents included mostly bike users (43.06%). The second and third main categories of respondents were motorized vehicle users (18.15%) and train combined with other mode users (13.43%). Among the means of transport combined with the train, the bicycle was present for 73.10% of the respondents. The age distribution in the sample was not fully representative of the targeted population, with an overrepresentation of individuals aged over 50 years old. However, it should be noted that the average age of the Italian population was 48 years old. The lowest mean age of respondents was the one for bus users (39 years old). Of the respondents, 61% were employed, and 4% were students.

Table 2. Sample distribution for the main transport modes.

Travel Mode	% of Sample	Mean Age (M)	SD	Sex
Bicycle	43.06	55.34	13.72	37.63 females; 0.65 other
Train only	4.72	48.90	14.94	41.18 females
By foot (pedestrians)	7.5	53.09	16.04	37.04 females
Train combined with other transport modes	13.43	50.15	15.44	30.34 females; 0.69 other
(Other transport mode is bike)	(73.10)	(48.38)	(15.01)	
Multiple transport modes excluding train	2.59	58.82	12.43	28.57 females
Bus	2.22	39.75	15.79	37.50 females
Motorized vehicles (scooter, private car, car sharing)	18.15	54.16	12.38	43.00 females
The mode of transport variates based on weather conditions	8.3	54.4	12.28	41.11 females; 3.33 other

2.2.1. Weights of the Indicators Common to the Groups

The indicators common to the different groups of respondents, which can be identified from Table 1, were calculated as the normalization from 0 to 1 of the weighted average of the answers to the survey, through the formula

$$\mathrm{P_j} = \frac{\left(\frac{\sum \mathrm{n_k} * \mathrm{r_k} + \sum \mathrm{n_h} * \mathrm{r_h} + \sum \mathrm{n_l} * \mathrm{r_l}}{\mathrm{n_k} + \mathrm{n_h} + \mathrm{n_l}} - 1\right)}{4} \quad (1)$$

where

P_j = the weight of the j-th indicator;
r_k = the response of a single person from generic group $k \neq h \neq l$;
r_h = the response of a single person from generic group $h \neq k \neq l$;
r_l = the response of a single person from generic group $l \neq k \neq h$;
n_k = the number of respondents from generic group $k \neq h \neq l$;
n_h = the number of respondents from generic group $h \neq k \neq l$;
n_l = the number of respondents from generic group $l \neq k \neq h$.

2.2.2. Weights from Technicians

The weights from group W were the normalized mean of the responses provided by technicians.

$$P_j = \frac{\left(\frac{\sum n_w * r_w}{n_w} - 1\right)}{4} \tag{2}$$

where

P_j = the weight of the j-th indicator;
r_w = the response of a single person from group W;
n_w = the number of respondents from group W.

2.2.3. Weights of the Categories

The calculation of the weight corresponding to a category was performed through the following formula:

$$P_i = \frac{\left(\frac{\sum_i \overline{P_{ji}} * n_i}{\sum_i n_i} - 1\right)}{4} \tag{3}$$

where

P_i = the weight of the i-th category;
n_i = the number of respondents from the group (Y, Z, W, and regular cyclists and non-cyclists).

3. Equation to Calculate the Accessibility (AxI)

For the definition of the AxI indicator, the last required step consisted of applying the different indexes calculated in Section 2, according to the following formula:

$$\text{AxI} = \frac{\sum_i I_{cati} * P_i}{\sum_i P_i} \tag{4}$$

where

AxI = the total station accessibility value;
I_{cati} = the performance of the i-th category;
P_i = the weight of the i-th category;
I_{cati} = the performance of the i-th category, calculated as follows:

$$I_{cati} = \frac{\sum_j s_j * P_j}{\sum_j S_{maxj} * P_j} \tag{5}$$

where

s_j = the value obtained during the inspection of the j-th indicator;
S_{maxj} = the maximum value obtainable during the inspection of the j-th indicator;
P_j = the weight of the j-th indicator.

The results of applying the indicator to a single railway station may be displayed on a weight-Icati graph. This type of graph showed on the x-axis the performance of each category (I_{cati}) and on the y-axis the corresponding weight (P_i). The graph was used to clearly define the priority of intervention among the categories of a single station.

Figure 4 shows the value of the eight categories for one railway station. For each railway station the priority of intervention was ordered when the value of I_{cati} was related to the weight P_i. In Figure 4 the priority of intervention is as follows:

1. The quality of infrastructure direction south (A dir. South);
2. The quality of infrastructure direction north (A dir. North);
3. Bike deposit (D);
4. Services for cyclists near the node (C);
5. The quality of infrastructure direction east (A dir. East);
6. The quality of infrastructure direction west (A dir. West);
7. Bike sharing (E);
8. Visibility of the area in front of the railway station and signs to direct cyclists inside the railway station (B).

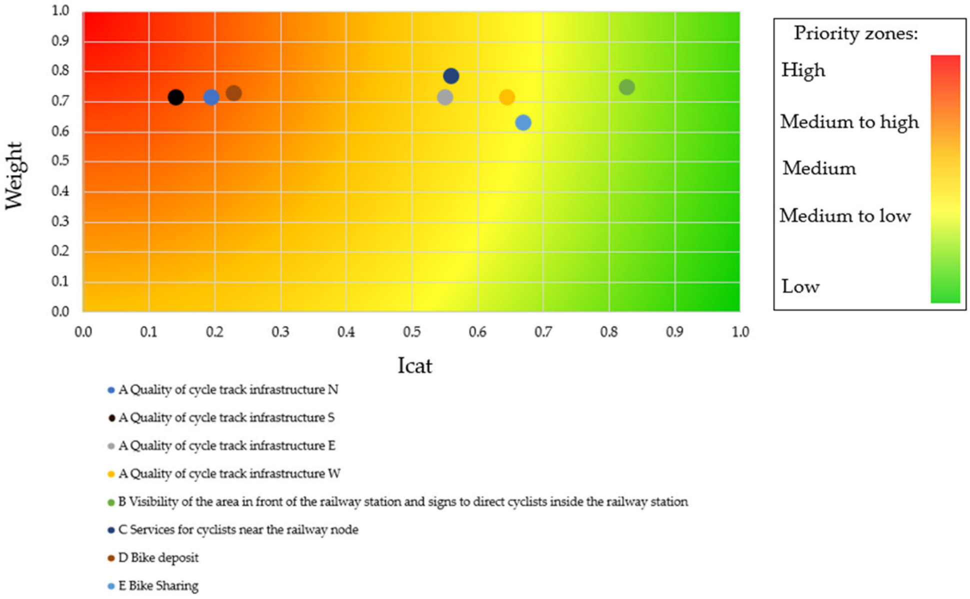

Figure 4. Representation of results for the single railway station.

The comparison among the different railway stations was performed by comparing the AxI values of the railway stations. This allowed a ranking among the railway stations where the least effective, the medium to least effective, the medium to most effective, and the most effective ranges could be identified. In particular, when $0 \leq \text{AxI} \leq 0.25$, the railway station was classified with a high priority of intervention; when $0.25 < \text{AxI} \leq 0.50$, the railway station had a medium-to-high priority of intervention; when $0.50 < \text{AxI} \leq 0.75$, the railway station had a medium-to-low priority of intervention; and when $0.75 < \text{AxI} \leq 1$, the railway station had the least priority of intervention.

4. Results

The proposed methodology was applied to 33 railway stations in a specific Italian region. Located in the northern part of Italy, this region has one of the highest gross domestic products per capita in the country. The region has an area of 22,446 m^2 and counts 4.5 million inhabitants (2023). The population density is 200 inhabitants per km^2, and, being one of the richest regions of Italy, it has a heterogeneous economy that includes agricultural activities, manufactural activities, food industries, automotive, and tourism. The railway stations analyzed were of different dimensions, including different types of services and train types. The railway stations examined had a daily passenger flow of 100 to 39,000 passengers in the capital of the region. Here, the railway station was served by high-speed and regional trains. It was connected to the city airport by an elevated monorail and to the city center and peripherical areas through the bus service. Other analyzed railway stations include 11 railway stations with a flow of passengers between 3100 and 9000 passengers, 7 railway stations with a flow of passengers between 700 and 1700 passengers per day, and 14 railway stations with a flow of passengers from 100 to 700 passengers per day. The 33 railway stations were all surveyed from November 2021 to February 2022. The results of the application of the AxI are reported in Table 3. The number of railway station was related to the number of passengers boarded on a train in one day. Railway station "1" was the one with the lowest passenger flow, up to station "33", which was the one with the highest flow.

Table 3. Application of the AxI to 33 railway stations of a specific Italian region. The table is ordered from the highest AxI to the lowest.

		Category of Indicator								
Railway Station	**Passengers/Day**	**A dir. North**	**A dir. South**	**A dir. East**	**A dir. West**	**B**	**C**	**D**	**E**	**AxI**
30	5350	0.75	0.68	0.84	0.75	1	0.86	0.69	0.79	0.8
32	11,235	0.71	0.79	0.80	0.80	0.49	0.95	0.84	1.00	0.80
26	3118	0.00	0.89	0.84	0.91	0.83	0.72	0.75	0.62	0.7
31	7836	0.56	0.64	0.64	0.59	0.83	0.54	0.55	0.88	0.65
33	46,483	0.74	0.40	0.74	0.77	0.50	0.77	0.61	0.61	0.64
19	862	0.69	0.75	0.70	0.74	0.66	0.77	0.00	0.70	0.63
9	300	0.83	0.83	0.83	0.83	0.83	0.54	0.00	0.00	0.59
25	2947	0.74	0.71	0.79	0.79	0.33	0.77	0.00	0.49	0.58
22	2011	0.57	0.61	0.59	0.71	0.66	0.95	0.00	0.16	0.54
23	2321	0.00	0.62	0.74	0.64	0.66	0.68	0.75	0.18	0.54
29	5281	0.46	0.74	0.49	0.00	0.83	0.68	0.94	0.00	0.53
20	1099	0.54	0.00	0.00	0.69	0.66	0.86	0.61	0.70	0.51
21	1521	0.59	0.62	0.59	0.39	0.50	0.68	0.50	0.00	0.49
12	377	0.00	0.78	0.83	0.00	0.66	0.86	0.00	0.70	0.48
10	300	0.78	0.74	0.00	0.74	0.49	0.72	0.17	0.00	0.47
24	2481	0.63	0.00	0.64	0.63	0.49	0.68	0.00	0.63	0.46
8	290	0.00	0.47	0.00	0.81	0.83	0.72	0.00	0.70	0.44
7	240	0.71	0.00	0.00	0.68	0.83	0.54	0.00	0.70	0.43
11	300	0.53	0.57	0.65	0.42	0.66	0.56	0.00	0.00	0.43
6	231	0.63	0.37	0.58	0.58	0.49	0.52	0.00	0.00	0.4
14	434	0.62	0.00	0.59	0.55	0.50	0.86	0.00	0.00	0.4
2	150	0.75	0.27	0.65	0.00	0.84	0.56	0.00	0.00	0.39
18	788	0.47	0.00	0.74	0.44	0.49	0.56	0.00	0.18	0.366
1	100	0.00	0.00	0.58	0.65	1.00	0.56	0.00	0.00	0.36
27	3539	0.00	0.89	0.00	0.00	0.50	0.79	0.00	0.70	0.35
16	700	0.65	0.54	0.00	0.00	0.49	0.54	0.00	0.16	0.3
5	200	0.71	0.00	0.00	0.00	0.83	0.68	0.00	0.00	0.29
28	3809	0.34	0.32	0.00	0.25	0.28	0.28	0.36	0.30	0.27
4	190	0.00	0.00	0.63	0.00	0.66	0.72	0.00	0.00	0.26
15	455	0.00	0.37	0.49	0.00	0.49	0.54	0.00	0.00	0.25
13	387	0.67	0.57	0.00	0.00	0.33	0.23	0.00	0.00	0.23
17	778	0.00	0.00	0.00	0.43	0.33	0.36	0.00	0.32	0.18
3	170	0.00	0.00	0.00	0.00	0.49	0.72	0.00	0.00	0.16

The results showed that only two of the railway stations analyzed fell within the least-priority intervention area (railway stations 30 and 32), and four railway stations fell within the high-priority intervention area. Among the railway stations with a flow lower than 800 passengers per day, only one fell in the medium to low priority, with an AxI = 0.59 (station 9), while the others (57% of railway stations analyzed) had an AxI between 0.16 and 0.48; all of these railway stations scored 0 in the category of bike sharing, except for station 10, which scored 0.17. Of the total of the railway stations analyzed, 66.7% scored 0 in the bike deposit category. Of the railway stations, 42.4% scored 0 in the bike sharing category, while 21.2% of railway stations had a total AxI indicator between 0.16 and 0.49. Two categories that never scored less than 0.23 for any of the railway stations analyzed were categories B and C. Among the 10 railway stations with AxI indicators classified as medium to low priority of intervention, only two railway stations had all category values (Icati) higher than 0. However, station 26, which had an AxI = 0.70 and scored 0 in the category A, north direction, scored higher than stations 31 and 33, which had all categories Icati $\neq 0$.

The railway stations ordered from 1 to 33 showed, in Figure 5, only a slight increase in the value of AxI. In fact, the average AxI from railway station 1 to 16 was equal to 0.37 SD = 0.11), that from railway station 17 to 23 was equal to 0.44 (SD = 0.16), and that from 24 to 33 was equal to 0.58 (SD = 0.18).

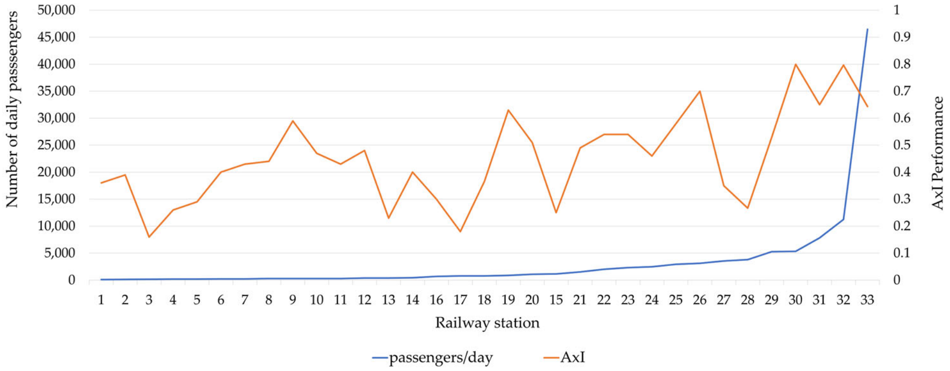

Figure 5. AxI value compared with the flow of passengers.

5. Discussion and Conclusions

The results of this study confirmed the applicability and effectiveness of the AxI indicator in evaluating the accessibility to railway stations for cyclists. By assessing 33 railway stations of different sizes in an Italian region, it was possible to identify critical areas for improvement and prioritize interventions. Railway stations with higher daily passenger flows exhibited a slightly higher AxI, which, however, did not indicate a correlation between station size and accessibility measures. The weak relation between the flow of passengers and AxI was confirmed from the linear regression analysis, where the number of passengers as the independent variable obtained an $R^2 = 0.190$ with p-value = 0.011. Some smaller stations demonstrated good accessibility scores, underscoring the importance of interventions on bike deposits, which were missing in most of the railway stations that had <700 passengers per day, and interventions on bike sharing, which were missing in 71% of the railway stations with <700 passengers per day. The linear regression analysis on the AxI showed that the most impacting categories with a null p-value were the infrastructure quality of the cycle track (category A) ($R^2 = 0.818$), the bike deposit (category D) ($R^2 = 0.401$), and the bike sharing (category E) ($R^2 = 0.354$). Considering an acceptable p-value < 0.05, the results also showed that the services for the cyclists (category C) were significant in the calculation of the AxI with an $R^2 = 0.321$ (p-value = 0.001), while for category B, the visibility of the area outside the railway station and the signs inside the railway stations had an $R^2 = 0.152$ (p-value = 0.025). To confirm the importance of these elements, Givoni and

Rietveld (2007) found that infrastructure provision, such as secure bike parking at stations, directly influenced the attractiveness of bike–train combinations for commuters [38]. A study by Martens (2007) emphasized the need for policies to support seamless intermodality, suggesting that while infrastructure was necessary, behavioral factors such as convenience and safety perceptions also played a pivotal role in encouraging cycling to stations [39]. Yet, this study was limited in scope, focusing on different forms of transport intermodality without a specific emphasis on bicycles.

This study expanded on previous methodologies by introducing a multilevel weighted indicator system focused on bike accessibility into railway stations, specific to bike–train intermodality improvement. Unlike traditional cost–benefit or cost-effectiveness analyses, the AxI indicator incorporated user-centered criteria, enabling a more nuanced understanding of how infrastructure investments could enhance bike–train intermodality. The AxI expanded also on the analytical hierarchy process (AHP). While the AHP allowed for structured decision-making with multiples levels of criteria, the AxI was more directly aligned with assessing cyclists' accessibility, providing a more forward, and thus less time-consuming, system for analysis. Compared with the condition-based monitoring, which was useful for detecting faults, the AxI set a step forward to a long term evaluation.

The AxI indicator may be representative of the Italian population since the sample of respondents has an average age of 50 years old, and the Italian population has an average age of 48 years old. On the other hand, the majority of respondents were frequent cyclers, and this was not totally representative of the geographical area studied. One of the criticalities of the tool was that since they need auditing in public spaces, they could be time-consuming [40]. To contrast this and make the use of the AxI more time-efficient, a guide to train surveyors will be drawn up. The guide is also a good way to engage the involved stakeholders in participating in the study and understand the importance of the application of the methodology. Moreover, the use of GIS mapping and satellite imagery could be a way to reduce the time consumed in the surveying of the single railway station.

Future research could focus on refining the AxI indicator further by integrating a validation of the weights, possibly through a virtual reality experience. The experience will include a bike simulator and relate the behavior of the cyclist with the answers to a questionnaire. The results will be compared with the actual weights of the AxI. The AxI indicator has the potential of being reproducible in other countries comparable to the Italian transportation system, population, and geographical characteristics. Future research will include exploring its application in other regions or countries with different infrastructure and policy environments. It is expected to need to adjust the AxI indicator for those railway stations that serve fewer than 100 people per day or those stations located in areas that are mostly residential and where the population is older. Older people tend, in fact, to prefer the use of private cars rather than the use of public transportation [41]. Additionally, longitudinal studies could assess the long-term impacts of infrastructure improvements on cycling and train use, providing further validation of the tool's effectiveness in promoting sustainable transportation. The study not only confirms the effectiveness of the AxI indicator in assessing the accessibility of railway stations for cyclists but also offers a roadmap for improving bike–train intermodality. By expanding on traditional methodologies and incorporating user-centered criteria, the AxI offers a more holistic evaluation tool. Its application has the potential to drive targeted investments in both large and small railway stations, with significant benefits for promoting sustainable, intermodal transportation systems.

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Institutional Review Board Statement: Ethics approval was not sought for the present study. the survey is conducted as anonymous from the beginning, there is no possibility to return to the respondent, and identify him or her. No name, last name, email, or other information that can be linked to a single specific person is collected. Also, no data that could lead to individuation, inference or correlability has been collected. In this case, there is no necessity to apply the privacy of personal data, and the European regulation 2016/679 is respected.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Section A of the indicator.

Indicator Number	Indicators	Description of Indicator
A1	The existence and proximity of the cycle path	The assessment includes whether there is a cycle path direct to one of the four cardinal points (north, south, east, and west) and the contiguity of it to the railway station. This aligns with regional laws (5 June 2017, n.10) aiming to improve daily commuting by promoting cyclability. A feasible cycle path is vital for encouraging active mobility [42]. If the cycle track is within a maximum distance of 500 m from the node of interest, it gets a score of "1", otherwise, "0" for absent. The distance that has been considered acceptable for the cycle path is 500 m as it corresponds to a 5 min walk.
A2	The cycle path distance from the railway station	The assessment is in the vicinity of the cycle path to the railway station. If it is located within 75 m, the score assigned is (1); if the cycle path is more than 75 m away, it gets a rating of (0), indicating it is farther and less convenient for cyclists [8].
A3	The pavement material	The prevailing pavement is rated based on the materials with a score of (2) for asphalt, (1) for self-locking pavement, and (0) for natural earth.
A4	The pavement quality	Factors include how well the pavement holds up and if there are any potential hazards like plant roots. The pavement quality is assessed as (2) for good, (1) for average, and (0) for poor.
A5	The number of lanes and the direction	Emilia-Romagna regional guidelines suggest that a two-way cycle path in an urban area is less safe than a one-way single-lane cycle track. One-way cycle paths get a score of (2), a two-way reserved for bicycle cycle path is given a score of (1), and a two-way cycle path receives a score of (0).
A6	The vertical separation from motor vehicle traffic	A raised cycle path is a bicycle facility that is paired with a furnishing zone between the cycle track and a motor vehicle travel lane and/or pedestrian area. A raised cycle track gets a score of (2) as it keeps motorists from entering the cycle track; a non-raised cycle track gets a score of (1); and in cases where there is no cycle track, the score is (0) [43].
A7	The type	A one- or two-way reserved, raised-level cycle track is assigned a rate of (6); a one- or two-way reserved, raised-level cycle track, separated from pedestrians by a painted line, is assigned a rate of (5); a one- or two-way unsegregated cycle track shared with pedestrians is assigned a rate of (4); a one- or two-way reserved, ground-level cycle track separated by motor vehicles with a painted line is assigned a rate of (3); a one-way reserved cycle track, opposite to the 30 km/h speed limit motor vehicle traffic flow, separated by motor vehicles with a painted line, is assigned a rate of (2); a one- or two-way unsegregated cycle track at ground level is assigned a rate of (1); and having no track is assigned a rate of (0).
A8	The geometrical standards	The Nuovo Codice della Strada defines a minimum width of 1.5 m for one-way paths and a minimum width of 1.25 m for two-way cycle tracks [44]. The adequacy of average geometric standards is marked as (1), while non-adequacy is marked as (0).
A9	The slope	The slope of the cycle path is crucial for user engagement and safety. A slope lower than 5% is rated as (1), and it is rated (0) in cases where the slope of the cycle path exceeds 5%.
A10	Punctual obstacles	Consideration is given to potential obstacles along the path, as associated to near misses. The assessment of punctual obstacles or standard reduction is rated as (2) when absent, (1) when rare, and (0) when frequent.
A11	Side conflicts	The presence of shops or driveways that could cause interference with cyclists on the cycle track are evaluated as (2) absent, (1) light, and (0) severe.
A12	Interference with pedestrians	The near-miss collisions with pedestrians are evaluated as absent (2), low (1), and high (0).
A13	Interference with motor vehicles	The near-miss collisions with motor vehicles are evaluated as absent (2), low (1), and high (0).

Table A1. *Cont.*

Indicator Number	Indicators	Description of Indicator
A14	The surface color of the cycle track	A distinctive coloration of dedicated lanes makes the infrastructure more attractive and safer [45]. A colored cycle track can score (2) for bright new coloring, (1) for color that needs maintenance, and (0) for no coloring.
A15	The horizontal signs	Horizontal signs on the cycle path play a crucial role in guiding cyclists and ensuring their safety. The assessment focuses on the presence of them: (1) present and (0) absent. The visibility of the edges of the cycle path is taken into consideration to ensure that cyclists have a clear understanding of the path boundaries to further enhance safety. Reflective border markings along the edges of the cycle path can contribute to improved visibility, especially during night and low-light conditions.
A16	The vertical signs	The assessment focuses on the presence and visibility of signs dedicated to cyclists, in relation to the cycle path [46]. The Nuovo Codice Della Strada states that the sign indicating the cycle path has to be present at the beginning of the cycle path and has to be repeated after every interruption. The rate of (2) is assigned to complete, (1) to averagely complete, and (0) to uncomplete.
A17	Address signs	This aspect focuses on the presence and quality of address signs directing cyclists toward significant landmarks or points of interest in the city. The address signs, recognizable by the brown color, are placed to allow the user to not consult a map while riding [47]. A rating of (2) is given when address signs are present and visible, a rating of (1) suggests that there is only a city map in the proximity of the railway stations, and a rating of (0) indicates the absence of any address signs.
A18	Lighting of the cycle path	The presence and quality of night lighting along the cycle path are crucial for ensuring safety and visibility, especially during low-light conditions. A rating of (2) denotes good lighting, a rating of (1) suggests average lighting, and a rating of (0) indicates the absence of any night lighting on the cycle path, which could pose significant safety risks, especially during nighttime cycling.
A19	Source of lighting	This criterion considers the source and type of lighting along the cycle path. A rating of (2) implies proper lighting designed specifically for the runway or zone 30, ensuring optimal visibility and safety for cyclists. A rating of (1) suggests that the lighting is sourced from public roads, and a rating of (0) indicates that lighting is sourced from private billboards.

Table A2. Section B of the indicator.

Indicator Number	Indicators	Description of Indicator
B1	Vertical signs toward cycle path	These signs are important to guide the cyclist from the platform to the cycle path or the bike parking racks. A rate of (2) is given for the presence of sings, a rate of (1) is given for distant and not visible signs, and (0) is assigned when there are no signs.
B2	Lighting of the area outside the railway station	The assessment of lighting around the railway station focuses on the presence and adequacy of lighting in the vicinity. This rating underlines the importance of addressing any lighting deficiencies to create a safer environment for commuters accessing and traversing the railway station. (1) is given for adequate lighting present, and (0) is given for lack of light.
B3	Vertical signs inside the railway station	These signs refer to the directions to lifts, exits, and platforms with bikes on hand. The rate of (2) is given for clear directions to lifts and exits, aiding navigation effectively; (1) is given for only signs directing to lifts; and (0) is given for the absence of vertical signs. Vertical signs complying with regulatory standards may include clear symbols, color-coded information, and standardized text, enhancing overall effectiveness. Assessment extends to signs within the railway station premises, aiming to guide cyclists effectively. These signs may include directions to bike parking areas, cycle-friendly routes, and other relevant information.
B4	The visibility of bicycle parking slots	The visibility of bicycle parking slots is essential for facilitating convenient access for cyclists. Easily visible parking slots from the entrance of the railway station ensure that cyclists can quickly locate and utilize designated parking areas. Poor visibility can lead to frustration and inconvenience for cyclists, potentially discouraging the use of bicycles as a mode of transportation. The rating (1) is given for parking slots are easily visible from the entrance, and the rating (0) is given for parking slots not visible from the entrance.
B5	The presence of "P" signage for bicycle parking	Clear signage helps cyclists to navigate the railway station premises and a secure parking facility. The rate of (1) is given for the presence of the bicycle parking area sign, and (0) is given for the absence of signage.
B6	The presence of signs directing to parking racks	These signs are important to guide the cyclist from the platform to the bike parking racks [48]. The rate (2) is given for signs that are present and very clear; (1) is given for signs that are present and not complete, while (0) is given for the absence of signs.

Table A3. Section C of the indicator.

Indicator Number	Indicators	Description of Indicator
C1	The presence of bike parking racks	A designated and secure area to park bikes has to be present in the railway station. A rating of (1) in given in cases where there are bike parking racks, and (0) is given in cases where there are none.
C2	The type of parking rack	Two distinct types of bike racks are evaluated. The first one, with a rate of (1), allows both the wheel and frame to be securely tied; the second type allows one to secure only the wheel and is assigned to a rate of (0).
C3	The availability of bike parking slots	Sufficient parking space ensures that users are able to secure the bicycle. The rate of (1) is given for the correct sizing of bike parking slots, and (0) is rated in cases where the bike parking spots are insufficient. As bike bicycle parking capacity is a dissatisfier of users, it is a need that must be fulfilled [49]. Indicator C3 is evaluated based on the comparison between the amount of bike racks present during the survey at the railway station and the amount of bike racks that should be present following the correct dimensioning. The recommendations on cycle parking spots developed by USTRA show that at the railway stations, the number of bike spots should be from one to four for every ten passengers [33]. For the calculation of indicator C3, it has been considered as one bike spot for every ten travelers.

Table A3. *Cont.*

Indicator Number	Indicators	Description of Indicator
C4	The bike repair kit	A pump column or tools for rapid adjustments are useful to cyclists in cases of minor repairs. The rate of (2) is given for the presence of the bike repair kit, (1) is given for a bike repair kit that does not work properly or is missing some tools, and (0) is selected in cases where there is not a bike repair column.
C5	Accessibility through lifts or ramps	The minimum dimension for a lift to fit a bicycle is 1.4 m depth and 1.10 m width. In cases where the lifts are absent or have a smaller dimension, ramps must be present. (1) is given for the presence of lifts and/or ramps, and (0) is given in cases of the absence of both facilities.
C6	The accessibility of the ticket office	Ramps or lifts that can facilitate the access of ticket boxes with the bike on hand are evaluated. In cases where it is accessible, the rate is (1); in cases where it is not accessible, the rate is (0).
C7	The presence of restrooms	Access to basic facilities is evaluated. A rating of (1) is given in cases where restrooms are present, and (0) is given in cases where restrooms are not present.

Table A4. Section D of the indicator.

Indicator Number	Indicators	Description of Indicator
D1	The presence of the bicycle deposit	A rating of (2) means that a bike deposit is available, (1) is given in cases where the bike deposit is not in place at the moment of survey but the project has been started, and (0) is for the absence of bicycle storage facilities.
D2	The location of the depot	Determining whether the bike depot is situated within or outside the railway station impacts the convenience for the cyclist. A rate of (1) means that the depot is situated inside the railway station, while a rating of (0) suggests that the depot is located outside the railway station.
D3	The distance of the deposit from the railway station	The distance of the bike depot from the railway station is assessed to gauge its accessibility for cyclists. A rating of (1) is given in cases where the deposit is located at a maximum distance of 75 m; for longer distances, the rating is (0).
D4	The number of bike deposits	The services provided by a bike deposit may be differentiated and improved in cases where the number of deposits is not limited to one. A rate of (1) is assigned in cases where there is more than one deposit, and (0) is assigned in cases where there are no deposits.
D5	The availability of bike parking spots inside the deposit	This rating evaluates whether the number of parking spots in the bike depot meets demand. Sufficient parking capacity ensures cyclists have ample space to store their bicycles comfortably, avoiding overcrowding and ensuring a positive experience. A rating of (1) is given for suitability, and (0) is given for incorrect dimensioning. Indicator C4 is evaluated based on the comparison between the number of bike spots present during the survey at the deposit and the number of bike spots that should be present following the correct dimensioning. The recommendations on cycle parking spots inside bike deposits developed by the regional guidelines on cyclability of Piemonte show that at the railway stations, the number of bike spots inside the deposit should be 4% of the total daily passengers [50].
D6	The cost of the service	the cost for parking the bike inside the bike deposit is evaluated. The rate is (1) for a gratuity service and (0) in cases where the service is paid.
D7	The availability of services for cyclists	The indicator determines if the bike deposit offers additional user services such as lockers, changing rooms, showers, toilets, or beverage machines. The rating is (1) for the presence of some services, and the rating is (0) for no service availability.
D8	The availability of services for bicycles	The indicator evaluates whether the bike depot offers services for bicycles, including repairs, inflating pumps, spare parts, accessories, or bicycle rental. The rating is (1) for the availability of services regardless of the costs and (0) in cases where no extra service is offered.
D9	The average occupancy level	A rating of (2) means the occupancy rate is less than 75% full, (1) means it is between 75% and 99% full, and (0) means it is over 100% full.
D10	The video surveillance system	This indicator determines if the bike deposit is equipped with video surveillance for security purposes. In cases where there is video surveillance system, the rating is (1), and in cases where it is absent, the rating is (0).
D11	The possibility to book a spot	The indicator evaluates whether a cyclist can book a parking spot in advance. Offering advance booking provides convenience and assurance of space availability. In cases where it is possible to book a spot in advance, the rating is (1); if not, the rating is (0).
D12	The access hours	This indicator assesses the opening hours of the bike depot. A rating of (2) is given in cases where the deposit is accessible every day of the week, 24 h per day, while in cases where the deposit is accessible only during peak hours, the rate associated is (1), and (0) suggests that the deposit is open for less than 3 h per day.
D13	The type of access	The method to access to the bike depot is rated (3) when it is granted through present personnel or an app, (2) indicates access via key or badge, (1) is used in cases where a public transport pass or health insurance card can be used, and (0) implies the use of a one-time ticket to access.

Table A5. Section E of the indicator.

Indicator Number	Indicators	Description of Indicator
E1	The presence of bike sharing stations	This indicator assesses the presence of bike sharing stations near the railway stations, which is linked to a rating of (1). The absence of the service is linked to a rating of (0).
E2	The presence of other micromobility services	The indicator refers to the presence of other micromobility sharing stations (e.g., e-scooters). The presence of the service is rated as (1), while the absence is linked to a rating of (0).

Table A5. *Cont.*

Indicator Number	Indicators	Description of Indicator
E3	The location of bike sharing stations	This indicator estimates the proximity of bike sharing stations to railway stations. A rating of (2) implies that the depot is within 75 m of the railway station, while a rating of (1) suggests it is situated between 75 to 100 m, and a rating of (0) indicates that it is located at a greater distance from the railway station.
E4	The number of bikes being shared	The indicator assesses whether the number of bikes available at sharing stations meets the demand of commuters. Sufficient availability ensures that commuters have access to bikes when needed. A rating of (1) is given for suitability, and (0) is given for incorrect dimensioning.
E5	Docking stations	If bike sharing is restricted to specific hubs for collection and drop-off, the rate is (0), while dockless bike share allows users the flexibility to pick up and drop off bikes at various locations (1).

References

1. European Environment Agency. *Decarbonising Road Transport—The Role of Vehicles, Fuels and Transport Demand*; EEA: Copenhagen, Denmark, 2021. [CrossRef]
2. Litman, T. Evaluating rail transit benefits: A comment. *Transp. Policy* **2007**, *14*, 94–97. [CrossRef]
3. Baum-Snow, N.; Kahn, M.E. Effects of Urban Rail Transit Expansions: Evidence from Sixteen Cities, 1970–2000. In *Brookings-Wharton Papers on Urban Affairs*; Brookings Institution Press: Washington, DC, USA, 2005; Volume 1, pp. 147–206. [CrossRef]
4. Shang, B.; Zhang, X. Study of Emission Reduction: Benefits of Urban Rail Transit. *Procedia-Soc. Behav. Sci.* **2013**, *96*, 557–564. [CrossRef]
5. Šperka, A.; Vojtek, M.; Široký, J.; Čamaj, J. Improvement of the last mile-specific issues in railway freight transport. *Sustainability* **2020**, *12*, 10154. [CrossRef]
6. Yan, X.; Levine, J.; Zhao, X. Integrating ridesourcing services with public transit: An evaluation of traveler responses combining revealed and stated preference data. *Transp. Res. Part C Emerg. Technol.* **2019**, *105*, 683–696. [CrossRef]
7. Martens, K. The bicycle as a feedering mode: Experiences from three European countries. *Transp. Res. Part D Transp. Environ.* **2004**, *9*, 281–294. [CrossRef]
8. Ministero delle Infrastrutture e della Mobilità Sestenibile. Piano Generale della Mobilità Ciclistica Urbana e Extraurbana 2022. Available online: https://www.mit.gov.it/nfsmitgov/files/media/notizia/2022-08/PG%20Mobilit%C3%A0%20Ciclista%20e%20allegati.pdf (accessed on 24 October 2024).
9. Gazzetta Ufficiale Della Repubblica Italiana. 10 October 2022. Available online: https://www.gazzettaufficiale.it/eli/id/2022/10/22/22G00165/SG (accessed on 24 October 2024).
10. Comunicazione della Commissione al Parlamento Europeo, al Consiglio, al Comitato Economico e Sociale Europeo e al Comitato delle Regioni, Piano D'azione Sulla Mobilità Urbana. 30 August 2009. Available online: https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=CELEX:52009DC0490 (accessed on 24 October 2024).
11. Osservatorio Nazionale. Sharing Mobility. 2023. Available online: https://osservatoriosharingmobility.it/wp-content/uploads/2023/10/VII-Rapporto-nazionale-sharing-mobility.pdf (accessed on 24 October 2024).
12. Piano Urbano della Mobilità Sostenibile. Available online: https://pumsbologna.it/ (accessed on 24 October 2024).
13. Linee di Indirizzo per la Progettazione dei Centri di Mobilità. Available online: https://pumsbologna.it/Progetti_in_corso (accessed on 24 October 2024).
14. Hached, W.; L'Hostis, A.; Gragera, A. Exploring the concept of 'mobility hubs' and abessing their impacts in two European cities. *Transp. Res. Procedia* **2023**, *72*, 3497–3504. [CrossRef]
15. 20° Rapporto Sulla Mobilità Degli Italiani. 27 November 2023. Available online: https://www.isfort.it/wp-content/uploads/2023/12/RapportoMobilita2023_Def.pdf (accessed on 24 October 2024).
16. Nelson, A.C.; Allen, D. If You Build Them, Commuters Will Use Them Association Between Bicycle Facilities and Bicycle Commuting. *Transp. Res. Rec.* **1997**, *1578*, 79–83. [CrossRef]
17. Zhao, P. The impact of the built environment on bicycle commuting: Evidence from Beijing. *Urban Stud.* **2014**, *51*, 1019–1037. [CrossRef]
18. Handy, S.L.; Xing, Y. Factors correlated with bicycle commuting: A study in six small U.S. cities. *Int. J. Sustain. Transp.* **2010**, *5*, 91–110. [CrossRef]
19. Beidenhauser, C. Bike-Train Integration. The Role of Bicycle Parking in Promoting Sustainable Transportation Along Norway's Jaeren line. 2024. Available online: https://hdl.handle.net/10037/33866 (accessed on 28 November 2024).
20. Acheampong, R.A. Towards Sustainable Urban Transportation in Ghana: Exploring Adults' Intention to Adopt Cycling to Work Using Theory of Planned Behaviour and Structural Equation Modelling. *Transp. Dev. Econ.* **2017**, *3*, 18. [CrossRef]
21. Boardman, A.E.; Greenberg, D.H.; Vining, A.R.; Weimer, D.L. *Cost-Benefit Analysis: Concepts and Practice*, 5th ed.; Cambridge University Press: Cambridge, UK, 2018. [CrossRef]
22. Robinson, R. Cost-benefit analysis. *Br. Med. J.* **1993**, *307*, 924–926. [CrossRef]

23. Browne, D.; Ryan, L. Comparative analysis of evaluation techniques for transport policies. *Environ. Impact Assess. Rev.* **2011**, *31*, 226–233. [CrossRef]
24. Belton, V.; Stewart, T.J. *Multiple Criteria Decision Analysis: An Integrated Approach*; Springer Science & Business Media: New York, NY, USA, 2002. [CrossRef]
25. Odu, G.O. Weighting methods for multi-criteria decision making technique. *J. Appl. Sci. Environ. Manag.* **2019**, *23*, 1449–1457. [CrossRef]
26. Coppola, P.; Deponte, D.; Vacca, A.; Messa, F.; Silvestri, F. Multi-Dimensional Cost-Effectiveness Analysis for Prioritizing Railway Station Investments: A General Framework with an Application to the Italian Case Study. *Sustainability* **2022**, *14*, 4906. [CrossRef]
27. Lee, K.K.H.; Chau, D.K.W. Condition Based Monitoring in Railway. *J. Int. Counc. Electr. Eng.* **2012**, *2*, 99–103. [CrossRef]
28. Nandan, S.; Geetika. Determinants of Customer Satisfaction on Service Quality: A Study of Railway Platforms in India. *J. Public Transp.* **2010**, *13*, 97–113. [CrossRef]
29. Gupta, S.; Datta, R. Prioritizing service attributes for quality up-gradation of Indian railway stations. *TQM J.* **2012**, *24*, 167–180. [CrossRef]
30. Yang, Z.; Fang, H.; Wei, G.; Mo, J.; Gao, X.; Zhang, S. An assessment of urban park accessibility using multi-source data in Hefei, China: A social equity perspective. *Land Degrad. Dev.* **2024**, *35*, 11. [CrossRef]
31. Ministero delle Infrastrutture e dei Trasporti. Available online: https://www.mit.gov.it/documentazione/codice-della-strada (accessed on 24 October 2024).
32. Linee Guida per il Sistema Regionale della Ciclabilità. Available online: https://mobilita.regione.emilia-romagna.it/mobility-sostenibile/mobilita-ciclistica/la-regione-per-la-mobilita-ciclistica (accessed on 24 October 2024).
33. Ufficio Federale delle Strade USTRA, Mobilità Ciclabile. Available online: https://www.astra.admin.ch/astra/it/home/temi/langsamverkehr0/veloverkehr.html (accessed on 24 October 2024).
34. Fernández-Heredia, Á.; Monzón, A.; Jara-Díaz, S. Understanding cyclists' perceptions, keys for a successful bicycle promotion. *Transp. Res. Part A Policy Pract.* **2014**, *63*, 1–11. [CrossRef]
35. Zhu, L.; Mujahid, A.; Macioszek, E.; Aghaabbasi, M.; Jan, A. Approaching sustainable bike-sharing development: A systematic review of the influence of built environment features on bike-sharing ridership. *Sustainability* **2022**, *14*, 5795. [CrossRef]
36. Guo, Y.; Yang, L.; Chen, Y. Bike Share Usage and the Built Environment: A Review. *Front. Public Health* **2022**, *10*, 848169. [CrossRef] [PubMed]
37. Zoli, A.; Pazzini, M.; Lantieri, C.; Vignali, V.; Raffaelli, K.; Gaspardo Moro, M.; Simone, A. Users' preferences on bike-train intermodality: What can induce travelers to use this type of intermodal transport? *Transp. Res. Procedia* **2024**, *in press*.
38. Givoni, M.; Rietveld, P. The access journey to the railway station and its role in passengers' satisfaction with rail travel. *Transp. Policy* **2007**, *14*, 357–365. [CrossRef]
39. Martens, K. Promoting bike-and-ride: The Dutch experience. *Transp. Res. Part A Policy Pract.* **2007**, *41*, 326–338. [CrossRef]
40. Belaroussi, R.; Issa, E.; Cameli, L.; Lantieri, C.; Adelé, S. Exploring Virtual Environments to Assess the Quality of Public Spaces. *Algorithms* **2024**, *17*, 124. [CrossRef]
41. Davey, J.A. Older people and transport: Coping without a car. *Ageing Soc.* **2007**, *27*, 49–65. [CrossRef]
42. Bach, B.; van Hal, E.; de Jong, M.I.; de Jong, T.M. *Urban Design and Traffic: A Selection Form Bach's Toolbox*; Stedenbouw en verkeer; een selectie uit de gereedschapskist van Bach; CROW: London, UK, 2006; p. 415.
43. NACTO, National Association of City Transportation Officials. *Urban Bikeway Design Guide*, 2nd ed.; Island Press: Washington, DC, USA, 2014; ISBN 9781610915656.
44. Normattiva il Portale delle Legge Vigente, Nuovo Codice della Strada. Available online: https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo:1992-04-30;285!vig= (accessed on 1 December 2024).
45. Autelitano, F.; Giuliani, F. Colored bicycle lanes and intersection treatments: International overview and best practices. *J. Traffic Transp. Eng. Engl. Ed.* **2020**, *8*, 399–420. [CrossRef]
46. Traffic Signs Manual. Available online: https://assets.publishing.service.gov.uk/media/5c78f895e5274a0ebfec719b/traffic-signs-manual-chapter-03.pdf (accessed on 26 December 2024).
47. Città Metropolitana di Bologna. Manuale d'uso Segnaletica Bicipolitana. 2018. Available online: https://www.bicipolitanabolognese.it/Engine/RAServeFile.php/f/allegati/Manuale_Segnaletica_Bicipolitana.pdf (accessed on 1 December 2024).
48. Ministère de la Transition Ecologique et de la Cohésion des Territoires. Stationnement des Vélos dans les Constructions, Dimensions et Caractéristiques. 2022. Available online: https://www.ecologie.gouv.fr/sites/default/files/documents/guide_stationnement_velo_constructions.pdf (accessed on 1 December 2024).
49. Van der Spek, S.C.; Scheltema, N. The importance of bicycle parking management. *Res. Transp. Bus. Manag.* **2015**, *15*, 39–49. [CrossRef]
50. Fabrizio, C.; Bracco, E. Linee Guida Cicloposteggi. 2023. Available online: https://www.regione.piemonte.it/web/sites/default/files/media/documenti/2023-04/linee_guida_cicloposteggi_0.pdf (accessed on 1 December 2024).

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Users' preferences on bike-train intermodality: what can induce travelers to use this type of intermodal transport?

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Abstract

Making railway stations accessible to all kinds of cyclists to improve bike-train intermodality is a challenge that must be met. This challenge is part of the European Community' objectives set out in Agenda 2030, as the transition from the use of private vehicles to the use of bicycles contributes to reducing emissions to air. One of the reasons why bicycles are still underused is the lack of security of the infrastructure and the absence of essential services. That is why it is necessary to know what the most urgent interventions are. This study aims to determine the types of action needed to improve bicycle-train intermodality according to people's preferences. A survey was carried out on a sample of the Italian population who use bicycles, regardless of age or gender, to understand what would lead travelers to choose that type of intermodal travel. The research found that the bike-train intermodality is influenced above all by the risk of theft of bicycles inside the railway station, the possibility or not to carry the bicycle on the train, and finally enjoy an easy access to the train station by bicycle.

Keywords: Intermodality; survey; bike train preferences

1. Introduction

Transportation has a significant impact on air pollution. Between 1990 and 2021 transport emissions of ammonia (NH3) increased by 109% and nitrous oxide (N2O) increased by 28% (European Environment Agency, 2023). Road

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travel accounts for three-quarters of transport emissions, of which the 45.1% come from passenger vehicles (Ritchie, 2020). However, one of the solutions to reduce the impact of road passenger transport, is the upgrading of intermodality (Bennaya & Kilani, 2023). Intermodality is the combination of two or more means of transport to reach one destination (Laplace et al., 2005; Stoilova & Kunchev, 2017). In this case, bike-train intermodality refers to the intermodal transport involving the use of bike and train to reach a destination. The benefits of an integrated bike-train transportation system include the depletion of energy use as there is a reduction in motor vehicles replaced with bicycles (Belloni & Maggi, 2022). In addition, cycling has the potential to make railway transport more flexible as it is the most efficient means of driving the "last mile" (Oeschger, Carrol, & Caulfield, 2020). This characteristic certainly also increases the attractiveness of the trip (Pazzini, et al., 2022). Despite the potential advantages of a multimodal transportation system, research into user perspectives is limited. To date, research has found that a person's bike modal choice can be explained by different factors, but no research has been done on bike-train intermodal choice. Giansoldati et al. (2021) highlights that in Italy the primary mode of transport to reach the railway station is the private car. Bell (2019) defined general user needs at intermodal hubs without providing a specific focus on the different means of transport. Hansson et al. (2019) developed research to analyze passenger preferences on public transport services, however, without focusing on the possibility of bike-train intermodality. Heinen et al. (2013) developed a survey throughout the Netherlands to understand the work-related factors on bicycle commuting, excluding infrastructural factors. In studying bike-train intermodality, limited research has been done on the preferences of travelers, although it seems very likely that many factors affect the modal choice (Kager, Bertolini, Te Brömmelstroet, 2016; Zuo et al. 2020; van Kuijk et al, 2022). To address this gap, this paper examines the factors that can influence all types of travelers to choose a trip that involves the combined use of bicycle and train. The research methodology develops a widespread survey of the Italian population taken on voluntary adhesion. The survey investigates the general attitude of the respondent to cycle and undertake a bike-train intermodal journey. In particular, the last part of the survey asks all the respondents to identify themselves as an intermodal user of bike-train who first takes the bike on the train and then leaves the bicycle at the railway station. In summary, this survey tests a large number of people, regardless of the usual modal choices, on the preferences towards infrastructure and services dedicated to cyclability and bike-train intermodality. The results of preferences on cyclability show similarities between people who regularly use their bicycle and individuals who do not use it. The most important factor is the necessity to have low interaction with motorized vehicles, while the results of the bike-train intermodality preferences show that the most important characteristic in that case is the presence of bike parking spots. This paper shows how, through a survey, bike-train intermodality can be improved efficiently. The current study is a follow up investigation to an earlier analysis on accessibility of bicycles inside railway stations (Pazzini, et al., 2023). The paper identified five categories that had to be evaluated when quantifying accessibility: the quality of the cycle track, the visibility and signs of the cycle track, the services provided by the railway station, the bike deposit and the bike sharing service. This paper explores these topics in a more representative manner, with the point of view of the regular user and the non-user. The present work is the first step of the creation of an accessibility indicator that can be useful for policymakers and railway managers to help in the decision-making process. The survey-based indicator is more accurate than a hard-data based indicator (Claveria, Monte, & Torra, 2016; Lehmann, 2015). For instance, the number of people who travel intermodally, or that currently use bike deposits, and bike sharing, or the trend during the years of the use of these services, may not be significant to the study as the aim of the indicator is to improve the service based on the features (investigated through surveying) that would actually induce travelers to switch the modal choice to bike and train. In particular, the indicator will be weighted through the analysis of the survey results (Gan, et al., 2017). The paper is structured as follows. The second chapter includes the research design and process of data collection. The following chapter illustrates the results and finally there is the discussion.

2. Methodology

A sample survey was proposed to the Italian population, regardless of age, gender, race, disability, economic status and other diverse background. It was distributed online via email and LinkedIn. The survey was taken by 1125 people and was accessible online for a period of 1 month. The average investigation time was 10 minutes. The survey was pretested through 20 interviews to identify questions that respondents may have difficulty understanding or interpreting (Collins, 2003). Pazzini et al. (2023) defined a methodology to measure the accessibility of bicycles inside railway stations. The research set out some indicators on a checklist that characterize bike-train intermodality. The survey was designed based on those indicators. The survey consists of a total of 21 questions and includes 9 multiple choice questions, 1 true or false question, 5 open questions and 6 questions in 5-points Likert scale questions.

The 21 questions can be identified in four parts:

- The first part concerns the socio-economic information of the user. Here the user is asked about gender, age, place of residence, level of education and profession.
- The second part of the survey goes in depth into the travel modes used to reach the workplace or school and deepens the reasons for each choice.
- The third part explores, first the propensity of the respondents to undertake a bike-train intermodal trip and then their propensity to use the bicycle as the daily modal choice.
- The fourth part investigates the preferences of the respondents when making a bike-train intermodal trip.

The third part consists of two different cases based on the attitude of the respondent to cycle. In case the respondent is not a regular cycler, a 5-points Likert scale question comes up to identify what characteristics would invert this habit (1- not increasing the propensity to cycle; 5- would increase propensity to cycle); in case the respondent regularly cycles, but does not feel confident while doing so, he/she is asked to answer a 5-points Likert scale question to identify the features that would give him/her more security (1- not increasing perception of safety; 5-would increase the perception of safety). The characteristics assessed in both cases are listed in Table 1.

Table 1. Part 3 Likert scale indicators in case the respondent does not use the bicycle as the first modal choice and in case the respondent cycles but does not feel safe.

		Respondent doesn't cycle (How would this feature increase your tendency to cycle?)	Respondent cycles but doesn't feel safe (How would this feature increase your perception of safety?)
1	Cycle paths protected with kerb	X	X
2	Direct and fast cycle paths even if they mean the use of a cycle lane	X	X
3	Safe, free parking spots	X	X
4	Bike sharing availability	X	
5	Good signs dedicated to cyclists	X	X
6	Presence of bike deposits	X	X
7	Low conflict with vehicular traffic	X	X
8	A better outfit (I do not use the bike because I have to be dressed in a specific way)	X	
9	Bike parking spots not overcrowded	X	
10	Availability of dressing rooms and showers at destination place	X	
11	A good cycle path lighting	X	X
12	Lower slope of the street	X	X
13	Closeness to points of interest	X	
14	Lower probability of theft	X	
15	Owning a low cost bike	X	
16	Reduced physical effort	X	
17	Lower air pollution	X	
18	Weather (warm, cold, rain)	X	
19	Cycle paths at raised level	X	X

The fourth part of the survey is made of four differentiated 5-points Likert scale questions, rating scales from 1 "less important" to 5 "most important", in which the respondent must assume he/she has to perform a bike-train intermodal trip. The topics identified for the four questions, specific to bike-train intermodality, are listed in Table 2. The questions proposed to the respondents are showed in the first line of Table 2. Indicators 13, 7 and 4 from Table 1 are also present in Part 4.

Table 2. Part 4 Likert scale indicators with relative questions

How important is the following characteristic of the cycle path that reaches the railway station?	How important is the presence of the following characteristic, or service, in the proximity of the railway station?	How important is the presence of the following characteristic, or service, assuming you are taking the bike on the train?	How important is the presence of the following characteristic, or service, assuming you are not taking the bike on the train?
13. Closeness (less than 75m) to the railway station	29. The lighting at the entrance of the railway station	34. Signs direct to lifts/ramps/ cycle paths	36. The visibility of bike racks entering/exiting the railway station
20. Direction of the cycle path	30. The absence of interference with pedestrians in the entrance of the railway station	35. The presence of ramps/lifts to reach platforms	37. The presence of bike racks
21. The absence of fixed obstacles	31. The absence of interference with vehicles in the entrance of the railway station		38. The possibility to tie up the bike frame and the wheel
22. The absence of interference with pedestrians	4. The presence of bike sharing		39. The distance of the bike deposit from the railway station
7. The absence of interference with vehicles	32. The presence of bike sharing without obligation to return in specific areas		40. The cost of the bike deposit
23. The maintenance of the cycle path	33. The presence of pumping column		41. The presence of services for the cyclist inside the bike deposit
24. The colouring of the cycle path compared to the external asphalt			42. The possibility to book in advance a slot inside the bike deposit
25. The presence of a one lane cycle path rather than two lanes two ways cycle path			43. The opening hours of the bike deposit
26. The absence of vehicles parked by the cycle path			44. The method to access the bike deposit
27. The absence of lateral conflict due to driveways			
28. The presence of signs dedicated to the points of interest			

3. Results

Among the 1125 submitted responses, a total of 1124 respondents logged usable responses on the core section of the survey (questions of part four). Of these, 44 (4%) did not specify the usual mode of transport; of these 39 (98.8%) were pensioners. Of the valid responses, among the people who specified the primary mode of transport, 465 (43.06%) reported the bicycle as their main travel mode to reach work (or school), 51 (4.72%) reported using the train, 145 (13.43%) reported using the train combined with another mode, where the “other mode” is the bicycle for 107 (9.5%) users. 81 (7.5%) walked, 2 (0.28%) used car sharing, 171 (15.83%) used their own car, 4 (0.28%) shared the car with another person, 19 (1.76%) used a motorbike, 28 (2.59%) used multiple means of transport (excluded train), 24 (2.22%) used the bus, 91 (8.3%) used different modes depending on the weather conditions.

3.1. Cycling preferences

Results from respondents are studied to define preferences on infrastructure dedicated to cycling and service for cyclists, by different types of bicycle users or non-users. Respondents who do not cycle are 15.9% with 55% male ratio. Among regular bicycle users (84.1%, with 63% male ratio) can be distinguished users who feel safe pedaling (15%, with 61.3% male ratio), and users who do not feel safe pedaling (85%, with 55% male ratio). Average (M) and standard deviation (SD) of characteristics from Table 1 are calculated and reported in Table 3 by non-cycler respondents (which include people who never use the bicycle or use it only once or twice a month) and by regular cyclers who do not feel safe (which include people who use their bicycle every day or one to three times per week).

Table 3. Mean and Standard Deviation of infrastructural/service availability preferences based on regular cyclists who don't feel safe and non-cyclers.

		Respondent does not cycle		Respondent cycles but does not feel safe	
n.		M	SD	M	SD
1	Cycle paths protected with kerb	4.19	1.17	4.36	1.07
2	Direct and fast cycle paths even if they mean the use of a cycle lane	3.54	1.40	3.74	1.15
3	Safe, free parking spots	4.13	1.26	3.82	1.35
4	Bike sharing availability	2.89	1.50		
5	Good signs dedicated to cyclists	3.66	1.41	3.92	1.14
6	Presence of bike deposits	3.87	1.27	3.90	1.21
7	Low conflict with vehicular traffic	4.48	1.10	4.47	0.91
8	A better outfit (I do not use the bike because I have to be dressed in a specific way)	2.54	1.43		
9	Bike parking spots not overcrowded	2.96	1.40		
10	Availability of dressing rooms and showers at destination place	2.82	1.55		
11	A good cycle path lighting	4.12	1.19	4.09	1.07
12	Lower slope of the street	2.91	1.45	2.15	1.14
13	Closeness to points of interest	3.37	1.43		
14	Lower probability of theft	4.36	1.21		
15	Owning a low-cost bike	2.68	1.37		
16	Reduced physical effort	2.53	1.42		
17	Lower air pollution	3.69	1.42		
18	Weather (warm, cold, rain)	3.67	1.34		
19	Cycle paths at raised level	3.28	1.61	3.25	1.44

Results from respondents who do not cycle show that, the most significant factors to improve cycling is to have a low conflict with vehicular traffic (M=4.48 and SD=1.10), and a lower probability of theft (M=4.36 and SD=1.21). Closely related to traffic interference and the risk of theft are the presence of cycle paths protected with kerb (M=4.19; SD=1.17) and the availability of safe and free parking spots (M=4.13; SD=1.26). The characteristics that least affect the use of bike are a reduced physical effort (M=2.53; SD=1.42), the outfit of the cyclist (M=2.54; SD=1.43) and the possess of a low-cost bicycle (M=2.68; SD=1.37). Results from respondents who do not feel safe cycling show that the cardinal factor to improve in cyclability is the low conflict with vehicular traffic (M=4.47; SD=0.91), leading to the second major factor being the cycle paths protected with kerb (M=4.36; SD=1.07). Lighting of the cycle path is also one of the most important factors (M=4.09; SD=1.07). The least important elements that affect the improvement of safety for the cyclers who do not feel safe are the slope of the street (M=2.15; SD=1.14) and the cycle path at raised level (M=3.25; SD=1.44).

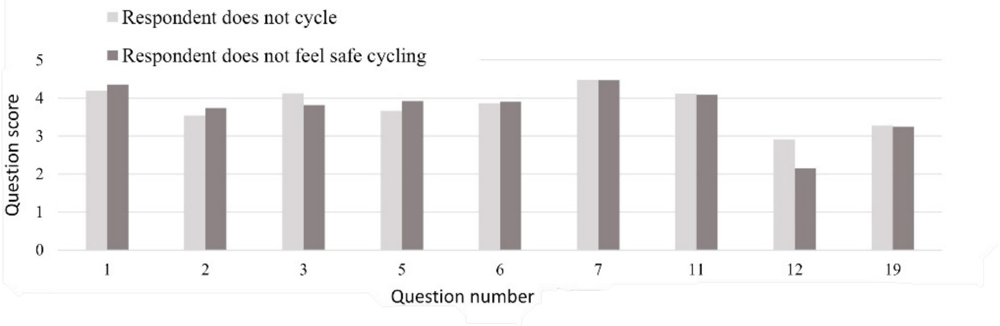

Fig. 1. Average preferences to improve cyclability

A comparison between users who regularly cycle and users who don't cycle (Fig.1) shows similarities among most of the infrastructural characteristics. The main discrepancies are shown in factors Question n.3 and Question n.12 with a difference of 0.31 and 0.76 between respondents who do not cycle and cyclists who do not feel safe. In general, the order of preferences for the results of the two groups is the same except for Question n.3 which stands in the sixth position for people who do not feel safe to pedal, against the third position for the people who do not cycle. In both cases, the highest importance is given to the low conflict with vehicular traffic (Question n.7), followed by cycle paths protected with kerb (Question n.1), and the least importance is given to a lower slope of the street (Question n.12). The trend of a higher SD for the least important factors in case of non-cycling respondents is not confirmed with the second type of respondents. The most significant example is shown by Question n.12 where the SD in a case is 1.45 and, in case the respondent is a cycler who does not feel safe, is 0.90.

3.2. Preferences regarding bike-train intermodality

Part 4 (Table 2) of the questionnaire, shows the characteristics of the infrastructure and services provided to users that are most important for an intermodal trip. The results shown in Fig. 2 represent the differences to the responses of the survey between people who make a bike-train intermodal trip every day or at least once a week (18% of total respondents, 70.6% males) and people who do not make intermodal travel but use their bike every day or at least once a week (63.1% of total respondents, 61.3% males).

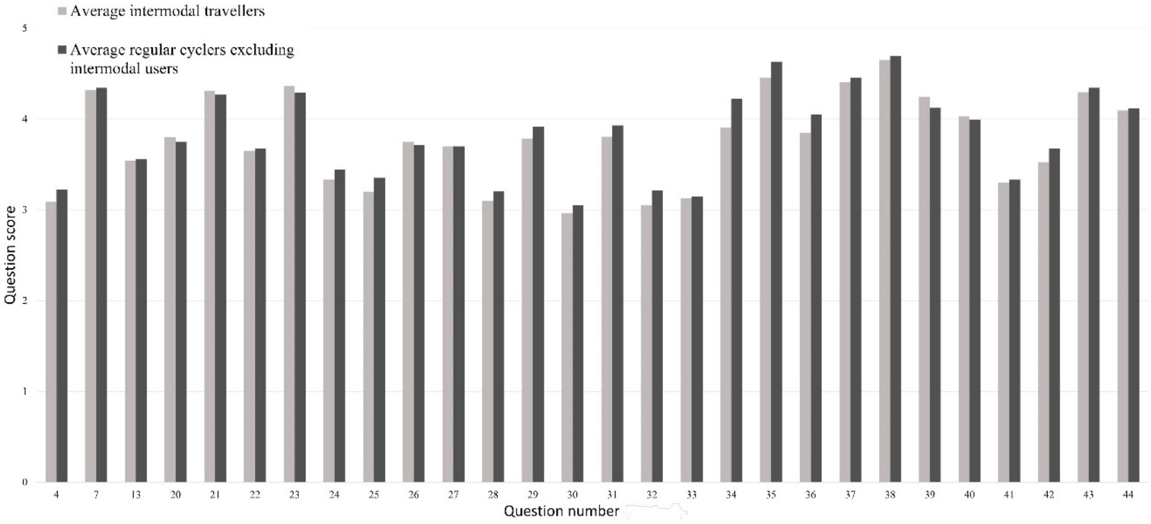

Fig. 2. Average preferences to improve bike-train intermodality

The main discrepancy is represented by indications for lifts/ramps/cycle paths (Question n. 34) with a mean of 4.22 (SD=1.00) for people who cycle and do not travel intermodally and an average of 3.91 (SD=1.12) for regular intermodal travelers. A difference of 0.20 between the two types of respondents is calculated for the visibility of bike racks entering/exiting the railway station (Question n. 36) that has an average of 4.05 (SD= 0.96) for non-intermodal travelers and 3.85 (SD=1.06) for intermodal travelers. The same average is obtained for the absence of lateral conflict due to driveways (Question n.27, M=3.70). Both types of users agree on the three most important characteristics that are: the possibility to tie up the bike frame and the wheel (Question n.38), the presence of ramps/lifts to reach platforms (Question n.35), and the presence of bike racks (Question n.37). Results also match on the least important factor that results to be the absence of interference with pedestrians at the entrance of the railway station (Question n.30). This characteristic is the only one that has average scores and importance below 3 (intermodal users, M=2.93; SD=1.17). In general, results from intermodal users show lower values than non-intermodal users.

4. Discussion and conclusion

This paper used a large-scale survey of people travelling using several different travel modes to compare five main areas of interest identified from an earlier work: quality of the cycle path, visibility and signs of the cycle path, services for cyclists, bike deposit and bike sharing. Different mode users were compared. Although different research has shown that private cars remain the most widely used mode of transport among Europe and in the Italian population, the survey may not be representative of the national population since the majority of respondents use the bike as the main modal choice (41.3%) (Gonzalo, Gomez, & Christidis, 2023; Gonzalo, Christidis, & Gomez, 2023; Sottile et al., 2021). The cause of this unbalance in the respondents may be due to the fact that who currently uses the bike is more inclined to respond to a survey that could possibly lead to improvements. The responses to the survey provided significant results. The results from users who do not usually cycle show a low SD, which increases for the factors that least affect the use of bicycles. This means that the factors that mostly affect cyclability are also the stronger ones compared to the other factors. The four most impacting factors to respondents who do not use a bicycle represent two main issues with their solutions. In fact, the low conflict with vehicular traffic (Table 3, question n.7), finds an acknowledgment into cycle tracks protected with kerbs (Table 3, question n.1). Similarly, the lower probability of theft (Table 3, question n.14) finds an acknowledgment in safe, free parking spots (Table 3, question n.3). The results also show that the choice of not using a bicycle is not affected by the physical effort (Table 3, question n.16), or by the availability of dressing rooms in the destination place. Question n.16 is however the feature with the highest SD (1.55). The comparison between people who cycle and don't feel safe, and people who do not cycle provides interesting results. For both types of respondents, the safety of the user expressed as a low interaction with vehicles, the type of protection and lighting of the cycle paths, are the factors that mostly influence the use of this mean of transport. Many studies have underlined the effect of some elements present in the route that discourage cyclists to choose this mode of transport. One of these are interceptions, sidewalks and different elements of infrastructure (Buehler & Dill, 2016; Aultman-Hall & F. Adams, 1998; Akar & Clifton, 2009). What links all these elements is the perception of safety. The responses on part four are deeply useful to induce all types of travelers to make an intermodal trip. This section finds most homogeneous responses with 0,73<SD<1,40, compared to the third part of the survey which has 0,90<SD<1,60. The characteristics with SD<0,97 for both cyclers and intermodal travelers are the possibility to tie the frame of the bike (question n.38), the presence of bike racks (n. 37), the maintenance of the cycle path (question n.23), the presence of ramps/lifts to reach platforms (question n.35), the distance of the bike deposit (question n.39), the time openings of bike deposit (question n.43). The reason for such a low SD is probably due to the fact that in this part of the survey all users are asked to put themselves at the same level, which could lead to unprecise results. In fact, here, the user expresses himself as someone who he may not be (Kalton & Schuman, 1982).

The strongest factor that is analyzed in both part three and part four is the interaction with vehicles which has the highest priority when analyzing cyclability for both cyclers who don't feel safe and non-cyclers (M=4,48). Acerra et al. (2023) demonstrated, through sperimentation, that cyclists give much attention to motorized vehicles on the road when riding. Also, they tend to drive through a less congested road when possible (Gardner, 1998). However, when asking specific questions on bike-train intermodality, the interaction with motorized vehicles is not considered as the priority, but gets behind the quality of the bike parking spots. This means that when undertaking a bike-train intermodal trip the priority is no longer the safety of the cyclist, but the one of the bicycles. The findings are of potential significance to policymakers and railway management systems. Policymakers could benefit in a number of ways from encouraging people to travel through the combination of bike and train: reduced pollution from private vehicles, reduced demand for parking, reduced commuting costs, healthier population. Railway management systems, meanwhile, could efficiently allocate resources, and encourage people to abandon the private vehicle in favor of the use of trains. Further research will investigate the specific needs of the population to encourage the use of train to develop bike- train intermodality so that the people who use the bike but do not yet use the train as a modal choice, will be facilitated to do so.

References

Acerra, E. M., Shoman, M., Imine, H., Brasile, C., Lantieri, C., & Vignali, V. (2023). The Visual Behaviour of the Cyclist: Comparison between Simulated and Real Scenarios. Infrastructures, 8(5), 92. doi:10.3390/infrastructures8050092

Akar, G., & Clifton, K. J. (2009). Influence of individual perceptions and bicycle infrastructure on decision to bike. Transportation Record Record, 2140(1). doi:10.3141/2140-18

Aultman-Hall, L., & F. Adams, M. (1998). SIdewalk bicycling safety issues. Transportation Research Record, 1636(1). doi:10.3141/1636-11

Bell, D. (2019, February 20). Intermodal mobility hubs and user needs. Social Sciences, 8(2), 65. doi:10.3390/socsci8020065

Belloni, E., & Maggi, S. (2022). Muoversi domani- Verso una mobilità più sostenibile. Milano, Itlay: FrancoAngeli.

Bennaya, S., & Kilani, M. (2023). Evaluating benefits of promoting intermodality and active modes in urban transportation: a microsimulation approach. Smart cities. Studies in Energy, Resource and Environmental Economics, 279-294. doi:10.1007/978-3-031-35664-3_15

Buehler, R., & Dill, J. (2016). Bikeway networks: A review of effects on cycling. Transport Reviews, 36(1), 9-27. doi:10.1080/01441647.2015.1069908

Claveria, O., Monte, E., & Torra, S. (2016, November 09). A data-driven approach to construct survey-based indicators by means of evolutionary algorithms. Social Indicators Research, 135, 1-14. doi:10.1007/s11205-016-1490-3

Collins, D. (2003, January 24). Pretesting survey instruments: An overview of cognitive methods. Quality of Life Research, 12, 229-238. doi:10.1023/A:1023254226592

European Environment Agency. (2023, December 18). Emissions of air pollutants from transport in Europe. Retrieved April 03, 2024, from https://www.eea.europa.eu/en/analysis/indicators/emissions-of-air-pollutants-from

Gan, X., Fernandez, I. C., Guo, J., Wilson, M., Zhao, Y., Zhou, B., & Wu, J. (2017, October). When to use what: methods for weighting and aggregating sustainability indicators. Ecological Indicators, 81, 491-502. doi:10.1016/j.ecolind.2017.05.068

Gardner, G. (1998). Transport implications of leisure cycling: prepared for driver information and traffic management division, department of the environment, transport and the regions. doi:ISSN 0968-4107

Giansoldati, M., Danielis, R., Rotaris, L. (2021, May). Train-feeder modes in Italy. Is there a role for active mobility?. Research in Transportation Economics, 86. doi: 10.1016/j.retrec.2020.100990

Vega-Gonzalo, M., Gomez, J., Christidis, P. (2023, June). How has COVID-19 changed private car use in European urban areas? An analysis of the effect of socio-economic characteristics and mobility habits. Transportation Research Part A: Policy and Practice,172. Doi: 10.1016/j.tra.2023.103679.

Vega-Gonzalo, M., Christidis, P., Gomez, J. (2023). Car Ownership and Post-COVID Urban Mobility across European Cities, Transportation Research Procedia, 69. doi: 10.1016/j.trpro.2023.02.176.

Hansson, J., Pettersson, F., Svensson, H., & Wretstrand, A. (2019, July 22). Preferences in regional and public transport: a literature review. European Transport Research Review, 11(38). doi:10.1186/s12544-019-0374-4

Heinen, E., Maat, K., & van Wee, B. (2013). The effect of work-related factors on the bicycle commute mode choice in the Netherlands. Transportation, 40, 23-43. doi:10.1007/s11116-012-9399-4

Kager, R., Bertolini, L., Te Brömmelstroet, M. (2016, March). Characterisation of and reflections on the synergy of bicycles and public transport. Transportation Research Part A: Policy and Practice, 85, 208-219. doi: org/10.1016/j.tra.2016.01.015.

Kalton, G., & Schuman, H. (1982). The effect of the question on survey responses: a review. J.R. Statistic Soc. A, 145, 42-73. Retrieved from https://deepblue.lib.umich.edu/bitstream/handle/2027.42/146916/rssa04317.pdf?sequence=1/1000

van Kuijk, R., Homem de Almeida Correia, G., van Oort, N., van Arem, B. (2022, December). Preferences for first and last mile shared mobility between stops and activity locations: A case study of local public transport users in Utrecht, the Netherlands. Transportation Research Part A: Policy and Practice, 166, 285-306. doi: 10.1016/j.tra.2022.10.008.

Laplace, I., Lenoir, N., Rebello, I., Pita, F., & Valadares, A. (2005). Intermodality and passenger transport. ETC 2005, European Transport Conference. Retrieved from https://enac.hal.science/hal-01021742

Lehmann, R. (2015). Survey-based indicators vs. hard data: what improves export forecasts in Europe? Ifo Working Paper, 196. doi:10419/108763

Oeschger, G., Carrol, P., & Caulfield, B. (2020, December). Micromobility and public transport integration: The current state of knowledge. Transportation Research Part D: Transport and Environment, 89(102628). doi:10.1016/j.trd.2020.102628

Pazzini, M., Lantieri, C., Vignali, V., Simone, A., Dondi, G., Luppino, G., & Grasso, D. (2022). Comparison between different territorial policies to support intermodality of public transport. Transportation Research Procedia, 60, 68-75. doi:10.1016/j.trpro.2021.12.010

Pazzini, M., Lantieri, C., Zoli, A., Simone, A., & Imine, H. (2023). Evaluation of railway station infrastructure to facilitate bike-train intermodality. Sustainability, 15(4), 3525. doi:10.3390/su15043525

Ritchie, H. (2020, October 6). OurWorldInData.org. Retrieved April 03, 2024, from https://ourworldindata.org/co2-emissions-from-transport

Sottile, E., Piras, F., Calli, D., Meloni, I. (2021, March). Why don't Italians cycle to work? An experimental analysis. Case Studies on Transport Policy, 9(1), 362-373. doi: 10.1016/j.cstp.2021.01.007.

Stoilova, S., & Kunchev, L. (2017, May 26). Study of criteria for evaluation of transportation with intermodal transport. Engineering for rural development, 349-357. doi:10.22616/ERDev2017.16.N070

Zuo, T., Wei, H., Chen, N., Zhang, C. (2020, April). First-and-last mile solution via bicycling to improving transit accessibility and advancing transportation equity, 99. doi: 10.1016/j.cities.2020.102614.

Validation of survey data via bicycle simulation in a multimodal bicycle-train context

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Abstract

Data analysis for policymaking processes are of extreme importance. However, in order for a data analysis to be accurate, the data collection has to be consistent and reliable. Questionnaire-based surveys often suffer from low response rates, introducing the risk of sample selectivity bias, as the collected data may not represent the behaviour of nonrespondents. Furthermore, even among respondents, incomplete answers can compound this bias, further compromising the validity of the findings. This paper proposes a methodology to validate data results comparing the perception of the population on what impacts the bicycle-train intermodal trip, to data collected from a bicycle simulation. The simulation data include the safety perceived while riding through a specific scenario (subjective) and data collected from an eye tracking device (objective). The data from the eye tracking device are the duration of fixations to the infrastructural elements and road dynamic elements (pedestrians and vehicles). First a Friedman test was conducted to find out whether the scenarios ridden by participants had different perceived levels of safety. Secondly a Wilcoxon signed-rank post-hoc test is done to verify which scenario has higher perceived safety. The following analysis includes correlating the duration of fixations to the post-simulation survey results, specifically with the elements that where validated when applying the Mann Whitney to the survey results with the post simulation survey results. Results show that it is possible to validate survey results through the examination of three different sources of data, a general survey, a post bicycle simulation survey and eye tracking data.

Keywords: data validation, eye tracker, bicycle simulator, questionnaire.

1. Introduction

In an era marked by rapid urbanization and increasing environmental concerns, transportation solutions have become a pillar to air quality. Intermodality, the integration of various modes of transportation to facilitate efficient and convenient travel, is one of the interventions that would reduce the use of private vehicles. The integration of bicycles and trains, in particular, offers reduced energy consumption and air and noise pollution resulting from the replacement of private motor vehicles with public transport or bicycles [1]. However, the success of this interchange is determined by the actual possibility for users to reach the railway station and therefore depends on numerous factors, such as the safety of the cyclist reaching the railway station or the availability of bicycle parking at destination [2]. In order to successfully implement the overall accessibility of a railway station, data on user preferences play a crucial role to correctly shape the infrastructure.

Data is fundamental in evidence-based policymaking, particularly in local planning as it empowers the citizens. It facilitates informed decision-making, enhances community engagement and helps challenge negative perceptions [3]. At multiple stages of the policy cycle, data are used to facilitate collaboration among stakeholders, ensuring quality assessments to inform decisions and enhance the effectiveness of policy implementation [4]. Most of the times a close collaboration between the policy maker and the data scientist, during iterative approaches, permits to turn the policy question into a suited data analysis question to deliver relevant insights [5]. The insights that result from interviewing the citizen help the local administrations to face the challenge of designing infrastructure and services that reflect the actual needs and behaviors of users, while encouraging the shift toward low-carbon transport modes. High-quality, context-specific data enables a better interpretation of mobility patterns, it helps identify barriers and opportunities of multimodal transport. For example, data can reveal gaps in bicycle parking availability at train stations, or socio-demographic differences in the propensity to combine cycling with rail.

In the last decades the need for information to track the public's behaviour, experiences, needs and preferences has risen. The survey is the most used social research method for collecting data from individuals in a population of interest. This led to the challenge of conducting high quality surveys. In general population surveys, the development of sampling frames that cover the full household population is hard [6]. The importance of data quality and reliability becomes fundamental. Reliance of data is usually found through diverse statistical techniques, and is not cross-validated through different data collection methods. The method of data collection significantly impacts the results, for example influencing response rates, data quality and the interpretation of information. In fact, different methodologies can yield varying outcomes. For instance, face-to-face computer assisted surveys and online probabilistic samples yield similar quality, while telephone interviews result in lower quality (R., 2012). Küfner et al. while comparing the potential impact on survey participation and nonresponse bias, of mail survey and web single and mixed mode designs, found no significant differences [7].

Transport data collection methodologies are commonly categorized into subjective and objective approaches, each offering strengths and limitations. Objective methods offer quantifiable and reliable insights into participants' responses. Among the most widely used objective tools are physiological sensors, simulators, and eye-tracking devices. Eye tracking has become an increasingly valuable tool in transport behavioral research, providing insights into driver attention, visual scanning patterns, and cognitive workload during complex navigation tasks. Eye tracking provides real-time, high-resolution data on visual attention, cognitive load, and decision-making processes [8]. This technology measures where, when, and how long a person looks at visual stimuli, enabling researchers allocate attention, interest levels, and cognitive strategies [9]. Questionnaires and observational studies have contributed significantly to understanding transport behavior, but they often lack the temporal precision or objectivity needed to capture in-the-moment cognitive processes [10]. Eye tracking addresses this gap by offering a direct measure of visual attention and information processing. For instance, in driving research, eye-tracking devices are used to assess gaze distribution across mirrors, the dashboard, the road, and surrounding environments, offering a window into how drivers allocate their attention under varying conditions [11]. Eye-tracking has been useful to evaluate the effectiveness of in-vehicle systems and roadside signage. Research by Recarte and Nunes demonstrated that cognitive distractions, such as mobile phone use, significantly reduce the number and duration of fixations on the road, indicating compromised situational awareness [12]. In public transport and pedestrian contexts, eye tracking has been used to study how individuals interact with complex multimodal environments, such as transit hubs and shared spaces [13]. Visual attention is a fundamental factor affecting cyclist safety, as riders must continuously monitor their surroundings to detect hazards, other road users, and infrastructural features [14] [15] [16]. Mobile eye-tracking technologies offer a powerful method to assess cyclists' gaze behaviour, capturing where, when, and how long riders look at roadway elements, and revealing how specific infrastructure elements (e.g. intersections, shared zones, pedestrian crossings) influence visual workload and hazard perception and how gaze is allocated under differing traffic conditions [17] [18] . Overall, eye-tracking provides a non-intrusive, high-resolution method for assessing visual attention in dynamic transport scenarios, allowing the design of safe, user-centered transportation systems. The present study employs eye-tracking in a simulator to examine how selected roadside elements affect cyclists' visual behavior and perceived risk, with the broader aim of informing infrastructure designs that improve safety while riding a bicycle to the railway station [19]. In multiple studies, the use of a bike simulator has shown absolute validity considering a set of diverse kinematic and behavioral variables, indicating its reliability for studying the behavior of cyclists [20], [21]. Ayad et al. demonstrated how the simulation used with the eyetracker is a combination that provides realistic results on the perceived safety [22].

Subjective methods are widely used in travel behavior research due to their ability to capture motivations, attitudes, and user satisfaction [23] [24] [25]. For instance, stated preference surveys model the mode choice under hypothetical scenarios, while revealed preference data collected via travel diaries provide insights into actual behaviour, even though they are subject to misreporting [26] [27]. Comfort, safety and convenience are important factors to predict mode, however, subjective perceptions are also relevant. Data collection from surveys to general population may not always be objective, and may not represent the full reality. Much research on pedestrian and cyclists focuses on understanding how environmental elements are perceived by users, but sometimes a simple survey could present an incomplete version of the actual situation [28]. To fill this gap, increasingly hybrid methods combining subjective and objective data are used to cross-validate findings and enrich interpretability [29]. De Magalhães et al. collected data from an urban quality of life survey and combined it with a very detailed slope map, in order to analyse the consistency of information stated by the respondent [30]. However, challenges persist in data integration, and potential sampling biases [31], [32].

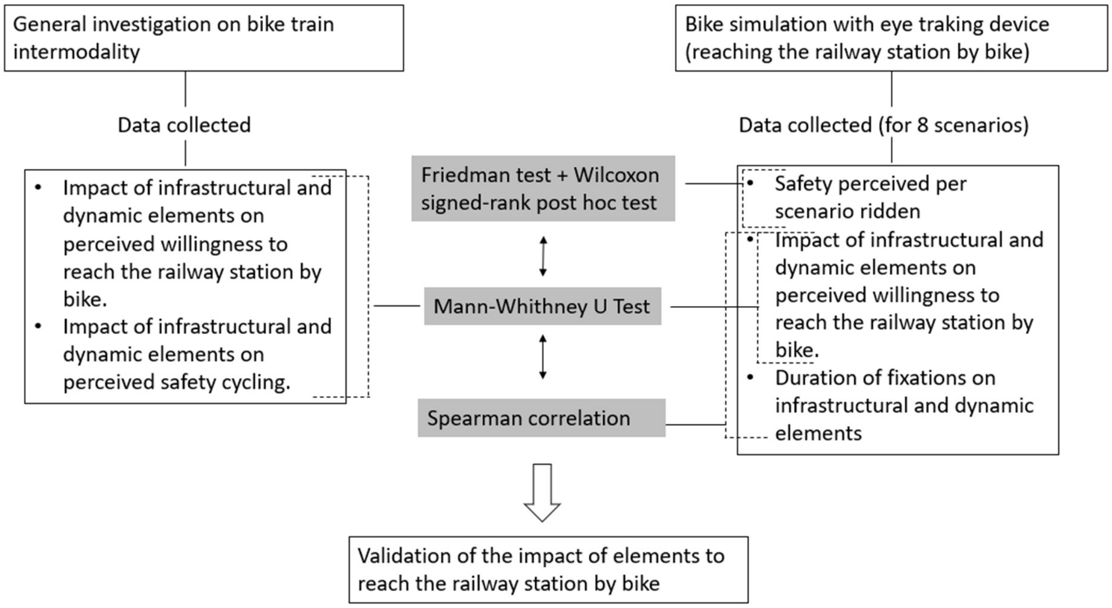
This research aims at filling the gap of validating a general population survey on infrastructure preferences with a post bike simulator survey with the use of an eye tracking device. Reingold et. al confirmed that eye tracking has the potential to be an important tool in the evaluation of data quality [33]. Some research concentrates on road users' perceptions in respect to safety, using images. Yao et al. carried on a study on the effect of the built environment on pedestrians perceived safety. The methodology combined the duration of fixations data with the results from a survey on perceived safety which was evaluated by looking at still images [34]. Brazil et al. used a similar methodology, but considering the user as a cyclist [35], and analysing the capability to detect hazards.

The present paper compares data obtained from subjective survey on the elements that engage the user in doing a bicycle train intermodal trip, to virtual simulation data. The simulation data include eye tracking data as representative of objective data and a post simulation questionnaire data, that is important to understand the perceptions of the user specifically associated to elements that have been faced just a few minutes earlier

2. Methodology

The main objective of the analysis is to investigate the reliability of a survey questionnaire on the impact infrastructural and dynamic road elements have on the willingness to reach the railway station by bicycle through the search for a new methodology to validate data from different sources [36]. A bicycle simulation experiment was carried out. Data collected by the simulation include survey results on the willingness of participants to reach the railway station by bicycle after facing obstacle elements and on the gaze behaviour obtained from the eye-tracking device. A graphical representation of the procedures followed is shown in figure 1

Figure 1. Structure of the analysis.



Given the inherent limitations of a simulated environment, the study focused on a selected set of dynamic and infrastructural elements, allowing for a more precise and controlled analysis:

- The existence of a cycle path;
- The direction of the cycle path, if necessary, the presence of a cycle lane;
- Bicycle lanes raised above road level;
- Bicycle lanes protected by curbs, or any physically unsurpassable limitation;
- Fixed obstacles on the cycle path;
- The interference with pedestrians;
- The interference with vehicles;
- The set of cyclist's dedicated signs- horizontal;
- The set of cyclist's dedicated signs- vertical;
- The cars parked on the side of the road/cycle path.

2.1 Survey on cyclability perception and bicycle-train intermodality

Previous research collected data from a survey campaign targeting the Italian population during November 2023 and April 2024. The survey was disseminated via emails sent to regional employees, university students and staff, as well as people taking part to an Italian cyclists' association. A total of 1125 responses were collected. Geographical coverage included 79% of residents in the North of Italy. The questionnaire collected information on elements that influence the willingness to reach the railway station by bicycle, and on the impact on safety perceived during a bicycle-train intermodal trip (cycling specific) [36]. For the purpose of the present research, , the answers to ten questions of the survey were analysed. Table 1 summarizes the questions screened from the survey and subsequently analysed. Responses were given on a 5-point Likert scale, where 1 corresponds to “not engaging/important” and 5 corresponds to “extremely engaging/important”.

Table 1. Structure of the likert scale questions of the survey on cyclability perception and bicycle-train intermodality.

II Part	III Part
How does this element affect the perceived safety while riding a bicycle?	**How does this element impact the willingness to undertake a bicycle-train intermodal trip?**
Bicycle lanes on direct and fast routes, even if it involves the use of a cycle lane	The absence of fixed obstacles on the path
Bicycle lanes elevated above road level	The absence of interference with pedestrians
Bicycle lanes on routes protected by curbs or bollards	The absence of interaction with vehicles
Reduced danger from vehicle traffic	The absence of vehicles parked next to the bicycle path
Good signage dedicated to cyclists	Direction of the cycle path, if necessary, the presence of a cycle lane

Table 2 displays the description of the sample. Since the survey campaign was spread through the subscribers of an Italian cycling association, the sample does not necessarily provide an accurate representation of the global population of Italian cities. The distribution of the sample shows an unbalanced profile of respondents in terms of transport modes, with 41.3% people identifying cycling as their preferred transport mode. Furthermore, the age between 55 and 64 years represents 30.92% of the total respondents, which is higher than national surveys where the average age in Italy is 48.2 years [37]. Under the educational aspect, the high school level counted for 35% of total respondents and master’s level 43%. According to ISTAT (National institute for statistics), 30.6% of adults had a university degree and 34.8% had interrupted their studies after middle school in 2023. Moreover, the private car was the preferred mode of transport for 82.9% of Italians [38] (Mobility of Italians between April and June 2022). According to a 2020 study, 60% of Italians use the bicycle at least “occasionally”, meaning once to six times per year [39], [40].

Table 2. Mean age, Standard Deviation and Gender ratio for the main transport modes.

SOCIO-ECONOMIC VARIABLES			TRANSPORT MODE				
Variables	Categories	Relative freq. (n=1127)	Category	Relative freq. (n=1127)	Mean Age	Standard deviation	Gender Ratio
Gender	Male	62%	Bicycle	41.3%	55.34	13.7	61.0% males; 39% females
	Female	38%					
	Other	1%					
Age	18–24	2.59%					
	25–34	9.38%	Train	4.5%	48.90	14.94	58.9% males; 41.1% females
	35–44	13.4%					
	45–54	17.87%					
	55–64	30.92%					
	65 or above	25.8%					
Education	Middle school	5%					
	High school	35%	Bicycle combined with train	9.5%	49.53	15.27	70% males; 30% females
	Bachelor	10%					
	Master	43%					
	PhD	8%					
Occupation	Unemployed	3%	Pedestrians and public transports	9.3%	50.69	16.9	61.7% males; 38.3% females
	Student	4%					
	Employed	62%					
	Retired	32%					
Residence location	Chief town of province	65.13%	Motorized vehicles (including car sharing)	17.3%	54.14	12.38	60.0% males; 40% females

	Northern half of Italy	80%	

2.2 Set up of simulation experiment

The simulation was set on a bicycle simulator located in the PICS-L laboratory at Gustave Eiffel University, France. All participants gave their informed consent, and the study was approved by the Ethics committee of Gustave Eiffel University in Marne-la-Vallée, France, with protocol number 2024-023. The simulation involved 33 participants, riding through a scenario made of eight scenarios that run on screens continuously without interruptions. The list of elements encountered by participants while riding is listed and divided for each scenario in order of appearance in table 3:

Table 3. Description of the simulated environment for each scenario.

Scenario	Description	Visual image
1	No cycle lane; cars parked on the right side of the road; three pedestrians; stoplight.	
2	Cycle lane with multiple cycle symbol markings, with edge of carriageway marking; cars parked on the right side of the bicycle lane; cars riding on the left of the participant; stoplight; three pedestrians.	
3	Cycle lane with multiple cycle symbol markings, with edge of carriageway marking; raised pedestrian path; three pedestrians; stoplight.	
4	Cycle lane on the left side, in the opposite direction of cars (and of participant); still car on the carriageway; stoplight; route for use by buses and pedal cycles only; no cycle lane; three pedestrians walking on adjacent raised pathway.	

5	Cycle lane with multiple cycle symbol markings, with edge of carriageway marking; “route for use by pedal cycles only” sign; single-lane cycle path with cars parked on the left and raised pedestrian pathway on the right side; bin can misplaced on the cycle path; pedestrian walking on the cycle path; “end of route for use by pedal cycle only” sign.	
6	Cycle lane with multiple cycle symbol markings, with edge of carriageway marking, in opposite direction of cars; car passing on the left side of the participant in the direction of the participant.	
7	No cycle lane; still red car on the carriageway; truck at the stoplight.	
8	“Route for use by pedal cycles and pedestrians only” sign; raised route for use by pedal cycles and pedestrians only; three pedestrians.	

The bicycle simulator shown in Figure 2 is made of a still standing bicycle with five screens, that reproduce a scenario of 2.5 km, in front of them. The principal components of the bicycle, creating a realistic cycling experience, include five displays shaped as five segments forming a nonagon. On the back of the cyclists, slightly moved to the left side, there is a sixth display which reproduces the part of the road that has just been ridden by the cyclist. To reproduce the road adhesion on the rear tire, a cylindrical asphalt specimen is present. To replicate the vibrations from the road surface’s irregularities, the simulator is equipped with three actuators. A lateral suspension is used to provide the user a feeling of turning right or left. Finally, a fixed fan in front of bicycles provides the wind perception while cycling. The fan speed is proportional to the cycling speed.

Figure 2. Bicycle simulator

The single experimental session started with a briefing to the participant who was blinded and therefore unaware of the purpose of the experiment. The real objectives of the study were not presented to participants and the instructions provided were formulated in such a way as to minimise the experimenter's effect. All users were told that the goal of the ride was to reach the railway station using the bicycle, to catch a train. After the introduction, the participant was asked to get on the bicycle and take a test ride to feel comfortable with the set up. During the experiment, participants were informed on the possibility to drop the simulation without suffering any consequences. The overall procedure of the experiment was as follows:

The overall procedure of the experiment is as follows:

1) Participants signed an informed consent, followed by a verbal explanation of the experimental process and key points of the experiment
2) The eye tracker was calibrated through the Tobii Pro lab software.
3) A practice session where the participant became confident with the bicycle simulator
4) The actual ride on the simulator with the 8 scenarios running without interruptions
5) The fill of a survey evaluating different aspects of the simulation.

A total of 22 participants wore the Tobii Pro 2 glasses to capture their eye movements. The eye movements of the other 11 participants were not recorded as they wore glasses. Tobii pro is an eye-tracking system to understand human cognitive abilities and behaviour as humans interact with systems, devices, vehicles, and objects or events in the surrounding environment. The eye tracker is used to examine a person's awareness of the surrounding and ability to respond effectively to potential hazards. The Tobii pro is made of 16 illuminators and four eye cameras integrated into scratch resistant lenses. It is equipped with a scenario camera with a 106° field view. The Tobii Glasses head unit should be mounted on the test participant's head (similar to a standard pair of glasses). The system must then be calibrated separately for each participant. During the calibration process, the test participant is asked to look for a few seconds at a Calibration Card held in front of the participant. The head unit consists of the parts shown in figure 3:

1. High-definition scenario camera – Captures a Full HD video of what is in front of the participant.
2. Microphone – Picks up sounds from the participant and its surroundings.
3. Eye tracking sensors – Records eye orientation e.g. the direction of the eye gaze.
4. IR illuminators – Illuminates the eyes to support the eye tracking sensors.
5. Micro connector – Connects to the recording unit via the supplied Head unit cable.
6. Cable guide – Guides the Head unit cable towards the participant's back.
7. Protective lens – Both clear and tinted versions supplied
8. Nose pad — Exchangeable and available in different sizes

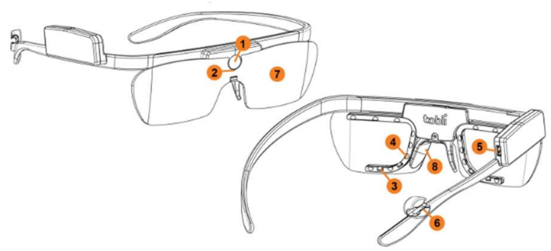


Figure 3. Tobii Pro Glasses components [41].

The gaze sample recorded for each participant ranged from a minimum of 67% to a maximum of 97%. 68.1% of participants had a gaze sample ≥ 90%, 22.7% of participants recorded a gaze sample between 80% and 89%, while 4.5% had a gaze sample < 79%. For the purpose of the research the gaze sample was measured in fixations. Fixations can be defined as the periods of time in which the eyes are relatively still, holding the central foveal vision in place so that the visual system can take in detailed information about what is being looked at.

2.2.1 Post-simulation survey

Each participant had to complete the post-simulation survey upon completing the simulation. The questionnaire contained the simulator sickness evaluation and information regarding three main areas: socioeconomical information, perceived safety for each of the eight scenarios and the influence of different infrastructural elements on the willingness to reach the railway station by bicycle. The perceived safety while cycling in each scenario was evaluated with rating from 1 (not safe) to 5 (extremely safe). The rating of every element in the scenario was done through a 5-point Likert scale where 1 represents "negative influence" and 5 represents "positive influence". The question proposed for every element was "What effect do the presence of the following elements have on your willingness to go to the train stations by bicycle?". The section regarding the influence of the infrastructural elements on the willingness to reach the railway station by bicycle varied for each scenario, based on the elements encountered. Table 4 summarizes the socioeconomic characteristics of the participants, divided based on the frequency of bicycle use. The participants to the simulation were 33, of which 22 males (66.7%). The gender distribution is predominantly representative of the male sample. As the simulation was carried out in France, the data were compared to the French population. According to INSEE, in 2022 males were 48.6 % in respect to females that were 51.4% of the total population [42]. The age distribution of the sample reveals a majority of participants aged between 25 and 34 years old for a total of 69.69% of the total participants, followed by the age range 18-24 years old that counts for 22.5%. Only 6.06% of respondents were aged 35 to 44 years. Compared to the French population where the mean age is 41, the sample is representative of younger people (the average age is 28.5 with a SD of 14.16). In terms of occupation, 27% of participants self-identified as student, while the remaining 73% as employed. The sample of respondents that cycle at least 4 times per week are 9.09%, which is representative of the French population that counts approximately 7% commuting by bicycle regularly [43].

Table 4. Sample characteristics.

SOCIO-ECONOMIC VARIABLES			TRANSPORT MODE				
Variables	Categories	Relative freq. (n=33)	Frequency of bicycle use	Relative freq. (n=33)	Mean Age	Standard deviation	Gender Ratio [%]
Gender	Male	66.7%	At least 4 days per week	9.09	30	14.16	100 male
	Female	33.3%					
Age	18–24	22.5%		6.06			
	25–34	69.69%	From 1 to 3 days per week		28.5	2.5	100 male
	35–44	6.06%			30		
	45–54	3%					
Occupation	Student	27%	From 1 to 3 times per month	18	27.33	9.94	33 male; 67 female
	Employed	73%	Less than once per month	51.5	28.47	5.58	74.5 male; 23.5 female
			Never	15.15	27.2	3.37	40 male; 60 female

2.2.2 Eye tracker data

Vehicles and pedestrians, as dynamic elements, inherently capture the individual's attention and generate gaze-following behaviour. Moreover, as potential risk factors, they naturally draw cyclist's focus [44]. The cyclist's focus can be measured through fixations. Fixations are defined as the periods of time where the eyes are relatively still, holding the central foveal vision in place so that the visual system can take in detailed information about what is being looked at. In Tobii Pro Lab, fixation is a sequence of raw gaze points, where the estimated velocity is below the velocity threshold set in the I-VT gaze filter. For the purpose of this research, fixations are measured as the duration on each element (also expressed as area of interest) seen by the participant. The duration of fixations (D_F) is the elapsed time between an interval start event until the first fixation occurs in that interval and in the target area of interest.

2.3. Statistical analysis

A non-parametric analysis has been chosen as the most suitable methodology for the purpose of this research since the data did not follow normal distributions, after the Shapiro Wilk test (p-value<0.05) and the Kolmogorov-Smirnov test (p-value<0.05) resulted significant, the data were ordinal and the sample is small. Figure 3 shows the structure of the analysis. All eight scenarios were compared based on the safety perception using Friedman and Wilcoxon post-hoc tests. Under the null hypothesis (H_0:), the independent variable, namely the scenario, is assumed to have no effect on the dependent variable, the safety perceived; the eight set of scores come from the same population. Symbolically expressed, H_0 : R_1=R_2= R_3=R_4= R_5=R_6= R_7=R_8. If these were true, the sums of the ranks R_j, would be similar. Alternatively, if the scenario changes the perceived safety, the R_{js} would be different. The computational formula for the Friedman test is given by equation (1):

$$Q = \frac{12}{Nk(k+1)}\left(\sum_{j=1}^{k} R_j^2\right) - 3N(k+1) \qquad (1)$$

Where k is the number of ranked observations, N is the number of subjects, and R_j are the ranked scores of safety per scenario. As the Friedman test result was significant, the Wilcoxon post-hoc test with Bonferroni correction was conducted to test the differences in safety perception between two scenarios. The Bonferroni corrected significance level is calculated through the equation (2):

$$z^* = \frac{\alpha}{m(m-1)} \qquad (2)$$

In this case m, the number of algorithms to be compared, is equal to 8 and $\alpha = 0.05$, thus $z^* = 0.0008$. The Wilcoxon signed-rank test is used to perform multiple comparison where decision depends only on two algorithms being compared.

The Mann-Whitney U test compared the evaluation of elements in the [cross-sectional] survey and the evaluation of elements in the post simulation survey. The aim of the Mann-Whitney U test is to test the null hypothesis that P(X<Y)=0.5, where X and Y are random samples of the two populations of interest, to assess statistical significance. Then, the duration of fixations (D_F) is related with the willingness of the element to reach the railway station through Spearman correlation. Spearman's rank correlation coefficient is a nonparametric (distribution-free) rank statistic proposed by Charles Spearman as a measure of the strength of an association between two variables. It is a measure of a monotone association that is used when the distribution of data makes Pearson's correlation coefficient undesirable or misleading [45].

3. Results

3.1 Post simulation survey: Perceived safety

The median and standard deviation (SD) of the perceived safety for each scenario, as the minimum and maximum evaluations are summarized in table 5.

Table 5. Descriptive statistics of safety per scenario

Scenario	N Responses	Mean (SD)	Median	Min	Max
1	33	2.58 (1.1)	2	1	4
2	33	2.67 (1.1)	3	1	4
3	33	3.64 (0.9)	4	2	5
4	33	2.91 (1.2)	3	1	5

5	33	3.82 (1.1)	4	1	5
6	33	3.48 (1)	4	1	5
7	33	2.27 (0.9)	2	1	4
8	33	3.85 (1)	4	2	5

Participants (N = 33) rated eight different scenarios on perceived safety using a 5-point Likert scale (1 = lowest, 5 = highest). Mean ratings for safety ranged from 2.3 (SD = 0.9) in Scenario 7 to 3.8 (SD = 1.1) in Scenario 5 and Scenario 8. Scenarios 3, 5, 6, and 8 were consistently rated higher with mean scores above 3.5. In contrast, Scenarios 1, 2, 4, and 7 received lower ratings, typically averaging below 3.0 for both values. Standard deviations ranged from 0.9 to 1.2, indicating moderate variability in responses. Minimum ratings vary from 1 to 2. Scenario 3 got a minimum rating of 2. Scenarios 1, 2 and 7 were never rated the maximum rank 5, but 4 at most. The Friedman test result showed that the type of scenario lead to statistically significant differences in perceived safety (Q (7) = 66.3494, p=0.0000). Consequently, the Wilcoxon signed rank test was conducted. Table 6 shows the mean rank for each scenario and the p-value from the Wilcoxon signed rank test. The results show that scenario 1, scenario 2, scenario 4 and scenario 7 are always evaluated with a lower safety, in respect to the other scenarios for which the Wilcoxon test results significant. Scenario 3 results to be safer than scenario 1 and 7. Scenario 7 is less safe than scenario 5,6 and 8.

Table 6. Mean rank of safety per scenario and Wilcoxon signed-rank test result

Scenario	Mean rank of safety	p-value Wilcoxon signed-rank test							
		1	2	3	4	5	6	7	8
1	3,45	-							
2	3,58	0.7425	-						
3	5,36	0.0002*	0.0000*	-					
4	3,85	0.4832	0.3676	0.0110	-				
5	5,95	0.0000*	0.0004*	0.3900	0.0052	-			
6	5,23	0.0008	0.0099	0.6340	0.0012	0.1173	-		
7	2,73	0.1850	0.1685	0.0000*	0.0388	0.0000*	0.0000*	-	
8	5,85	0.0001*	0.0000*	0.2052	0.0002*	0.8470	0.3085	0.0000*	-

*Sig. < 0.0008

3.2 Post simulation survey: Element impact on the willingness to reach the railway station

The perceived impact that each element had on the participants (I_W) is summarized for each scenario in table 7, where 1 stands for low impact and 5 stands for high impact. As each scenario was made of different infrastructural characteristics or different interactions, the element evaluated per each scenario are variable.

Table 7. Descriptive statistics of variables

I_W	Scenario (Median)										
Element evaluated	1	2	3	4	5	6	7	8	Min	Max	Median
The absence of a cycle path	1								1	5	1
A physically crossable cycle path delimitation		2	2						1	5	2
The existence of a preferential lane for bicycles and buses				2					1	5	2
The existence of a cycle lane (opposite to vehicles direction)					4	3			1	5	3
Riding on a cycle path raised above road level								3	1	5	3
The interference with pedestrian	2	3	3		2			2	1	5	2
The absence of vehicles parked on the side of the cycle path			4	4					1	5	4
The interference with cars passing		2	2			2			1	4	2
The presence of cars parked at road level, on the					3				1	5	3

left side of the cycle path raised above road level											
The presence of cars parked on the side of the cycle path	2	2							1	4	2
The horizontal signs					4				1	5	4
The fixed obstacle (represented by a bin can)					1				1	4	1
The obstacle (represented by a stopped bus on the side of the shared road)				2					1	4	2
The obstacle (represented by a stopped car on the side of the shared road)							2		1	4	2
The vertical signs					4				1	5	2

The absence of a cycle path and the bin can as an obstacle received the lowest median score of 1. Other obstacles (bus and cars stopped on the side of the road) received a median of 2. The absence of vehicles parked alongside the cycle path and the presence of horizontal signage both attained higher median scores of 4. Riding on a cycle path raised above road level achieved a median score of 3, as well as the presence of cars parked on the left side of a cycle path.

3.3 General survey on bicycle-train intermodality VS post simulation survey (per element)

Results from the general survey were compared to results of the post-simulation survey. Although the first survey was made of two distinct questions, one on the impact an element has on perceived safety when cycling and the other on the impact the presence of an element has on the willingness to reach the railway station, the data collected was treated, for simplicity, as a whole. Table 8 shows the mean values of the impact each element has on the willingness to go to the railway station for the two surveys, and the mean absolute differences between the two (ΔM). In addition, table 8 reports the p-value from the Wilcoxon Mann Whitney test.

Table 8. Mean and standard deviation from the two surveys, ΔM**,** and p-value from Wilcoxon Mann Whitney

Element	Level of willingness to cycle per element (Mean and Standard deviation)			
	Post-simulation survey	General survey	|ΔM|	p-value
The existence of the cycle path	3.50 (0.82)	3.72(1.18)	0.22	0.0143*
The direction of the cycle path (if necessary, the presence of a cycle lane)	4.21 (1.14)	3.65(1.157)	0.56	0.17
Bicycle lanes raised above road level	3.27 (1.31)	3.26(1.45)	0.01	0.954
Bicycle lanes protected by curbs, or any physically unsurpassable limitation	3.87 (1.11)	4.34(1.08)	0.47	0*
The absence of fixed obstacles on the cycle path	4.27 (0.74)	4.28(1.07)	0.01	0.5848
The absence of interference with pedestrians	3.57 (0.60)	3.65(1.16)	0.08	0.1767
The absence of interference with vehicles	3.98 (0.67)	4.36(0.89)	0.38	0*
A proper set of cyclist's dedicated horizontal signs	3.5 (0.76)	3.91(1.16)	0.41	0.0072*
A proper set of cyclist's dedicated vertical signs	4.03 (0.92)	3.91(1.16)	0.12	0.8601
The absence of interference with vehicles parked on the side of the road	3.89 (0.69)	3.68(1.21)	0.21	0.7035

*Sig.<0.05

Significant differences were observed for only four elements: the presence of a cycle path, the presence of an unsurpassable protection, the absent interference with vehicles and the presence of horizontal signs. In these four cases, results in the general survey showed a higher willingness to cycle to the railway station compared to the results in the post-simulation survey, with highly significant p-values ($p < 0.02$). The presence of an unsurpassable line shows the highest difference (|ΔM|=0.47), followed by the presence of horizontal signs (|ΔM|=0.41) and the absent interference with vehicles (|ΔM|=0.38). The least difference between the two group of respondents is given to the existence of the cycle path (|ΔM|=0.22). This suggests a potential overestimation of the importance of these elements in the general survey, which might lack experiential realism. No significant differences were found for other elements, including the existence of cycle path above road level, the absence of fixed obstacles, and the absent interference with pedestrians, indicating comparable evaluations between the two data collection methods. The existence of a cycle lane opposite to traffic flow revealed the highest mean willingness in the post-simulation (|ΔM|=0.56), though this difference did not reach statistical significance ($p = 0.17$).

3.4 Post simulation survey VS Fixations metrics (per element per scenario)

The second step of the data processing includes an understanding on how the elements studied may be related with the attention given to them. Table 9 summarizes the duration of fixations per element per scenario.

Table 9. Duration of fixations mean and standard deviation per element per scenario

D_F	Mean (Standard deviation)							
Scenario	Delimitation of the cycle path	Vehicles parked on the side of the cycle path	Interaction with vehicles	Interaction with pedestrians	Fixed obstacles on the cycle path	Horizontal signage	Vertical signage	Vehicles as dynamic obstacles
1	2242.0 (997.02)	5232.05 (5846.48)	1603.5 (50.20)	3192.09 (3399.87)	321.00	1818.5 (993.49)	3154.91 (2608.2)	0
2	3870.81 (2492.28)	14819.5 (9104.99)	3291.55 (2579.09)	1045.63 (975.4552)	537.5 (103.94)	9236.68 (7369.8)	7472.23 (5092.5)	0
3	4361.96 (3478.37)		9642.86 (7036.79)	1334.00 (1302.90)	1272.42 (1172.68)	7936.32 (6775.3)	4936.86 (3661.9)	527.50 (324.00)
4	2368.58 (1798.46)	4344.35 (3763.01)	4184.29 (3478.16)	4570.19 (3614.17)	993.84 (770.86)	4636.23 (3038.1)	5515.82 (4794.0)	6174.15 (5871.3)
5	1278.75 (1104.07)		189	261.33 (167.39)	3114.32 (2306.72)	5663.27 (2495.9)	723.2 (645.65)	3559
6	1062.13 (1171)		1511.21 (1191.04)			865.29 (585.51)		606.67 (394.71)
7	1303.5 (1662.41)		1235 (633.57)	277			5638.48 (3861.5)	4683.67 (2839.35)
8	1642.58 (1357.19)	4445.81 (3827.77)	4440.8 (5094.55)	4215.05 (3127.43)	1820.06 (2044.43)		739.06 (606.59)	

The percentage duration of fixations (%D_F) has been calculated to allow comparison of results within the area of interests (AoI) of the different scenarios from the simulation experiment with Spearman correlation. The results are summarized in table 10.

Table 10. Spearman correlation between percentage duration of fixation and impact of the element on the willingness to reach the railway station.

Element	%D_F; impact on willingness	
	Spearman rho	p-value
Cycle path protected by a surpassable limitation	-0.0681	0.6591
Cars parked on the side of the cycle path	-0.3696	0.0140*
Interaction with vehicles	-0.0221	0.8607
Interaction with pedestrians	-0.2134	0.0254*
Fixed obstacles on the cycle path	-0.2157	0.3316
Horizontal signs	0.0138	0.9511
Vertical signs	0.0802	0.7214

*Sig.<0.05

Among the elements, the presence of cars parked along the side of the cycle path showed a significant negative correlation with %D_F (rho = -0.3696, p = 0.0140), suggesting that this factor is associated with reduced willingness to reach the railway station by bicycle. Similarly, interaction with pedestrians was negatively correlated with %D_F (rho = -0.2134, p = 0.0254), indicating a potential impact on cyclists' willingness to reach railway station. Other variables, including surpassable protections, vehicle interactions, punctual obstacles, and signage (horizontal and vertical), did not demonstrate statistically significant correlations.

In order to define whether the highest duration of fixation was given to the presence of pedestrians or the cars parked on the side of the road, the specific scenarios are analysed. The scenarios in which both elements are present are scenarios 1, 2, 4, and 8. A Mann-Whitney test between the percentage of fixations of the two elements within each scenario provided significance difference (p-value<0.00001) in scenario 2, resulting in giving more attention to the cars parked on the right rather than to pedestrians (rank sum=736.5; 253.5).

4. Discussions and conclusions

This study contributes to the research by defining a new methodology to validate data**.** By investigating the topic from the cyclists' perspective, the present study highlights the importance of seamless cycling journey to reach the train station by bicycle. The findings from the bicycle simulation experiment show that a higher perception of safety is found in cycling situations with the presence of cycle path. Cycle path gives an assurance of where cyclists need to position themselves on the road. It is evident from the findings that participants' perception of safety was low when there was no cycling infrastructure or when cycling on a cycle lane in between motorized vehicles, similar to previous findings [46], [47]. In the safer scenarios, participants also interacted with motorized vehicles, parked cars, and pedestrians. It is possible that in these situations, participants might feel safer because they were not exposed to traffic with higher speed than bicycles and they had good visibility of their environment, as opposed to the situation where they cycled next to motorized traffic and parked cars [47], [48].The feeling of safety when cycling while interacting with pedestrians is also found in previous research [49]. Delaney et al. found that cyclists are positive about sharing the road with pedestrians despite the need to being attentive to pedestrians' sudden movements [50]. Nevertheless, the elements that contribute to a higher perception of safety might not contribute to a higher willingness to cycle. The correlation analysis, concerning the duration of fixation and willingness to cycle, suggested that the interaction with pedestrians and the presence of parked cars create the cycling situation less desirable. This is in line with previous research [48], [51], that an interaction between cyclists and other road users, particularly pedestrians and motorized vehicles, is not desirable. Evans-Cowley & Akar (2014) also found similar findings concerning the role of parked vehicles in decreasing the willingness to cycle [49]. By comparing the ranking and distributions of two elements with the Wilcoxon Mann Whitney test (table 8), it could be verified that the cars parked on the side of the road have a higher (negative) impact on the willingness to reach the railway station by bike, than the interference with pedestrians. In fact, the comparison of the survey results among the cars parked on the side of the cycle path and among the pedestrian interference did not result significant possibly due to the structure of the scenario. Scenario 8 is the only scenario where the element "cars parked on the side of the road" is represented by cars parked at road level on the left side of a raised shared path with pedestrians, which represents the cyclist's route. Scenarios 1 and 2, are among the ones rated the least safe. Therefore, it can be suggested that dedicated cycling infrastructure with less interference from other road users is desirable for cycling to the railway station. Further investigation might be needed to know if there is a threshold to which extent an interaction between cyclists and other road users is still acceptable by the cyclists. The comparison between the general survey and post-simulation survey validated some elements that contribute to willingness to cycle to train stations. First of all, it was possible to define the importance of some infrastructural and dynamic elements while riding a trip to the railway station. It was found that the willingness to reach the railway station by bicycle is impacted mainly by the absence of fixed obstacles on the cycle path, by the quality and presence of vertical signs and by the absence of cars parked on the side of the cycle path. Less impacting, but equally noteworthy, are the existence of a cycle lane in the direction opposite to cars, the absent interference with pedestrians and the existence of a cycle path raised above road level. However, results show that the similarities between the response distributions for the importance of the existence of a cycle path, the presence of an unsurpassable protection for cyclists' safety, the absent interference with cars and the presence of horizontal signs were not statistically significant. In particular, the scenarios that were rated the least safe, where also the ones where the most impacting element was present (or absent). The current study also found overestimation of importance rating for some elements in the general survey. Overall, the results indicate that immersive or experiential methods, e.g., simulation, may temper respondents' self-reported comfort or willingness to cycle, especially in relation to dynamic and potentially stressful elements (e.g., passing cars or lack of clear markings). However, this could be due to the fact that respondents of the general survey are mainly frequent cyclists, compared to the simulation participants. These findings underscore the importance of integrating realistic data collection tools in transport planning, as they may reveal more conservative, and arguably more realistic, attitudes towards cycling infrastructure. Future research should focus on interaction effects between infrastructural or dynamic elements, since the impact on the willingness to reach the railway station could be amplified or diminished.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] E. Belloni e S. Maggi, Muoversi domani- verso una mobilità più sostenibile, FrancoAngeli, 2022.

[2] I. Bittner, «Velo-city 2024 in Ghent: Cyclists Love Tranis - It's Complicated!,» 20 June 2024. [Online]. Available: https://interreg-danube.eu/projects/active2public-transport/news/velo-city-2024-in-ghent-cyclists-love-trains-its-complicated. [Consultato il giorno 09 September 2025].

[3] I. G. Johnson, A. Puussaar, J. Manuel e P. Wright, «Neighbourhood data: exploring the role of open data in locally devolved policymakig processes,» *Proceedings of the ACM on Human-Computer Interaction,* vol. 2, n. 83, November 2018.

[4] J. Verstraete, F. Acar, G. Concilio e P. Pucci, «Turning Data into Actionable Policy Insights,» *SpringerBriefs in Applied Sciences and Technology(),* 2021.

[5] J. Verstraete, F. Acar, G. Concilio e P. Pucci, «Turning data into actionable policy insights,» *The data shake,* 2021.

[6] M. Couper, «New developments in survey data collection,» vol. 43, pp. 121-145, 2017.

[7] B. Küfner, J. Sakshaug, S. Zins e C. Globisch, «The impact of mail, web, and mixed-mode data collection on participation in establishment surveys,» *Journal of survey statistics and methodology,* vol. 13, n. 1, 2024.

[8] A. T. Duchowski, «Eye tracking methodology; theory and practice,» *Qualitative Market Research: an international journal,* vol. 10, n. 2, pp. 217-220, 2007.

[9] K. Holmqvist, M. Nyström, R. Andersson, R. Dewhurst, H. Jarodzka e J. van de Weijer, «Eye tracking: a comprehensive guide to methods and measures,» 2011.

[10] D. Kaplan e D. Su, «On imputation for planned missing data in context questionnaires using plausible values: a comparison of three designs,» *Large-scale Assess Educ,* vol. 6, n. 6, 2018.

[11] G. Underwood, P. Chapman, K. Bowden e D. Crundall, «Visual search while driving: skill and awareness during inspection of the scene,» *Transp. Res. Part F: Traffic, psychology and behaviour,* vol. 5, n. 2, pp. 87-97, June 2002.

[12] M. A. Rrecarte e L. Nunes, «Effects of verbal and spatial-imaginery tasks on eye fixations while driving,» *J Exp Psychol Appl.,* vol. 6, n. 1, pp. 31-43, Mar 2000.

[13] J. de Winter, P. Bazilinskyy, D. Wesdorp, V. de Vlam, B. Hopmans, J. Visscher e D. Dodou, «How do pedestrians distribute their visual attention when walking through a parking garage? An eye-tracking study,» *Ergonomics,* vol. 64, n. 6, pp. 793-805, 29 Jan 2021.

[14] F. Kchour, S. Cafiso e G. Pappalardo, «Understanding cyclist's visual behaviour using eye tracking technology: a systematic review,» *Sensors,* vol. 25, n. 1, 24 Dec 2024.

[15] M. Li, Y. Zhang, T. Chen, H. Du e K. Deng, *Accident Analysis & Prevention,* vol. 209, 2025.

[16] K. Kircher e C. Ahlström, «Attentional requirements on cyclists and drivers in urban intersections,» *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 68, pp. 105-117, Jan 2020.

[17] S. Ma, W. Zhang, R. B. Noland e C. J. Andrews, «Eye tracking measures of bicyclists' behaviour and perception: a systematic review,» *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 107, pp. 52-68, Nov 2024.

[18] N. Kovacsova, J. Winter, A. Schwab, M. Christoph, T. D.A.M e M. Hagenzieker, «Riding performance on a conventional bicycle and a pedelec in low speed exercises: Objective and subjective evaluation of middle-aged and older persons,» *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 42, n. 1, pp. 28-43, Oct 2016.

[19] O. S., J. Oxley e M. Stevenson, «Validation of a bicycle simulator for road safety research,» *Accident analysis & prevention,* vol. 100, pp. 53-58, March 2017.

[20] A. Baldassa, F. Orsini, G. Bono, M. Tagliabue, M. Gastaldi e R. Rossi, «Validation of a bicycle simulator for cyclist-vehicle interaction analysis,» *Transp. Res. Procedia,* 2025.

[21] E. Acerra, M. Shoman, H. Imine, C. Brasile, C. Lantieri e V. Vignali, «The Visual Behaviour of the Cyclist: Comparison between Simulated and Real Scenarios,» vol. 8, n. 5, 2023.

[22] L. Ayad, H. Imine, F. De Crescenzio e C. Lantieri, «Bicycle simulator use to evaluate safety risks and perceptions for enhanced sustainable urban mobility,» *Sustainability,* vol. 16, n. 22, 2024.

[23] P. R. Stopher e S. P. Greaves, «Household travel surveys: where are we going?,» *Transp. res part A: Policy and practive,* vol. 41, n. 5, pp. 367-381, 2007.

[24] K. W. Axhausen, «Concepts of travel behaviour research,» 2007.

[25] J. Calvey, J. Shackleton, M. Taylor e R. Llewellyn, «Engineering condition assessment of cycling infrastructure: cyclists' perceptions of satisfaction and comfort,» *Transportation research part A: policy and practice,* vol. 78, pp. 134-143, August 2015.

[26] J. Louviere, D. A. Hensher e J. Swait, «Stated choice methods: analysis and application,» Cambridge University Press, 2000.

[27] L. Shang e Y. Chandra, «An overview of stated preference methods: what and why,» in *Descrete choice experiments using R*, Springer Nature, 2023, pp. 1-7.

[28] A. Hull e C. O'Holleran, «Bicycle infrastructure: can good design encourage cycling?,» *Urban, planning and transport research,* vol. 2, n. 1, 2014.

[29] G. Xiao, Z. Juan e C. Zhang, «Detecting trip purposes from smartphone-based travel surveys with artificial neural networks and particle swarm optimization,» *Transp. Res. Part C: Emerging technologies,* vol. 71, pp. 447-463, Oct. 2016.

[30] D. J. A. de Magalhães e I. Belcavello Rigatto, «Individual perceptiond of critical factors on route affectivng the willingness of direct commuting trips by bicycle in a hilly city,» *Transportation,* pp. 127-153, 2025.

[31] W. M. K. &. v. W. B. Bohte, «Measuring Attitudes in Research on Residential Self-Selection and Travel Behaviour: A Review of Theories and Empirical Research.,» vol. 29, n. 3, pp. 325-357.

[32] C. Hau, W. Xia, S. Ryan, J. Firth, J. Linardon e J. Torous, «Smartphone monitoring and digital phenotyping apps for schizophrenia: A review of the academic literature,» *Schizophrenia Research,* vol. 281, pp. 237-248, 2025.

[33] E. Reingold, «Eye tracking research and technology: Towards objective measurement of data quality,» vol. 22, n. 3-4, 07 Mar. 2014.

[34] S. Yao, N. Wang e J. Wu, «How does the built environment affect pedestrian perception of road safety on sidewalks? Evidence from eye-tracking experiments,» *Transp. Res. Part F: Traffic Psychology and Behaviour,* vol. 110, pp. 57-73, April 2025.

[35] A. O. a. B. C. W. Brazil, «Using eye-tracking technology and Google street view to understand cyclists' perceptions,» in *IEEE 20th International Conference on Intelligent Transportation Systems (ITSC)*, Yokohama, Japan, 2017.

[36] A. Zoli, M. Pazzini, C. Lantieri, V. Vignali, K. Raffaeli, M. Gaspardo Moro e S. Andrea, «Users' preferences on bike-train intermodality: what can induce travelers to use this type of intermodal transport?,» in *Transportation Research Procedia*, 2025.

[37] «Italy Demographics 2025,» [Online]. Available: https://www.worldometers.info/demographics/italy-demographics/. [Consultato il giorno 15 Sept 2025].

[38] «Mobilità degli italiani tra aprile e giugno 2022,» 9 May 2022. [Online]. Available: https://www.istat.it/comunicato-stampa/la-mobilita-degli-italiani-le-intenzioni-tra-aprile-e-giugno-2022/. [Consultato il giorno 15 Sept 2025].

[39] «Share of individuals using personal bicycles and/or bike sharing in Italy in 2020, by macro-region,» [Online]. Available: https://www.statista.com/statistics/1122248/individuals-using-bicycles-by-area-in-italy/#:~:text=According%20to%20a%20survey%20conducted,their%20bicycles%20at%20least%20occasionally. [Consultato il giorno 15 Sept. 2025].

[40] C. Robert Pace e J. Friedlander, «The meaning of response categories: how often is "occasionally", "often", and "very often"?,» *Res. High Educ.,* vol. 17, pp. 267-281, 1982.

[41] «Eye tracking guide,» [Online]. Available: https://www.tobii.com/learn-and-support/get-started/eye-tracking-guide. [Consultato il giorno 15 Sept 2025].

[42] «Demographic report 2022,» 17 Jan 2023. [Online]. Available: https://www.insee.fr/en/statistiques/6797730. [Consultato il giorno 15 Sept 2025].

[43] «Résultats détaillés de l'enquête mobilité des personnes de 2019,» 22 Dec. 2021. [Online]. Available: https://www.statistiques.developpement-durable.gouv.fr/resultats-detailles-de-lenquete-mobilite-des-personnes-de-2019. [Consultato il giorno 15 Sept. 2025].

[44] F. Kchour, S. Cafiso e G. Pappalardo, «Understanding Cyclists' Visual Behavior Using Eye-Tracking Technology: A Systematic Review.,» *Sensors,* vol. 25, n. 22, 2025.

[45] J. C. F. G. S. D. &. P. J. de Winter, «Comparing the Pearson and Spearman correlation coefficients across distributions and sample sizes: A tutorial using simulations and empirical data.,» *Psychological Methods,* vol. 21, n. 3, pp. 273-290.

[46] M. Nazemi, M. van Eggermond, A. Erath, D. Schaffner, M. Joos e K. Axhausen, «Studying bicyclists' perceived level of safety using a bicycle simulator combined with immersive virtual reality,» *Accident analysis & prevention,* vol. 151, n. 105943, March 2021.

[47] E. Chataway, S. Kaplan, T. Nielsen e C. Prato, «Safety perceptions and reported behavior related to cycling in mixed traffic: A comparison between Brisbane and Copenhagen,» *Transp. Res. Part F: Traffic Psychology and Behaviour,* vol. 23, pp. 32-43, March 2014.

[48] M. Ferreira, P. Costa, D. Abrantes, J. Hora, S. Felìcio, M. Coimbra e T. Dias, «Identifying the determinants and understanding their effect on the perception of safety, security, and comfort by pedestrians and cyclists: A systematic review,» *Transp. Res. Part F: Traffic Psychology and Behaviour,* vol. 91, pp. 136-163, 2022.

[49] J. S. &. A. G. Evans-Cowley, «StreetSeen Visual Survey Tool for Determining Factors that Make a Street Attractive for Bicycling.,» *Transp. Res. Record,* vol. 2468, n. 1, pp. 19-27, 2014.

[50] H. Delaney, G. Parkhurst e S. Melia, «Walking and cycling on shared-use paths: the user perspective.,» vol. 170, n. 3, pp. 175-184, 1 Sept. 2017.

[51] E. Paschalidis, M. Prodromou, S. Basbas e I. Politis, «Investigation of Cyclists' Attitudes and Perceptions Towards other,» *International Journal of Transportation,* vol. 5, n. 2, pp. 33-46, 2017.

[52] E. Heinen, B. van Wee e K. Maat, «COmmuting bu bicycle: an overview of the literature,» *Transport Reviews,* vol. 30, n. 1, pp. 59-96, 02 December 2009.

[53] Directorate-General for Mobility and Transport, «EU road fatalities drop by 3% in 2024, but progress remains slow,» 18 March 2025. [Online]. Available: https://transport.ec.europa.eu/news-events/news/eu-road-fatalities-drop-3-2024-progress-remains-slow-2025-03-18_en#:~:text=5%20min%20read-,EU%20road%20fatalities%20drop%20by%203%25%20in%202024%2C%20but%20progress,to%20600%20fewer%20lives%20lost.. [Consultato il giorno 24 03 2025].

[54] C. A. Mulvaney, S. Smith, M. C. Watson, J. Parkin, C. Coupland, P. Miller, D. Kendrick e H. McClintock, «Cycling infrastructure for reducing cycling injuries in cyclists,» *Cochrane Database Syst Rev,* vol. 2015, n. 12, 10 December 2015.

[55] C. C. Reynolds, M. A. Harris, K. Teschke, P. A. Cripton e M. Winters, «The impact of transportation infrastructure on bicycling injuries and crashes: a review of the literature,» *Environ Health,* vol. 8, n. 47, 21 October 2009.

[56] D. Jahanshahi, S. Costello, K. Dirks, S. Chowdhury e B. v. Wee, «Understanding Perceptions of Cycling Infrastructure Provision and its Role in Cycling Equity,» *Transportation Research Record,* vol. 2677, n. 3, pp. 820-835, 2023.

[57] L. Yang, S. Sahlqvist, A. McMinn, S. J. Griffin e D. Ogilivie, «Interventions to promote cycling: systematic review,» *BMJ,* vol. 341, n. c5293, 13 August 2010.

[58] S. M. Eleonora Belloni, «MUOVERSI DOMANI,» [Online].

[59] D. E. Crundall e G. Underwood, «Effects of experience and processing demands on visual information acquisition in drivers.,» *Taylor & Francis,* vol. 41, n. 4, 1998.

[60] D. de Magalhães e I. Rigatto, «Individual perceptions of critical factors on route affecting the willingness of direct commuting trips by bicycle in a hilly city.,» *Transportation,* vol. 52, pp. 127-153, 2025.

[61] R. M. R., «Impact of the mode of data collection on the quality of survey questions in social sciences,» 2012.

[62] D. de Magalhães e I. Rigatto, «Individual perceptions of critical factors on route affecting the willingness of direct commuting trips by bicycle in a hilly city,» *Transportation,* vol. 52, 2023.

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Regione Emilia-Romagna

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

REGIONE PIEMONTE

PREPAIR

Guida per l'applicazione dell'indicatore di accessibilità ciclabile nelle stazioni ferroviarie

Report on information and recommendations on the planning of intermodal transport facilities and policies (bike + local public transport, with particular reference to the railway stations)

Lo sviluppo dell'intermodalità treno-bicicletta

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https://mobilita.regione.emilia-romagna.it/

Federazione Italiana Ambiente e Bicicletta è un'organizzazione ambientalista che promuove l'uso quotidiano della bicicletta e il cicloturismo per proteggere l'ambiente e contrastare la crisi climatica.

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PREPAIR

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Report on information and recommendations on the planning of intermodal transport facilities and policies (bike + local public transport, with particular reference to the railway stations)

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Abstract

The document provides a detailed guide for the application of the cycling accessibility indicator in railway stations, with the aim of developing and promoting train-bicycle intermodality. The integration between cycling and rail transport represents a strategic opportunity to reduce the use of private cars, reduce air pollution and improve the efficiency of sustainable mobility.

After an introduction on the environmental and social benefits of the combined use of bicycles and trains, the document analyzes the main factors that influence cycling accessibility in railway stations. Among these, key parameters are defined for the evaluation, divided into five main categories: the quality of the cycling infrastructure (presence and characteristics of cycle paths), visibility and signage (indications for cyclists, lighting, accessibility to the platforms), services for cyclists (bike parking, repair kits, lifts), the presence of bicycle stations (secure depots with ancillary services) and bike sharing (availability and location of shared bicycles).

The indicator is applied through a structured checklist and a scoring system based on weights assigned to each parameter, which allows to obtain a final evaluation of the bicycle accessibility of the railway station. The total score allows the stations to be classified into four levels of accessibility: Platinum (excellence in cycling accessibility), Gold (good level with room for improvement), Silver (medium accessibility) and Bronze (limited accessibility with the need for improvement measures).

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The guide describes in detail the methodology for collecting and analyzing data, specifying how to organize the survey team, carry out on-site inspections and fill in the evaluation forms. In addition, case studies relating to four representative railway stations are presented, highlighting the strengths and weaknesses of each infrastructure analyzed.

This tool is proposed as a practical reference for public administrations, railway managers and sustainable mobility professionals, offering objective criteria for the design and improvement of cycling accessibility in railway areas. The ultimate goal is to encourage train-bike intermodality, promoting more efficient, safe and environmentally friendly modes of travel.

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Come consultare questa guida

Introduzione

Perché valutare il livello di intermodalità?

Che cos'è un indicatore di accessibilità e qual è la sua utilità?

Parte 1

Definizione e descrizione dei parametri utili

Come misurare gli elementi che definiscono l'accessibilità?

Quando misurare gli elementi che definiscono l'accessibilità?

Parte 2

Organizzare il team

Effettuare il sopralluogo

Interpretare i risultati

Parte 3

Stazione Platinum:
Bologna

Stazione Gold:
Cuneo

Stazione Silver:
Collegno

Stazione Bronze:
Ozzano dell’Emilia

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Introduzione

Trasformare la stazione ferroviaria

Intermodalità treno-bici

Indicatore di accessibilità

Perché valutare il livello di intermodalità?

Che cos’è un indicatore di accessibilità e qual è la sua utilità?

Trasformare la stazione ferroviaria

Lo spostamento tramite modalità di trasporto attive come la bicicletta potrebbe ben coniugarsi con il trasporto ferroviario, il quale, a sua volta, rappresenta un’alternativa virtuosa all’automobile privata con un basso impatto ambientale. I benefici potenziali di un sistema integrato bicicletta-treno, infatti, sono molteplici, soprattutto dal punto di vista ambientale. Tra questi, la riduzione del consumo di energia e dell’inquinamento atmosferico e acustico, derivanti dalla sostituzione dei veicoli a motore individuali con il trasporto pubblico e la bicicletta [1].

Anche nel caso in cui la bicicletta sostituisca solo per pochi chilometri il viaggio motorizzato, i benefici in termini di riduzione delle emissioni risultano significativi, poiché le emissioni iniziali del motore sono comunque importanti. Al contrario, se l’accesso alla stazione ferroviaria o l’uscita dalla stazione stessa viene effettuato in auto, anche per brevi tratti, si rischia di ridurre il vantaggio derivato dall’uso del treno come mezzo di trasporto sostenibile [1]. Oltre ai benefici ambientali, la sostituzione dei viaggi in auto con il sistema integrato bicicletta-treno può contribuire a ridurre la congestione del traffico e la necessità di posti auto. Inoltre, la bicicletta può anche rendere il trasporto ferroviario più flessibile, soddisfacendo le diverse esigenze individuali grazie alla sua capillarità “porta a porta”, caratteristica che il treno non possiede.

Il treno, altresì, consente alla bicicletta di coprire distanze chilometriche che difficilmente potrebbe percorrere e di viaggiare più rapidamente. Inoltre, è stato dimostrato che favorire l’intermodalità bicicletta-treno migliora l’attrattività e l’efficienza di un viaggio [2]. Il successo di tale interscambio è tuttavia determinato dall’effettiva possibilità per l’utente di raggiungere la stazione, e ciò dipende da numerosi fattori. Tra questi vi sono sicuramente le caratteristiche del viaggio, in termini di durata e orario della giornata, le caratteristiche della stazione ferroviaria e del treno.

La propensione a utilizzare la bicicletta dipende inoltre dalla sicurezza, da una rete di piste ciclabili ben collegate, da politiche che disincentivino l’uso delle auto, dalla convenienza di utilizzo della bici come modalità di trasporto e infine da un efficiente sistema di trasporto pubblico integrato con i servizi ciclabili [3]. Pertanto, un sistema integrato bicicletta-treno offre una combinazione unica di capillarità e velocità che nessun altro mezzo di trasporto, né singolarmente né in combinazione con altri, può garantire. In sostanza, la combinazione treno-bicicletta rappresenta uno dei migliori esempi di multimodalità, un modo efficiente e intelligente di spostarsi che preserva l’ambiente e consente di risparmiare tempo e denaro.

Intermodalità treno-bici

Treno-bici

L'utilizzo della bicicletta influisce positivamente su salute e ambiente e rende il trasporto ferroviario più flessibile. La combinazione treno-bicicletta rappresenta uno dei migliori esempi multimodali, un modo efficiente di spostarsi preservando l'ambiente e risparmiando tempo. È evidente quanto la presenza di un'infrastruttura sicura e versatile sia importante nell'utilizzo della bicicletta. La scelta di questo mezzo è influenzata da diversi fattori, come un basso flusso di automobili, limiti di velocità più bassi, assenza di inquinamento atmosferico.

In Italia l'integrazione bici-treno è riconosciuta dalla Legge, 11/01/2018 n° 2 (G.U. 31/01/2018), Disposizioni per lo sviluppo della mobilità in bicicletta (art. 3 c. 3 lettera H, art. 5 c. 3, art, 8 c. 1 e 2) e dal vigente Piano Generale della Mobilità Ciclistica (G.U. 12/10/2022). Tale integrazione si fonda sull'accesso alle stazioni per chi si reca in bicicletta, sulla presenza di cicloparcheggi e/o velostazioni presso le stazioni e sull'accessibilità al binario e al treno per chi decide di proseguire il viaggio con la bicicletta al seguito.

COMBINAZIONI INTERMODALI TRENO-BICI

- **Possibilità di trasportare la bicicletta sul treno.** Necessità di rafforzare l'intermodalità in quanto si arriva al binario direttamente con la bicicletta su un treno attrezzato.
- **Possibilità di raggiungere la stazione con la bicicletta e poi parcheggiarla.** Si elimina la problematica del trasporto fisico della bici sul treno, ma i parcheggi per biciclette devono essere sicuri e sorvegliati.
- **Utilizzo di bike sharing o e-scooter sharing**, si elimina il rischio del furto, soluzione più smart, ma anche più onerosa.

INTERMODALITÀ

In questo contesto si inserisce la creazione dei **Centri di Mobilità**, intesi come veri e propri hub urbani per il trasporto intermodale, luoghi identitari dove diversi tipi di servizi vengono offerti alla comunità, in grado di migliorare la qualità e la vitalità dei Comuni metropolitani unendo funzione urbana e trasportistica. L'attrattiva di questi centri deve orientare e facilitare la mobilità di cittadini, pendolari e turisti, verso spostamenti a piedi, in bicicletta o con mezzi pubblici e condivisi, ovvero verso l'utilizzo di mezzi di trasporto a basso impatto ambientale. Inoltre, la realizzazione di tali centri prevede la partecipazione attiva della comunità, chiamata ad esprimere i propri bisogni per un migliore utilizzo delle infrastrutture esistenti su concetti chiave come accessibilità, intermodalità sostenibile, attrattività, identità-riconoscibilità, scalabilità, infrastrutturazione informatica.

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Indicatore di accessibilità

L'obiettivo di questa guida è quello di illustrare, a coloro che intendono accedere alle stazioni ferroviarie in bicicletta, come utilizzare l'**indicatore di accessibilità**. Tra gli scopi dell'indicatore di accessibilità vi è quello di evidenziare i punti in cui è più importante allocare risorse per rendere realmente intermodale una stazione ferroviaria.

DATI PER LA COMPILAZIONE

DATI INFRASTRUTTURALI

Dati reperibili in loco, ovvero tramite un'ispezione attiva della stazione ferroviaria e dei suoi dintorni

Per ottenere i dati infrastrutturali è necessario effettuare un sopralluogo, preferibilmente durante gli orari di punta, al fine di valutare anche la capacità dell'infrastruttura.

DATI DI FLUSSO

Considera l'interazione tra domanda e offerta, fornendo informazioni oggettive sul livello di utilizzo della rete ciclabile, della stazione ferroviaria e dei relativi servizi

Flusso giornaliero: numero di persone che sale sul treno ogni giorno.
Il dato può essere reperito dalle pubbliche amministrazioni o dai gestori delle ferrovie. Nel caso questo non fosse possibile, è necessario condurre indagini o effettuare stime dei flussi.

Misurare l'impatto
delle trasformazioni necessarie

Ottenere i dati
sullo stato dell'arte
dell'infrastruttura e dei servizi

Migliorare i servizi
dell'infrastruttura ciclabile

Rafforzare l'intermodalità
tra treno e bicicletta

Life
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Parte 1

1.1
Selezione dei parametri utili

A. Qualità dell’infrastruttura ciclabile
B. Visibilità del piazzale della stazione e segnaletica interna alla stazione
C. Servizi per il ciclista in prossimità della stazione
D. Velostazione
E. Bike sharing

1.2
Definizione del momento migliore per raccogliere i dati

Definizione e descrizione dei parametri utili

Come misurare gli elementi che definiscono l’accessibilità?

Quando misurare gli elementi che definiscono l’accessibilità?

1.1 Selezione dei parametri utili

Per incentivare i viaggi intermodali, è necessario fornire soluzioni che soddisfino le esigenze degli utenti, creando una rete di trasporto capillare, efficiente e coadiuvata da infrastrutture specifiche in corrispondenza dei nodi di scambio. L'indicatore di accessibilità deve perciò includere quei servizi essenziali da fornire ai ciclisti che intraprendono un viaggio intermodale utilizzando il treno e la bicicletta, in base a normative e linee guida sia italiane sia internazionali, per garantire l'eccellenza da più punti di vista. L'indicatore di accessibilità per incrementare l'intermodalità treno-bici è realizzato intorno alla parola chiave "accessibilità", rispondendo a due domande fondamentali:

1. **Quanto è sicuro un ciclista che raggiunge la stazione ferroviaria?**
2. **Quanto è sicura una bicicletta parcheggiata nei pressi della stazione ferroviaria?**

Le risposte coinvolgono due settori principali, quello delle infrastrutture e quello dei servizi. Le infrastrutture riguardano la sicurezza della pista ciclabile, la sua qualità, la geometria e la sua illuminazione. I servizi a disposizione dei ciclisti sono, invece, per esempio, il bike sharing o il deposito biciclette. Tutte le caratteristiche principali, reperite in letteratura o attraverso l'esperienza di tecnici ed esperti, sono elencate in una checklist, sviluppata consultando la teoria di "Road safety performance review" [4] e uno studio condotto dal Comune di Roma sulle piste ciclabili della capitale [5].

La checklist valuta i dispositivi infrastrutturali e i servizi forniti dalla stazione ed è divisa in cinque categorie, ognuna caratterizzata da specifici indicatori, a cui è assegnato un peso diverso sulla base di un questionario somministrato alla popolazione italiana.

Ad ogni indicatore è assegnato un punteggio da 0 a 6 a seconda delle opzioni disponibili per la caratteristica definita.

Sulla base dei flussi, vengono valutati i servizi offerti dalla stazione. In particolare, il numero di posti bici in una stazione è considerato sufficiente se pari al 4% del flusso giornaliero, mentre il numero di parcheggi per biciclette è considerato sufficiente in presenza di 1 posto ogni 10 passeggeri «saliti» [6, 7, 8].

1.1 Selezione dei parametri utili

A. Qualità dell’infrastruttura ciclabile

Sulla base del Decreto 30 novembre 1999, n. 557 *Regolamento recante norme per la definizione delle caratteristiche tecniche delle piste ciclabili* e delle *Linee guida per il sistema regionale della ciclabilità* (L.r. n. 10/2017) si considera:

INDICATORE DI ACCESSIBILITÀ CICLABILE NELLE STAZIONI FERROVIARIE		Peso	Nome della stazione ferroviaria
	Data e ora del sopralluogo		
A	**Qualità dell'infrastruttura della pista ciclabile DIR xxx**	**0,71**	
1	La pista ciclabile vicina (distanza massima considerata: 500 m) al nodo di interesse è: (1) esistente o zona 30; (0) assente	0,68	
2	Se la pista/corsia ciclabile è presente si trova: (1) entro 75 m dalla stazione (0) oltre 75 m	0,64	
3	La pavimentazione prevalente è: (2) asfaltata o simile; (1) autobloccanti o simili; (0) terra naturale	0,63	
4	La qualità della pavimentazione della pista ciclabile: (2) buona; (1) media (0) scarsa	0,10	
5	Tipo di pista ciclabile se presente: (2) unidirezionale per ciascun lato della strada, (1) bidirezionale riservata alle biciclette, (0) bidirezionale	0,58	
6	Tipo di pista ciclabile se presente: (2) a livello sopraelevato; (1) a livello della strada; (0) non presente	0,56	
7	La pista ciclabile è: (6) in sede propria, uni o bidirezionale, su livello rialzato; (5) su corsia riservata, uni o bidirezionale, su livello rialzato separata da pedoni con una linea attraversabile dipinta a terra; (4) promiscua, uni o bidirezionale, condivisa con pedoni (3) su corsia riservata, uni o bidirezionale, a livello della carreggiata stradale, separata da automobili con una linea attraversabile dipinta a terra; (2) corsia a senso unico ricavata dalla carreggiata stradale in senso opposto su una strada a senso unico con un limite di velocità di 30 km/h separata da automobili con una linea tratteggiata attraversabile dipinta sul terreno; (1) promiscua, uni o bidirezionale, a livello della carreggiata stradale(corsia ciclabile per doppio senso ciclabile); (0) nessuna delle precedenti	0,83	
8	Gli standard geometrici medi sono adeguati? (1) Sì; (0) No	0,94	
9	La pendenza del percorso non supera il 5%? (1) Sì; (0) No	0,31	
10	Ostacoli puntuali, riduzione degli standard sono: (2) assenti; (1) rari; (0) frequenti	0,82	
11	Conflitto laterale da negozi o vialetti: (2) assente; (1) leggero; (0) grave	0,67	
12	Conflitto con il traffico pedonale: (2) assente; (1) leggero; (0) grave	0,66	
13	Conflitto con il traffico veicolare: (2) assente; (1) leggero; (0) grave	0,78	
14	La pista ciclabile è: (2) colorata (ben visibile); (1) mediamente visibile; (0) non colorata	0,60	
15	La segnaletica orizzontale del comportamento dei ciclisti per muoversi correttamente è: (1) presente (0) assente	0,73	
16	La segnaletica verticale di guida del comportamento dei ciclisti è adeguata? (2) molto buona; (1) discreta; (0) scarsa	0,73	
17	Segnaletica verso i luoghi di interesse della città: (2) presente ed eccellente ; (1)discreta; (0) assente	0,55	
18	La pista ciclabile è dotata di illuminazione notturna: (2) molto buona; (1) discreta; (0) assente	0,77	
19	Tipo di illuminazione: (2) propria della pista; (1) stradale pubblica; (0) cartellone pubblicitario	0,31	
Totale			**0,00**

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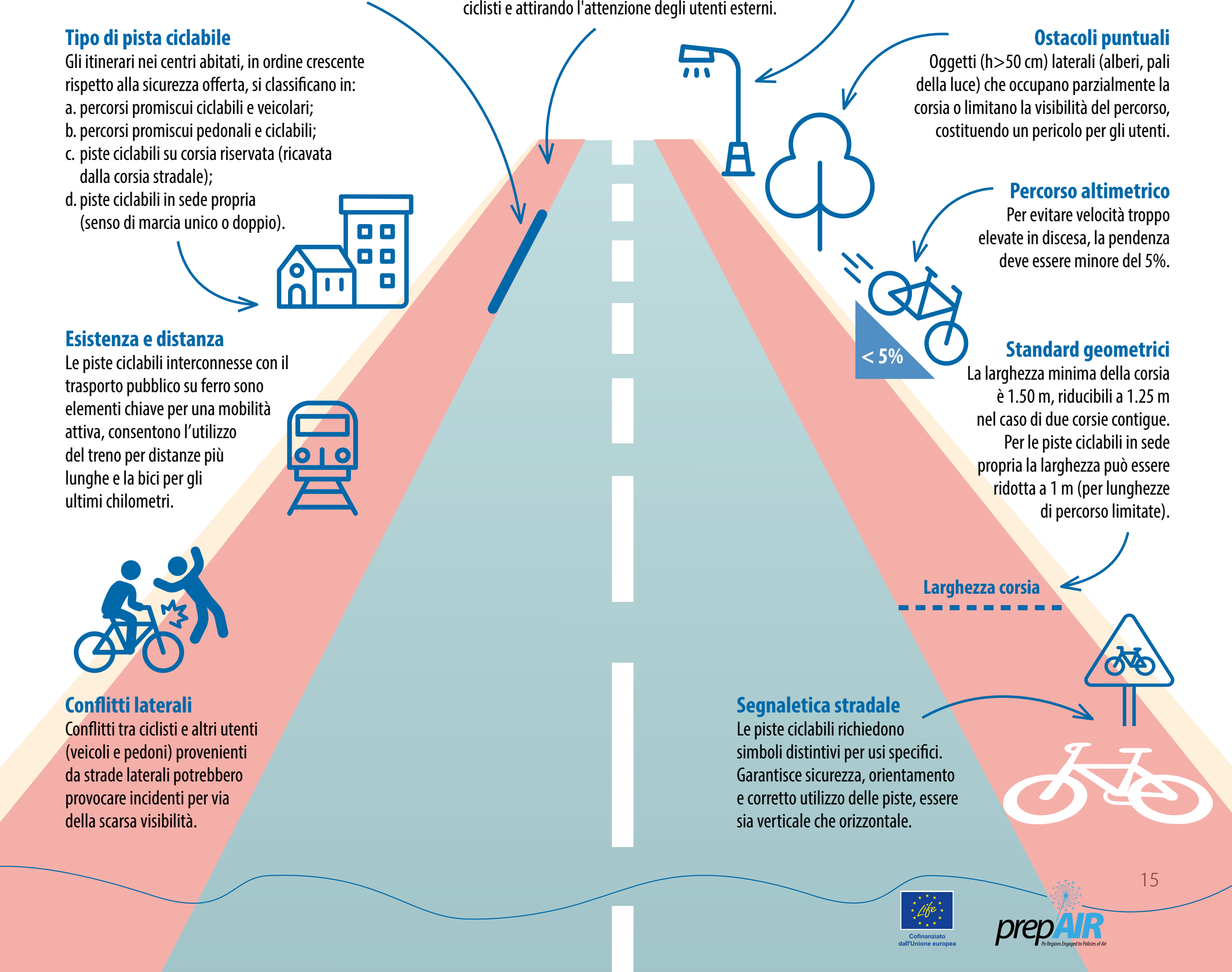

Delimitazione pista ciclabile

Le piste ciclabili ricavate sulla carreggiata stradale sono separate dal traffico mediante segnaletica orizzontale, bitume colorato e cordoli. Le piste possono essere realizzate su parti della strada esterne alla carreggiata o rialzate.

Tipo di pista ciclabile

Gli itinerari nei centri abitati, in ordine crescente rispetto alla sicurezza offerta, si classificano in:

a. percorsi promiscui ciclabili e veicolari;
b. percorsi promiscui pedonali e ciclabili;
c. piste ciclabili su corsia riservata (ricavata dalla corsia stradale);
d. piste ciclabili in sede propria (senso di marcia unico o doppio).

Esistenza e distanza

Le piste ciclabili interconnesse con il trasporto pubblico su ferro sono elementi chiave per una mobilità attiva, consentono l'utilizzo del treno per distanze più lunghe e la bici per gli ultimi chilometri.

Conflitti laterali

Conflitti tra ciclisti e altri utenti (veicoli e pedoni) provenienti da strade laterali potrebbero provocare incidenti per via della scarsa visibilità.

Tipo di pavimentazione

Si prediligono asfalti lisci, che garantiscono maggior scorrevolezza, confort e aderenza. È consigliabile colorare le piste ciclabili nei luoghi che necessitano di elevata visibilità, migliorando l'orientamento dei ciclisti e attirando l'attenzione degli utenti esterni.

Illuminazione

Impatta gli utenti e i periodi di utilizzo della ciclabile, consente alle persone di sentirsi al sicuro. Si verifica se l'illuminazione è propria della pista, stradale o dovuta a cartelloni pubblicitari luminosi.

Ostacoli puntuali

Oggetti (h>50 cm) laterali (alberi, pali della luce) che occupano parzialmente la corsia o limitano la visibilità del percorso, costituendo un pericolo per gli utenti.

Percorso altimetrico

Per evitare velocità troppo elevate in discesa, la pendenza deve essere minore del 5%.

Standard geometrici

La larghezza minima della corsia è 1.50 m, riducibili a 1.25 m nel caso di due corsie contigue. Per le piste ciclabili in sede propria la larghezza può essere ridotta a 1 m (per lunghezze di percorso limitate).

Segnaletica stradale

Le piste ciclabili richiedono simboli distintivi per usi specifici. Garantisce sicurezza, orientamento e corretto utilizzo delle piste, essere sia verticale che orizzontale.

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1.1 Selezione dei parametri utili

B. Visibilità del piazzale della stazione e segnaletica interna alla stazione

Se le piste non sono indicate all'interno o all'esterno della stazione ferroviaria, i ciclisti potrebbero ridurre la loro sicurezza utilizzando un'altra opzione, o un diverso mezzo di trasporto.

È necessario che all'interno della stazione sia presente una **segnaletica di guida** dei comportamenti dei ciclisti per muoversi correttamente. Con ciò si intende l'insieme dei segnali riguardanti l'**accessibilità ai binari** (su bici o con bici trasportata a mano), eventuale **accessibilità dei ciclisti all'interno degli ascensori** (è consentito solo se è possibile mantenere la bici in orizzontale con entrambe le ruote a terra), **indicazione dei parcheggi o dei depositi** presenti nei pressi della stazione in modo da minimizzare il conflitto con gli altri utilizzatori della stazione.

		Peso	Valore
B	**Visibilità del piazzale della stazione e segnaletica della stazione**	**0,75**	
1	I segnali verticali indicanti le piste ciclabili sono: (2) presenti e vicini; (1) presenti ma distanti o non chiaramente visibili; (0) assenti	0,78	
2	L'illuminazione è presente nella zona esterna alla stazione ferroviaria? (1) Sì; (0) No	0,73	
3	Quali cartelli verticali sono presenti all'interno della stazione ferroviaria? (2) Indicazioni per gli ascensori, indicazioni per l'uscita (per persone che trasportano biciclette); (1)indicazione per gli ascensori; (0) nessuno	0,78	
4	I parcheggi delle biciclette sono visibili dall'ingresso della stazione ferroviaria? (1) Sì; (0) No	0,74	
5	Il parcheggio delle biciclette è contrassegnato da segnaletica verticale? (1) Sì; (0) No	0,10	
Totale ponderato			0,00

SEGNALETICA DI GUIDA

BINARI

ASCENSORI

PARCHEGGI O DEPOSITI

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1.1 Selezione dei parametri utili

C. Servizi per il ciclista in prossimità della stazione

Come da Decreto 30 novembre 1999, n. 557 *Regolamento recante norme per la definizione delle caratteristiche tecniche delle piste ciclabili* (Capo I art.11):

"Ogni progetto di pista ciclabile deve essere corredato dall'individuazione dei luoghi e delle opere ed attrezzature necessarie a soddisfare la domanda di sosta per i velocipedi ed eventuali altre esigenze legate allo sviluppo della mobilità ciclistica, senza che si abbiano intralci alla circolazione stradale, specialmente dei pedoni".

		Peso	Valore
C	**Servizi per ciclisti in prossimità del nodo ferroviario**	**0,79**	
1	Sono presenti rastrelliere ad accesso libero per il parcheggio delle biciclette? (1) Sì; (0) No	0,85	
2	I tipo di rastrelliere è: (0) basso: si può solo legare la ruota (es. Volta, Holanda, Rotterdam); (1) alto: si possono legare sia la ruota che il telaio (es. Eindhoven, Trombone, Provenza) o entrambi	0,91	
	IL NUMERO DI PARCHEGGI PER BICICLETTE È:		
3	Il numero di rastrelliere ad accesso libero è adatto alle esigenze? (1) Sì; (0) No	1,00	
4	È presente un kit di riparazione bici (o colonnina per il gonfiaggio)? (1) Sì; (0) No	0,54	
5	Accessibilità binari: sono presenti ascensori (dimensione minima 1,40 m x 1,10 m) o scivoli per accedere alle piattaforme? (1) Sì; (0) No	0,89	
6	La biglietteria è accessibile con la bicicletta (ad es. tramite rampe)? (1) sì; (0) no	0,38	
7	Sono presenti servizi igienici all'interno della stazione? (1) Sì; (0) No	0,75	
8	È consentito viaggiare con la bicicletta personale sull'autobus? (1) Sì; (0) No	0,25	
Totale ponderato			**0,00**

In questa sezione si fa riferimento alle "Linee guida per il sistema regionale della ciclabilità (L.r. n. 10/2017)" e al "Piano Urbano della Mobilità Sostenibile (PUMS) del Comune di Bologna".

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1.1 Selezione dei parametri utili

D. Velostazione

I depositi di biciclette sono strutture ampie e chiuse, progettate per consentire agli utenti di parcheggiare il proprio mezzo in modo sicuro. Questi spazi sono pensati per proteggere le biciclette da furti, intemperie, atti vandalici. Di norma, l'**accesso a tali depositi è a pagamento** e avviene attraverso l'uso di tessere magnetiche, applicazioni o documenti di identità. Un'evoluzione dei depositi sono le **velostazioni**, presso le quali è possibile trovare, oltre ad un parcheggio sicuro per il proprio mezzo, anche servizi di supporto per i ciclisti, quali ciclofficina, punto informativo, aree ristoro e servizi igienici.

		Peso	Valore
D	**Deposito bici**	**0,73**	
1	È presente almeno un deposito biciclette (massimo 200m dalla stazione ferroviaria)? (2) Sì; (1) Previsto; (0) No	0,72	
2	Il deposito è all'interno o all'esterno della stazione ferroviaria? (1) all'interno o entrambi; (0) all'esterno	0,44	
3	Il deposito bici si trova a: (1) 75 metri dalla stazione ferroviaria; (0) più di 75 metri dalla stazione ferroviaria	0,78	
4	Esiste più di un deposito? (1) Sì; (0) No	0,50	
	Il numero di posti del deposito è ...		
5	Il numero di posti è adatto alle esigenze? (1) Sì; (0) No	1,00	
6	Il deposito dispone di un servizio (1) gratuito o (0) a pagamento di deposito biciclette?	0,73	
7	Il deposito dispone di servizi per gli utenti (armadietti e spogliatoi, docce e servizi igienici, distributori di bevande)? (1) Sì; (0) No	0,58	
8	Il deposito dispone di servizi per biciclette (riparazioni, pompe gonfiabili, ricambi e accessori in vendita, noleggio biciclette)? (1) Sì; (0) No	0,58	
9	Qual è il livello medio di occupazione del deposito bici? (2) < 75%; (1) 75% < occup. < 99%; (0) > 100%	0,69	
10	Il deposito bici è dotato di videosorveglianza? (1) Sì; (0) No	0,69	
11	È consentito prenotare un posto in anticipo all'interno del deposito bici? (1) Sì; (0) No	0,66	
12	Il deposito bici è accessibile: (2) 24/7; (1) solo nelle ore di punta (07:00-08:00; 13:00-14:00; 17:00-18:00); (0) meno di 3 ore al giorno	0,83	
13	Il deposito biciclette è accessibile tramite: (3) personale o app; (2) chiave/ badge; (1) pass per i mezzi pubblici/tessera sanitaria; (0) biglietto una tantum	0,77	
Totale ponderato			**0,00**

Si riportano le voci analizzate considerando: "PRESTO: Promoting Cycling for Everyone as a Daily Transport Mode (Promozione dell'uso della bicicletta come mezzo di trasporto giornaliero per tutti)", "Piano Urbano della Mobilità Sostenibile (PUMS) del Comune di Bologna", "Linee guida per il sistema regionale della ciclabilità (L.r. n. 10/2017)" e le linee guida "FIAB (Federazione Italiana Amici della Bicicletta)", "Piano Urbano della Mobilità Sostenibile (PUMS) del Comune di Bologna".

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1.1 Selezione dei parametri utili

D. Velostazione

Capacità:
Un servizio effettivamente utile prevede un numero di rastrelliere per biciclette adeguato alle esigenze, ovvero al numero di potenziali fruitori del servizio. Le linee guida per il sistema regionale della ciclabilità stabiliscono che, per determinare il numero adeguato di stalli da realizzare nei pressi delle stazioni ferroviarie, è necessario considerare il numero complessivo di passeggeri al giorno. Gli spazi da destinare al parcheggio di cicli dovrebbero variare tra il 10% e il 30% del totale.

Presenza e distanza:
Secondo le indicazioni del PUMS, il deposito biciclette dovrebbe essere ben visibile e facilmente raggiungibile e trovarsi entro un raggio massimo di 200m dalla stazione ferroviaria in modo tale da incoraggiarne l’utilizzo.

max 200 m

Accessibilità:
Oltre ai sistemi di accesso al servizio (badge, chiavi, app), si intende anche la fascia oraria in cui è possibile usufruire del deposito cicli. Queste strutture sono perlopiù utilizzate da pendolari e viaggiatori, motivo per cui è necessario che siano fruibili 24 ore su 24 o, quantomeno, nelle ore di punta.

24 h

Tipologia servizio di sicurezza:
La gestione e il controllo degli accessi ai depositi cicli possono essere affidati a personale dedicato o essere, in parte o completamente, automatizzati. La sorveglianza da parte di personale è ben vista dagli utenti, poiché fornisce contatto immediato e concreto in caso di problemi aumentando il livello di sicurezza percepita. Il personale può essere supportato da sistemi parzialmente automatizzati, come sistemi di sorveglianza e dispositivi di accesso elettronici. Nel caso di depositi completamente automatizzati, invece, il personale non è presente.

Servizi:
Per promuovere l’uso dei depositi, è vantaggioso che in essi siano presenti servizi aggiuntivi per gli utenti, quali spogliatoi, servizi igienici, armadietti, deposito borse e bagagli e distributori di bevande. Inoltre, è bene prevedere servizi per le biciclette: kit di riparazione, pompe, vendita di ricambi e accessori e noleggio bici.

1.1 Selezione dei parametri utili

E. Bike Sharing

Il **bike sharing** ("biciclette condivise") è un sistema di noleggio bici che consente di rendere le biciclette più accessibili e raggiungere luoghi non coperti dai trasporti pubblici. Gli utenti si registrano al servizio attraverso un'**apposita app**, con cui possono localizzare e prenotare le bici disponibili, che vengono così sbloccate per l'uso. Dopo l'utilizzo, gli utenti lasciano il mezzo in apposite aree o parcheggi, dove viene bloccato e reso disponibile per nuovi utilizzi. Questo sistema è sempre più popolare e alle bici "meccaniche" sono affiancate quelle elettriche (e-bike), in modo da raggiungere anche la popolazione che non vuole o non può faticare mentre pedala. I benefici sono molteplici, tra cui il calo dell'affollamento dei mezzi pubblici, l'eliminazione del rischio di furto del proprio mezzo e il risparmio di tempo.

		Peso	Valore
E	**Bike Sharing**	**0,63**	
1	È presente il servizio di bike sharing? (1) Sì; (0) No	0,71	
2	Sono presenti altri servizi di micromobilità? (1) Sì; (0) No	0,81	
3	Le stazioni di bike sharing si trovano a: (2) meno di 75 metri; (1) 75-500 metri; (0) più di 500 metri dalle stazioni ferroviarie	0,75	
4	Il numero di bike sharing è adatto alle esigenze? (1) Sì; (0) No	0,94	
5	La bicicletta in share deve essere lasciata in un hub specifico? (1) Sì; (0) No	0,54	
Totale ponderato			**0,00**

Esiste anche il **bike sharing comunale**, un servizio di condivisione, offerto da enti pubblici o privati, all'interno di una città. Gli utenti possono noleggiare biciclette da stazioni designate a tale scopo, utilizzarle per brevi spostamenti e restituirle alle stazioni una volta completato l'uso. Solitamente per accedere al servizio si utilizzano chiavi, app o abbonamenti scansionabili. Per tutte le modalità gli utenti devono accettare i termini e le condizioni del servizio e possono essere soggetti a tariffe di utilizzo o cauzioni per l'uso delle biciclette.

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1.1 Selezione dei parametri utili

F. Flussi e dimensionamento

F	FLUSSI E DIMENSIONAMENTO	Valore
1	FLUSSO GIORNALIERO [numero totale di persone che salgono sul treno; **pers./giorno**]	
3	**NUMERO DI RASTRELLIERE NECESSARIE**	0
4	**NUMERO DI POSTI NECESSARI NEL DEPOSITO BICI**	0

PRESENZA E DISTANZA DEL BIKE SHARING

La presenza di un servizio di bike sharing nei pressi delle stazioni ferroviarie contribuisce a:

- **Facilitare gli spostamenti** da e verso la stazione;
- **Promuovere il turismo locale:** i turisti che arrivano in treno possono utilizzare le biciclette condivise per esplorare il territorio;
- **Incentivare l'intermodalità**, consentendo agli utenti sprovvisti di bici di combinare facilmente la stessa con altri mezzi di trasporto pubblico.

Secondo le linee guida del PUMS, affinché tale servizio abbia un impatto significativo, dovrebbe trovarsi entro un raggio di circa 250 m dalla stazione.

TIPOLOGIA DI BIKE SHARING

- **A stazione fissa:** biciclette disponibili in stazioni fisse distribuite sul territorio; agli utenti è consentito prendere una bicicletta da una stazione e riconsegnarla in un'altra;
- **Bike sharing free flow:** biciclette non legate a stazioni fisse; le bici possono essere prese o lasciate in qualsiasi luogo all'interno di una data area.

Il secondo di questi sistemi offre maggiore flessibilità rispetto al primo e risulta quindi più competitivo.

ULTERIORI SERVIZI DI MICROMOBILITÀ

Si intendono modalità di trasporto leggere ed efficienti per spostamenti brevi. Esempi di micromobilità possono essere i **monopattini** e i **ciclomotori elettrici.**

1.2 Definizione del momento migliore per raccogliere i dati

Compresi gli indicatori da analizzare, è necessario impostare il lavoro per una corretta raccolta dati, fattore molto importante per l'analisi della qualità di una infrastruttura.

Il momento migliore per raccogliere i dati in loco è durante l'orario di punta della stazione ferroviaria, in quanto è possibile valutare, anche visivamente, la massima capacità della stazione stessa.

A seconda delle necessità, l'indicatore può avere utilità e finalità differenti e, di conseguenza, cambia il momento in cui raccogliere i dati. È possibile utilizzarlo, per esempio, per effettuare un confronto tra situazione pre- e post-intervento per valutarne l'efficacia.

In tal caso la raccolta dati deve essere compiuta tre volte: la prima antecedente l'intervento, la seconda immediatamente successiva ai cambiamenti progettuali e la terza dopo mesi dalla fine dell'intervento.

Al fine di avvalorare la raccolta dati in fasi diverse del progetto, è fondamentale ripetere i sopralluoghi nelle stesse condizioni orarie e metereologiche.

Raccolta dati precedente all'intervento:

- Comprendere il funzionamento della stazione ferroviaria analizzata;
- Prendere nota di orario, stagione e momento della giornata in cui sono stati raccolti i dati, poiché la raccolta post-intervento andrà fatta nelle stesse condizioni;
- Comprendere le necessità del committente;
- Scattare numerose foto.

Raccolta dati immediatamente successiva all'intervento:

- Documentare e comunicare i cambiamenti;
- Migliorare i dettagli del progetto in base alle osservazioni correnti.

Raccolta dati successiva all'intervento:

- Accertare i cambiamenti a lungo termine;
- Impostare i lavori futuri in base ai risultati del progetto in esame;
- Valutare l'impatto e l'efficacia dei cambiamenti.

Parte 2

Organizzare il team

Effettuare il sopralluogo

Interpretare i risultati

2.1 Organizzare il team

Definiti e compresi i valori da analizzare, occorre stabilire come procedere per effettuare il sopralluogo considerando il numero di ispettori disponibili, le condizioni e dimensioni della stazione e il numero di ore necessarie per ogni raccolta dati.

Scelta dell'ispettore

Il team di ispettori può essere composto da dipendenti pubblici, dipendenti del gestore nazionale delle ferrovie, tecnici o studenti universitari. Al termine dell'ispezione di ogni stazione, il team si dovrà riunire per confrontare i risultati, affinché il valore assegnato ad ogni caratteristica sia confermato. Infatti, solo quando i risultati dell'ispezione coincidono, significa che questa è stata efficace.

Formazione del Team

Durante il training, alla squadra di ispettori verranno comunicati gli obiettivi del sopralluogo, il metodo, gli strumenti necessari, e l'organizzazione pratica dello svolgimento.

Pianificazione degli orari e dei luoghi

Essendo consigliato l'utilizzo del treno per spostarsi tra stazioni, è necessario, nel caso in cui si debba ispezionare più di una stazione, definire un programma in base agli orari dei treni, considerando per ogni stazione almeno 45 minuti per il sopralluogo.

È consigliato effettuare i sopralluoghi durante gli orari di punta delle stazioni ferroviarie che, solitamente, sono:

- picco della mattina: 7:00-8:59
- picco di metà giornata: 13:00-14:49
- picco tardo pomeriggio: 17:00-19:59

È molto importante che il team si senta al sicuro durante il sopralluogo e che abbia ben compreso lo **scopo** del sopralluogo stesso.

Comunicare gli obiettivi

- Spiegare gli obiettivi al team
- Studio della mappa della stazione ferroviaria.

Definire il luogo e gli orari del sopralluogo

Se il sopralluogo deve essere svolto su più stazioni ferroviarie, definire il percorso. Spostarsi preferibilmente in treno così da seguire i percorsi realisticamente utilizzati dai viaggiatori.

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2.1 Organizzare il team

Esempio

Prima della partenza definire le tempistiche necessarie alla esecuzione dell'ispezione. Per ogni stazione è consigliato impostare una mappa delle aree circostanti, al fine di minimizzare i tempi di orientamento all'interno e nei pressi della stazione ferroviaria. La mappa della stazione prima della partenza deve includere i punti cardinali, gli accessi alla stazione, le eventuali velostazioni, le piste ciclabili nelle diverse direzioni.

Mappa per l'ispezione

Programmazione oraria

Stazioni	Orario di arrivo	Orario di partenza	Orario di arrivo alla destinazione
Bologna		7.33	8.31
Parma	8.31	9.27	11.13
Faenza	11.13	13.10	13.55

Organizzare i materiali da portare in sito
Munirsi di fotocamera, computer e stampe delle schede dell'indicatore da compilare, una per ogni stazione in cui si effettua il sopralluogo.

Conoscere l'indicatore e saperlo compilare
Rivedere l'indicatore prima del sopralluogo per avere chiari i punti da attenzionare.

2.2 Effettuare il sopralluogo

Schede di rilievo

A seguito dell'organizzazione del team, della pianificazione oraria e del luogo, è possibile effettuare il sopralluogo. In questa fase, si parte con tutti gli strumenti necessari, fotocamera, PC o tablet, indicatore da compilare in formato cartaceo o su tablet e mappa della stazione analizzata con punti cardinali. È fortemente consigliato raggiungere la stazione con una bicicletta al fine di identificare meglio i punti critici. Dopo il sopralluogo è importante creare una cartella in cui venga specificato data del sopralluogo e una sottocartella per ogni stazione ferroviaria con il nome della stazione e l'orario. Successivamente all'organizzazione delle fotografie in cartelle è possibile compilare una **scheda preimpostata descrittiva** della stazione.

Le caratteristiche da descrivere a seguito di un sopralluogo sono quindi:

1 Informazioni sulla presenza di **rampe** o **ascensori**. Le dimensioni dell'ascensore e l'accessibilità con bici a mano di tutti i binari.

2 Presenza di **bike sharing**, distanza dalla stazione, e tipologia di servizio.

3 Caratteristiche di **accessibilità**, illuminazione, presenza del trasporto pubblico, e cartellonistica direzionale interna ed esterna alla stazione.

4 **Rastrelliere** per biciclette, quantità, tipologia, distanza e loro visibilità dall'ingresso della stazione ferroviaria.

5 Presenza e caratteristiche pratiche della **velostazione**, numero di posteggi, tipologia di accesso, orari di apertura.

6 Descrizione delle **piste ciclabili** inclusa illuminazione, segnaletica, pavimentazione, direzione e larghezza delle corsie.

Fotocamere e cellulari

Raccogliere immagini che documentino gli indicatori per poterle riguardare nel momento della compilazione dell'indicatore

Mappa del sito

Per un orientamento più efficace è bene portare con sé una mappa della stazione ferroviaria avendo precedentemente indentificato i punti da attenzionare

Cordella metrica

Per misurare la larghezza della pista ciclabile, delle sue corsie e le dimensioni dell'ascensore diretto ai binari, è consigliabile l'utilizzo di una cordella metrica

Suggerimenti per le immagini pre e post intervento

- Effettuare il sopralluogo nelle stesse condizioni metereologiche e orarie
- Scattare diverse fotografie, con diverse angolazioni per essere in grado di riprodurre e paragonare lo stesso scatto

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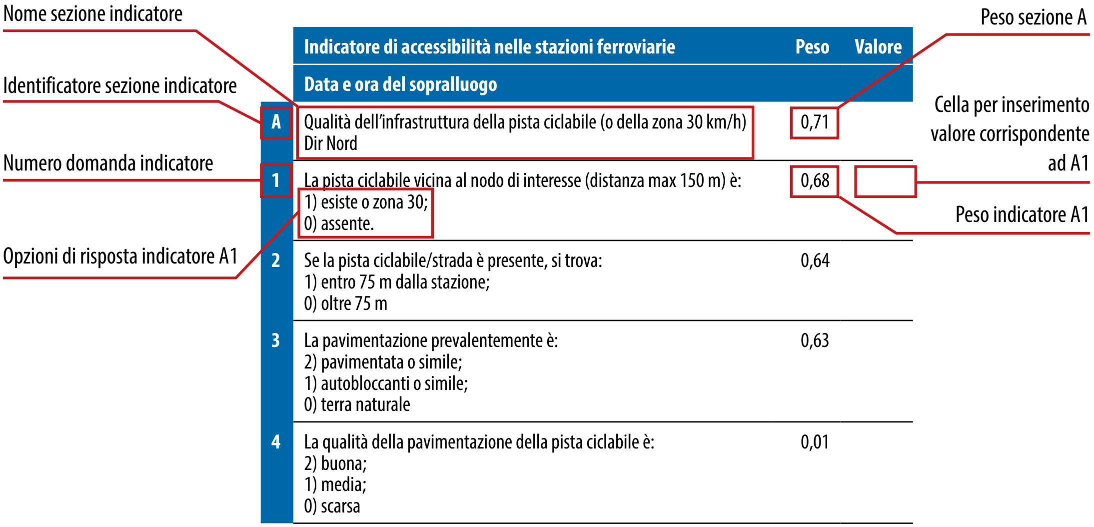
2.2 Effettuare il sopralluogo

Compilare l'indicatore

In rapporto al numero di opzioni che ogni indicatore consente di avere, il valore da inserire all'interno dell'indicatore cambia.
L'indicatore si trova in formato Excel e nel file sono presenti due fogli:
1) Come utilizzare l'indicatore brevemente;
2) Indicatore da compilare: è necessario inserire nella quarta colonna il valore relativo all'aspetto illustrato nella riga corrispondente.



Nome sezione indicatore

Identificatore sezione indicatore

Numero domanda indicatore

Opzioni di risposta indicatore A1

Peso sezione A

Cella per inserimento valore corrispondente ad A1

Peso indicatore A1

	Indicatore di accessibilità nelle stazioni ferroviarie	Peso	Valore
	Data e ora del sopralluogo		
A	Qualità dell'infrastruttura della pista ciclabile (o della zona 30 km/h) Dir Nord	0,71	
1	La pista ciclabile vicina al nodo di interesse (distanza max 150 m) è: 1) esiste o zona 30; 0) assente.	0,68	
2	Se la pista ciclabile/strada è presente, si trova: 1) entro 75 m dalla stazione; 0) oltre 75 m	0,64	
3	La pavimentazione prevalentemente è: 2) pavimentata o simile; 1) autobloccanti o simile; 0) terra naturale	0,63	
4	La qualità della pavimentazione della pista ciclabile è: 2) buona; 1) media; 0) scarsa	0,01	

2.2 Effettuare il sopralluogo

Compilare l'indicatore

Dopo aver compilato la quarta colonna, è necessario completare anche gli indicatori della sezione F nella terza colonna. In particolare, deve essere compilato l'indicatore F1 e le celle grigie F2 e F3 si auto-compileranno.

F	FLUSSI E DIMENSIONI	Valore
1	Flusso giornaliero (numero totale di persone che salgono sul treno; **pers./giorno**)	
2	**Numero di rastrelliere necessarie**	0
3	**Numero di posti necessari nel deposito bici**	0

Esempio di compilazione sezione A

La sezione A deve essere compilata tenendo a mente le seguenti descrizioni degli indicatori:

Verificare l'esistenza della pista ciclabile
La valutazione considera la presenza di una pista ciclabile e la sua vicinanza alla stazione ferroviaria. Ciò è in linea con le leggi regionali (5 giugno 2017, n.10) [9] che mirano a migliorare il pendolarismo quotidiano promuovendo l'uso della bicicletta. Avere una pista ciclabile vicina è fondamentale per incoraggiare la mobilità attiva. Se la pista ciclabile si trova entro una distanza massima di 150 m dal nodo di interesse, ottiene un punteggio di "1" per esistente o zona 30, altrimenti "0" per assente.

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2.2 Effettuare il sopralluogo

La distanza della pista ciclabile dal nodo

La valutazione esamina la vicinanza della pista ciclabile o della strada alla stazione ferroviaria. Se è entro 75 metri, ottiene un punteggio di (1), il che significa che è vicina e facile da raggiungere. Se invece dista più di 75 metri, ottiene un punteggio di (0), indicando che è più lontana e meno comoda per i ciclisti.

Esame del tipo e della qualità della pavimentazione

Questa valutazione riguarda il tipo di pavimentazione e la sua qualità, che **sono fondamentali** per la sicurezza degli utenti. I fattori includono la tenuta della pavimentazione e l'eventuale presenza di potenziali pericoli come le radici delle piante. Le valutazioni vanno da "2" per una pavimentazione eccellente a "0" per condizioni pessime. La pavimentazione prevalente è valutata in base al tipo: (2) per pavimentazione o simili, (1) per autobloccanti o simili e (0) per terra naturale. La qualità della pavimentazione è valutata come (2) per BUONA, (1) per MEDIA e (0) per PESSIMA.

Comprendere i diversi tipi di piste ciclabili

In base alle linee guida, si tiene conto delle limitazioni alle piste ciclabili bidirezionali nelle aree urbane per motivi di sicurezza, assegnando loro un punteggio "0". Le piste a senso unico ricevono un "1", le piste esclusivamente ciclabili un "2" e le strade con un limite di velocità di 30 km/h un "1". Un tipo non chiaro riceve uno "0".

Due indicatori per il tipo di pista ciclabile

(2) - a senso unico per ogni lato della strada, (1) - a doppio senso riservata alle biciclette e (0) - a doppio senso. Un altro indicatore per il tipo e la posizione è una valutazione multicriteriale basata su diversi scenari - valutazione da 6 a 0.

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2.2 Effettuare il sopralluogo

Rispetto degli standard geometrici
rispettare gli standard legali e le linee guida, assicurando che le larghezze dei percorsi siano in linea con le normative che prevedono una larghezza di 1,5 m per i percorsi a senso unico e una larghezza laterale minima di 1,25 m per i percorsi multipli. Sono necessarie indicazioni chiare per qualsiasi riduzione della larghezza dei percorsi. L'adeguatezza degli standard geometrici medi è contrassegnata da "1" per SÌ e "0" per NO.

Verifica della pendenza delle piste ciclabili
la pendenza della pista ciclabile è fondamentale per il coinvolgimento degli utenti. Si preferisce una pendenza inferiore al 5% per gestire la velocità e accogliere gli utenti meno agili nella navigazione in salita. Risposta SI (1) o NO (0) per sapere se la pendenza della pista ciclabile/strada supera il 5%.

Avvertenze sui potenziali ostacoli
si tiene conto dei potenziali ostacoli lungo il percorso, in quanto possono influire sulla larghezza. Si fa attenzione a non compromettere la sicurezza degli utenti. Valutazione degli ostacoli puntuali, riduzione standard: (2)-ASSENTE, (1)-RARO e (0)-FREQUENTE. Conflitto laterale da parte di negozi o passi carrai: (2)-ASSENTE, (1)-LEGGERO, (0)-GRAVE.

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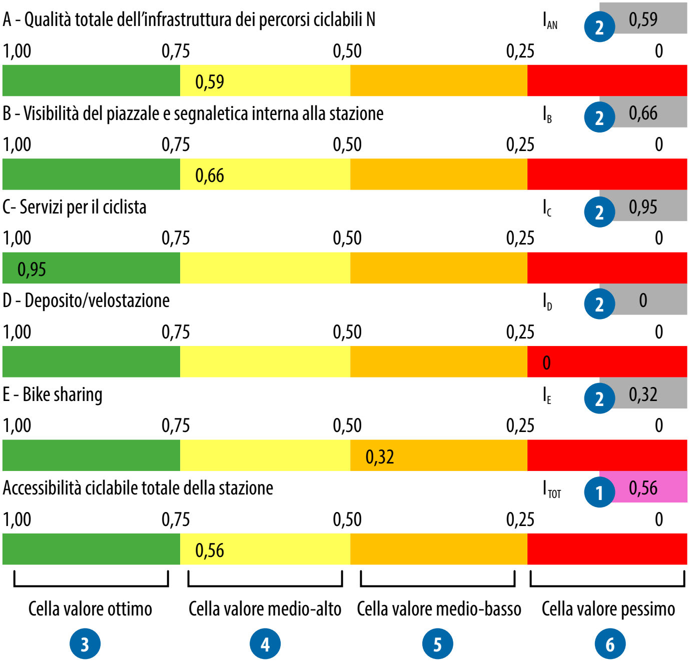
2.3 Come interpretare l'indicatore

La performance di ogni categoria dell'indicatore (I_X) viene compilata automaticamente nella tabella dei risultati mostrati in figura G. Il colore della cella in cui ricade il valore della categoria indica il livello di accessibilità. La media pesata di tutte le categorie indica il valore **totale di accessibilità ciclabile** della stazione ferroviaria (I_{TOT}).

A Qualità dell'infrastruttura ciclabile (valutata su 4 direzioni N,S,E,O)
B Visibilità del piazzale della stazione e segnaletica interna
C Servizi per il ciclista
D Deposito/velostazione
E Bike sharing

Figura G



① La **cella viola 1** indica il valore totale I_{TOT} di **accessibilità della stazione ferroviaria** presa in esame, ovvero la media pesata di tutte le categorie.

② Le **celle grigie** nella sezione dei risultati indicano il valore dell'indicatore della **categoria** corrispondente.

③ Se l'indicatore della categoria è all'interno della **cella verde (0,75 < I_x < 1)** allora il valore di accessibilità della categoria è **ottimo** (esempio categoria C).

④ Nel caso in cui il valore dell'indicatore corrispondente appaia nella cella gialla **(0,50 < I_x < 0,76)** significa che il valore di accessibilità di quell'indicatore è **medio-alto** (esempio categorie A, B, Accessibilità totale).

⑤ Nel caso in cui il valore dell'indicatore corrispondente appaia nella cella **arancione (0,25 < I_x < 0,51)** significa che il valore di accessibilità di quell'indicatore è **medio-basso** (esempio categoria E).

⑥ Se il valore dell'indicatore corrispondente appare nella cella **rossa (0 < I_x < 0,26)** significa che il valore è **basso** (esempio categoria D).

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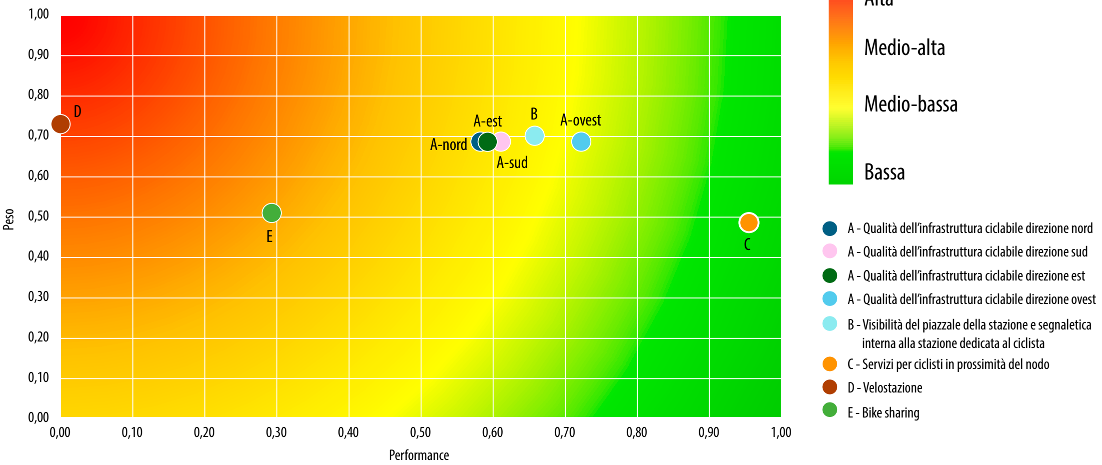
2.3 Come interpretare l'indicatore

È possibile interpretare i risultati dell'indicatore attraverso un **grafico peso-performance (Ix).** Nella figura H, sull'asse delle x è rappresentata la performance della singola categoria ottenuta dalla compilazione dell'indicatore; sull'asse delle y è rappresentato il peso di ogni categoria (parametro fisso dell'indicatore). Il grafico mostra nell'area in rosso le categorie con performance bassa e peso alto, nell'area verde le categorie con performance elevata e peso basso. Per stabilire la priorità degli interventi, il grafico deve essere interpretato da sinistra verso destra. Le categorie dell'indicatore con alta priorità di intervento sono quelle con performance più bassa e peso più alto (fig. H categoria D). Le categorie dell'indicatore con bassa priorità di intervento sono quelle con performance più alta a parità di peso (fig. H categoria C).

Nel grafico la priorità di intervento risulta:
1) D
2) E
3) A-NORD
4) A-EST
5) A-SUD
6) B
7) A-OVEST
8) C

Figura H - Esempio applicativo del grafico peso-performance



Parte 3

3.1 Stazione Platinum: Bologna centrale

Sezione A

A	Indicatore	Peso	Nord	Sud	Est	Ovest
1	La pista ciclabile vicina al nodo di interesse (distanza massima considerata: 150 m) è: (1) esistente o zona 30; (0) assente	0,68	1	1	1	1
2	Se la pista ciclabile/corsia è presente si trova: (1) entro 75 m dalla stazione (0) oltre 75 m	0,64	1	0	1	1
3	La pavimentazione prevalente è: (2) asfaltata o simile; (1) autobloccanti o simili; (0) terra naturale	0,63	2	1	2	2
4	La qualità della pavimentazione della pista ciclabile: (2) buona; (1) media (0) scarsa	0,10	2	2	2	2
5	Tipo di pista ciclabile se presente: (2) unidirezionale per ciascun lato della strada, (1) bidirezionale riservata alle biciclette, (0)bidirezionale	0,58	0	2	1	1
6	Tipo di pista ciclabile se presente: (2) a livello sopraelevato; (1) a livello della strada; (0) non presente	0,56	2	0	2	2
7	La pista ciclabile è: (6) riservata, uni o bidirezionale, su livello rialzato; (5) riservata, uni o bidirezionale, su livello rialzato separata da pedoni con una linea attraversabile dipinta a terra; (4) promiscua, uni o bidirezionale, condivisa con pedoni; (3) corsia riservata, uni o bidirezionale, a livello della carreggiata stradale, separata da automobili con una linea attraversabile dipinta a terra; (2) corsia a senso unico ricavata dalla carreggiata stradale in senso opposto su una strada a senso unico con un limite di velocità di 30 km/h separata da automobili con una linea tratteggiata attraversabile dipinta sul terreno; (1) promiscua, uni o bidirezionale, a livello della carreggiata stradale; (0) nessuna delle precedenti	0,83	5	0	5	6
8	Gli standard geometrici medi (se adiacenti al percorso pedonale) sono adeguati? (1) Sì; (0) No	0,94	1	1	1	1
9	La pendenza della pista ciclabile/strada non supera il 5%? (1) Sì; (0) No	0,31	0	0	1	1
10	Ostacoli puntuali, riduzione degli standard sono: (2) assenti; (1) rari; (0) frequenti	0,82	2	2	0	1
11	Conflitto laterale da negozi o vialetti: (2) assente; (1) leggero; (0) grave	0,67	2	2	2	2
12	Conflitto con il traffico pedonale: (2) assente; (1) leggero; (0) grave	0,66	1	1	1	2
13	Conflitto con il traffico veicolare: (2) assente; (1) leggero; (0) grave	0,78	2	0	2	2
14	La pista ciclabile è: (2) colorata (ben visibile); (1) mediamente visibile; (0) non colorata	0,60	0	0	0	0
15	La segnaletica orizzontale del comportamento dei ciclisti per muoversi correttamente è: (1) presente (0) assente	0,73	1	0	0	1
16	La segnaletica di guida del comportamento dei ciclisti è adeguata? (2) molto buona; (1) discreta; (0) scarsa	0,73	1	0	2	1
17	Segnaletica verso i luoghi di interesse della città: (2) presenti ed eccellenti (marroni); (1) presente solo la mappa della città; (0) assente	0,55	1	1	1	0
18	La pista ciclabile è dotata di illuminazione notturna: (2) buona; (1) media; (0) assente	0,77	1	2	2	1
19	Tipo di illuminazione: (2) propria della pista; (1) stradale pubblica; (0) stradale	0,31	2	1	2	1

3.1 Stazione Platinum: Bologna centrale

Sezione A

⑤ ⑥ ⑦ ⑭ ⑮ **Tipologia della pista ciclabile:** piste ciclabili bidirezionali


ovest


nord

● Ingresso

🟥 Pista ciclabile

① **Verificare l'esistenza della pista ciclabile:** la pista ciclabile è presente in tutte le quattro principali direzioni

⑮ ⑯ ⑰ **Segnaletica verticale e orizzontale della pista:** piste ciclabile indicata da segnaletica ad inizio del percorso e dopo ogni interruzione


est


nord

3.1 Stazione Platinum: Bologna centrale

Sezione B

B	Indicatore	Peso	Valore
1	La segnaletica verticale interna alla stazione che indichi la pista ciclabile è: (2) presente e vicina; (1) presente ma distante o non chiaramente visibile; (0) assente	0,78	1
2	L'illuminazione è presente nella zona esterna alla stazione ferroviaria? (1) Sì; (0) No	0,73	1
3	Quali cartelli verticali sono presenti all'interno della stazione ferroviaria? (2) Indicazioni per gli ascensori, indicazioni per l'uscita (per persone che trasportano biciclette); (1)indicazione per gli ascensori; (0) nessuno	0,78	1
4	I parcheggi per biciclette sono visibili dall'ingresso della stazione ferroviaria? (1) Sì; (0) No	0,74	0
5	Il parcheggio delle biciclette è contrassegnato da un cartello? (1) Sì; (0) No	0,01	1

② **Illuminazione esterna della stazione**

① ③ **Verifica della segnaletica interna alla stazione:** visibilità, accuratezza e presenza della segnaletica dedicata al ciclista

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3.1 Stazione Platinum: Bologna centrale

Sezione C

C	Indicatore	Peso	Valore
1	Sono presenti rastrelliere per il parcheggio delle biciclette? (1) Sì; (0) No	0,85	1
2	I tipo di rastrelliere è: (0) basso: si può solo legare la ruota (es. Volta, Holanda, Rotterdam); (1) alto: si possono legare sia la ruota che il telaio (es. Eindhoven, Trombone, Provenza) o entrambi.	0,91	1
	IL NUMERO DI PARCHEGGI PER BICICLETTE È:		2205
3	Il numero di rastrelliere è adatto alle esigenze? (1) Sì; (0) No	1,00	0
4	C'è un kit di riparazione bici (possibilmente solo la colonna della pompa)? (1) Sì; (0) No	0,54	1
5	Accessibilità: ci sono ascensori (dimensione minima 1,40x1,10) o scivoli per accedere alle piattaforme? (1) Sì; (0) No	0,89	1
6	Accessibilità: la biglietteria è accessibile in bicicletta (ad es. tramite rampe)? (1) sì; (0) no	0,38	1
7	Ci sono servizi igienici all'interno della stazione? (1) Sì; (0) No	0,75	1
8	È consentito viaggiare con la bicicletta personale sull'autobus? (1) Sì; (0) No	0,25	0

6 **Accessibilità biglietteria**

1 **Presenza parcheggio biciclette**

● Ingresso principale

▬ Posteggio biciclette

5 **Accessibilità ascensori**

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3.1 Stazione Platinum: Bologna centrale

Sezione D

D	Indicatore	Peso	Valore
1	C'è un deposito biciclette (massimo 200m dalla stazione ferroviaria)? (2) Sì; (1) Previsto; (0) No	0,72	2
2	Il deposito è all'interno o all'esterno della stazione ferroviaria? (1) all'interno o entrambi; (0) all'esterno	0,44	0
3	Il deposito bici si trova a: (1) 75 metri dalla stazione ferroviaria; (0) più di 75 metri dalla stazione ferroviaria	0,78	1
4	Esiste più di un deposito? (1) Sì; (0) No	0,50	1
	Il numero di posti del deposito è....		1000
5	Il numero di posti è adatto alle esigenze? (1) Sì; (0) No	1,00	0
6	Il deposito dispone di un servizio (1) gratuito o (0) a pagamento di deposito biciclette?	0,73	0
7	Il deposito dispone di servizi per gli utenti (armadietti e spogliatoi, docce e servizi igienici, distributori di bevande)? (1) Sì; (0) No	0,58	1
8	Il deposito dispone di servizi per biciclette (riparazioni, pompe gonfiabili, ricambi e accessori in vendita, noleggio biciclette)? (1) Sì; (0) No	0,58	1
9	Qual è il livello medio di occupazione del deposito bici? (2) <75%; (1) 75%<occup.<99%; (0) >100%	0,69	1
10	Il deposito bici è dotato di videosorveglianza? (1) Sì; (0) No	0,69	1
11	È consentito prenotare un posto in anticipo all'interno del deposito bici? (1) Sì; (0) No	0,66	1
12	Il deposito bici è accessibile: (2) 24/7; (1) solo nelle ore di punta (07:00-08:00; 13:00-14:00; 17:00-18:00); (0) meno di 3 ore al giorno	0,83	2
13	Il deposito biciclette è accessibile tramite: (3) personale o app; (2) chiave/ badge; (1) pass per i mezzi pubblici/tessera sanitaria; (0) biglietto una tantum	0,77	3

7
8
12

Servizi deposito

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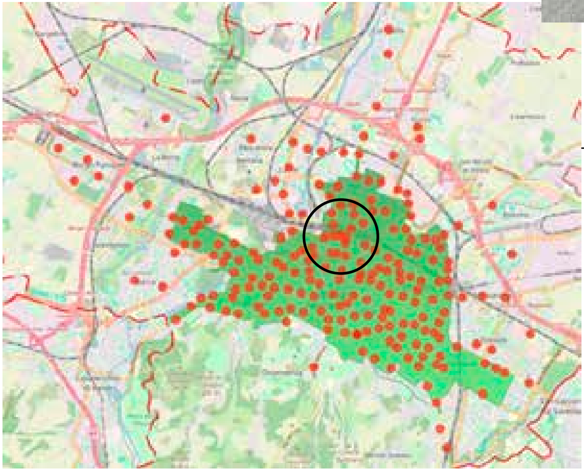
3.1 Stazione Platinum: Bologna centrale

Sezione E

E	Indicatore	Peso	Valore
1	E' presente il servizio di bike sharing? (1) Sì; (0) No	0,71	1
2	Sono presenti altri servizi di micromobilità? (1) Sì; (0) No	0,81	0
3	Le stazioni di bike sharing si trovano a: (2) meno di 75 metri; (1) 75-500 metri; (0) più di 500 metri dalle stazioni ferroviarie	0,75	2
4	Il numero di bike sharing è adatto alle esigenze? (1) Sì; (0) No	0,94	1
5	La bicicletta in share deve essere lasciata in un hub specifico? (1) Sì; (0) No	0,54	1

① ③ **Bike sharing**



○ Stazione Centrale

● Principali stalli bike sharing

Fonte: https://www.comune.bologna.it/servizi-informazioni/bike-sharing-bologna

3.1 Stazione Platinum: Bologna centrale

Sezione F

F	Dato	Valore
1	**FLUSSO GIORNALIERO [numero totale di persone che salgono sul treno; pers./giorno]**	46483
2	NUMERO DI RASTRELLIERE NECESSARIE	5346
3	NUMERO DI POSTI NECESSARI NEL DEPOSITO BICI	1859

L'indicatore da compilare è F1.
Gli indicatori F2 ed F3 sono calcolati automaticamente in funzione di F1.

Per informazioni sul dimensionamento dei punti 3 e 4 vedere pagina 13

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3.1 Stazione Platinum: Bologna centrale

A - Qualità totale dell'infrastruttura dei percorsi ciclabili N I_{AN} 0,74

1,00 0,75 0,50 0,25 0

0,74

A - Qualità totale dell'infrastruttura dei percorsi ciclabili S I_{AS} 0,40

1,00 0,75 0,50 0,25 0

0,40

A - Qualità totale dell'infrastruttura dei percorsi ciclabili E I_{AE} 0,74

1,00 0,75 0,50 0,25 0

0,74

A - Qualità totale dell'infrastruttura dei percorsi ciclabili O I_{AO} 0,77

1,00 0,75 0,50 0,25 0

0,77

B - Visibilità del piazzale e segnaletica interna alla stazione I_B 0,50

1,00 0,75 0,50 0,25 0

0,50

C- Servizi per il ciclista I_C 0,77

1,00 0,75 0,50 0,25 0

0,77

D - Deposito/velostazione I_D 0,78

1,00 0,75 0,50 0,25 0

0,78 0

E - Bike sharing I_E 0,82

1,00 0,75 0,50 0,25 0

0,82

Accessibilità ciclabile totale della stazione I_{TOT} **0,69**

1,00 0,75 0,50 0,25 0

0,69

Interpretare i risultati

Elementi che necessitano di intervento

- Qualità dell'infrastruttura ciclabile direzione sud

Elementi che non necessitano di intervento

- Qualità dell'infrastruttura ciclabile direzione nord
- Qualità dell'infrastruttura ciclabile direzione est
- Visibilità del piazzale della stazione e segnaletica interna alla stazione
- Deposito

Elementi che non necessitano di intervento

- Qualità dell'infrastruttura ciclabile direzione ovest
- Servizi dedicati ai ciclisti
- Bike sharing

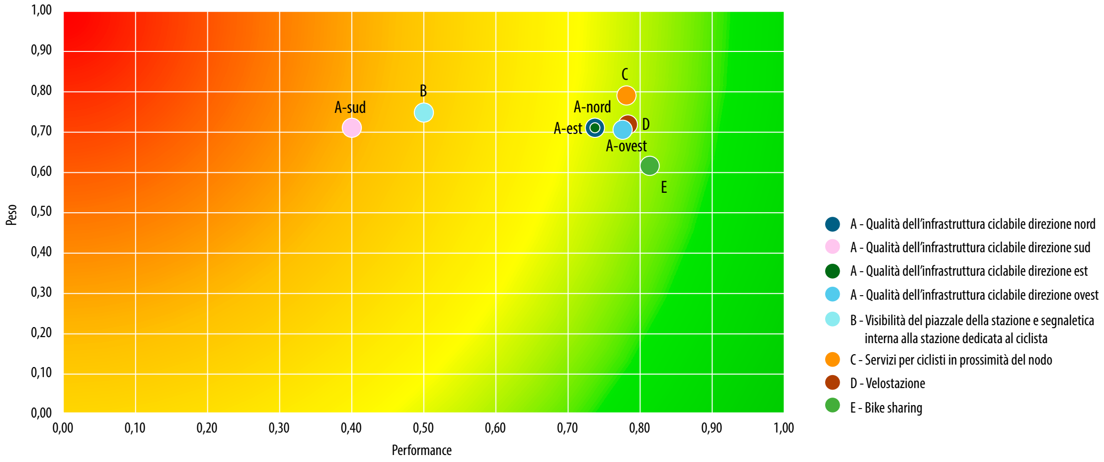
3.1 Stazione Platinum: Bologna centrale

Interpretare i risultati

I risultati sono mostrati nella tabella a sinistra con diversi colori a seconda della priorità di intervento. Per la stazione di Bologna centrale 3 categorie non necessitano di intervento e ricadono quindi nella zona verde. Le restanti 6 categorie sono ordinate secondo la priorità di intervento. Nessuna categoria risulta «urgente». I risultati sono visualizzabili nel grafico peso- performance.

L'ordine di priorità degli interventi risulta:

1 - Qualità infrastruttura ciclabile sud
2 - Visibilità del piazzale della stazione e segnaletica propria della stazione
3 - Qualità infrastruttura ciclabile nord
4 - Qualità infrastruttura ciclabile est
5 - Servizi per i ciclisti in prossimità del nodo
6 - Qualità dell'infrastruttura ciclabile ovest
7 - Deposito per biciclette
8 - Bike sharing



3.1 Stazione Platinum: Bologna centrale

Intervento 1 – Infrastruttura ciclabile direzione sud

Gli indicatori che non raggiungono gli standard massimi sono i numeri: 2, 3, 6, 7, 9, 12, 13, 14, 15, 16, 17, 19. Se non è possibile intervenire su tutti gli elementi che costituiscono ogni indicatore, è possibile dare un ordine di priorità anche all’interno della singola Sezione. In questo caso l’ordine degli interventi da effettuare è:

13	**Il percorso riguarda una corsia preferenziale in una zona 30, pertanto l’interazione con i veicoli è elevata**
7	**Non esiste una pista ciclabile ma solo una zona 30**
15 16	**Non è presente alcun tipo di segnaletica dedicata ai ciclisti**
12	**Il conflitto con i pendoni deriva dal fatto che è una zona altamente frequentata, e dalla presenza del porticato a lato della carreggiata**
2	**La distanza del percorso è considerata maggiore di 75 m poiché non omogeneo fino a quel punto**
3	**La pavimentazione è composta da sanpietrini**
14	**Non essendo presente una pista, non esiste una separazione di colore rispetto alla carreggiata**
6	**Il percorso è a livello strada**
17	**Non esiste segnaletica di indirizzamento verso i punti di interesse**
9	**Non è presente alcun tipo di segnaletica dedicata ai ciclisti**
19	**L’illuminazione è della strada**

3.1 Stazione Platinum: Bologna centrale

Intervento 2 – Visibilità del piazzale della stazione e segnaletica

Gli indicatori che non raggiungono gli standard massimi sono i numeri: 1, 3, 4.
In questo caso l'ordine degli interventi da effettuare è:

1 **Non esiste segnaletica all'interno o nel piazzale della stazione che indichi la presenza di eventuali percorsi ciclabili**

3 **Non esiste segnaletica all'interno o nel piazzale della stazione che indichi il percorso da effettuare per raggiungere i binari con bici a carico**

4 **I parcheggi per biciclette non sono visibili dall'uscita della stazione**

3.1 Stazione Platinum: Bologna centrale

Intervento 3 – Infrastruttura ciclabile direzione nord

Gli indicatori che non raggiungono gli standard massimi sono i numeri: 5, 7, 9, 12, 14, 16, 17, 18. In questo caso l'ordine degli interventi da effettuare è:

18 **L'illuminazione della pista deriva dall'illuminazione della carreggiata e non è specifica della pista ciclabile**

16 **La segnaletica verticale può essere migliorata**

12 **Il conflitto con i pedoni è dovuto al fatto che la pista non è in sede propria**

14 **La pista non ha un colore differente rispetto alla carreggiata**

5 **La pista è a doppio senso di marcia e non in sede propria**

17 **È utile inserire la segnaletica riguardante i punti di interesse della città**

9 **La pista ha pendenza > 5% poiché si trova su un ponte. All'interno della stazione ferroviaria potrebbe essere inserita segnaletica che indichi un'uscita ciclabile a nord per ovviare il tratto pendente**

7 **La pista ciclabile è separata dai pedoni tramite una linea di delimitazione valicabile**

Cofinanziato dall'Unione europea

3.2 Stazione Gold: Cuneo

Data sopralluogo: 02/2025

Sezione A

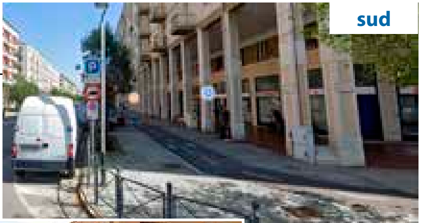
A	Indicatore	Peso	Nord	Sud	Est	Ovest
1	La pista ciclabile vicina (distanza massima da considerare 500m) al nodo di interesse è: (1) esistente o zona 30; (0) assente	0.68	1	1	1	1
2	Se la pista ciclabile/corsia è presente si trova: (1) entro 75 m dalla stazione (0) oltre 75 m	0.64	0	1	1	1
3	La pavimentazione prevalente è: (2) asfaltata o simile; (1) autobloccanti o simili; (0) terra naturale	0.63	2	2	2	2
4	La qualità della pavimentazione della pista ciclabile: (2) buona; (1) media (0) scarsa	0.1	2	2	2	2
5	Tipo di pista ciclabile se presente: (2) unidirezionale per ciascun lato della strada, (1) bidirezionale riservata alle biciclette, (0)bidirezionale	0.58	2	1	1	1
6	Tipo di pista ciclabile se presente: (2) a livello sopraelevato; (1) a livello della strada; (0)non presente	0.56	2	2	1	2
7	La pista ciclabile è: (6) riservata, uni o bidirezionale, su livello rialzato; (5) riservata, uni o bidirezionale, su livello rialzato separata da pedoni con una linea attraversabile dipinta a terra; (4) promiscua, uni o bidirezionale, condivisa con pedoni; (3) corsia riservata, uni o bidirezionale, a livello della carreggiata stradale, separata da automobili con una linea attraversabile dipinta a terra; (2) corsia a senso unico ricavata dalla carreggiata stradale in senso opposto su una strada a senso unico con un limite di velocità di 30 km/h separata da automobili con una linea tratteggiata attraversabile dipinta sul terreno; (1) promiscua, uni o bidirezionale, a livello della carreggiata stradale; (0) nessuna delle precedenti	0.83	6	6	6	5
8	Gli standard geometrici medi (se adiacenti al percorso pedonale) sono adeguati? (1) Sì; (0) No	0.94	1	1	1	1
9	La pendenza della pista ciclabile/strada non supera il 5%? (1) Sì; (0) No	0.31	1	1	1	1
10	Ostacoli puntuali, riduzione degli standard sono: (2) assenti; (1) rari; (0) frequenti	0.82	2	2	2	2
11	Conflitto laterale da negozi o vialetti: (2) assente; (1) leggero; (0) grave	0.67	2	1	1	2
12	Conflitto con il traffico pedonale: (2) assente; (1) leggero; (0) grave	0.66	1	1	1	1
13	Conflitto con il traffico veicolare: (2) assente; (1) leggero; (0) grave	0.78	1	1	1	1
14	La pista ciclabile è: (2) colorata (ben visibile); (1) mediamente visibile; (0) non colorata	0.60	2	2	2	1
15	La segnaletica orizzontale del comportamento dei ciclisti per muoversi correttamente è: (1) presente (0) assente	0.73	1	1	0	1
16	La segnaletica di guida del comportamento dei ciclisti è adeguata? (2) molto buona; (1) discreta; (0) scarsa	0.73	2	2	1	2
17	Segnaletica verso i luoghi di interesse della città: (2) presenti ed eccellenti (marroni); (1) presente solo la mappa della città; (0) assente	0.55	0	0	0	0
18	La pista ciclabile è dotata di illuminazione notturna: (2) buona; (1) media; (0) assente	0.77	2	2	2	1
19	Tipo di illuminazione: (2) propria della pista; (1) stradale pubblica; (0) stradale	0.31	1	1	1	1

3.2 Stazione Gold: Cuneo

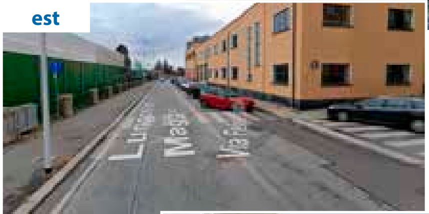
Sezione A

5 6 7 14 15 **Tipologia della pista ciclabile**

sud



est

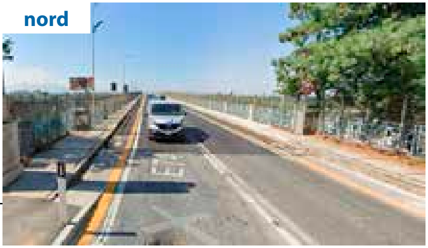


ovest

1 **Verificare l'esistenza della pista ciclabile:** la pista ciclabile è presente in tutte le quattro principali direzioni

16 17 **Segnaletica della pista**

nord



Cofinanziato dall'Unione europea

3.2 Stazione Gold: Cuneo

Sezione B

B	Indicatore	Peso	Valore
1	La segnaletica verticale interna alla stazione che indichi la pista ciclabile è: (2) presente e vicina; (1) presente ma distante o non chiaramente visibile; (0) assente	0,78	2
2	L'illuminazione è presente nella zona esterna alla stazione ferroviaria? (1) Sì; (0) No	0,73	1
3	Quali cartelli verticali sono presenti all'interno della stazione ferroviaria? (2) Indicazioni per gli ascensori, indicazioni per l'uscita (per persone che trasportano biciclette); (1) indicazione per gli ascensori; (0) nessuno	0,78	0
4	I parcheggi per biciclette sono visibili dall'ingresso della stazione ferroviaria? (1) Sì; (0) No	0,74	1
5	Il parcheggio delle biciclette è contrassegnato da un cartello? (1) Sì; (0) No	0,10	0

5 **Visibilità rastrelliere all'esterno della stazione**

3.2 Stazione Gold: Cuneo

Sezione C

C	Indicatore	Peso	Valore
1	Sono presenti rastrelliere per il parcheggio delle biciclette? (1) Sì; (0) No	0,85	1
2	I tipo di rastrelliere è: (0) basso: si può solo legare la ruota (es. Volta, Holanda, Rotterdam); (1) alto: si possono legare sia la ruota che il telaio (es. Eindhoven, Trombone, Provenza) o entrambi	0,91	0
	IL NUMERO DI PARCHEGGI PER BICICLETTE È:		48
3	Il numero di rastrelliere è adatto alle esigenze? (1) Sì; (0) No	1,00	1
4	C'è un kit di riparazione bici (possibilmente solo la colonna della pompa)? (1) Sì; (0) No	0,54	1
5	Accessibilità: ci sono ascensori (dimensione minima 1,40 x 1,10) o scivoli per accedere alle piattaforme? (1) Sì; (0) No	0,89	1
6	Accessibilità: la biglietteria è accessibile in bicicletta (ad es. tramite rampe)? (1) sì; (0) no	0,38	1
7	Ci sono servizi igienici all'interno della stazione? (1) Sì; (0) No	0,75	1
8	È consentito viaggiare con la bicicletta personale sull'autobus? (1) Sì; (0) No	0,25	0

6 **Accessibilità biglietteria**

3.2 Stazione Gold: Cuneo

Compilare l'indicatore

Sezione D

D	Indicatore	Peso	Valore
1	C'è un deposito biciclette (massimo 200m dalla stazione ferroviaria)? (2) Sì; (1) Previsto; (0) No	0,72	2
2	Il deposito è all'interno o all'esterno della stazione ferroviaria? (1) all'interno o entrambi; (0) all'esterno	0,44	0
3	Il deposito bici si trova a: (1) 75 metri dalla stazione ferroviaria; (0) più di 75 metri dalla stazione ferroviaria	0,78	1
4	Esiste più di un deposito? (1) Sì; (0) No	0,50	0
	Il numero di posti del deposito è....		50
5	Il numero di posti è adatto alle esigenze? (1) Sì; (0) No	1,00	0
6	Il deposito dispone di un servizio (1) gratuito o (0) a pagamento di deposito biciclette?	0,73	1
7	Il deposito dispone di servizi per gli utenti (armadietti e spogliatoi, docce e servizi igienici, distributori di bevande)? (1) Sì; (0) No	0,58	0
8	Il deposito dispone di servizi per biciclette (riparazioni, pompe gonfiabili, ricambi e accessori in vendita, noleggio biciclette)? (1) Sì; (0) No	0,58	1
9	Qual è il livello medio di occupazione del deposito bici? (2) <75%; (1) 75%<occup.<99%; (0) >100%	0,69	1
10	Il deposito bici è dotato di videosorveglianza? (1) Sì; (0) No	0,69	1
11	È consentito prenotare un posto in anticipo all'interno del deposito bici? (1) Sì; (0) No	0,66	0
12	Il deposito bici è accessibile: (2) 24/7; (1) solo nelle ore di punta (07:00-08:00; 13:00-14:00; 17:00-18:00); (0) meno di 3 ore al giorno	0,83	2
13	Il deposito biciclette è accessibile tramite: (3) personale o app; (2) chiave/ badge; (1) pass per i mezzi pubblici/tessera sanitaria; (0) biglietto una tantum	0,77	3

① ② ⑤ ⑧ **Esistenza deposito**

Credits: Studio 3mark Cuneo e Oscar Bernelli Fotografo

⑩ ⑫ ⑬ **Per trovare le informazioni sulla velostazione: https://www.comune.cuneo.it/ambiente-mobilita-e-protezione-civile/biciclette/biciclette/velostazione.html**

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3.2 Stazione Gold: Cuneo

Sezione E

E	Indicatore	Peso	Valore
1	È presente il servizio di bike sharing? (1) Sì; (0) No	0,71	0
2	Sono presenti altri servizi di micromobilità? (1) Sì; (0) No	0,81	1
3	Le stazioni di bike sharing si trovano a: (2) meno di 75 metri; (1) 75-500 metri; (0) più di 500 metri dalle stazioni ferroviarie	0,75	0
4	Il numero di bike sharing è adatto alle esigenze? (1) Sì; (0) No	0,94	0
5	La bicicletta in share deve essere lasciata in un hub specifico? (1) Sì; (0) No	0,54	0

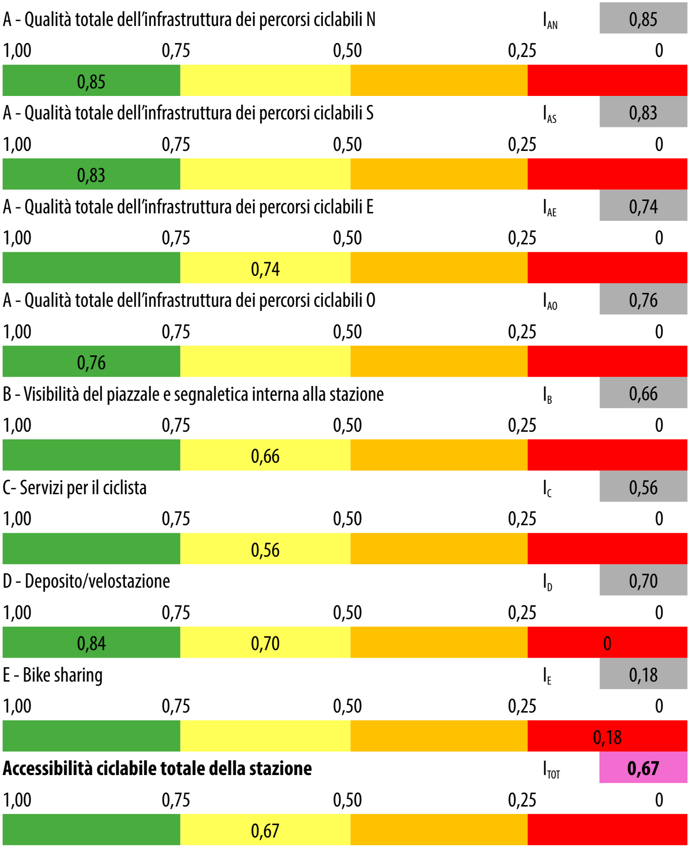
Sezione F

F	Dato	Valore
1	**FLUSSO GIORNALIERO [numero totale di persone che salgono sul treno; pers./giorno]**	2064
2	NUMERO DI RASTRELLIERE NECESSARIE	238
3	NUMERO DI POSTI NECESSARI NEL DEPOSITO BICI	83

L'indicatore da compilare è F1.
Gli indicatori F2 ed F3 sono calcolati automaticamente in funzione di F1.

Per informazioni sul dimensionamento dei punti 3 e 4 vedere pagina 13

3.2 Stazione Gold: Cuneo



Interpretare i risultati

Elementi che necessitano di intervento

- Bike sharing

Elementi che necessitano di intervento

- Servizi dedicati ai ciclisti
- Visibilità del piazzale della stazione e segnaletica
- Deposito
- Qualità dell’infrastruttura ciclabile direzione est

Elementi che non necessitano di intervento

- Qualità dell’infrastruttura ciclabile direzione ovest
- Qualità dell’infrastruttura ciclabile direzione nord
- Qualità dell’infrastruttura ciclabile direzione sud

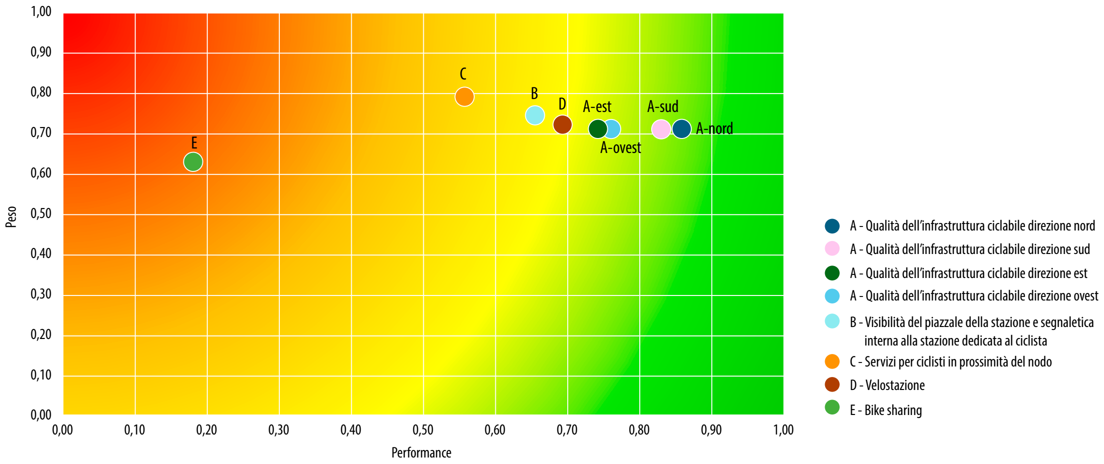
3.2 Stazione Gold: Cuneo

Interpretare i risultati

I risultati sono mostrati nella tabella a sinistra con diversi colori a seconda della priorità di intervento. Per la stazione di Cuneo 3 categorie non necessitano di intervento. Solo la categoria 'Bike sharing' risulta «urgente». Sulle restanti 4 categorie possono essere effettuati alcuni interventi di miglioramento. I risultati sono visualizzabili nel grafico peso-performance.

L'ordine di priorità degli interventi risulta:

1 - Bike sharing
2 - Servizi per i ciclisti in prossimità del nodo
3 - Visibilità del piazzale della stazione e segnaletica propria della stazione
4 - Deposito per biciclette
5 - Qualità infrastruttura ciclabile est
6 - Qualità dell'infrastruttura ciclabile ovest
7 - Qualità infrastruttura ciclabile sud
8 - Qualità infrastruttura ciclabile nord



3.2 Stazione Gold: Cuneo

Intervento 1 – Bike sharing

Gli indicatori che non raggiungono gli standard massimi sono i numeri: 1 e conseguentemente anche i 3, 4, 5. Essendo presnete solo il servizio di monopattini condivisi, sarebbe necessario inserire il servizio di bike sharing al fine di estendere la scelta modale a un maggiore numero di persone.

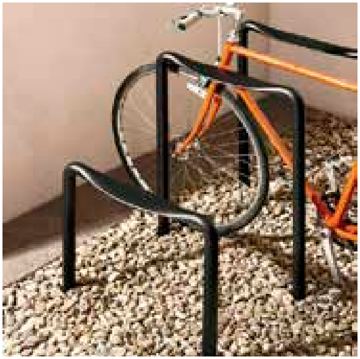
Intervento 2 – Servizi dedicati al ciclista

Gli indicatori che non raggiungono gli standard massimi sono i numeri: 2, 3, 4. L'ordine di priorità di intervento è:

3 **Il numero minimo di posteggi per biciclette pubblici dovrebbe essere 238**

2 **Il tipo di rastrelliera in cui è possibile legare anche il telaio aumenta la percezione della sicurezza dell'utente**

4 **Una colonnina di riparazione o gonfiaggio bici è un servizio utile per i viaggiatori**



3.2 Stazione Gold: Cuneo

Intervento 3 – Visibilità del piazzale della stazione e segnaletica interna alla stazione

Gli indicatori che non raggiungono gli standard massimi sono i numeri: 3, 5. L'ordine di priorità di intervento tra questi è:

③ **Dovrebbe essere inserita segnaletica relativa alla direzione degli ascensori per raggiungere i binari**

⑤ **È possibile segnalare le rastrelliere con segnaletica verticale 'P'**

Stazione di Torino Porta Susa

3.3 Stazione Silver: Collegno

Data sopralluogo: 02/2025

Sezione A

A	Indicatore	Peso	Nord	Sud	Est	Ovest
1	La pista ciclabile vicina (distanza massima da considerare 500m) al nodo di interesse è: (1) esistente o zona 30; (0) assente	0.68	1	1	1	1
2	Se la pista ciclabile/corsia è presente si trova: (1) entro 75 m dalla stazione (0) oltre 75 m	0.64	1	1	1	0
3	La pavimentazione prevalente è: (2) asfaltata o simile; (1) autobloccanti o simili; (0) terra naturale	0.63	2	1	2	2
4	La qualità della pavimentazione della pista ciclabile: (2) buona; (1) media (0) scarsa	0.1	2	2	2	1
5	Tipo di pista ciclabile se presente: (2) unidirezionale per ciascun lato della strada, (1) bidirezionale riservata alle biciclette, (0)bidirezionale	0.58	1	0	1	2
6	Tipo di pista ciclabile se presente: (2) a livello sopraelevato; (1) a livello della strada; (0)non presente	0.56	2	2	2	2
7	La pista ciclabile è: (6) riservata, uni o bidirezionale, su livello rialzato; (5) riservata, uni o bidirezionale, su livello rialzato separata da pedoni con una linea attraversabile dipinta a terra; (4) promiscua, uni o bidirezionale, condivisa con pedoni; (3) corsia riservata, uni o bidirezionale, a livello della carreggiata stradale, separata da automobili con una linea attraversabile dipinta a terra; (2) corsia a senso unico ricavata dalla carreggiata stradale in senso opposto su una strada a senso unico con un limite di velocità di 30 km/h separata da automobili con una linea tratteggiata attraversabile dipinta sul terreno; (1) promiscua, uni o bidirezionale, a livello della carreggiata stradale; (0) nessuna delle precedenti	0.83	4	4	6	5
8	Gli standard geometrici medi (se adiacenti al percorso pedonale) sono adeguati? (1) Sì; (0) No	0.94	1	1	1	1
9	La pendenza della pista ciclabile/strada non supera il 5%? (1) Sì; (0) No	0.31	1	1	1	1
10	Ostacoli puntuali, riduzione degli standard sono: (2) assenti; (1) rari; (0) frequenti	0.82	2	2	2	2
11	Conflitto laterale da negozi o vialetti: (2) assente; (1) leggero; (0) grave	0.67	2	1	2	2
12	Conflitto con il traffico pedonale: (2) assente; (1) leggero; (0) grave	0.66	1	1	2	2
13	Conflitto con il traffico veicolare: (2) assente; (1) leggero; (0) grave	0.78	2	2	2	2
14	La pista ciclabile è: (2) colorata (ben visibile); (1) mediamente visibile; (0) non colorata	0.60	0	0	0	1
15	La segnaletica orizzontale del comportamento dei ciclisti per muoversi correttamente è: (1) presente (0) assente	0.73	0.5	0	1	1
16	La segnaletica di guida del comportamento dei ciclisti è adeguata? (2) molto buona; (1) discreta; (0) scarsa	0.73	1	1	2	1
17	Segnaletica verso i luoghi di interesse della città: (2) presenti ed eccellenti (marroni); (1) presente solo la mappa della città; (0) assente	0.55	2	2	1	2
18	La pista ciclabile è dotata di illuminazione notturna: (2) buona; (1) media; (0) assente	0.77	2	2	2	2
19	Tipo di illuminazione: (2) propria della pista; (1) stradale pubblica; (0) stradale	0.31	1	1	1	1

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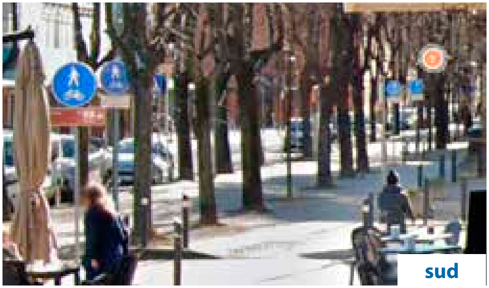
3.3 Stazione Silver: Collegno

Sezione A

5 6 7 14 15 **Tipologia della pista ciclabile**

1 **Verificare l'esistenza della pista ciclabile:** la pista ciclabile è presente in tutte le quattro principali direzioni

16 17 **Segnaletica della pista**



3.3 Stazione Silver: Collegno

Compilare l'indicatore

Sezione B

B	Indicatore	Peso	Valore
1	La segnaletica verticale interna alla stazione che indichi la pista ciclabile è: (2) presente e vicina; (1) presente ma distante o non chiaramente visibile; (0) assente	0.78	2
2	L'illuminazione è presente nella zona esterna alla stazione ferroviaria? (1) Sì; (0) No	0.73	1
3	Quali cartelli verticali sono presenti all'interno della stazione ferroviaria? (2) Indicazioni per gli ascensori, indicazioni per l'uscita (per persone che trasportano biciclette); (1) indicazione per gli ascensori; (0) nessuno	0.78	0
4	I parcheggi per biciclette sono visibili dall'ingresso della stazione ferroviaria? (1) Sì; (0) No	0.74	0
5	Il parcheggio delle biciclette è contrassegnato da un cartello? (1) Sì; (0) No	0.10	0

5 **Visibilità rastrelliere all'esterno della stazione**

3.3 Stazione Silver: Collegno

Sezione C

C	Indicatore	Peso	Valore
1	Sono presenti rastrelliere per il parcheggio delle biciclette? (1) Sì; (0) No	0.85	1
2	I tipo di rastrelliere è: (0) basso: si può solo legare la ruota (es. Volta, Holanda, Rotterdam); (1) alto: si possono legare sia la ruota che il telaio (es. Eindhoven, Trombone, Provenza) o entrambi	0.91	1
	IL NUMERO DI PARCHEGGI PER BICICLETTE È:		43
3	Il numero di rastrelliere è adatto alle esigenze? (1) Sì; (0) No	1.00	0
4	C'è un kit di riparazione bici (possibilmente solo la colonna della pompa)? (1) Sì; (0) No	0.54	0
5	Accessibilità: ci sono ascensori (dimensione minima 1,40 x 1,10) o scivoli per accedere alle piattaforme? (1) Sì; (0) No	0.89	1
6	Accessibilità: la biglietteria è accessibile in bicicletta (ad es. tramite rampe)? (1) sì; (0) no	0.38	1
7	Ci sono servizi igienici all'interno della stazione? (1) Sì; (0) No	0.75	0
8	È consentito viaggiare con la bicicletta personale sull'autobus? (1) Sì; (0) No	0.25	0

1 2 **Presenza parcheggio biciclette**

5 **Accessibilità ascensori**

3.3 Stazione Silver: Collegno

Compilare l'indicatore

Sezione D

D	Indicatore	Peso	Valore
1	C'è un deposito biciclette (massimo 200m dalla stazione ferroviaria)? (2) Sì; (1) Previsto; (0) No	0.72	2
2	Il deposito è all'interno o all'esterno della stazione ferroviaria? (1) all'interno o entrambi; (0) all'esterno	0.44	0
3	Il deposito bici si trova a: (1) 75 metri dalla stazione ferroviaria; (0) più di 75 metri dalla stazione ferroviaria	0.78	1
4	Esiste più di un deposito? (1) Sì; (0) No	0.50	0
	Il numero di posti del deposito è....		16
5	Il numero di posti è adatto alle esigenze? (1) Sì; (0) No	1.00	0
6	Il deposito dispone di un servizio (1) gratuito o (0) a pagamento di deposito biciclette?	0.73	0
7	Il deposito dispone di servizi per gli utenti (armadietti e spogliatoi, docce e servizi igienici, distributori di bevande)? (1) Sì; (0) No	0.58	0
8	Il deposito dispone di servizi per biciclette (riparazioni, pompe gonfiabili, ricambi e accessori in vendita, noleggio biciclette)? (1) Sì; (0) No	0.58	0
9	Qual è il livello medio di occupazione del deposito bici? (2) <75%; (1) 75%<occup.<99%; (0) >100%	0.69	2
10	Il deposito bici è dotato di videosorveglianza? (1) Sì; (0) No	0.69	1
11	È consentito prenotare un posto in anticipo all'interno del deposito bici? (1) Sì; (0) No	0.66	0
12	Il deposito bici è accessibile: (2) 24/7; (1) solo nelle ore di punta (07:00-08:00; 13:00-14:00; 17:00-18:00); (0) meno di 3 ore al giorno	0.83	2
13	Il deposito biciclette è accessibile tramite: (3) personale o app; (2) chiave/badge; (1) pass per i mezzi pubblici/tessera sanitaria; (0) biglietto una tantum	0.77	3

① **Esistenza deposito**

② **Localizzazione deposito**

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3.3 Stazione Silver: Collegno

Sezione E

E	Indicatore	Peso	Valore
1	È presente il servizio di bike sharing? (1) Sì; (0) No	0.71	0
2	Sono presenti altri servizi di micromobilità? (1) Sì; (0) No	0.81	1
3	Le stazioni di bike sharing si trovano a: (2) meno di 75 metri; (1) 75-500 metri; (0) più di 500 metri dalle stazioni ferroviarie	0.75	0
4	Il numero di bike sharing è adatto alle esigenze? (1) Sì; (0) No	0.94	0
5	La bicicletta in share deve essere lasciata in un hub specifico? (1) Sì; (0) No	0.54	0

Presenza altri mezzi di micromobilità 2

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3.3 Stazione Silver: Collegno

Sezione F

F	Dato	Valore
1	**FLUSSO GIORNALIERO [numero totale di persone che salgono sul treno; pers./giorno]**	768
2	NUMERO DI RASTRELLIERE NECESSARIE	88.32
3	NUMERO DI POSTI NECESSARI NEL DEPOSITO BICI	30.72

L'indicatore da compilare è F1.
Gli indicatori F2 ed F3 sono calcolati automaticamente in funzione di F1.

Per informazioni sul dimensionamento dei punti 3 e 4 vedere pagina 13

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3.3 Stazione Silver: Collegno

Interpretare i risultati

A - Qualità totale dell'infrastruttura dei percorsi ciclabili N			I_{AN}	0,77
1,00	0,75	0,50	0,25	0
0,77				
A - Qualità totale dell'infrastruttura dei percorsi ciclabili S			I_{AS}	0,67
1,00	0,75	0,50	0,25	0
	0,67			
A - Qualità totale dell'infrastruttura dei percorsi ciclabili E			I_{AE}	0,89
1,00	0,75	0,50	0,25	0
0,89				
A - Qualità totale dell'infrastruttura dei percorsi ciclabili O			I_{AO}	0,87
1,00	0,75	0,50	0,25	0
0,87				
B - Visibilità del piazzale e segnaletica interna alla stazione			I_{B}	0,50
1,00	0,75	0,50	0,25	0
		0,50		
C- Servizi per il ciclista			I_{C}	0,54
1,00	0,75	0,50	0,25	0
	0,54			
D - Deposito/velostazione			I_{D}	0,65
1,00	0,75	0,50	0,25	0
	0,65		0	
E - Bike sharing			I_{E}	0,18
1,00	0,75	0,50	0,25	0
			0,18	
Accessibilità ciclabile totale della stazione			I_{TOT}	**0,64**
1,00	0,75	0,50	0,25	0
	0,64			

Elementi che necessitano di intervento

- Bike sharing

Elementi che necessitano di intervento

- Visibilità del piazzale della stazione e segnaletica

Elementi che necessitano di intervento

- Qualità dell'infrastruttura ciclabile direzione sud
- Servizi dedicati ai ciclisti

Elementi che non necessitano di intervento

- Qualità dell'infrastruttura ciclabile direzione nord
- Qualità dell'infrastruttura ciclabile direzione ovest
- Qualità dell'infrastruttura ciclabile direzione est

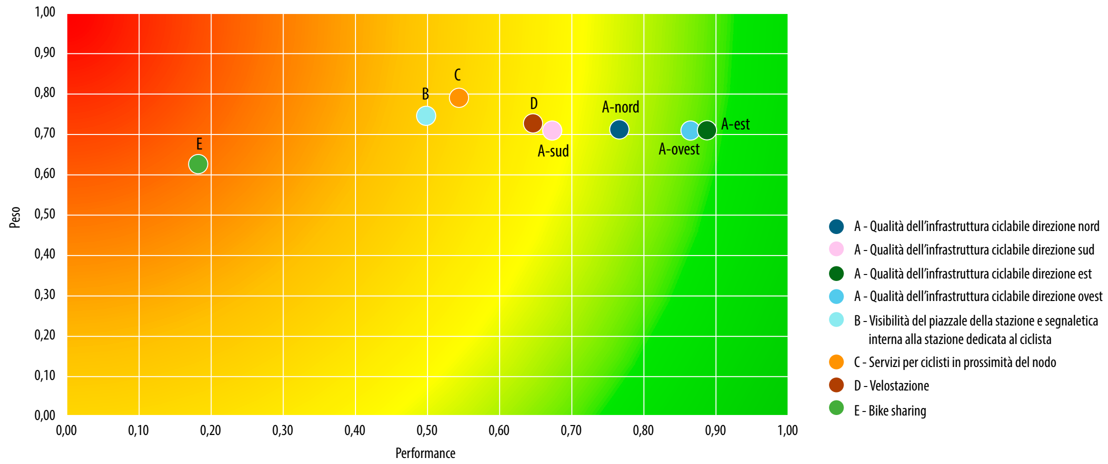
3.3 Stazione Silver: Collegno

Interpretare i risultati

I risultati sono mostrati nella tabella con diversi colori a seconda della priorità di intervento. Per la stazione di Collegno, 3 categorie ricadono nella 'zona verde'. Il bike sharing non è presente, ma è presente il servizio di monopattini in condivisione.

L'ordine di priorità degli interventi risulta:

1 - Bike sharing
2 - Visibilità del piazzale della stazione e segnaletica propria della stazione
3 - Servizi per i ciclisti in prossimità del nodo
4 - Deposito per biciclette
5 - Qualità infrastruttura ciclabile sud
6 - Qualità infrastruttura ciclabile nord
7 - Qualità dell'infrastruttura ciclabile ovest
8 - Qualità infrastruttura ciclabile est



3.3 Stazione Silver: Collegno

Intervento 1 – Bike sharing

Gli indicatori che non raggiungono gli standard massimi sono i numeri: 1 e conseguentemente anche i 3, 4, 5. Essendo presente solo il servizio di monopattini condivisi, sarebbe necessario inserire il servizio di bike sharing al fine di estendere la scelta modale a un maggiore numero di persone.

Intervento 2 – Visibilità del piazzale della stazione e segnaletica interna alla stazione

Gli indicatori che non raggiungono gli standard massimi sono i numeri: 3, 4, 5. L'ordine di priorità di intervento tra questi è:

3 **Dovrebbe essere inserita segnaletica relativa alla direzione degli ascensori per raggiungere i binari**

4 **È importante rendere visibili i posteggi bici dall'uscita della stazione**

5 **È possibile segnalare le rastrelliere con segnaletica verticale 'P'**

3.3 Stazione Silver: Collegno

Intervento 3 – Servizi dedicati al ciclista

Gli indicatori che non raggiungono gli standard massimi sono i numeri: 3, 4, 7, 8. L'ordine di priorità si intervento è:

- 3 **Il numero minimo di posteggi per biciclette pubblici dovrebbe essere 89**
- 7 **I servizi igienici sono assenti e dovrebbero essere progettati**
- 4 **Una colonnina di riparazione o gonfiaggio bici è un servizio utile per i viaggiatori**
- 8 **La possibilità di caricare la bicicletta sugli autobus in un nodo multimodale consente maggiore scelta e flessibilità**

3.4 Stazione Bronze: Ozzano dell'Emilia

Data sopralluogo: 01/2023

Sezione A

A	Indicatore	Peso	Nord	Sud	Est	Ovest
1	La pista ciclabile vicina (distanza massima da considerare 150m) al nodo di interesse è: (1) esistente o zona 30; (0) assente	0,68	1	1	1	1
2	Se la pista ciclabile/corsia è presente si trova: (1) entro 75 m dalla stazione (0) oltre 75 m	0,64	1	1	1	1
3	La pavimentazione prevalente è: (2) asfaltata o simile; (1) autobloccanti o simili; (0) terra naturale	0,63	1	1	1	1
4	La qualità della pavimentazione della pista ciclabile: (2) buona; (1) media (0) scarsa	0,10	2	2	2	2
5	Tipo di pista ciclabile se presente: (2) unidirezionale per ciascun lato della strada, (1) bidirezionale riservata alle biciclette, (0)bidirezionale	0,58	0	0	0	0
6	Tipo di pista ciclabile se presente: (2) a livello sopraelevato; (1) a livello della strada; (0) non presente	0,56	2	2	2	2
7	La pista ciclabile è: (6) riservata, uni o bidirezionale, su livello rialzato; (5) riservata, uni o bidirezionale, su livello rialzato separata da pedoni con una linea attraversabile dipinta a terra; (4) promiscua, uni o bidirezionale, condivisa con pedoni; (3) corsia riservata, uni o bidirezionale, a livello della carreggiata stradale, separata da automobili con una linea attraversabile dipinta a terra; (2) corsia a senso unico ricavata dalla carreggiata stradale in senso opposto su una strada a senso unico con un limite di velocità di 30 km/h separata da automobili con una linea tratteggiata attraversabile dipinta sul terreno; (1) promiscua, uni o bidirezionale, a livello della carreggiata stradale; (0) nessuna delle precedenti	0,83	4	4	4	4
8	Gli standard geometrici medi (se adiacenti al percorso pedonale) sono adeguati? (1) Sì; (0) No	0,94	1	1	1	1
9	La pendenza della pista ciclabile/strada non supera il 5%? (1) Sì; (0) No	0,31	1	1	1	1
10	Ostacoli puntuali, riduzione degli standard sono: (2) assenti; (1) rari; (0) frequenti	0,82	2	2	2	2
11	Conflitto laterale da negozi o vialetti: (2) assente; (1) leggero; (0) grave	0,67	2	2	2	2
12	Conflitto con il traffico pedonale: (2) assente; (1) leggero; (0) grave	0,66	2	2	2	2
13	Conflitto con il traffico veicolare: (2) assente; (1) leggero; (0) grave	0,78	2	2	2	2
14	La pista ciclabile è: (2) colorata (ben visibile); (1) mediamente visibile; (0) non colorata	0,60	2	2	2	2
15	La segnaletica orizzontale del comportamento dei ciclisti per muoversi correttamente è: (1) presente (0) assente	0,73	1	1	1	1
16	La segnaletica di guida del comportamento dei ciclisti è adeguata? (2) molto buona; (1) discreta; (0) scarsa	0,73	2	2	2	2
17	Segnaletica verso i luoghi di interesse della città: (2) presenti ed eccellenti (marroni); (1) presente solo la mappa della città; (0) assente	0,55	1	1	1	1
18	La pista ciclabile è dotata di illuminazione notturna: (2) buona; (1) media; (0) assente	0,77	2	2	2	2
19	Tipo di illuminazione: (2) propria della pista; (1) stradale pubblica; (0) stradale	0,31	2	2	2	2

3.4 Stazione Bronze: Ozzano dell'Emilia

Sezione A

5
6
7
14
15

Tipologia della pista ciclabile

● Ingresso principale

▨ Pista ciclabile

18
19

Illuminazione della pista

1 **Verificare l'esistenza della pista ciclabile:** la pista ciclabile è presente in tutte le quattro principali direzioni

3.4 Stazione Bronze: Ozzano dell'Emilia

Sezione B

B	Indicatore	Peso	Valore
1	La segnaletica verticale interna alla stazione che indichi la pista ciclabile è: (2) presente e vicina; (1) presente ma distante o non chiaramente visibile; (0) assente	0,78	2
2	L'illuminazione è presente nella zona esterna alla stazione ferroviaria? (1) Sì; (0) No	0,73	1
3	Quali cartelli verticali sono presenti all'interno della stazione ferroviaria? (2) Indicazioni per gli ascensori, indicazioni per l'uscita (per persone che trasportano biciclette); (1) indicazione per gli ascensori; (0) nessuno	0,78	1
4	I parcheggi per biciclette sono visibili dall'ingresso della stazione ferroviaria? (1) Sì; (0) No	0,74	1
5	Il parcheggio delle biciclette è contrassegnato da un cartello? (1) Sì; (0) No	0,10	1

① ③ **Verifica della segnaletica interna alla stazione:** visibilità, accuratezza e presenza della segnaletica dedicata al ciclista

② **Illuminazione esterna della stazione**

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3.4 Stazione Bronze: Ozzano dell'Emilia

Sezione C

C	Indicatore	Peso	Valore
1	Sono presenti rastrelliere per il parcheggio delle biciclette? (1) Sì; (0) No	0,85	1
2	I tipo di rastrelliere è: (0) basso: si può solo legare la ruota (es. Volta, Holanda, Rotterdam); (1) alto: si possono legare sia la ruota che il telaio (es. Eindhoven, Trombone, Provenza) o entrambi.	0,91	1
	IL NUMERO DI PARCHEGGI PER BICICLETTE È:		32
3	Il numero di rastrelliere è adatto alle esigenze? (1) Sì; (0) No	1,00	1
4	C'è un kit di riparazione bici (possibilmente solo la colonna della pompa)? (1) Sì; (0) No	0,54	0
5	Accessibilità: ci sono ascensori (dimensione minima 1,40x1,10) o scivoli per accedere alle piattaforme? (1) Sì; (0) No	0,89	1
6	Accessibilità: la biglietteria è accessibile in bicicletta (ad es. tramite rampe)? (1) sì; (0) no	0,38	1
7	Ci sono servizi igienici all'interno della stazione? (1) Sì; (0) No	0,75	0
8	È consentito viaggiare con la bicicletta personale sull'autobus? (1) Sì; (0) No	0,25	0

① **Presenza parcheggio biciclette**

⑤ **Accessibilità ascensori**

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3.4 Stazione Bronze: Ozzano dell'Emilia

Sezione D

D	Indicatore	Peso	Valore
1	C'è un deposito biciclette (massimo 200m dalla stazione ferroviaria)? (2) Sì; (1) Previsto; (0) No	0,72	0
2	Il deposito è all'interno o all'esterno della stazione ferroviaria? (1) all'interno o entrambi; (0) all'esterno	0,44	0
3	Il deposito bici si trova a: (1) 75 metri dalla stazione ferroviaria; (0) più di 75 metri dalla stazione ferroviaria	0,78	0
4	Esiste più di un deposito? (1) Sì; (0) No	0,50	0
	Il numero di posti del deposito è....		0
5	Il numero di posti è adatto alle esigenze? (1) Sì; (0) No	1,00	0
6	Il deposito dispone di un servizio (1) gratuito o (0) a pagamento di deposito biciclette?	0,73	0
7	Il deposito dispone di servizi per gli utenti (armadietti e spogliatoi, docce e servizi igienici, distributori di bevande)? (1) Sì; (0) No	0,58	0
8	Il deposito dispone di servizi per biciclette (riparazioni, pompe gonfiabili, ricambi e accessori in vendita, noleggio biciclette)? (1) Sì; (0) No	0,58	0
9	Qual è il livello medio di occupazione del deposito bici? (2) <75%; (1) 75%<occup.<99%; (0) >100%	0,69	0
10	Il deposito bici è dotato di videosorveglianza? (1) Sì; (0) No	0,69	0
11	È consentito prenotare un posto in anticipo all'interno del deposito bici? (1) Sì; (0) No	0,66	0
12	Il deposito bici è accessibile: (2) 24/7; (1) solo nelle ore di punta (07:00-08:00; 13:00-14:00; 17:00-18:00); (0) meno di 3 ore al giorno	0,83	0
13	Il deposito biciclette è accessibile tramite: (3) personale o app; (2) chiave/badge; (1) pass per i mezzi pubblici/tessera sanitaria; (0) biglietto una tantum	0,77	0

3.4 Stazione Bronze: Ozzano dell'Emilia

Sezione E

E	Indicatore	Peso	Valore
1	E' presente il servizio di bike sharing? (1) Sì; (0) No	0,71	0
2	Sono presenti altri servizi di micromobilità? (1) Sì; (0) No	0,81	0
3	Le stazioni di bike sharing si trovano a: (2) meno di 75 metri; (1) 75-500 metri; (0) più di 500 metri dalle stazioni ferroviarie	0,75	0
4	Il numero di bike sharing è adatto alle esigenze? (1) Sì; (0) No	0,94	0
5	La bicicletta in share deve essere lasciata in un hub specifico? (1) Sì; (0) No	0,54	0

Sezione F

F	Dato	Valore
1	**FLUSSO GIORNALIERO [numero totale di persone che salgono sul treno; pers./giorno]**	300
2	NUMERO DI RASTRELLIERE NECESSARIE	34
3	NUMERO DI POSTI NECESSARI NEL DEPOSITO BICI	12

L'indicatore da compilare è F1.
Gli indicatori F2 ed F3 sono calcolati automaticamente in funzione di F1.

Per informazioni sul dimensionamento dei punti 3 e 4 vedere pagina 13

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3.4 Stazione Bronze: Ozzano dell'Emilia

A - Qualità totale dell'infrastruttura dei percorsi ciclabili N I_{AN} 0,83

1,00	0,75	0,50	0,25	0
🟩 0,83	🟨	🟧	🟥	

A - Qualità totale dell'infrastruttura dei percorsi ciclabili S I_{AS} 0,83

1,00	0,75	0,50	0,25	0
🟩 0,83	🟨	🟧	🟥	

A - Qualità totale dell'infrastruttura dei percorsi ciclabili E I_{AE} 0,83

1,00	0,75	0,50	0,25	0
🟩 0,83	🟨	🟧	🟥	

A - Qualità totale dell'infrastruttura dei percorsi ciclabili O I_{AO} 0,83

1,00	0,75	0,50	0,25	0
🟩 0,83	🟨	🟧	🟥	

B - Visibilità del piazzale e segnaletica interna alla stazione I_{B} 0,83

1,00	0,75	0,50	0,25	0
🟩 0,83	🟨	🟧	🟥	

C- Servizi per il ciclista I_{C} 0,72

1,00	0,75	0,50	0,25	0
🟩	🟨 0,72	🟧	🟥	

D - Deposito/velostazione I_{D} 0

1,00	0,75	0,50	0,25	0
🟩	🟨	🟧	🟥 0	

E - Bike sharing I_{E} 0

1,00	0,75	0,50	0,25	0
🟩	🟨	🟧	🟥 0	

Accessibilità ciclabile totale della stazione I_{TOT} **0,62**

1,00	0,75	0,50	0,25	0
🟩	🟨 0,62	🟧	🟥	

Interpretare i risultati

Elementi che necessitano di intervento

- Deposito
- Bike sharing

Elementi che necessitano di intervento

- Servizi dedicati ai ciclisti

Elementi che non necessitano di intervento

- Qualità dell'infrastruttura ciclabile direzione nord
- Qualità dell'infrastruttura ciclabile direzione sud
- Qualità dell'infrastruttura ciclabile direzione ovest
- Qualità dell'infrastruttura ciclabile direzione est
- Visibilità del piazzale della stazione e segnaletica

Cofinanziato dall'Unione europea

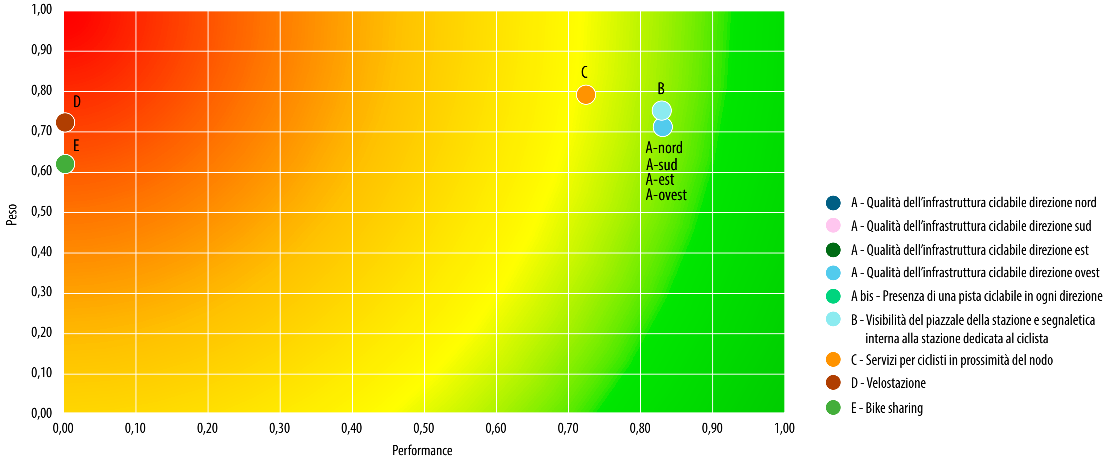
3.4 Stazione Bronze: Ozzano dell'Emilia

Interpretare i risultati

I risultati sono mostrati nella tabella con diversi colori a seconda della priorità di intervento. Per la stazione di Ozzano dell'Emilia solo 3 categorie necessitano di intervento e ricadono ricadendo una nella zona gialla e due nella zona rossa. Le restanti 5 categorie sono considerate come «non necessarie di intervento». Essendo sia il deposito sia il bike sharing valutate con «0», la priorita di intervento si stabilisce in base alla categoria con il peso maggiore (vedere sezione A).

L'ordine di priorità degli interventi risulta:

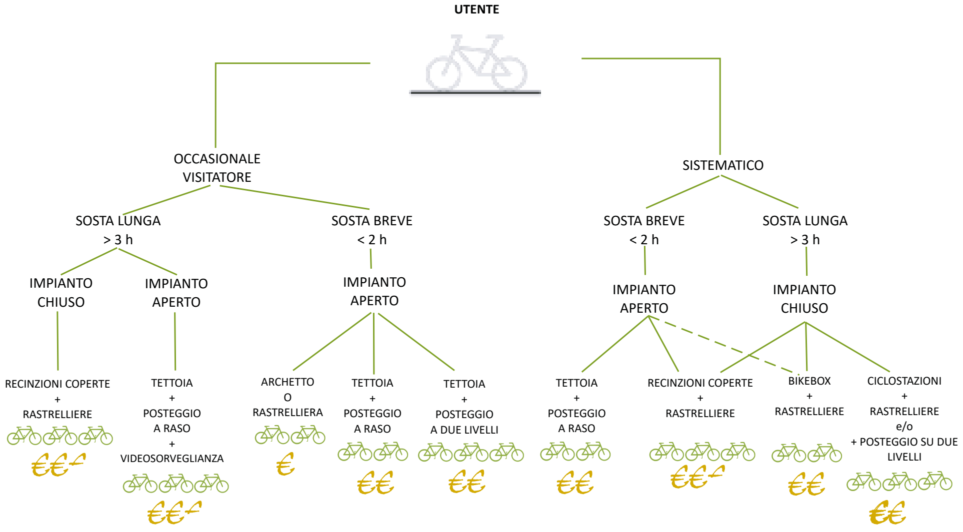
1 - Deposito per biciclette
2 - Bike sharing
3 - Servizi per i ciclisti in prossimità del nodo
4 - Visibilità del piazzale della stazione e segnaletica propria della stazione
5 - Qualità infrastruttura ciclabile nord
6 - Qualità infrastruttura ciclabile est
7 - Qualità infrastruttura ciclabile sud
8 - Qualità dell'infrastruttura ciclabile ovest



3.4 Stazione Bronze: Ozzano dell'Emilia

Intervento 1 – Deposito biciclette

Il primo elemento da attenzionare riguarda il deposito per biciclette. In questo caso il deposito è non presente. È necessario definire uno spazio e una tipologia di deposito, correttamente dimensionata.
Si consiglia di consultare le **linee guida cicloposteggi** della Regione Piemonte. Di seguito si riporta un estratto che mostra uno schema ramificato per la scelta del cicloposteggio più idoneo partendo dalla classificazione del tipo di utente principale.[1]



LEGENDA

Quantità di stalli a parità di spazio disponibile

€ Costo d'investimento

Gradimento dell'utenza

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[1] Regione Piemonte, FIAB, AMP. (2018, Maggio). *Linee Guida Cicloposteggi.* https://www.regione.piemonte.it/web/temi/mobilita-trasporti/mobilita-ciclistica/mobilita-ciclistica

3.4 Stazione Bronze: Ozzano dell'Emilia

Intervento 2 – Bike sharing

Non è presente servizio di bike sharing. Per una corretta progettazione e inserimento di questo servizio è consigliabile consultare «Obis: Optimising Bike Sharing in European Cities».[1]

Intervento 3 – Servizi dedicati al ciclista

Gli indicatori che non raggiungono gli standard massimi sono i numeri: 4, 7, 8. In questo caso l'ordine degli interventi da effettuare è:

7 **Non sono presenti i servizi igienici all'interno della stazione**

4 **Non è presente una colonnina per riparazione e gonfiaggio di biciclette**

8 **Non è consentito caricare la bicicletta sul bus**

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[1] Intelligent Energy Europe Programme (IEE). (2011, Giugno). *Obis: Optimising Bike Sharing in European Cities.* http://mobility-workspace.eu/wp-content/uploads/OBIS_Handbook_EN.pdf

Bibliografia

Riferimenti utili

[1] S. M. Eleonora Belloni, «MUOVERSI DOMANI» [Online].

[2] M. Pazzini, C. Lantieri, V. Vignali, A. Simone, G. Dondi, G. Luppino e Grasso, «Comparison between different territorial policies to support intermodality of public transport» [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2352146521009108?ref=pdf_download&fr=RR-2&rr=95d78b7f78b8f940.

[3] J. Wang, L. Mirza, A. Cheung e S. Moradi, «Understanding factors influencing choices of cyclists and potential cyclists: a case study at the University of Auckland».

[4] UNECE, «UNECE SUSTAINABLE DEVELOPMENT GOALS» [Online]. Available: https://unece.org/road-safety-performance-review.

[5] Agenzia per il controllo e la qualità dei servizi pubblici locali del Comune di Roma, «Indagine sulle piste ciclabili a Roma» Roma, 2010.

[6] Vélo & Territoires, «https://www.velo-territoires.org/actualite/2021/06/10/lom-90-000-places-de-stationnements-velo-securises-gares/#» [Online].

[7] Regione Piemonte, AMP e FIAB, «Linee Guida Cicloposteggi» [Online]. Available: https://www.regione.piemonte.it/web/sites/default/files/media/documenti/2023-04/linee_guida_cicloposteggi_0.pdf.

[8] Ufficio federale delle strade USTRA, «Posteggi per cicli: Raccomandazioni per la pianificazione, la realizzazione e l'esercizio. Manuale» Svizzera, 2008.

[9] Regione Emilia Romagna. Linee Guida per il Sistema Regionale Della Ciclabilità (L.r. n. 10/2017) - In Coordinamento con il Progetto Life Integrato PREPAIR. Maggio 2019. [online]: https://mobilita.regione.emilia-romagna.it/allegati/convegni_presentazioni/2019/mag2019_lineeguidaciclabilita/lineeguidaciclabilita_allegato1.pdf/@@download/file/lineeguidaciclabilita_allegato1.pdf

Appunti

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Cofinanziato
dall'Unione europea

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Regione Emilia-Romagna

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