Cleaner and Responsible Consumption 2 (2021) 100019

Contents lists available at ScienceDirect

Cleaner and Responsible Consumption

journal homepage: www.journals.elsevier.com/cleaner-and-responsible-consumption

The Go2School project for promoting cycling to school: A case study in Palermo[☆]

Marco Migliore [*], Gabriele D'Orso, Alessandro E. Capodici

Department of Engineering, University of Palermo, Transport Research Group, Viale Delle Scienze Building 8, 90128, Palermo, Italy

ARTICLE INFO

Keywords:
Bikesharing
Cycling to school
School trips
Mode choice
Sustainability

ABSTRACT

The identification of transport policy measures able to reduce the use of private cars for home-to-school travel is very relevant to reduce congestion during peak hours and to ensure that the areas around schools have livable environments. An action that policymakers could apply is promoting cycling to school through the introduction of bikesharing programs and creating safe routes to school through the construction of new cycle infrastructure. The aim of the paper has been, therefore, to assess if these policies could lead the high-school students to cycle to school, considering the city of Palermo as a case study. The goal is reached through the calibration of a modal choice model based on Stated Preference interviews. The costs that the local authority have to support have been compared with the benefits that the realization of new cycle paths entails in terms of the modal shift, reduction of car mileage and reduction of the externalities. According to the model, the construction of the new cycle paths will lead to an impressive increase in the use of the bicycle for home-to-school travel and also to greater use of public transport, due to the multimodality guaranteed by the bikesharing stations near the railway stations and tram stops.

1. Introduction

In an urban context, schools are certainly among the most important traffic attractors at rush hour. For this reason, the choice of the mode of transport used for home-to-school travel can have a major impact on traffic congestion and the livability of the areas around the schools. In those cities where the private car is the most used mode of transport for home-to-school travel, the levels of air and noise pollution often exceed the limits set by law in the areas around schools (Boniardi et al., 2019). Therefore, policymakers have to provide valid alternatives to the private car, allowing students to reach the school without being accompanied by their parents by car.

The actions that policymakers could put in place are certainly multiple: firstly, to allow students living near the school to reach it by walking, the local authority could improve the pedestrian accessibility of the school through the creation of safe pedestrian routes to school and the realization of walkable urban areas (D'Orso and Migliore, 2020). This can be put into practice by controlling the quality of pedestrian walkways, investments in existing pedestrian infrastructure and the establishment of “Pedibus”, i.e. a caravan of students walking to school chaperoned by adults that could promote the sustainable mobility and the importance of making exercise among children; further action may consist in encouraging public transport, through discounted season tickets for students, a timetable and a set of runs that meet the needs of the students, the placement of stops near the schools. Another strategy to be applied can be the promotion of carpooling (Dewan and Ahmad, 2007), which is possible through the introduction of the mobility manager in schools, who can favor the planning of shared trips knowing the origins of the movements of the students.

The promotion of cycling and new mobility services, such as bikesharing, can also be a valid aid in reducing the number of private cars involved in home-to-school travel and, consequently, in reducing atmospheric and acoustic emissions (Zhang and Mi, 2018). Also, the benefits that the use of transport modes such as walking and cycling has on the health of students, as active modes of transport, need to be taken into account (Fulton et al., 2005; Schofield et al., 2005).

The aim of this paper is to analyze the effectiveness of the promotion of cycling, through the construction of new infrastructures, and the

---

[☆] This work was carried out within the research project n. 20174ARRHT, “WEAKI TRANSIT: WEAK-demand areas Innovative TRANsport Shared services for Italian Towns”, which is funded by the PRIN (Programmi di Ricerca Scientifica di Rilevante Interesse Nazionale) of the Italian Ministry of Education, University and Research.

[*] Corresponding author.
E-mail addresses: marco.migliore@unipa.it (M. Migliore), gabriele.dorso@unipa.it (G. D'Orso), alessandro.capodici@unipa.it (A.E. Capodici).

https://doi.org/10.1016/j.clrc.2021.100019
Received 29 December 2020; Received in revised form 6 May 2021; Accepted 6 May 2021
2666-7843/© 2021 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

introduction of a bikesharing program for schools. Thus, we aim to assess the influence of the new bike lanes in the future modal share and also, thanks to a calibrated modal choice model, evaluating the effective utilization of the new bike routes, taking into account the potential mobility demand and the distribution of O-D (Origin-Destination) pairs. Moreover, we assessed the economic feasibility of the new bikesharing system and the new cycle paths. The city of Palermo doesn't present criticisms in its topography, thanks to the flatness of its territory, so people can easily cycle. The main issues are the status of the existing bike lanes and the poor connection between the routes of the cycling network. These issues explain the very low bike modal share, highlighted in Fig. 1, with only 0.9% of residents travelling to school by bike (ISTAT, 2011), whilst most of the residents go to school walking or by car as a passenger.

So, it has been evaluated for a real case study if the investment costs for the construction of new cycle infrastructure prevail over the benefits that a modal shift in favor of cycling and bikesharing brings.

The Go2School project, a station-based bikesharing program for schools to be activated in the city of Palermo, has been chosen as a case study. This project involves the extension of the Palermo cycle network through the construction of new cycle paths near the schools that are involved in the initiative. Thanks to this bikesharing program, it can be possible to increase the actual modest bicycle usage in all age groups. Our work also tries to find the reasons of this low bike usage through a survey submitted to high school students and a demand model, in which we highlighted safety attributes. The model implemented in this study has also given great importance to travel time, determining it with accuracy for each O-D pair and each considered mode of transport. Moreover, our study has taken into account the bikesharing mode in the model for the representation of modal choices of high-school students.

After the review of the scientific literature concerning the application of demand orientation policies for home-to-school travel and the models for representing students' modal choices in Section 2, the case study is presented in Section 3. The method for assessing the effectiveness of the infrastructure measures and their feasibility is described in Section 4. In Section 5 and Section 6 the findings and the conclusions are illustrated.

2. Background

Driving-to-school is generally one of the main causes of urban congestion. Considering Beijing as a case study, Lu et al. (2017) found that workdays during school holidays have a traffic congestion index 20% lower than that of non-school-holiday workdays. Identifying the spatial separation of schools and homes as one of the reasons motivating students to move towards motorized transport in home-to-school trips, they proposed to increase the number of school buses.

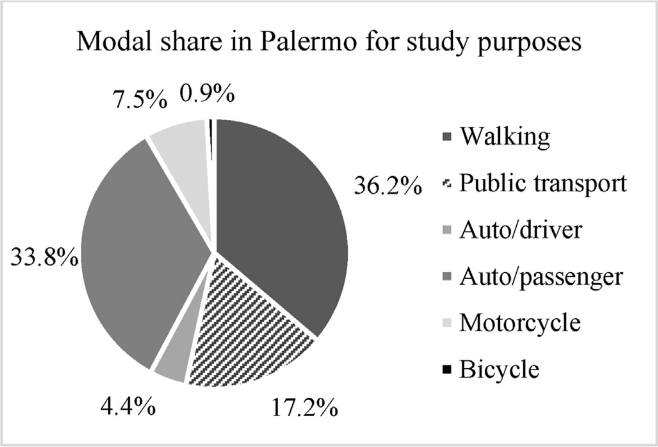

Fig. 1. Modal share of the residents in Palermo travelling for study purposes (ISTAT, 2011).

In fact, adolescents enrolled in the closest schools have five times higher rates of active transport and lower rates of motorized transport to school compared to their counterparts (Mandic et al., 2017).

One of the policies to guide students towards sustainable modes of transport in order to reduce urban congestion is mobility management at the school level. As investigated by Texeira et al. (2019), soft mobility management measures such as park and stride (parking the car 1 km away from school and walking the remaining distance), the dissemination of a school route map containing the most accessible and convenient routes, the introduction of safe parking banners that alert parents about parking illegally near the school perimeter, and contests among students about the sustainability of their school trips are important tools in order to change the students' mobility habits.

However, many factors significantly stimulate the use of cars in school commuting. Among these factors, Zhang et al. (2017) identified car ownership, poor walking/cycling environment, and adults' convenience for escorting students. Students are more inclined to choose cars when their departure time is at rush hour compared to the other time. Moreover, the longer distance encourages the use of motorized transport as well as a high household income.

As Zhang et al. noted, a problematic issue is the poor pedestrian accessibility to schools. Improving walkability of the area around schools can reduce the number of students chauffeured by car (Vitale et al., 2019). Moreover, safety around the school is not to be overlooked. Boansi et al. (2019) identified risky travel behaviors such as jaywalking, dropping off at areas not designated as bus stops or riding bicycles without helmets as the most common causes of traffic collisions and fatalities around the schools.

In addition to trip distance and household income, other factors influence the mode choice for school journeys. Lidbe et al. (2020) found that also school grade, gender, ethnicity, home ownership, region (urban or rural), household vehicle count, and gas price strongly affect students' choice behavior. Besides, they highlighted that students prefer walking to school for distances up to one mile, whereas the likelihood of auto alternative decreases with students' age. Moreover, the propensity to cycling is greater for male students than for female ones.

A shift from car to cycling makes it possible to decrease congestion levels in the morning peak hours and mitigate externalities of the transportation system, as Rabl and de Nazelle (2012) highlighted. In fact, they estimated the benefits due to the change in mobility habits taking into account the change in exposure to air pollution for the individuals, the health benefit due to a higher level of physical activity, and the health benefit for the population due to reduced pollution and the risk of accidents.

A model to follow is certainly identified in Odense, Denmark, a perfect city for cyclists, where there are 341 miles of bike paths and even kindergartners ride to school. It was possible because, in recent years, the municipality has focused on extending the cycle network and improving its quality (e.g., new asphalt standards and cycle highways), whilst increasing accessibility through the introduction of hire cycles and adapting infrastructure to cargo cycles and electric cycles, e.g., introducing new parking spaces (Fenton, 2017). Municipalities are also adopting measures to discourage driving in urban areas, pursuing a better quality of the transport system and the urban environment. Among these policies, we can find parking policies, traffic-calming measures, and pedestrianized city centers (Kuhnimhof et al., 2012), but also sales taxes on new cars, parking fees, license fees, car ownership taxations, and land use policies, making car use less convenient, more expensive than other transport modes, and less necessary for everyone (Pucher and Buehler, 2008).

Even the use of technology and advertising campaigns, with the implementation of smartphone apps that motivate students to cycle or walk more, can be innovative solutions to increase the shift to active modes (Nielsen and Haustein, 2019). In particular, the introduction of a bikesharing service for students could be an incentive to reduce the use of private cars in the home-to-school travel.

The principle of a bikesharing service is simple: bikesharing users access bicycles on an as-needed basis. The bikesharing companies provide a variety of pickup and drop-off locations (bikesharing docks), and trips can be point-to-point, round-trip, or both, allowing the bikes to be used for one-way transport and for multimodal connectivity (first-and-last mile trips or many-mile trips) (Shaheen et al., 2012). A dockless bikesharing service is also possible: the user can pick up the bicycle anywhere and drop off it anywhere within a rental area.

The bikesharing service could be an effective solution for students because they generally have favorable attitudes towards cycling, such as being physically active, having an environmentally friendly behavior, and saving money and time during home-to-school trips. In fact, Kaplan et al. (2015) found that cycling is positively related to these favorable attitudes towards cycling, but also to the interest in bicycle technology and perceived cycling ease. Perceived cycling ease is related to factors such as the weather, traffic, and distance. Moreover, favorable norms towards cycling such as cycling with friends and family, drivers' respect for cyclists and the perception of cycling as a pleasant activity have a great importance in choosing bikesharing.

The use of bikesharing in a student population has been analyzed by Manca et al. (2019). Running an SP survey, they noticed that the bikesharing use is fostered by saving money, reducing pollution, and above all avoiding road congestion during a public transport strike. In addition, other reasons to prefer bikesharing are associated to its flexibility than a car or a taxi in the congestion, whereas the propensity to cycle is reduced mainly because of safety concerns.

However, bikesharing could have positive effects on bicycle safety perception, which is a factor that greatly affects the choice of the cycling mode by students: Martin et al. (2016) found that people generally considered bicycling with bikesharing bikes to be safer than with regular bikes. The bicycle design was one of the primary reasons bikesharing was thought to be safer.

Moreover, as Shaheen et al. (2010) highlighted, there are other benefits of bikesharing that students can enjoy: flexibility, emission reduction, physical activity, reduction in congestion and fuel use, less financial costs, and fostering of multimodality. They pointed out that these benefits are promoting bikesharing, gradually replacing trips previously made by car.

Many studies are demonstrating this contribute of bikesharing on the car substitution and the car travel reduction. For example, from analyses conducted in 2012 for the cities of Melbourne and London, Fishman et al. (2014) showed that bikesharing contributed to a high car driving reduction, respectively 115,826 km and 632,841 km in less. Moreover, in Minnesota, Melbourne and Brisbane the car reduction percentages were relatively high, equal to 19%, 21% and 19% respectively.

From a case study in Delft, the Netherlands, Ma et al. (2020) observed interesting percentages of reduction on private car/passenger and taxi for three bikesharing companies: Mobike (37.04%), OV-fiets (33.61%) and Swapfiets (32.04%). Other percentages of switch from private car to shared bikes were determined by Shaheen et al. (2010), finding percentages equal to 16% and 7% for the cities of Washington, D.C. and Lyon respectively.

Barbour et al. (2019) conducted a noticeable survey focused also on mode substitution, and found that out of 301 respondents, almost half of them (140) said that they would have chosen a car for their trips if bikesharing was not available, whilst the remaining 161 would have chosen another mode of transport, such as bus, walking or their private bike.

As cited in chapter 1, the promotion of bikesharing services helps to reduce atmospheric and acoustic emissions. With regard to the private car reduction percentages above mentioned, Shaheen et al. (2010) found that Washington, D.C. and Lyon had registered reduction of 37,000 and 7720 kg of CO_2 respectively. Zhang and Mi (2018), meanwhile, thanks to bikesharing system in Shanghai, estimated a saving of 8358 tons of petrol and a decrease of CO_2 and NO_x emissions amounting to 25,240 and 64 tons respectively. However, Sun and Ertz (2021), in their study focused on environmental impact of diverse mobility modes, showed that the greenhouse gas (GHG) emission factor of a station-based bikesharing service is not negligible. For the analyzed cities of Beijing and Toronto, the mean values of this GHG emission factor are 63.19 g CO_2-eq/pkm (pkm = passenger per km) and 64.00 g CO_2/pkm respectively, with an average GHG emission factor of 63.6 g CO_2/pkm, which is around six times that of private bikes (10.5 g CO_2/pkm). Moreover, there are other GHG emission sources associated to docks and stations and the rebalancing activities throughout the life cycle of station-based bikesharing bikes (equal to 43% and 35% of the total GHG emissions). This analysis has been carried out also by Fishman et al. (2014), estimating CO_2 emissions, fuel and distance traveled for the fleet rebalancing in the cities of London, Washington, D.C., Minnesota and Melbourne.

Nevertheless, there are other limitations in bikesharing access and adoption, such as racial, educational and income barriers. Howland et al. (2017) highlighted a low bikesharing use in three U.S. systems when stations are located in neighborhoods with lower income residents and high rate of people of color. They also found a low bikesharing stations density in less-affluent neighborhoods; also, other barriers are represented by credit card requirements and siting stations in low-income communities, causing a limited ridership. Thus, the authors suggest subsidized membership as a possible solution to overcome cost barriers and pursue an equity improvement in bikesharing use.

Proposing bikesharing as a possible solution for home-to-school travel, in order to reduce the car-dependency, the present study investigates the mode choice behaviors of high school students. Thus, this research is based on the scientific literature about travel choice behavior modelling, with particular reference to random utility models and stated preference methods (Ben-Akiva and Lerman, 1985; Daly and Rohr, 1998; Louviere et al., 2000; Ortùzar and Willumsen, 1994; Permain et al., 1991).

3. Case study

3.1. The “Go2School” project

The Go2School project aims to create a station-based bikesharing service for students of four high schools. The project is promoted and implemented by the Municipality of Palermo, Amat Palermo SpA, which is the city public transport company that also manages the shared mobility services, and the University of Palermo. The four schools involved in the project are located in the central area of Palermo. They are (Fig. 2):

- Liceo Linguistico “Ninni Cassarà";
- Liceo Scientifico “Albert Einstein”, Palermo;
- Istituto Tecnico Economico e per il Turismo “Pio La Torre”;
- Istituto Tecnico Industriale “Vittorio Emanuele III”, Palermo.

The Go2School Project, even being a mobility service designed for high-school students, is part of the broader city plan of sustainable mobility, which is a crucial factor in the socio-economic evolution of the city of Palermo.

This bikesharing program wants to encourage this sustainable modal alternative among students, integrating with the existing AmiGO station-based bikesharing service. It also aims to fulfill the growing demand for transport services supplementary and complementary to local public transport and to reduce the use of private vehicles in the city center.

The project also envisages the construction of new bikesharing stations distributed throughout the city, some of which are located in the immediate proximity of the school buildings, and the introduction of a large fleet consisting of two-seater bicycles, useful for promoting a greater socialization among the students who will use this service. Since the Palermo cycle network is discontinuous and there are no cycle paths around the schools that allow the creation of safe home-to-school routes, new cycle paths will be designed and built near the schools in order to

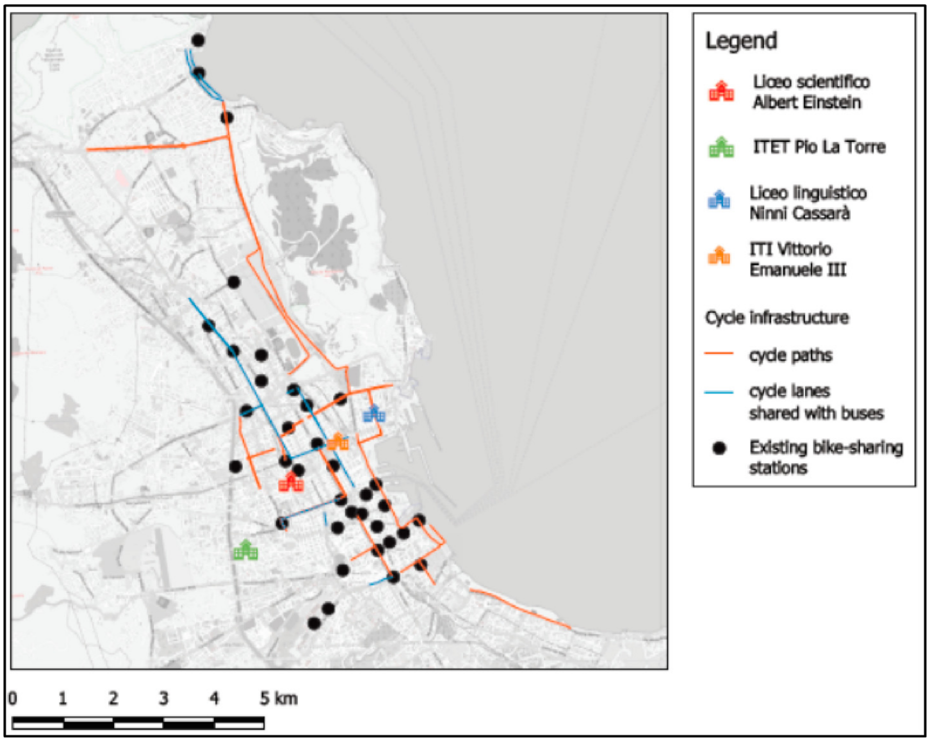

Fig. 2. The four schools of the Go2School project and the cycle network in Palermo.

allow the students of the four schools involved to safely carry out their daily school trips.

3.2. *The stated preference survey*

To assess the potential of the project, a Stated Preference survey was carried out: students were asked to fill out an online questionnaire. The questionnaire was administered to students in a computer laboratory during school hours. The sample and the number of valid interviews, not containing inconsistencies and errors, are reported in Table 1.

The penetration rate of the sample is quite high (29%), so the sample is significant. The presence of the interviewers at the time of filling in the questionnaire by the students made it possible to clarify any doubts and have a good number of valid interviews (1,074). Only 5% of the interviews were affected by errors and rejected.

The questionnaire has three main parts. The first part seeks socio-demographic information with questions relating to student characteristics (gender, age, grade), the address of the student's home, built-environment attributes. The questionnaire included also a question on the possible veto of parents on the use of bicycles related to safety issue. The second part asks the students to describe their current mobility habits for school trips (primary mode of travel, trip chain). The third part is the SP exercise: it described a future scenario that included the presence of cycle paths near the schools and a greater number of bike-sharing stations in the city. The students, therefore, indicated their propensity to use the bikesharing service in the hypothesized future scenario.

Table 1
Survey sampling.

School	Enrolled students	Sample	Valid interviews	Penetration Rate
ITET Pio La Torre	938	227	213	24.2%
Liceo Scientifico A. Einstein	834	298	283	35.7%
Liceo Linguistico N. Cassarà	606	190	187	31.4%
ITI Vittorio Emanuele III	1521	416	391	27.4%
Total	3899	1131	1074	29%

The main results of the survey are described by D'Orso et al. (2020). The mobility habits of the students of the four schools are shown in Fig. 3.

It is noted that considering the students of the four schools as a whole, public transport is the dominant mode of transport, although around 23% of students walk to school. However, the percentage of students who are accompanied by their parents in private cars is considerable (22%). Especially for Pio La Torre High School, the private car is the preferred mode of transport for students.

The reason why students do not ride a bike to school has been investigated and concerns mainly the lack of safety.

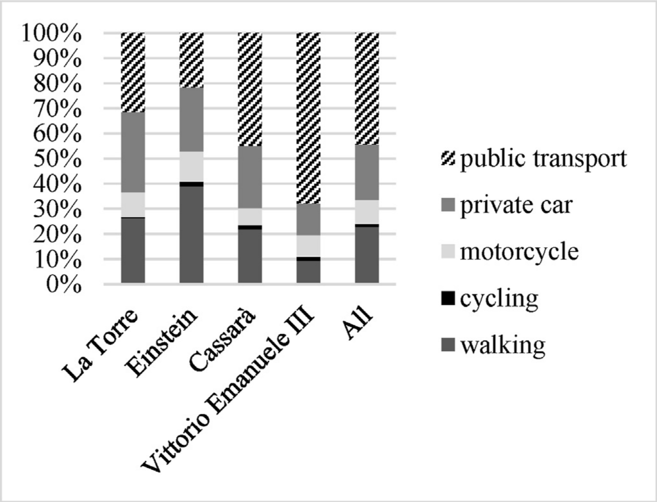

Fig. 3. Mobility habits of the interviewed students.

3.3. The modal choice model

The questionnaire made it possible to calibrate a modal choice model for determining the choice probability for different modes of transport. The model – a multinomial Logit model – considers the user as a rational decision-maker who assigns a perceived utility to the modal alternatives and chooses among them the one that maximizes the utility. The utility was calculated in this case study by referring to the cost perceived by the student and the travel time of the different modes of transport for home-to-school travel. The modes of transport taken into consideration by the model are walking, cycling, motorcycle, private car and public transport. The private car was considered concerning the trip as a passenger as the sample consisted mainly of minors without a driving license. Regarding public transport, we considered all the public transport modes that can be used for the various origin-destination *o-d* pairs (home-school), such as city buses, suburban buses, trams, and trains, as well as their combination. Costs and travel times for public transport have, therefore, been assessed based on the most convenient travel strategies for each home-to-school trip, considering the minimum hyperpath and three types of time (walking time to and from stops, waiting time, in-vehicle time). The time spent walking to and from bus stops or railway stations have been doubled to homogenize it with the in-vehicle time, while the waiting time has been multiplied by a factor α equal to $\alpha = 1$ for trams, train, high-frequency urban bus services and extra-urban buses, since the service regularity is good, and $\alpha = 4$ for low-frequency lines, to take into account the discrepancy between scheduled and completed runs.

The length of the routes on foot has been obtained using Google Maps, as well as the travel time by car, taking into account the level of congestion on the morning rush hour. To calculate the walking time for each O-D pair, a speed of 0.6 m/s has been assigned to pedestrians. This value has been chosen to attribute a disutility to walking, halving the average pedestrian speed of 4 km/h. For determining travel times, a speed of 10 km/h has been assigned to travel by bicycle, while an average speed of 20 km/h for residents of Palermo and 45 km/h for residents in neighboring municipalities has been considered for motorcycles.

Cycling/bikesharing was not considered as an available mode for extra-urban trips and trips shorter than 300 m, and walking was not considered as an available mode for school trips longer than 3 km.

Table 2 lists the variables considered by the model. The number of cases considered was extended with respect to the calibration performed by D'Orso et al. (2020).

The first calibration has found that some variables are not statistically significant, having a p-value higher than the threshold (0.05). Therefore, a stepwise regression method has been applied in order to eliminate all the variables having a poor predictive contribution. In particular, a stepwise regression with backward elimination has been adopted: starting from the complete model, all the variables that have not statistical significance have been eliminated. This allows, therefore, to have a new calibration not affected by non-significant variables.

Table 3 shows the results of the calibration process, performed with the statistics software STATA. We had 2145 cases instead of the 1074 valid interviews reported in Table 1, because we doubled the total valid interviews varying the CYCLE_INFRASTRUCTURE variable from 0 to 1 (for a total of 2148 cases); hence, we analyzed both actual and future scenarios, discarding only 3 cases for which the future scenario is the same of the actual scenario because they are related to journeys shorter than 300 m. The utility functions for each mode of transport are reported below. The time variable, to which only one coefficient was assigned, was significant: the longer the travel time for a mode of transport, the more students choose a different mode of transport. The cost was not significant. This outcome is not surprising because students tend not to perceive the monetary cost due to the use of the private car, not facing this expense alone as they are accompanied by their parents. $\mathrm{ASA_{bike}}$ and $\mathrm{ASA_{motorcycle}}$ are the alternative specific constant of respectively bike and motorcycle alternative: they are significant (p-value equal to 0) and strictly negative, highlighting the dangerousness of these two modes of transport compared to the other alternatives. We found a positive relationship between students' age and their tendency to use motorcycles. On the contrary, the use of private cars decreased with an increase in age. This could be attributed to the fact that when children get older they seek a more independent lifestyle and refuse to be accompanied by parents by car. Moreover, we found a higher propensity for boys to cycle to school, while girls are more willing to reach the school by car with their parents. This could be attributed to a high sense of unsafety perceived more by girls than by boys. These findings concerning the likelihood of both travel by car and riding to school are in line with the results obtained by Lidbe et al. (2020).

Table 2
Description of explanatory variables used in the model.

Variable	Description
GENDER	1: Female/0: Male
AGE	Age of children between 13 and 20 years old
TIME	Travel time to school assessed for all the modal alternatives available from O to D
CYCLE_INFRASTRUCTURE	1: If there are new cycle paths that make it safe the home-to-school trip/0: Otherwise
BIKESHARING_DOCKS	1: If there are new bikesharing stations near the student's home/0: Otherwise

The CYCLE_INFRASTRUCTURE variable was found to be very positive: this means that, in the presence of a safe home-to-school cycle path, the students attribute a high utility to cycling. The variable that took into account the presence of bikesharing stations near the house of the students was not significant, as it was collinear with the variable CYCLE_INFRASTRUCTURE.

3.4. Model results for Einstein and Pio La Torre schools

In order to understand which infrastructure measures have the greatest benefits both in attracting users and in terms of economic impact for the community, the theoretical approach described by D'Orso and Migliore (2019) and D'Orso and Migliore (2017) has been used.

This approach is based on determining the surplus of user satisfaction, the reduction of mileage by car - and, therefore, the reduction of negative externalities - and investment costs. Furthermore, in this method we also took into consideration technical constraints, such as the longitudinal slope and the type of road because the excessive difference between the speed of the cars and bicycles increases the risk of accidents. The design of the new cycle paths started with the identification of the optimal location of the new bikesharing docks, based on the knowledge of the distribution of students' homes in the area. A valid help was provided by GIS software. The following factors were then taken into account for the tracing of the routes that the new cycle paths must follow: technical constraints (roads with insufficient width, roads with high traffic flows, absence of safe cycle crossings); the interaction with the vehicular flow, trying to locate the cycle paths in road axes in which the vehicular flow was not disturbed; the demand to be served, trying to connect the bikesharing stations located in the areas where the demand is concentrated with the schools following the shortest route; intermodality, considering the presence of cycle paths near the most important intermodal nodes, such as railway stations and tram stops. The analysis of this factors produced the results showed in the following Figs. 4 and 5.

Particular attention was paid to the safety of the cycle paths, especially at road intersections. In fact, Fig. 6 shows the design of a safe cycle crossing.

Only Einstein High School and Pio La Torre High School were considered in the application of the methodology, due to their proximity to the new designed bike paths.

Therefore, only Einstein and Pio La Torre students were considered. Fig. 7 shows the students' mobility habits descriptive statistics as assessed through the questionnaire. The distribution of Einstein students and Pio La Torre students respectively with respect to the distance

Table 3
Calibration results with STATA.

$$V_{on\ foot} = \beta_t \cdot t_{on\ foot}$$

$$V_{bike} = \beta_t \cdot t_{bike} + \beta_{c.i.} \cdot Cycle\ Infrastructure + \beta_{gender\ bike} \cdot Gender + \beta_{ASC\ bike} \cdot ASC_{bike}$$

$$V_{motorcycle} = \beta_t \cdot t_{motorcycle} + \beta_{age\ motorcycle} \cdot Age + \beta_{ASC\ motorcycle} \cdot ASC_{motorcycle}$$

$$V_{car} = \beta_t \cdot t_{car} + \beta_{age\ car} \cdot Age + \beta_{gender\ car} \cdot Gender$$

$$V_{public\ transport} = \beta_t \cdot t_{public\ transport}$$

Significant variables	Coeff. β	Stand. Error	z	p-value	[95% Conf. Interval]	
Time	−0.017	0.001	−12.42	0.000	−0.020	−0.015
ASA_{bike}	−3.928	0.270	−14.54	0.000	−4.457	−3.398
$ASA_{motorcycle}$	−6.711	1.008	−6.66	0.000	−8.687	−4.736
Cycle_infrastructure	4.145	0.271	15.31	0.000	3.614	4.675
$Age_{motorcycle}$	0.258	0.063	4.08	0.000	0.134	0.382
Age_{car}	−0.140	0.008	−18.65	0.000	−0.155	−0.125
$Gender_{bike}$	−0.304	0.145	−2.09	0.037	−0.589	−0.019
$Gender_{car}$	0.927	0.124	7.48	0.000	0.684	1.169

Number of observations = 9212; Number of cases = 2145.
Initial value of Log likelihood = −4999.309; Final Log likelihood = −2343.315.
Wald chi2(8) = 980.97; Prob > chi2 = 0.000; rho squared = 0.53.

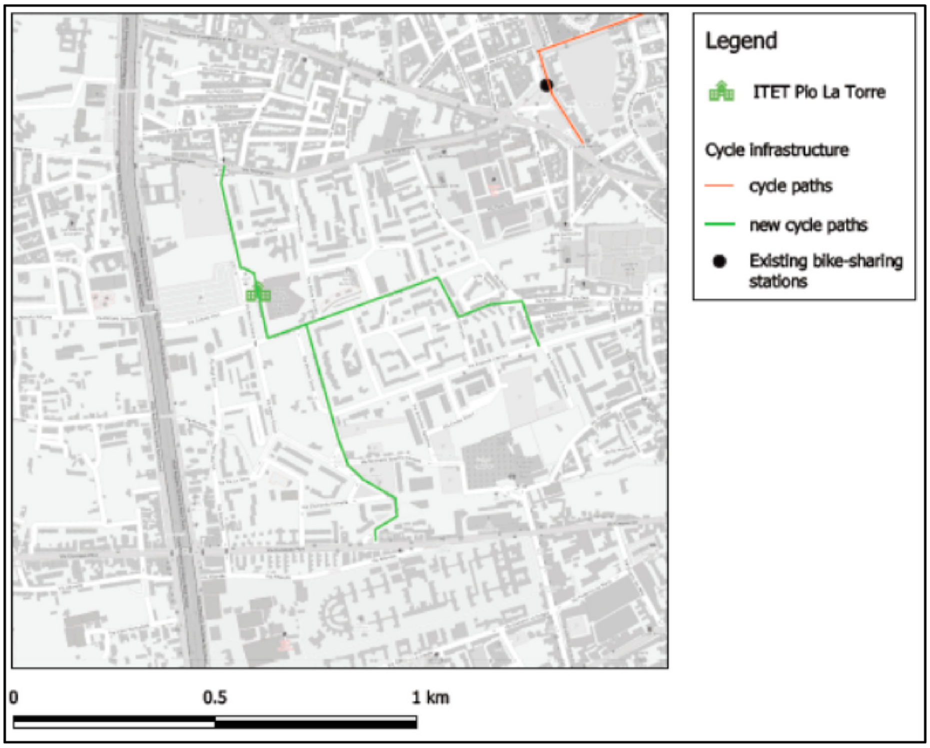

Fig. 4. The new cycle paths planned by the Go2School project near Pio La Torre High School.

between home and school is shown in Fig. 7 (a) and (b). It is noted almost half of the interviewed students live at a distance of more than 3 km from La Torre High School. Fig. 7 (c) and (d) shows how mobility habits vary with gender and age. Further, Fig. 7 (e) and (f) shows that commute distance is negatively correlated with walking.

Fig. 7 (c) and (d) show how private car is chosen especially by girls, and on the other hand the likelihood of riding a bike is prevalent among male students. Besides, Fig. 7 (e) and (f) highlight walking as the preferred mode choice among high school students for home-to-school distances up to 1 km (1.5 km for Pio La Torre High School). Those results are in accordance with the findings of Lidbe et al. (2020).

Considering the significant variables obtained, the utility perceived by the user for the different modes of transport was determined for each O-D pair. Therefore, for each O-D pair, it was assessed whether the presence of the new cycle paths could create a safe cycle path between home and school. When this occurred the CYCLE_INFRASTRUCTURE variable went from 0 in the current scenario to 1 in the future scenario. Out of a total of 283 O-D pairs for Einstein High School, 77 are served by new cycle paths, while for Pio La Torre High School the O-D pairs served by new cycle paths are 40 out of a total of 213. Moreover, the model takes

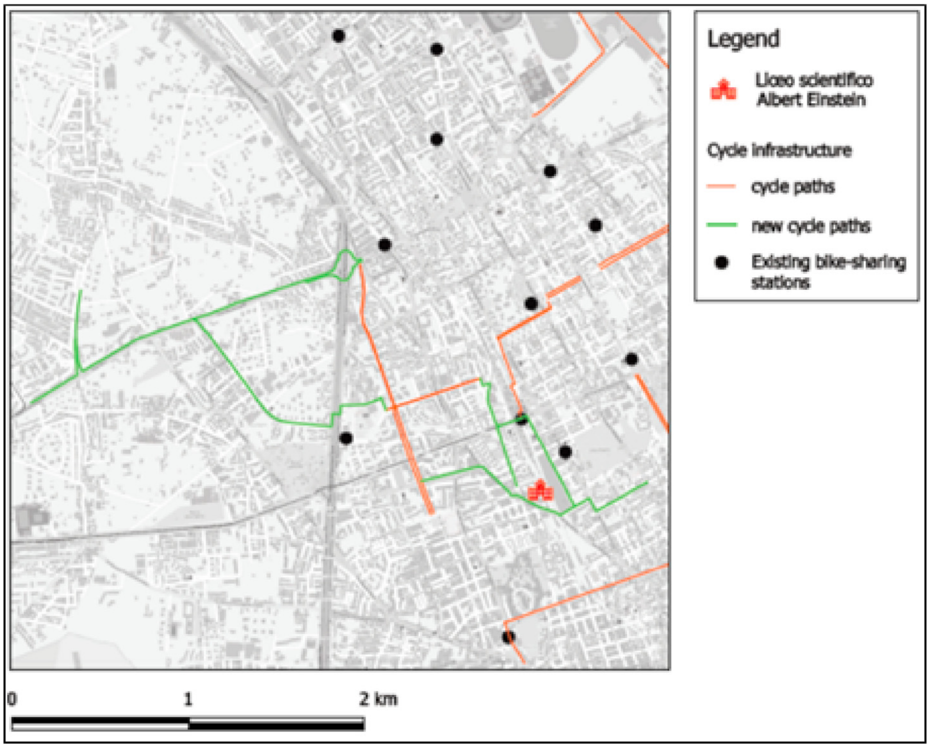

Fig. 5. The new cycle paths planned by the Go2School project near Albert Einstein High School.

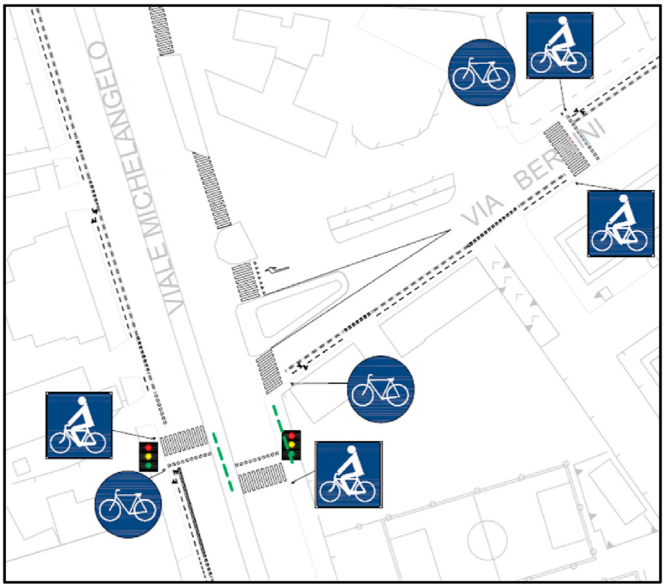

Fig. 6. Design of cycle paths: detail of the cycle crossing in Via Bernini.

into account the intermodality of bikesharing with the public transport network. The intermodality between cycling and public transport must be incentivized to ensure that urban mobility benefits in terms of reducing the use of private cars. It is possible to take the bike on trams and trains, and stations could become cycling demand aggregation points: students who live far from school can reach the nearest station to the institute by rail, and then continue their trip by bicycle, owned or shared. Therefore, the model considers the possibility that cycling is used for last-mile journeys. However, this possibility is only realized for Einstein High School, being near an important railway junction. La Torre students, on the other hand, cannot use railway stations or tram stops as interchange nodes.

In order to take into account the intermodality between public transport and bikesharing, for the O-D pairs where it was a possibility, the travel time for public transport was recalculated for the future scenario, considering the arrival with the public transport at the station and the last-mile travel by cycling. This occurrence occurred for 110 O-D pairs of Einstein High School.

By applying the coefficients found in the calibration phase for the variables found to be significant, we then calculated the average probability of choice for each mode of transport considered in the present situation and the future situation (Fig. 8).

Fig. 8 (a) refers to the modal shift of Einstein students for whom the realization of new cycle paths creates a safe cycle path from home to school.

As noted, for these students the cycling modal share increases significantly compared to the current situation, at the expense of other modes of transport. In particular, we are witnessing a 12% decrease in the use of public transport and a 6% decrease in the use of private cars. It should also be noted that the walking modal share is also reduced (−22%), which does not produce environmental benefits.

Fig. 8 (b) refers to the modal choices calculated by the model for students for whom the realization of the new cycle paths does not create a safe cycle route from home to school. It can be seen how we are witnessing an increase in public transport (+4%) because now students have the possibility of moving the last mile using the bicycle. This modal shift occurs mainly at the expense of the private car (−1%), but also of walking (−2%): this means that students who, in the current situation, walk to school over long distances will prefer to use public transport to reach the station, and then continue their trip riding the bicycle. Finally, Fig. 8 (c) refers to Pio La Torre students for whom a safe home-school course is activated. Cycling to school increases significantly compared to the current situation, while public transport (−14%) and private cars (−5%) decrease. The percentage of students who choose to reach the school by walking decreases a lot (−21%), thanks to the introduction of new cycle paths in the future scenario.

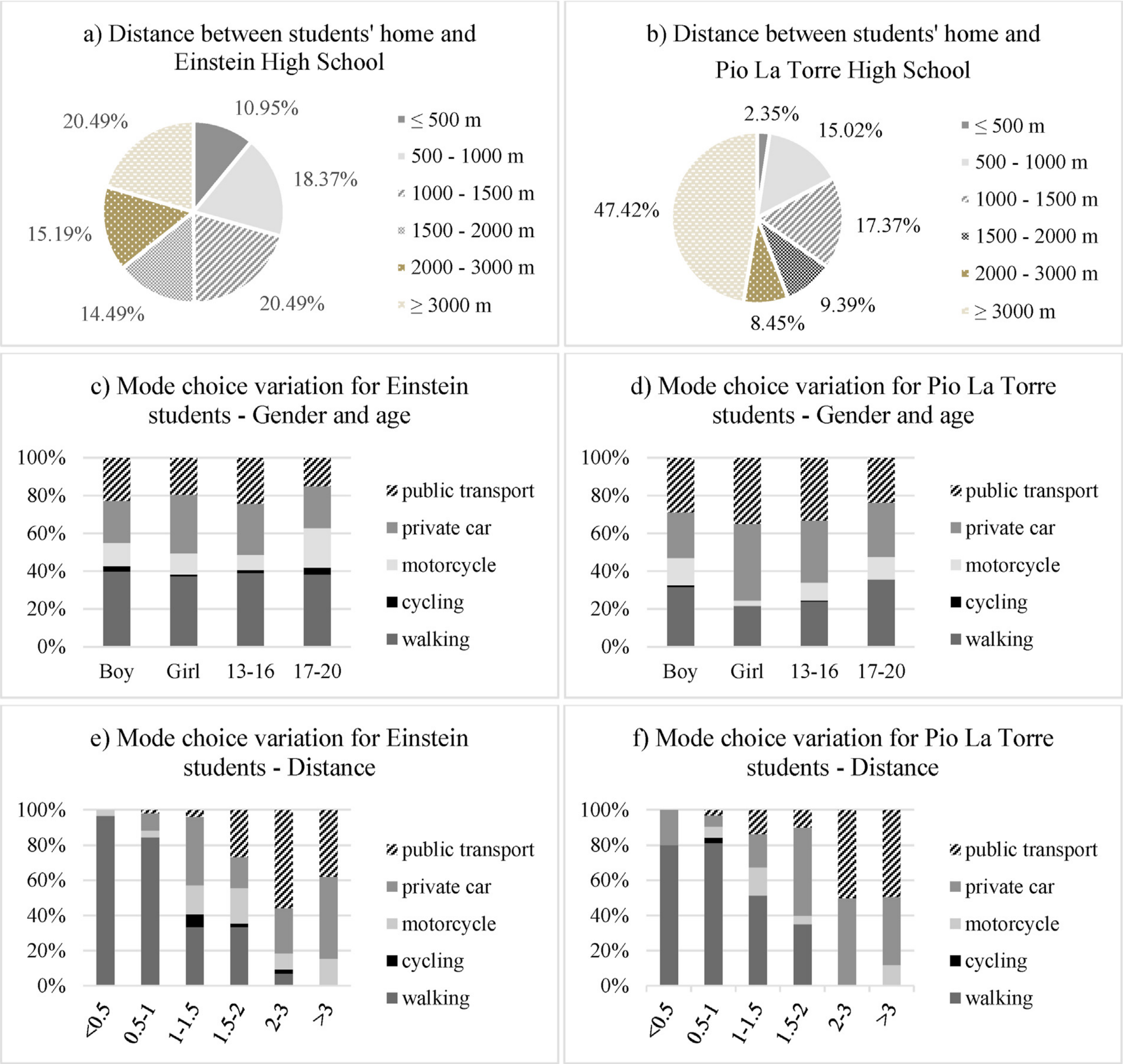

Fig. 7. Students' mobility habits descriptive statistics: a) distribution of Einstein students with respect to the distance between home and school; b) distribution of Pio La Torre students with respect to the distance between home and school; c) mode choice variation by gender and age for Einstein students; d) mode choice variation by gender and age for Pio La Torre students; e) mode choice variation by distance between home and school for Einstein students; f) mode choice variation by distance between home and school for Pio La Torre students.

3.5. The economic feasibility of the infrastructure measures

Once the choice probabilities were known, it was decided to determine the economic feasibility of the scheduled infrastructure measures and carry out an economic analysis determining their costs and benefits. The cycle paths have been grouped into two functional blocks: the block of the cycle paths near Einstein High School and the block of the cycle paths near La Torre High School. The grouping was thus created because the two functional blocks are separated from each other, as there are no connections between the tracks that serve Einstein High School and those that serve Pio La Torre High School.

The division into two functional blocks led to the identification of different scenarios for which to provide economic analysis. The scenarios considered and the key assumptions followed for the economic analysis are shown in Table 4.

For b), c) and d) scenarios the amount of time saved by users was assessed. This users' saving time was subsequently evaluated in economic terms, referring to the value of time, following the method described in point (2) of Table 4.

The benefits due to the reduction in mileage by private car were also calculated according to point (3) of Table 4: therefore, the economic benefits deriving from the reduction of air and noise pollution and CO_2 emissions, and the reduction of costs for the use of private cars were considered. The latter was considered to take into account the fact that the model considered the cost to be insignificant, because it was not perceived by the students, but this cost is actually addressed by the user. These benefits were calculated as described in points (4), (5), (6), and (12) of Table 4 respectively. Finally, the construction costs and the operating costs have been calculated for the two functional blocks. Their values were assessed as described in points (13) and (14) of Table 4 respectively. The economic performance of the infrastructure measures in the different scenarios is assessed with two main indicators: the Net Present Value (NPV) and the Internal Rate of Return (IRR).

The NPV for every scenario was computed to understand the profitability of the projected investment.

The NPV is computed by the following formula:

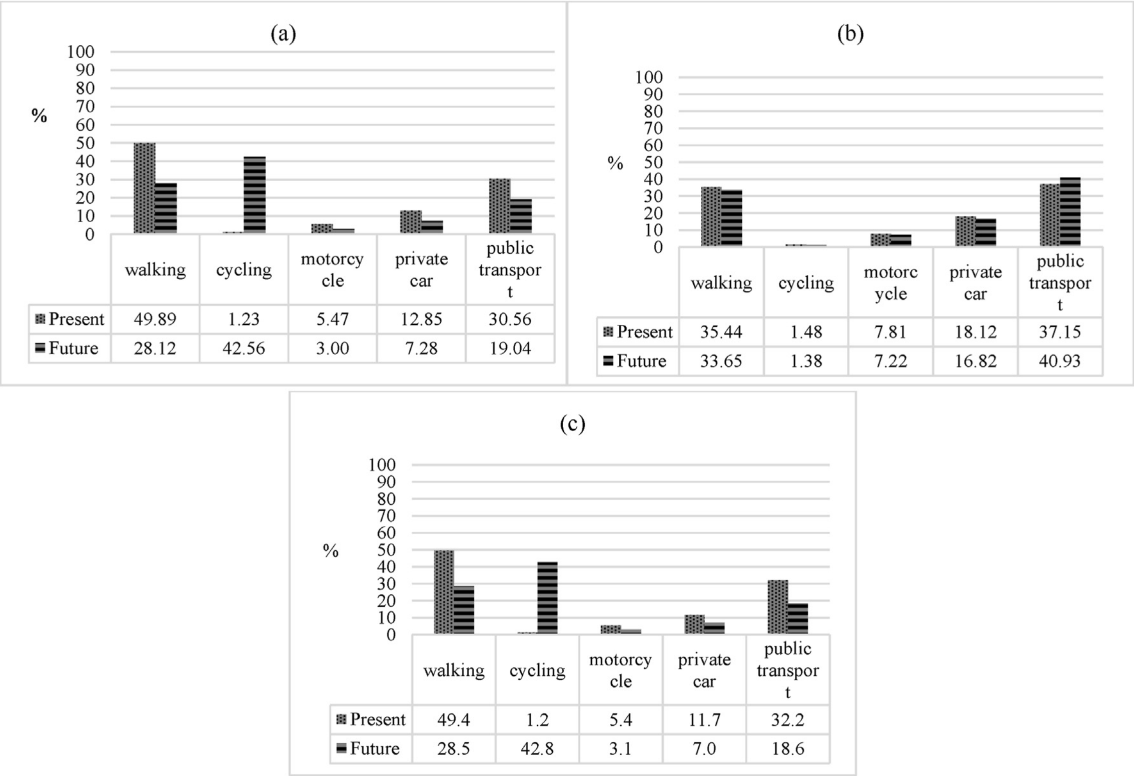

Fig. 8. Mode choice probabilities (a) for Einstein students for whom a safe cycle path between home and school exists, (b) for Einstein students for whom a safe cycle path between home and school does not exist, (c) for Pio La Torre students for whom a safe cycle path between home and school exists.

$$NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1 + i_t)^t}$$

The period forecasted for the analysis is of 30 financial years. B_t and C_t are economic benefits and costs, respectively, occurring at time t; i_t is the social discount rate, here considered as constant $i_t = 3\%$. For each scenario the year in which there is the equilibrium point between benefits and costs was assessed. For the scenario b) the equilibrium point between costs and benefits is in the third year. For the scenario c) it is in the fourth year, while for the scenario d) it is in the third year.

Finally, the Internal Rate of Return (IRR), i.e. the social discount rate able to realize a NPV = 0, was evaluated in each scenario.

The feasibility of the infrastructure measures for each scenario has to satisfy the condition: NPV >0, benefits-costs > 0 and IRR > social discount rate.

Table 5 shows the results of the economic analysis carried out for the various scenarios. Because of the existence of black spots along every bike lane (e.g., road intersections, crosswalks, and driveways) which could create insecurity for cyclists, the future users' modal split may be different from the mode choice probabilities previously estimated. Hence, it has been supposed a different future modal split for each O-D pair, considering a reduction of mode choice probabilities by a coefficient of 0.5 applied to the difference between the actual and the future modal choices. Then, a sensitivity analysis was performed for the three scenarios, evaluating the new benefits, the new NPV and the new IRR.

The results are summarized in Table 6.

For the three scenarios it has been assessed the year in which there is the new equilibrium point between benefits and costs. For the scenario b) the equilibrium point is reached in the third year. For the scenario c) it is in the tenth year, while for the scenario d) it is in the fourth year.

4. Discussion

As Ermagun and Samimi (2015) mentioned, multinomial Logit models are rarely used to explain school travel mode choice, while several studies used descriptive analysis and binary logit models. The present study demonstrates how multinomial Logit models are a valuable tool to analyze the mode choice behavior of high school students. Ermagun and Samimi also found that few studies had good coverage on the alternative modes for high-school students and pointed out that travel time, cost and specifications of the transit system have received limited attention. In order to overcome these limitations, the present model explored the possible modal alternatives for home-to-school trips, paying utmost attention to the estimate of travel time and cost for each mode of transport.

From the choice probabilities assessed in Section 4, a first conclusion can be drawn. The introduction of cycle paths around schools produces a modal shift effect from walking to cycling. This means that the planned infrastructure measures have attractive effects only for the students who live near the school, failing to determine considerable modal shift from the private car by those who live further away. Safe home-to-school routes are only realized near the schools, so those who do not live in this area find it difficult to cycle to school, still considering cycling as an unsafe mode of transport.

Therefore, the local authority should develop a network of safe cycle paths for multiple *o-d* pairs and different categories of users in the Sustainable Urban Mobility Plan.

It has also been found that the integration between cycling and the railway system can be an effective strategy for the most distant users. This finding is in line with previous studies (Shelat et al., 2018; Zuo et al., 2020).

From the results obtained from the economic analysis, it can be inferred that in all scenarios the benefits far outweigh the costs: the infrastructure measures can be justified also considering only the users' saving time. For Pio La Torre High School, it should be pointed out that if users' saving time had not been considered, the benefits produced by the reduction in mileage by car, being limited, would not have covered the costs and, therefore, would not have been able to justify the planned

Table 4
Key assumptions.

(1) **Scenarios** a) Current status: absence of cycle paths and bikesharing stations near the schools. Already existing cycle paths perceived as safe by the user or in progress have been taken into account. Students can only use the private bicycle in an unsafe manner;
b) Construction of cycle paths and bikesharing stations near Einstein High School;
c) Construction of cycle paths and bikesharing stations near La Torre High School;
d) Construction of cycle paths and bikesharing stations in the vicinity of both schools.

(2) **Monetary valuation of the users' saving time**
The users' saving time per day for home-to-school trips, compared to scenario a), was determined for the other scenarios (b, c, and d), considering for every mode of transport the difference in choice probability between the current scenario and the future one, and the travel times between the origins (home) and the destination (school). This users' saving time, determined for the sample of students interviewed, was related to the universe (total number of students in the school). In the estimate of the users' saving time per year, also, the school-to-home trip, multiplying by 2, and the school days present in a year in Italy (200), multiplying by 200, were taken into account. Finally, the monetary value of the saving time per year was assessed multiplying the saving time per year by the value of time. Based on studies carried out for the city of Palermo, the latter was set equal to 5.4 €/h (Catalano et al., 2008).

(3) **Reduction of distances traveled by car**
The reduction of mileage by car per day for home-to-school trips, compared to scenario a), was determined for the other scenarios (b, c, and d), considering the difference in choice probability for the private car between the current scenario and the future one, and the distances on the road network between the origins (student homes) and the destination (school). This reduction, determined for the sample of students interviewed, was related to the universe (total number of students in the school). In the estimate of the annual reduction of kilometers traveled by car, also the school-to-home trip, multiplying by 2, and the school days present in a year in Italy (200), multiplying by 200, were taken into account.

(4) **Public benefit from reduced air pollution**
Based on studies carried out for the city of Palermo, the monetary valuation of the benefits deriving from the reduction of air emissions is assumed to be equal to 0.0242 €/km per car (Ricardo—AEA DG Move, 2014).

(5) **Public benefit from reduced noise pollution**
Based on studies carried out for the city of Palermo, the monetary valuation of the benefits deriving from the reduction of noise emissions is assumed to be equal to 9.40 €/km per 1000 cars (Ricardo—AEA DG Move, 2014).

(6) **Public benefit from reduced CO_2 emissions**
Based on the output values reported in the EU "Handbook on the external costs of transport" for the climate costs per transport mode and vehicle type, the monetary valuation of the benefits deriving from the reduction of CO_2 emissions is assumed to be equal to the average value of 0.0190 €/km per car (Handbook on the external costs of transport, 2019).

(7) **Minor or greater revenue due to modal split in favor of public transport**
Minor or greater revenue due to modal split in favor of public transport have not been considered as they are the result of a greater or lesser monetary outlay by individual users. It should be noted that the monetary cost of the school trip, perceived by the student, was not significant in the calibration phase of the model.

(8) **Reduction of city congestion**
It was not considered in the study because the number of students replacing the private car by bicycle is quite limited and the areas in which the new cycle paths insist are not very extensive. The presence of new cycle paths could however give rise to a modal split in favor of the bicycle also for other categories of users, but the determination of this effect goes beyond the objectives of the case study.

(9) **Increased city congestion due to the introduction of cycle paths**
It was not considered in the study as the design of the new cycle paths followed the criterion of trying to minimize interferences between them and the vehicular flow.

(10) **Increase or reduction of distances traveled by public transport**
Minor or major mileage for public transport was not considered as modal shift to public transport does not justify the increase or decrease in the number of journeys to be made.

(11) **Reduction of distances traveled by motorcycles**
They are assumed negligible since the small number of students who shift from motorcycle to more sustainable modes of transport.

(12) **Reduction of costs due to the lower number of kilometers traveled by car**
The reduction of costs for the use of the private car due to the reduction in kilometers traveled was considered. A saving of € 0.45/km per car was considered, based on studies carried out for the city of Palermo (Catalano et al., 2008).

(13) **Investment costs**
The costs of the new cycle infrastructure were calculated on the basis of the tender specifications of the AMAT company, considering the cost of the materials (paint, floor mats, separator elements) and the cost of labor. The cost of the cycle paths near Einstein High School amounts to about € 350,000. The cost of the cycle paths near La

Table 4 (*continued*)

Torre High School amounts to about € 200,000. The basic hypothesis is that it will take 1 year for the realization of the new cycle infrastructure (first year). The annual quotas, net of VAT, were calculated considering a 30-year amortization period and a 3% amortization rate, as well as taking into account the residual value of the infrastructure at the end of the amortization period (assumed to be 30% of the investment cost).

(14) **Operating costs**
The annual operating costs were calculated as 5% of the investment costs. The operating expenses will occur from the second year.

Table 5
Economic analysis: costs and benefits of the introduction of bikesharing and the creation of new cycle paths planned by the Go2School project.

	Scenario b	Scenario c	Scenario d
Benefits (A):			
1) Value of the users' saving time [€ per year]	155,484.5	56,401.56	211,886.06
2) Reduction of air pollution [€ per year]	582.55	88.19	670.74
3) Reduction of noise pollution [€ per year]	226.28	34.26	260.54
4) Reduction of CO_2 emissions [€ per year]	457.38	69.24	526.62
5) Reduction of costs due to lower car mileage [€ per year]	10,832.59	1639.98	12,472.57
Total [€ per year]	167,583.3	58,233.23	225,816.53
Costs (B):			
1) Investment costs [€ per year]	10,716.2	6082.6	16,798.8
2) Operating costs [€ per year]	15,003.07	8515.83	23,518.9
Total [€ per year]	25,719.27	14,598.43	40,317.7
(A) – (B) [€ per year]	141,864.03	43,634.8	185,498.83
NPV [€]	2,711,628.4	825,216.9	3,536,845.3
IRR	50.85%	29.18%	43.01%

Table 6
Sensitivity analysis: costs and benefits of the introduction of bikesharing and the creation of new cycle paths planned by the Go2School project for the new future users' mode choice probabilities.

	Scenario b	Scenario c	Scenario d
Benefits (A):			
6) Value of the users' saving time [€ per year]	124,916.03	28,200.78	153,116.81
7) Reduction of air pollution [€ per year]	291.28	44.10	335.38
8) Reduction of noise pollution [€ per year]	113.14	17.13	130.27
9) Reduction of CO_2 emissions [€ per year]	228.69	34.62	263.31
10) Reduction of costs due to lower car mileage [€ per year]	5416.30	819.99	6236.29
Total [€ per year]	130,965.44	29,116.62	160,082.06
Costs (B):			
3) Investment costs [€ per year]	10,716.2	6082.6	16,798.8
4) Operating costs [€ per year]	15,003.07	8515.83	23,518.9
Total [€ per year]	25,719.27	14,598.43	40,317.7
(A) – (B) [€ per year]	105,246.17	14,518.19	119,764.36
NPV [€]	1,993,902.4	254,518.3	2,248,420.69
IRR	38.64%	11.79%	29.2%

infrastructural measures: this occurs because car and motorcycle demand overall decreases in the future scenario only by 5% and 2% respectively.

The NPV is positive in all scenarios: between the three scenarios the most economically advantageous is d), involving the construction of cycle paths and bikesharing docks near both schools. Scenario c) has a worse NPV compared with scenario a); this occurs because of greater social benefits in realizing cycle paths near Einstein High School.

Moreover, in the scenario b) IRR is greater compared with the other scenarios.

Similar results were obtained from the sensitivity analysis. The benefits, although reduced, outweigh both the investment and the operating costs. Both the NPV and the IRR have seen a decrease because of the new hypothesis on the future users' modal choice, but they are still positive for each scenario. The most economically advantageous scenario is still d), which shows the highest NPV, whilst the highest IRR is registered for the scenario b), like the results reported in Table 5.

5. Conclusion

The paper describes a feasibility study trying to give an answer to a real issue: the possible changes in the mobility habits of high-school students have been investigated following the possible introduction of a bikesharing service dedicated to them and the realization of cycle paths in the areas around the schools. The creation of the Go2School project in Palermo, Italy, was an important opportunity to evaluate the propensity of Palermo students to cycle to school. Therefore, the case study has been addressed in a real context, starting from real data for developing a demand analysis, a mode choice model and a benefit-cost evaluation. Thanks to these analyses, we pointed out the importance in realizing bike routes that take into account the potential demand distribution and the competitive and available mobility alternatives resulting from the model calibration. An absolute relevance of the safety factor in the mode choice was found, so the modal shift to cycling or bikesharing takes place only if a safe home-school route is realized, otherwise this mode is perceived as a source of danger by students and parents. The study also made it possible to assess which of the planned interventions are more convenient in terms of the ratio between construction costs and benefits deriving from a greater use of the bike and the reduction in kilometers traveled by private car. The results obtained from both the benefit-cost analysis and the sensitivity analysis show that the proposed investments are very profitable. If policymakers invest on cycle paths the city community have an economic return. The creation of cycle paths and the implementation of a bike-sharing program for schools can also improve urban sustainability, promoting a change in mobility habits towards sustainable transport modes.

A limitation of the study is not having considered the availability of bicycles in the bikesharing station, which is a factor that influences the probability of students choosing this mode. Further studies will be carried out to extend the methodology to the other schools involved in the Go2School project and to perform the SP survey involving students' family, in order to collect the whole family behavior. Moreover, further research will be carried out also to analyze employees' future modal choice thanks to this methodology.

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.

Acknowledgments

The authors thank the AMAT Palermo S.p.A. Company for their involvement in the Go2School project.

References

Barbour, N., Zhang, Y., Mannering, F., 2019. A statistical analysis of bike sharing usage and its potential as an auto-trip substitute. J. Transport Health 12 (February), 253–262. https://doi.org/10.1016/j.jth.2019.02.004.

Ben-Akiva, M., Lerman, S., 1985. Discrete Choice Analysis: Theory and Application to Travel Demand. MIT Press, Cambridge, Massachusetts.

Boniardi, L., Dons, E., Campo, L., Van Poppel, M., Int Panis, L., Fustinoni, S., 2019. Annual, seasonal, and morning rush hour Land Use Regression models for black carbon in a school catchment area of Milan, Italy. Environ. Res. 176, 108520. https://doi.org/10.1016/J.ENVRES.2019.06.001.

Catalano, M., Lo Casto, B., Migliore, M., 2008. Car sharing demand estimation and urban transport demand modelling using stated preference techniques. European Transport 40, 33–50.

Daly, A.J., Rohr, C., 1998. Forecasting demand for new travel alternatives. In: Gärling, T., Laitila, T., Westin, K. (Eds.), Theoretical Foundations for Travel Choice Modelling. Pergamon Press, Amsterdam, Netherlands.

Dewan, K.K., Ahmad, I., 2007. Carpooling: a step to reduce congestion. Eng. Lett. 14 (1), 61–66.

D'Orso, Gabriele, Migliore, Marco, 2017. A GIS-based methodology to estimate the potential demand of an integrated transport system. Computational Science and its applications - ICCSA 2017. In: Gervasi, Osvaldo, et al. (Eds.), In: Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 10407. Springer, pp. 525–540.

D'Orso, G., Migliore, M., 2019. Cycling for home-to-school travel in Palermo: a method for assessing the optimal allocation of new cycling infrastructure. In: Misra, S., et al. (Eds.), Computational Science and its Applications – ICCSA 2019. ICCSA 2019. Lecture Notes in Computer Science, vol. 11620. Springer (Cham).

D'Orso, G., Migliore, M., 2020. A GIS-based method for evaluating the walkability of a pedestrian environment and prioritised investments. J. Transport Geogr. 82, 102555 https://doi.org/10.1016/J.JTRANGEO.2019.102555.

D'Orso, G., Migliore, M., Attanasio, M., Enea, M., Di Maria, G., Lo Monaco, R., Caminiti, D., Marchese, M., Bongiorno, N., 2020. School bike sharing program: will it succeed? Transport. Res. Procedia 47, 171–178.

Ermagun, A., Samimi, A., 2015. Promoting active transportation modes in school trips. Transport Pol. 37, 203–211. https://doi.org/10.1016/J.TRANPOL.2014.10.013.

Fenton, P., 2017. Sustainable mobility in the low carbon city: digging up the highway in Odense, Denmark. Sustain. Cities Soc. 29, 203–210. https://doi.org/10.1016/J.SCS.2016.11.006.

Fishman, E., Washington, S., Haworth, N., 2014. Bike share's impact on car use: evidence from the United States, Great Britain, and Australia. Transport. Res. Transport Environ. 31, 13–20. https://doi.org/10.1016/j.trd.2014.05.013.

Fulton, J.E., Shisler, J.L., Yore, M.M., Caspersen, C.J., 2005. Active transportation to school: findings from a national survey. Res. Q. Exerc. Sport 76 (3), 352–357.

Howland, S., McNeil, N., Broach, J., Rankins, K., MacArthur, J., Dill, J., 2017. Breaking Barriers to Bike Share: Insights on Equity from a Survey of Bike Share System Owners and Operators. https://doi.org/10.15760/trec.173. NITC-RR-884a.

ISTAT, 2011. Spostamenti Per Studio O Lavoro – Censimento.

Kaplan, S., Manca, F., Nielsen, T.A.S., Prato, C.G., 2015. Intentions to use bike-sharing for holiday cycling: an application of the Theory of Planned Behavior. Tourism Manag. 47, 34–46. https://doi.org/10.1016/j.tourman.2014.08.017.

Kuhnimhof, T., Buehler, R., Wirtz, M., Kalinowska, D., 2012. Travel trends among young adults in Germany: increasing multimodality and declining car use for men. J. Transport Geogr. 24, 443–450. https://doi.org/10.1016/j.jtrangeo.2012.04.018.

Lidbe, A., Li, X., Adanu, E.K., Nambisan, S., Jones, S., 2020. Exploratory analysis of recent trends in school travel mode choices in the U.S. Transp. Res. Interdiscip. Perspect. 6 https://doi.org/10.1016/j.trip.2020.100146.

Louviere, J., Hensher, D., Swait, J., 2000. Stated Choice Methods: Analysis and Application. Cambridge University Press, Cambridge.

Lu, M., Sun, C., Zheng, S., 2017. Congestion and pollution consequences of driving-to-school trips: a case study in Beijing. Transport. Res. Transport Environ. 50, 280–291. https://doi.org/10.1016/J.TRD.2016.10.023.

Ma, X., Yuan, Y., Van Oort, N., Hoogendoorn, S., 2020. Bike-sharing systems' impact on modal shift: a case study in Delft, The Netherlands. J. Clean. Prod. 259, 120846 https://doi.org/10.1016/j.jclepro.2020.120846.

Manca, F., Sivakumar, A., Polak, J.W., 2019. The effect of social influence and social interactions on the adoption of a new technology: the use of bike sharing in a student population. Transport. Res. C Emerg. Technol. 105, 611–625. https://doi.org/10.1016/j.trc.2019.02.010.

Mandic, S., Sandretto, S., García Bengoechea, E., Hopkins, D., Moore, A., Rodda, J., Wilson, G., 2017. Enrolling in the Closest School or Not? Implications of school choice decisions for active transport to school. J. Transp. Heal. 6, 347–357. https://doi.org/10.1016/J.JTH.2017.05.006.

Martin, E., Cohen, A., Botha, J., Shaheen, S., 2016. Bikesharing and Bicycle Safety. Report 12-54. Mineta Transportation Institute.

Move, Ricardo-AEA.DG., 2014. Update of the Handbook on External Costs of Transport.

Nielsen, T.A., Haustein, S., 2019. Behavioural effects of a health-related cycling campaign in Denmark: evidence from the national travel survey and an online survey accompanying the campaign. J. Transp. Heal. 12, 152–163. https://doi.org/10.1016/J.JTH.2018.12.003.

Ortuzar, J., Willumsen, L., 1994. Modelling Trasport. John Wiley & Son.

Permain, D., Swanson, J., Kroes, E., Bradley, M., 1991. Stated Preference Techniques: a Guide to Practice. Steer Davies Gleave and Hague Consulting Group, London.

Poku-Boansi, M., Amoako, C., Atuah, D.O., 2019. Urban travel patterns and safety among school children around Accra, Ghana. J. Transp. Heal. 15, 100660 https://doi.org/10.1016/J.JTH.2019.100660.

Pucher, J., Buehler, R., 2008. Cycling for everyone: lessons from europe, 2074 Transport. Res. Rec. 58–65. https://doi.org/10.3141/2074-08.

Rabl, A., de Nazelle, A., 2012. Benefits of shift from car to active transport. Transport Pol. 19, 121–131. https://doi.org/10.1016/J.TRANPOL.2011.09.008.

Schofield, G., Schofield, L., Mummery, K., 2005. Active transportation: an important part of adolescent physical activity. Youth Stud. Aust. 24 (1), 43–47.

Shaheen, S., Guzman, S., Zhang, H., 2010. Bikesharing in europe, the americas, and asia. Transport. Res. Rec. (2143), 159–167. https://doi.org/10.3141/2143-20.

Shaheen, S., Martin, E., Cohen, A., Finson, R., 2012. Public Bikesharing in North America: Early Operator and User Understanding. Report 11-26. Mineta Transportation Institute.

Shelat, S., Huisman, R., van Oort, N., 2018. Analysing the trip and user characteristics of the combined bicycle and transit mode. Res. Transport. Econ. 69, 68–76. https://doi.org/10.1016/j.retrec.2018.07.017.

Sun, S., Ertz, M., 2021. Environmental impact of mutualized mobility: evidence from a life cycle perspective. Sci. Total Environ. 772, 145014 https://doi.org/10.1016/j.scitotenv.2021.145014.

Teixeira, J.F., Silva, C., Neves, J.V., 2019. School mobility management case study: German School of Oporto (Deutsche Schule zu Porto). Case Stud. Transp. Pol. 7, 13–21. https://doi.org/10.1016/J.CSTP.2018.11.002.

Vitale, M., Millward, H., Spinney, J., 2019. School siting and mode choices for school travel: rural–urban contrasts in Halifax, Nova Scotia, Canada. Case Stud. Transp. Pol. 7, 64–72. https://doi.org/10.1016/J.CSTP.2018.11.008.

Zhang, Y., Mi, Z., 2018. Environmental benefits of bike sharing: a big data-based analysis. Appl. Energy 220, 296–301.

Zhang, R., Yao, E., Liu, Z., 2017. School travel mode choice in Beijing, China. J. Transport Geogr. 62, 98–110. https://doi.org/10.1016/J.JTRANGEO.2017.06.001.

Zuo, T., Wei, H., Chen, N., Zhang, C., 2020. First-and-last mile solution via bicycling to improving transit accessibility and advancing transportation equity. Cities 99, 102614. https://doi.org/10.1016/j.cities.2020.102614.