



Fostering active citizen participation and co-design of evidence-based sustainable mobility solutions: a case of Italian schools

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Abstract

Citizen involvement in urban transport planning is crucial for developing policies that respond to the real needs of the community, promoting inclusivity, equity, and social responsibility. The BEC2SCHOOL project aims at providing communities and policy-makers with methods and tools to enhance public participation in transport decision-making processes and foster the co-design of sustainable mobility solutions, taking advantage of smart technologies and citizen sensing. Pilot schools are selected and invited to install low-cost traffic sensors. Workshops and training sessions on sustainable mobility and transport externalities are organized. The workshops include students' participation in a co-design process for the requalification of school street areas, using a multicriteria approach. This study presents the first results of the participatory process implemented in one workshop held at a school in the city of Catania, Italy. This approach aims at supporting the evaluation and selection of the solutions to improve sustainable mobility near schools, considering the data collected by sensors, and actively involving the students by directly inferring their opinions. In particular, the workshop integrated methodological innovations, such as the use of low-cost traffic sensors and the application of a multi-criteria approach in the co-design process, which allowed students to actively and effectively be engaged. Preliminary results highlighted students' priorities in social and environmental areas, with a strong emphasis on reducing pollution and improving road safety. Additionally, the effectiveness of involving schools directly in the participatory design process was confirmed, showing how a data-driven approach can enhance the impact of the proposed solutions. Results confirm the effectiveness of a participatory data-driven approach in analysing problems and co-creating solutions together with stakeholders, paving the way for future initiatives that actively engage school communities in the creation of more sustainable and liveable cities.

Keywords: Public participation, transport sustainability, transport co-design, smart data, stakeholder engagement, participatory design

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1. Introduction

In recent decades, transport planning has undergone a notable evolution, shifting from a technocratic approach to a participatory one. Nowadays, the central role of the individual is increasingly recognized, focusing on their cognitive and decision-making processes (Vitale, 2010). This has led to the overcoming of overly simplified models in favour of a more realistic and complex view of human behaviour related to mobility demand. As early as the 1960s, Jacobs (1961) and Arnstein (1969) emphasized the importance of citizen participation in planning decisions, recognizing their ability to actively influence the decision-making process. Effective management of public participation reduces gaps between different perspectives, motivates local actors in choosing solutions that are reasonable and shared by the community (Nared, 2020). The lack of public participation is also one of the main causes of project failures, as demonstrated by local protests against public infrastructure, often linked to the so-called “NIMBY” syndrome (Le Pira et al., 2017). According to Sagaris (2018), trying to convince residents of the usefulness of a project without first listening to and integrating their needs and expectations can lead to failures both in the participation process and in the project or plan itself. Involving all actors in decision-making processes is thus essential to adopt solutions that truly respond to the needs of communities, especially in urban policies, where citizens have different opinions. This trend is becoming a structured phase also in transport planning, which traditionally was more focused on environmental and economic aspects. Indeed, the social dimension is becoming fundamental to obtain political support in promoting behavioural changes necessary for the success of sustainable transport projects (Sagaris, 2018).

A participatory approach in transport planning promotes inclusion, accessibility, and social responsibility, contributing to greater equity and quality of mobility services. Accessibility is closely linked to equity, as it represents the extent to which land use and transport systems enable community members to move to reach an activity or destination (Van Wee, et al., 2011).

The importance of actively involving people in the transport decision-making process is today widely recognized and considered essential to achieving effective and shared results (Le Pira et al., 2020). Different methods can be used to support participation. Assefa et al. (2024) used an integration of multicriteria decision-making (MCDM) methods (AHP, ELECTRE), the involvement of qualified stakeholders, and the use of Monte Carlo simulation to address decision complexity regarding a tram train system in a transparent and replicable manner. A further contribution to the methodological discussion comes from the analysis of a tactical urbanism intervention carried out in a street in Bologna (Ceccarelli et al., 2023), where part of the roadway was transformed into a public space dedicated to children. In this case, the analysis of the intervention is based on a data-driven method that uses computer vision techniques, georeferencing, and spatial analysis tools to monitor pedestrian flows through the processing of videos recorded in the area before and after the intervention. This approach allowed mapping pedestrian behaviours with high precision, translating movements into spatial and temporal data to assess the intensity and nature of space use.

Ellis et al. (2015) underline the importance of including children in the urban planning process. They used a case study in Belfast, where children were involved in evaluating their local environment, providing reflections on issues affecting their daily lives. Results revealed that children’s concerns were very similar to each other, such as the need for flexible play spaces, as well as improved traffic management and cleanliness of public

spaces. The active participation of stakeholders, such as children and in general school students, represents an essential element in transport planning processes, as they possess in-depth knowledge of transport infrastructure and public mobility services, derived from daily experience. As emphasized by Nostikasari (2015), students provide experience-based knowledge, a type of knowledge that is fundamentally important for identifying concrete and effective solutions. Moreover, their involvement is even more relevant considering that the transition to more sustainable forms of mobility implies, in most cases, a change in individual and collective behaviour (Nared, 2019).

1.1 Research gap and study objectives

Literature reveals the possibility of constructing hybrid methodological models capable of integrating the different dimensions of the urban design process. Qualitative investigation allows exploring perceived needs and social representations of urban space, particularly among younger groups; the multi-criteria approach introduces a level of comparison among alternatives, fundamental for infrastructure planning; finally, the digital monitoring of behaviours through collected data offers empirical verification of the effects produced by interventions, contributing to a more informed and adaptive decision-making cycle. All this highlights the importance of including real users—citizens, students, experts—as legitimate actors in urban transformation paths. Nevertheless, participation is often looked as a compulsory step of the decision-making process, depriving it from its effectiveness (Le Pira, 2018). In particular, the youngest are usually not considered among stakeholder groups, leaving an important gap. Besides, to have an active role in the decision-making process, citizens should be empowered, and data are fundamental in this respect. Following the citizen sensing approach, employing low-cost sensors can be useful to evidence local issues and empowers citizens to use the data they collect (Coulson et al., 2021). This also supports Citizen Science, when the public voluntarily helps conduct scientific research.

Based on this premise, this paper aims to propose a citizen sensing-participatory approach involving school students in transport decision-making, filling a still underexplored gap: the integration of citizen perception, empowered by data and particularly that of young people, into decision-making processes related to urban mobility. To this end, a participatory approach is presented that actively involves school students in monitoring and analysing mobility data, promoting their role in defining sustainable solutions. Preliminary results of the BEC2SCHOOL project are presented, in particular the results of a workshop with one of the schools involved in the Project. The goal is to demonstrate the effectiveness of a participatory approach in promoting sustainable mobility solutions, paving the way for future initiatives that actively involve school communities in building more sustainable and liveable cities.

The remainder of the paper is organised as follows. Section 2 introduces the research framework, with a description of the Project. Section 3 presents the participatory analysis performed in a case study of a school in Catania (Italy), while section 4 describes and discusses the results obtained. This will pave the way for further evaluation and identification of suitable solutions to be proposed to policy-makers. Section 5 concludes the paper identifying limitations and future research directions.

2. Research framework: the BEC2SCHOOL project

The BEC2SCHOOL project, funded by the Italian Ministry of University and Research as part of the PRIN 2022 PNRR call, aims to develop bottom-up approaches in decision-making processes for sustainable urban mobility. This approach encourages active listening and the elicitation of ideas coming directly from the participants involved, promoting a horizontal and inclusive participation model. The initiative aims to actively involve citizens, particularly young people, providing them with practical tools to collect and analyse urban traffic and environmental data in the spaces they experience daily, such as the area around the school. The ultimate goal is to co-create, together with them, sustainable mobility solutions to be presented to policy-makers. One of the most important aspects of the Project is raising awareness among new generations on the issues of sustainable mobility through participatory processes. The project also promotes the creation of participation mechanisms involving all stakeholders: schools, institutions, families, students, and local administrators. This collaborative approach facilitates the dialogue between citizens and institutions, promoting solutions towards more sustainable, fair, and community-oriented transport systems.

Fig. 1 succinctly reports the different phases of the Project, that can be divided in the following steps:

1. Firstly, schools were selected and were involved via an initial meeting, during which we presented the aims of the initiative and explained the application process.

2. Next, traffic sensors were installed, accompanied by training sessions on how to use the devices and interpret the data.

3. The monitoring phase was then launched, and the sensors continuously recorded data related to traffic counts in the areas surrounding the schools. The data collected can be visualized on a publicly accessible platform, and used to identify mobility-related critical issues.

4. Finally, a co-design process with the involved stakeholders was initiated. This allowed for the development of design solutions tailored to the specific context of each school.

Pilot schools were selected based on a context spatial analysis considering specific criteria, such as the presence of infrastructures dedicated to sustainable mobility, e.g. bike lanes and sidewalks, the existence of traffic and air quality issues, and their geographic location (Giuffrida and Le Pira, 2025); moreover, their participation in the project was volunteer. They are located in three Italian cities, i.e. Andria, Catania and Milan, providing different contexts ranging from small to medium and big cities, and different education levels. The chosen sensors are Telraam sensors (Telraam, 2025), which are low-cost sensors continuously monitoring a street from a building window, providing data on flow and speed of various modes of transport, including light and heavy motorized vehicles, two-wheel users, and pedestrians, displayed on an openly accessible dashboard. Traffic data can also be used to simulate the environmental impact, e.g. via specific modelling approaches and software like ENVI-met. In general, they represent the starting point of the co-design phase with stakeholders, aimed at finding suitable solutions to improve the accessibility of the schools, to be promoted and discussed with policy-makers.

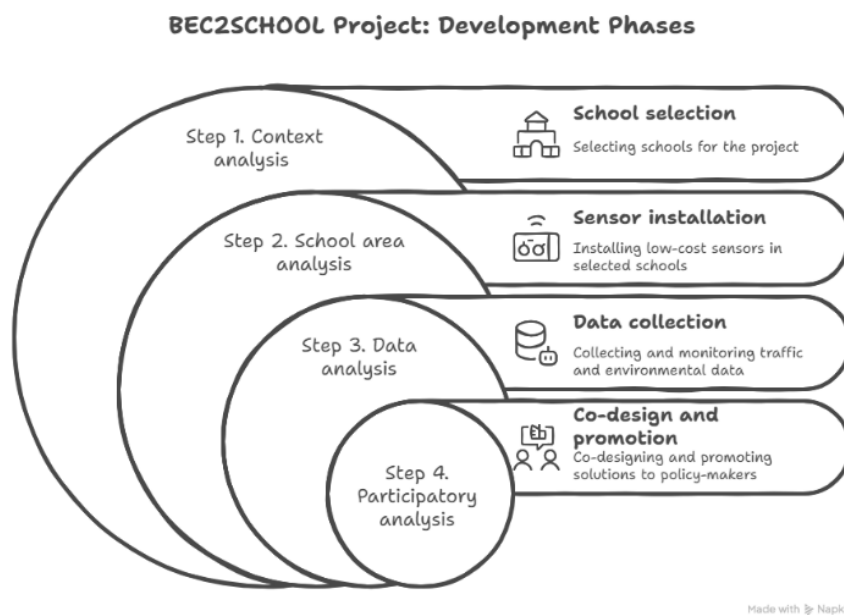


Fig. 1: Steps of the BEC2SCHOOL project

Data and methods for the step 4 related to the participatory analysis and co-design process that took place in one of the schools and the related results are presented in the following section.

3. Participatory analysis: application to a case study

3.1 The school context and traffic data analysis

This paper analyses the case of the a comprehensive school in Catania. In particular, it presents the results of the workshop that was held in February 2025.

The Institute is composed of two buildings located in a central and well-connected area of the city. The venues host the classes of the kindergarten, primary school, and lower secondary school. Although situated in an area well connected via main roads, the surrounding area of the institute can experience heavy traffic, especially during peak hours, such as early in the morning and late in the afternoon. Parking availability nearby is limited during these times, but there are still some areas where one can park around the institute. The institute is well-served by public transport, with several bus lines connecting the area to other parts of Catania. Additionally, a nearby metro station is present, making public transport a convenient alternative; however, Catania is a city with a high mode share in favour of private transport, and parents usually take the children to schools by car. The area surrounding the school is equipped with pedestrian crossings and traffic lights, but during the school entrance and exit times, pedestrian traffic increases significantly, sometimes causing safety concerns. Moreover, the commercial vitality of the area, characterized by the presence of shops, offices, and residential buildings, contributes to traffic congestion, particularly during peak hours.

, Three Telraam sensors have been installed in the institute venues to collect traffic data for the area around the school, two to monitor the first building hosting the lower

secondary school, and one to monitor the other venue. These streets were chosen since they are the ones surrounding the school buildings, with a particular attention to those where their school entrance is placed. The data collection procedure started at the end of November 2024 and it is still ongoing.

Figure 2 illustrates the average hourly traffic trends observed during a typical weekday for the three monitored roads. The data refer to the time range in the months of February and March 2025:

- Street 1 where the main entrance of the lower secondary school is located exhibits the highest traffic volumes among the three roads. Traffic increases sharply from 06:00, reaching approximately 400 vehicles/hour by 08:00, with a peak between 12:00 and 13:00, exceeding 500 vehicles/hour. A decline follows in the early afternoon, succeeded by a secondary peak between 17:00 and 18:00, corresponding to typical evening return times. This is then followed by a rapid decrease in vehicle flow.

- Street 2 (secondary entrance of the lower secondary school) and Street 3 (kindergarten and primary school) experience significantly lower traffic volumes, ranging between 50 and 150 vehicles/hour. Despite their lower intensity, both streets display a similar diurnal pattern, with peaks during the morning and late afternoon hours.

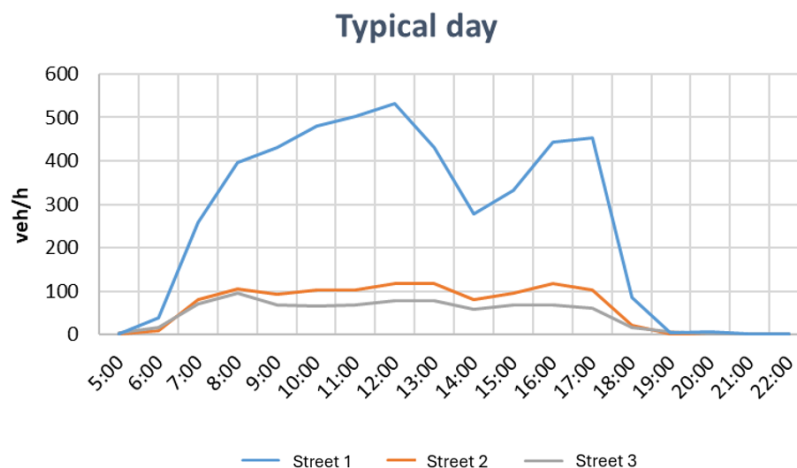


Fig. 2: Average Hourly Traffic Trend on a Typical Weekday

Figure 3 shows daily traffic volumes for each road:

- Street 1 is confirmed to be the primary traffic artery, registering approximately 5,500 vehicles/day on weekdays, with a slight drop on Thursdays. On Saturdays, traffic decreases to around 4,000 vehicles/day, followed by a more pronounced drop on Sundays (approximately 2,500 vehicles/day).

- Street 2 shows relatively stable volumes, fluctuating between 1,300 and 1,500 vehicles/day on weekdays, with a gradual decline over the weekend.

- Street 3 records the lowest traffic volumes, around 1,000 vehicles/day on weekdays, which also decrease over the weekend.

To complement the analysis of Street 1, data on average hourly speeds for the analysed period are also presented (Figure 4). The majority of vehicles travels at speeds below 30 km/h, particularly during the central hours of the day, where this category represents up to 80% of the total traffic. However, around 20% of the vehicles travel between 30 and 50 km/h, a range that could significantly increase the risk of accidents and their

consequences. Speeds between 50 and 70 km/h are marginal (below 10%), with a slight prevalence during early morning hours and between 14:00 and 15:00. Nonetheless, the data show that at certain times of the day, vehicles exceed legal speed limits.

Street 1, although classified as a local road, displays consistently high traffic volumes throughout the weekday, with peak hours exceeding 500 vehicles/hour. This suggests that the road may be serving as a through-route, a function which is inconsistent with its local designation. Such conditions warrant measures to protect the road from intense vehicular flow, particularly given the presence of schools.

Street 2 and street 3 have lower and more appropriate traffic volumes for their classification as local roads (approximately 1,000–1,500 vehicles/day). Nonetheless, both roads show traffic patterns typical of school and commuter flows, with peaks observed in the morning and late afternoon.

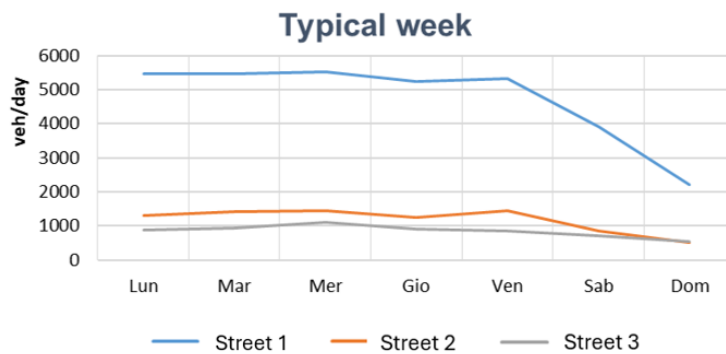


Fig. 3: Average Daily Traffic Volume during a Typical Week

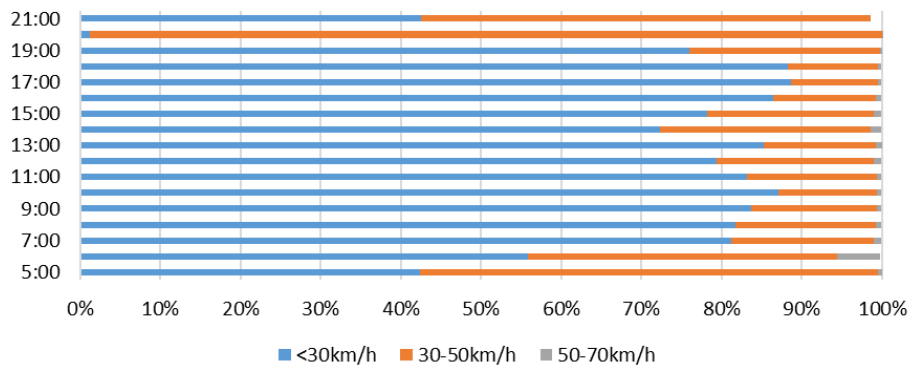


Fig. 4. Average Hourly Vehicle Speeds for the analysed period for Street 1

3.2 The workshop: design and implementation

Starting from the results of the traffic data analysis, and in order to ensure the active involvement of the most relevant stakeholders based on a bottom-up approach, several workshops were organized with the students of the schools involved in the initiative. The workshops were structured in two main phases, combining theoretical training and practical activities. In the first phase, the students were sensitized to key themes related to sustainable mobility, such as the environmental and social impacts of transport, and best practices adapted to similar urban contexts (Fig. 5a). Topics related to road safety

were also addressed to raise awareness among students about risks and possible solutions to improve safety in school areas. The traffic sensor technology and the dashboard were presented. Students had the opportunity to interact directly with the sensors, gaining a practical understanding of their use and the issues related to the negative impacts of traffic. Data collected and presented in subsection 3.1 were presented to the students, providing a detailed view of road congestion during different time slots and the mobility issues associated with it. This approach fostered greater awareness of traffic management issues, stimulating potential solutions to improve urban liveability.

The second practical part of the workshop consisted of a participatory design activity. With the support of the research team and teachers, students were invited to imagine and rethink the space around their schools. The general objective of the analysis was to improve the liveability of the space around the school. Together with the students, a decision-making hierarchy was established, which will later be used for the analysing different solutions via multicriteria methods, according to structured approaches (see e.g. Gonzalez-Urango et al., 2020).

The practical activity involved four classes of lower secondary school, each composed of about 20 students. Each student was involved in an ideation process by writing suggestions and ideas on coloured papers, all aimed at the common goal of making the surrounding environment more sustainable and liveable. The ideas were then organized on a large board showing the three main areas of sustainability: environmental, economic, and social (Fig. 5b). This framework allowed for a clear mapping and visualization of how each proposal could address one or more sustainability criteria, thus facilitating a deeper discussion on priorities and potential solutions.



Fig. 5: Pictures from the workshop: (a) theoretical training; (b) practical activity

To analyse students' proposals, a qualitative methodological approach was adopted, supported by thematic coding, following the methodological steps suggested by Braun and Clarke (2006). The main objective of the process was to identify conceptual repetitions within the qualitative data emerging from the ideas proposed by the participants. The coding was conducted manually, with the aim of bringing out the dominant themes and better understanding the distribution and frequency of the ideas expressed by the students.

The re-reading of the observations (Ritchie et al., 2013) collected during the activity allowed for the identification of thematic codes, which were associated with the main dimensions of sustainable mobility proposed to students.

To support this analysis and translate it into quantitative data, a thematic coding system was developed, associating each proposal with a descriptive code representing its main dimension (codes 1-3) and category (codes A-C). The coding not only organized the information in a systematic way but also made it possible to quantify the recurrence of

the themes, allowing for comparison between the different categories and providing a solid basis for making informed decisions consistent with the evidence emerging from the group work.

Each proposal was then placed into the corresponding category, depending on the topic addressed. This made the entire analysis system even more precise and functional, as it allowed for a comprehensive reading of the results. Furthermore, the frequency with which each theme was mentioned was indicated, highlighting the level of consensus and the importance attributed by the participants to certain topics.

4. Results and discussion

During the workshop, participants made a total of 205 proposals.

The categories identified for each sustainability dimension are:

- 1) Social dimension:
 - a) Accessibility and Safety
 - b) Socialization and Gathering Spaces
 - c) Education and Community Awareness
- 2) Economic dimension:
 - a) Traffic Management Improvement
 - b) Support from Public Administration
 - c) Investments in Green Infrastructure
- 3) Environmental dimension:
 - a) Reduction of Air Pollution
 - b) Creation of Green Spaces
 - c) Sustainable Resource Management

This facilitated a more precise classification and a detailed understanding of the priorities expressed by the participants.

As shown in Table 1, overall, the environmental dimension recorded the highest number of contributions, with a total of 82 proposals (40% of the total), followed by the social dimension with 77 proposals (38%), and finally the economic dimension, with 46 proposals (22%).

Within the social dimension, the Accessibility and Safety subcategory (1A) includes 28 proposals focused on improving road safety, accessibility for people with disabilities, and the quality of pedestrian or cycling infrastructures. The Socialization and Gathering Spaces subcategory (1B) received 4 proposals, highlighting the need to create public environments for meeting and relationship-building. The Education and Community Awareness subcategory (1C) recorded 45 proposals, showing a marked interest in increasing educational and training activities related to sustainable mobility, environmental respect, and active citizenship. Awareness raising is particularly important for school street projects implying a closure of the street, since it can be contested by stakeholders because of diverse interests (e.g. of school, residents and retailers) (Distefano et al., 2025).

The economic dimension reveals significant insights. The Traffic Management Improvement subcategory (2A) highlighted 2 proposals related to reducing congestion in school areas and transport costs.

The Support from Public administration subcategory (2B) includes 11 proposals focused on economic incentives and investments in public transport. Particularly significant is the Investments in Green Infrastructure subcategory (2C), which gathers 33

proposals aimed at creating green areas, valued not only for their environmental importance, but also for the potential indirect economic benefits, such as territorial enhancement and increased attractiveness of urban spaces.

Regarding the environmental dimension, the subcategory Reduction of Air Pollution (3A) gathered 42 proposals focused on strategies aimed at decreasing emissions linked to urban traffic, including the promotion of electric vehicles, public transport, and pedestrian mobility. In the subcategory Creation of Green Spaces (3B), 33 proposals were formulated concerning the planning and creation of urban natural areas, considered essential to improving air quality and overall environmental well-being. Finally, in the subcategory Sustainable Resource Management (3C, 7 proposals), most of the contributions emphasized the need to reduce energy and material consumption, promoting more responsible practices focused on long-term sustainability.

Table 1: Thematic coding table based on student proposals

	<i>1.A Accessibility and Safety</i>	<i>1.B Socialization and Gathering Spaces</i>	<i>1.C Education and Community Awareness</i>
SOCIAL	14 Making the school area more accessible and safer for people with disabilities 6 Improving road safety 3 Improving the condition of sidewalks and roads 3 Creating school streets 2 Creating cycle paths	4 Increasing meeting and socializing spaces that allow social well-being	17 Educational activities on the importance of using sustainable transport modes to reduce air pollution 9 Educational activities aimed at encouraging practices such as separate waste collection 7 Educational activities on Road Rules 5 Educational activities on the importance of avoiding consumption 4 Educational activities on the importance of keeping the environment clean 3 Educational activities on respect for public spaces
	<i>2.A Traffic Management Improvement</i>	<i>2.B Support from public administration</i>	<i>2.C Investments in green infrastructure</i>
ECONOMIC	2 Improving school traffic management by reducing congestion and costs	6 Economic supports from the public administration 4 Reducing transport costs 1 Investing in public transport	33 Creating green areas that would bring indirect economic benefits, such as the enhancement of the surrounding area, the increase in the attractiveness of the neighbourhood and the increase in the value of real estate
	<i>3.A Reduction of Air Pollution</i>	<i>3.B Creation of Green Spaces</i>	<i>3.C Sustainable Resources Management</i>
ENVIRONMENTAL	7 Reducing traffic pollution 1 encourage the use of electric vehicles 4 Encourage the use of public transport 14 encourage the use of bicycles 9 encourage walking 7 avoid using the car	33 Planning of green spaces that contribute to improving air quality	5 Avoiding consumption 2 Implementation of sustainable practices such as the use of recyclable materials

The results emerging from the workshop show a rather balanced distribution between the social and environmental dimensions, with a slight predominance of the latter. This data suggests that in the analysed school context, environmental issues represent a clearly perceived priority by the students. The strong incidence of proposals in the field of environmental and civic education also highlights a perception of sustainable change as a cultural process before being infrastructural. This element confirms the formative potential of actively involving young people in urban planning processes, not only as recipients but also as active subjects. The lesser representativeness of the economic dimension could be attributed to a more limited familiarity of students with topics related to incentives, costs, or investments. However, the numerous proposals on green infrastructure demonstrate an implicit awareness of the connection between environmental quality and indirect economic benefits, suggesting an interconnected vision of sustainability.

Overall, the priorities expressed by the students are consistent with the workshop's objectives, contributing to outlining areas of intervention that reflect the needs directly perceived by the youngest users of the school urban space. This workshop represents the baseline for the ones organized at the other schools involved in the Project. Its structure is easily replicable to other contexts and allow comparisons among schools implying different educational levels.

5. Conclusion

This paper presented the first results of a participatory workshop with school students, aimed at understanding their opinions regarding potential strategies to increase school area liveability. Students received a specific training on sustainable mobility and were shown the results of the traffic monitoring performed via low-cost sensors installed on school windows within the BEC2SCHOOL project. Then, they were asked to express their ideas using coloured sheets on a dashboard that were analysed using a qualitative approach. The environmental dimension was students' primary interest. Key proposals focused on reducing air pollution through sustainable transport. They also highlighted the importance of urban green spaces for well-being and air quality. A clear sensitivity towards sustainable resource management, emphasizing responsible consumption and recycling, was also evident. These data indicate strong ecological awareness and a preference for practical sustainability solutions among students.

This first qualitative and thematic analysis represents a basis on which to build future more structured and in-depth investigations. Of course, results are limited to the single case study; this limitation reduces the possibility of generalization, as the socio-economic, infrastructural, and cultural factors influencing urban mobility dynamics may vary significantly in different contexts. To consolidate the effectiveness of the approach, it will be necessary to extend its application to other schools, expand the empirical base. Moreover, in future research, the data collected and organized can be used to apply a multicriteria approach, such as the AHP (Analytic Hierarchy Process) method, which will allow to assign specific priorities and weights to the different factors that emerged, thus facilitating the definition of shared strategies. This will make it possible to integrate the social, economic and environmental dimensions of sustainable mobility into a complex, but at the same time accessible, evaluation model, with the aim of guiding effective interventions consistent with the identified needs. The results obtained, although limited to a single case study, can be considered a methodological starting point towards the

development of a broader and replicable approach, aimed at understanding more precisely the real needs expressed by local communities, with particular attention to the school community. Planning towards territorial and environmental justice cannot disregard an approach that simultaneously values the collective involvement of communities and the empirical evidence provided by data.

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