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DATA-DRIVEN TREND ANALYSIS ON SUSTAINABLE AND SMART MOBILITY IN ITALY

Summary. This paper presents a data-driven trend analysis of sustainable, shared, and zero-crash mobility within the Italian context, serving as a starting point for research aimed at assessing the current level of knowledge regarding novel mobility concepts and challenges. A pilot sample of 30 respondents over the age of 60 years old was selected for the prototype survey interview conducted to evaluate their knowledge and perceptions concerning the transition towards sustainable and smart mobility. Key findings from the interviews provided valuable insights into older adults' understanding of the topic and their expectations, offering a foundation for future policies and inclusive initiatives to contextualize Italian experiences within global trends in sustainable mobility for urban planners and policymakers.
Keywords: sustainability, cities, smart mobility, road infrastructure, survey interview

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1. INTRODUCTION

Sustainable urban mobility is rapidly advancing driven by digital innovations and growing environmental awareness, with goals to reduce emissions and improve road system efficiency and accessibility in built environments [1,2]. Transforming road infrastructure with smart technologies and ensuring resilience against challenges like climate change and urbanization are increasingly essential [3,4]. As urbanization continues – with over 60% of the European population projected to live in cities – issues such as traffic congestion, road safety, infrastructure deterioration, and air pollution have become critical, emphasizing the urgent need for smart mobility solutions [5]. Road infrastructure plays a vital role in shaping urban dynamics by impacting economic growth, promoting social inclusion and access to public transportation, and ensuring environmental sustainability [6]. Well-designed road systems enhance accessibility for diverse users, emphasizing the need to understand how evolving infrastructure influences user experiences and societal trends while supporting eco-friendly innovations for sustainable and safe mobility [7,8]. To become smarter, road infrastructure should incorporate four core aspects: self-awareness via real-time monitoring of road conditions and traffic; interactive information sharing among connected intelligent devices, sensor networks, and databases; self-adaptation for automatic adjustments to traffic variations; and energy harvesting from road pavements to power smart systems [4,9]. In this context, road infrastructure needs advanced communication, sensors, and data analytics, with smart traffic systems utilizing real-time data to improve traffic flow and fuel efficiency [9]. Innovations like adaptive traffic signals and vehicle-to-everything communication can enhance safety and efficiency by enabling communication between vehicles and infrastructure [10]. The expansion of Big Data via smart devices and digital communities also allows for extensive data collection while safeguarding privacy and data quality [7]. However, a holistic design approach is essential to ensure the resilience of road infrastructure, maintaining the functionality of roads and intersections under stress [11]. Circularity in road construction and management is crucial, focusing on sustainable materials, resource recycling, and waste minimization to balance current needs with future sustainability [12]. Key questions still include making mobility authentically smart, developing resilient infrastructure, and integrating circularity with emerging technologies. Adapting to new mobility models is vital for the future of cities and residents' well-being.

Based on the above, this study examines trends in sustainable, shared, and zero-crash mobility in Italy to explore the dilemma between traditional road network designs and modern urban mobility challenges. As Italian cities rapidly expand and evolve, it is crucial to adapt road infrastructure to meet changing transportation needs. Data-driven trend analysis prompted us to initiate research to assess the current level of knowledge surrounding sustainable and smart mobility concepts. From an inclusive perspective, we conducted a prototype survey interview with a pilot sample of respondents over 60 years old to evaluate their awareness of sustainable and smart mobility, as well as their perceptions and experiences related to the topic. The key findings from the face-to-face interview phase provided valuable contextual insights, deepening our understanding of older adults' needs and expectations regarding urban mobility. These insights can serve as a foundation for developing effective policies and inclusive initiatives that address the specific needs of older adults, while also contextualizing Italy's experiences within global trends to contribute to the discourse on sustainable mobility for urban planners and policymakers facing similar challenges.

After reviewing mobility concepts and data-driven analysis of sustainable, shared, and zero-crash mobility in Italy (Section 2), the research methodology involving surveys with elderly participants is detailed in Section 3. Section 4 presents and analyses the results, with conclusions in Section 5.

2. INSIGHTS FROM MOBILITY CONCEPTS AND DATA TRENDS

Urban mobility in Italy is evolving to address modern challenges and foster healthier and more interconnected communities [13,14]. As urban populations grow and transportation demands increase, sustainable mobility policies are essential to efficiently manage infrastructure and adapt to new mobility trends, improving residents' well-being. Smart urban planning is vital in integrating diverse transport modes – like buses, bicycles, and shared systems – into a cohesive, inclusive, and environmentally sustainable network [13-15]. Investments in road infrastructure should encourage active lifestyles, while advances in connected and automated mobility aim to enhance traffic management and safety, leading to a more efficient urban transport system [9]. Data collection is key to understanding mobility trends and creating liveable cities. In Italy, a centralized system aggregates local authorities' data to produce annual reports that compare mobility patterns over time (e.g., [14,15]). The following sections analyze trends in sustainable, shared, and zero-crash mobility in Italy to assess the current situation.

2.1. Trends in Sustainable Mobility

Mobility trends indicate that Italy has a high motorization rate, with about 694 passenger cars per thousand inhabitants in 2023 [13]. Fig. 1, based on Eurostat data as of January 2025, provides a benchmark for comparing vehicle ownership and usage across EU countries [13].

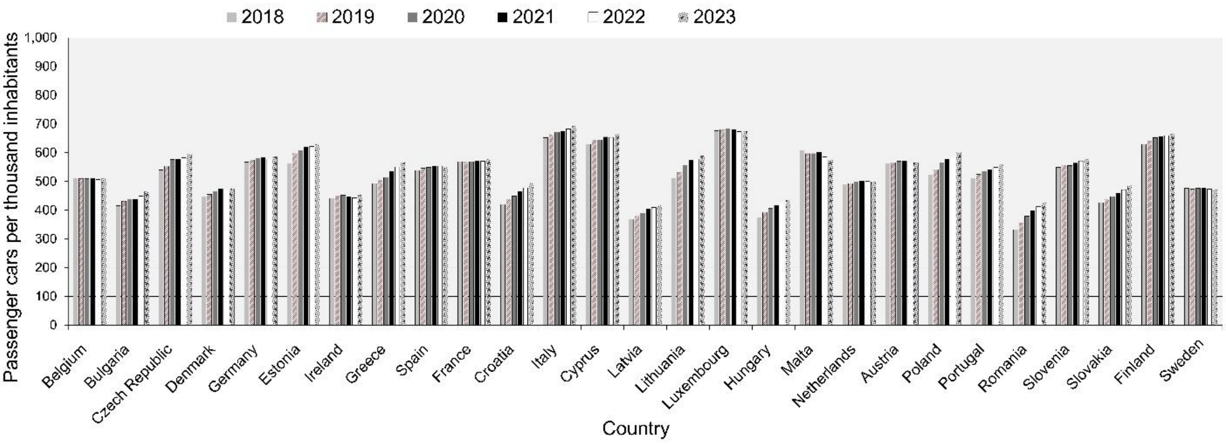


Fig. 1. Motorization rates in the EU 27
Source: data elaborated by the authors from [13]

In 2023, Italy had the highest car ownership in the EU, surpassing the average of just under 600 cars per thousand inhabitants. Fig. 2 compares passenger car counts per thousand inhabitants in Italy and major EU economies like France, Germany, Spain, and Poland over the years. Urban mobility data indicate rising vehicle motorization rates in Italian cities, with progress towards sustainable transportation lagging, emphasizing the need for stronger efforts to promote greener options. Although use of bicycles, public transport, and electric vehicles is increasing, the share of low-emission cars remains relatively modest [14].

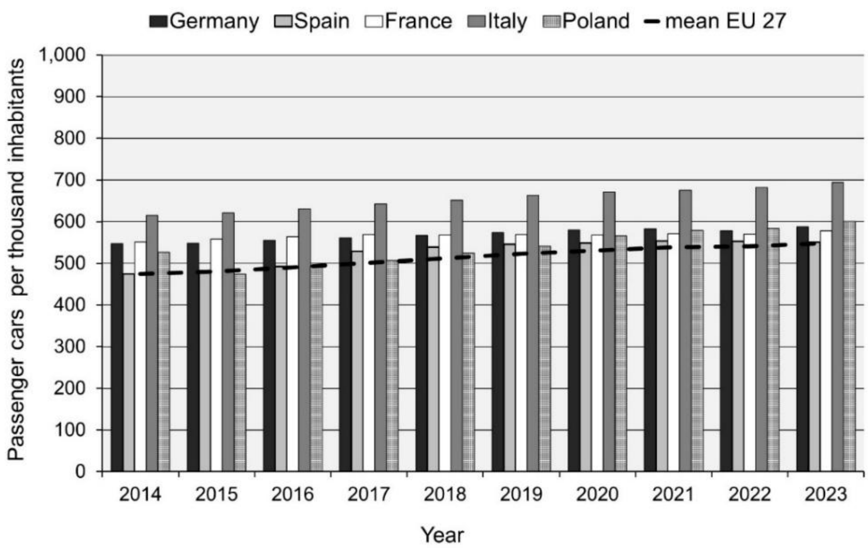
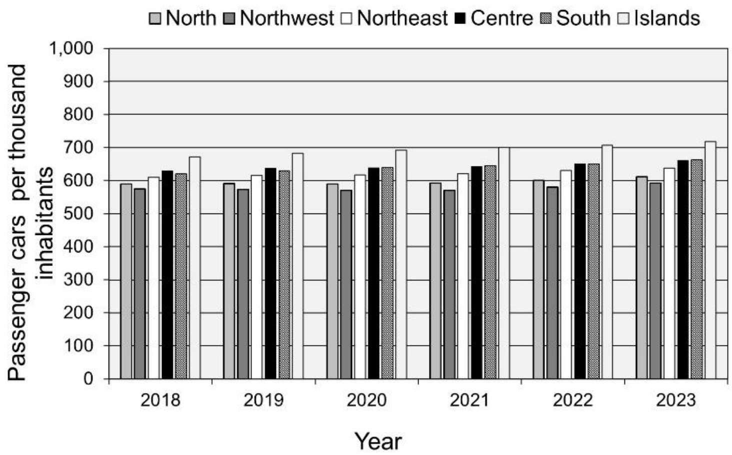
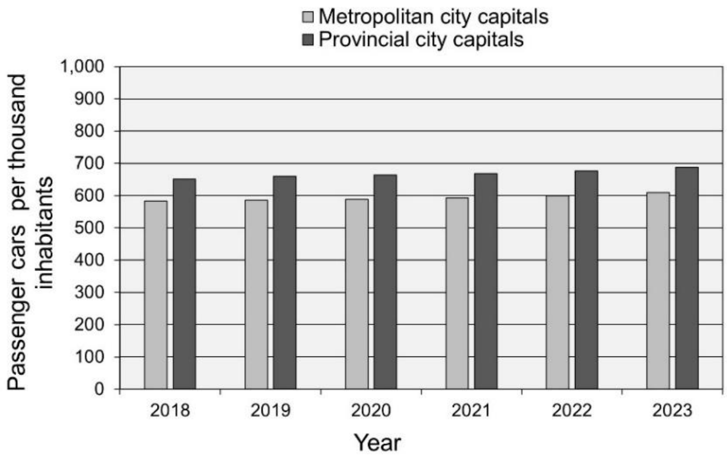


Fig. 2. Passenger cars per thousand inhabitants in European countries.
Note: mean EU is the mean value recorded in the EU countries
per year during the considered timeframe
Source: data elaborated by the authors from [13]

Fig. 3 shows Italy's motorization rates from 2018 to 2023, measured as passenger cars per thousand inhabitants, categorized by geographical area and city type – metropolitan city capitals (larger urban areas) and provincial capitals (main cities of provinces). Differences among macro-areas are influenced by variations in road infrastructure and public transport. Densely populated Italian cities often have lower motorization rates due to available public transport, walkable environments, and cycling options, which reduce reliance on private cars and promote sustainable mobility. These geographical differences in 2023 show variation from previous years [14]: northern capitals have 612 passenger cars per thousand inhabitants, central capitals 660, and southern capitals 662 (see Fig. 3a). Larger metropolitan city capitals average 609 cars per 1,000 inhabitants, while provincial capitals have 687, compared to the overall average of 648 per thousand inhabitants across all capitals [14]. Cities with extensive public transport, especially in northern areas (see Fig. 3a) and metropolitan city capitals (see Fig. 3b), tend to have lower motorization rates due to better public transport options [14]. In 2023, most Italian metropolitan capitals experienced higher motorization rates compared to 2018, except Turin, which slightly decreased from 640 to 638 cars per 1,000 inhabitants. Notably, Southern cities like Naples, Palermo, Messina, and Catania saw the largest increases [14]. Between 2021 and 2023, vehicle density – vehicles per kilometre of urbanized area – was about 60% higher in metropolitan capitals than in provincial capitals [14]. Further details are provided in Fig. 4. Fig. 4a features a stacked bar chart illustrating the annual percentage changes in passenger cars by fuel type – gasoline, diesel, and low-emission cars (such as gas or bi-fuel, electric, and hybrid) – in Italian cities from 2018 to 2023 [14,15]. Between 2018 and 2023, the growth of gasoline cars slowed by about 6%, and diesel cars by 12%, largely driven by a rise in low-emission vehicles, which accounted for approximately 50% of new registrations since 2020 [14]. In 2023, Venice has one of the lowest shares of gasoline cars, while Rome and Milan lead in low-emission vehicle adoption. Southern cities like Naples, Palermo, and Cagliari also closely follow in embracing low-emission options [14]. Fig. 4b presents the pollution potential index of passenger cars by city capital type, evaluating vehicle composition based on emission class (Euro 1 to Euro 6) and fuel type (gasoline, diesel, gas, bi-fuel, electric, and hybrid).



(a)

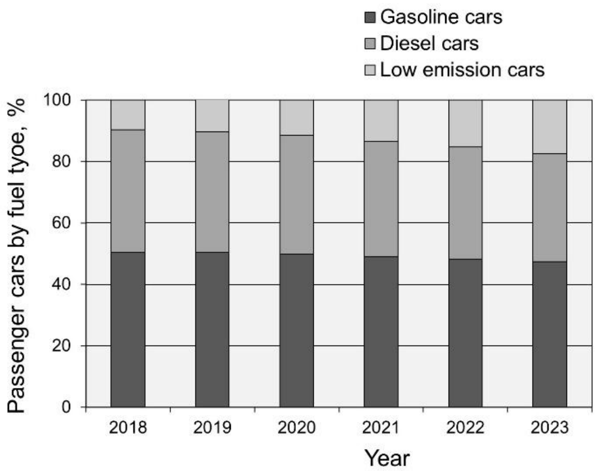


(b)

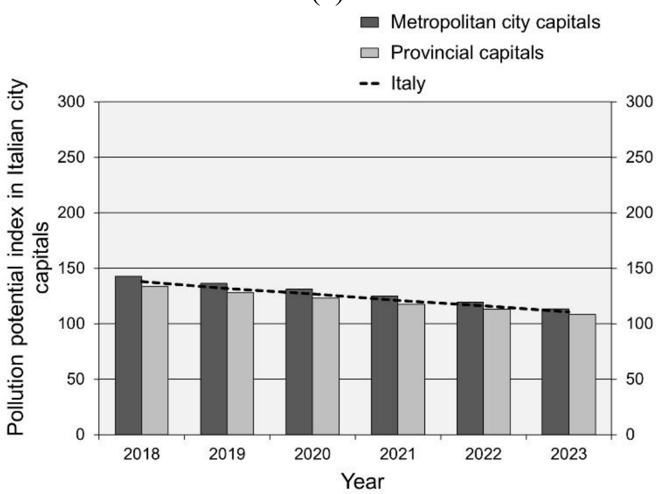
Fig. 3. Motorization rates in passenger cars per thousand inhabitants in Italy by (a) geographical area and (b) type of city (metropolitan city capitals and provincial capitals) Source: data elaborated by the authors from [14]

Vehicles are categorized into high, medium, or low pollutant potential levels: high (Euro 0 to Euro 3), medium (Euro 4 to Euro 6), and low (gas or bi-fuel, electric, and hybrid vehicles). Notably, Euro 0 cars, registered before December 31, 1992, are included, while pre-Euro 4 hybrid cars are excluded from the low pollutant potential category [14]. The pollution potential index is 100 when high-and low-polluting vehicles are equal in number. Values above 100 indicate more high-polluting vehicles, while values below 100 signify a dominance of low-polluting vehicles. Overall, data shows a consistent decrease in pollutant potential over time (see Fig. 4b). However, in southern cities with older vehicle fleets, the indicator remains higher in 2023 compared to the North and Centre, where there's a closer balance between polluting vehicles and low-emission options compared to the South [14,15].

The energy transition is advancing gradually, with electric cars remaining a small proportion compared to gasoline vehicles. Since 2019, the adoption of low-emission cars has increased, mainly due to the rise of hybrid vehicles combining electric and combustion engines.



(a)



(b)

Fig. 4. Environmental indicators in Italy (2018-2023): (a) Passenger cars percentages by fuel type; (b) Pollution potential index of cars by city capital, compared to Italy's overall trend based on averages from provincial and metropolitan city capitals
Source: authors' elaboration based on [14,15]

However, the largest segment continues to be gas (methane or LPG) and bi-fuel cars, still classified as fossil fuel-powered (see Fig. 5). Italy has the highest car ownership in the EU but is gradually transitioning towards sustainable transportation. Despite the increasing adoption of low-emission vehicles, older and more polluting cars are still widespread, particularly in the South. Recognizing regional disparities underscores the urgent need to enhance public transportation and promote shared mobility solutions. Ongoing monitoring, data collection, and strategic planning are crucial to fostering greener mobility in Italian cities.

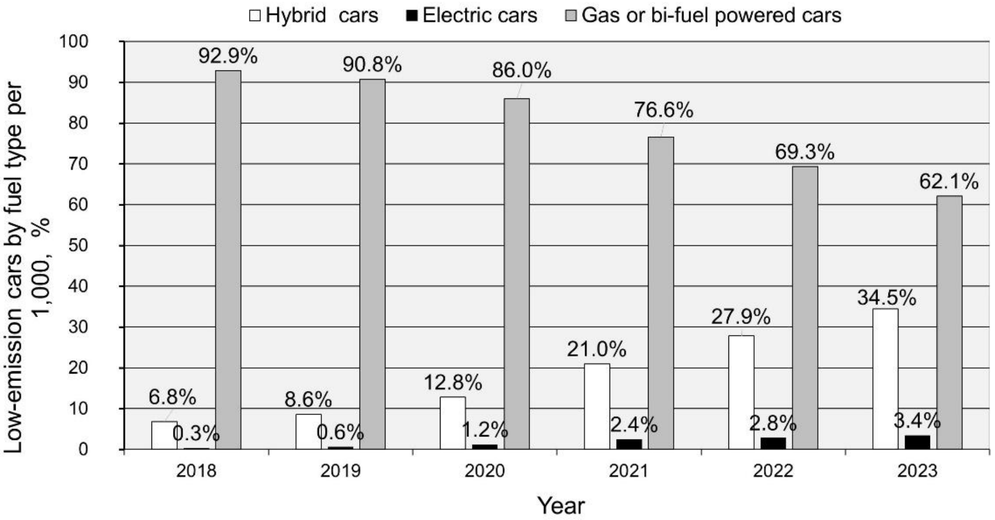


Fig. 5. Percentages of low-emission cars by fuel type per 1,000 cars
Source: data elaborated from the authors from [14]

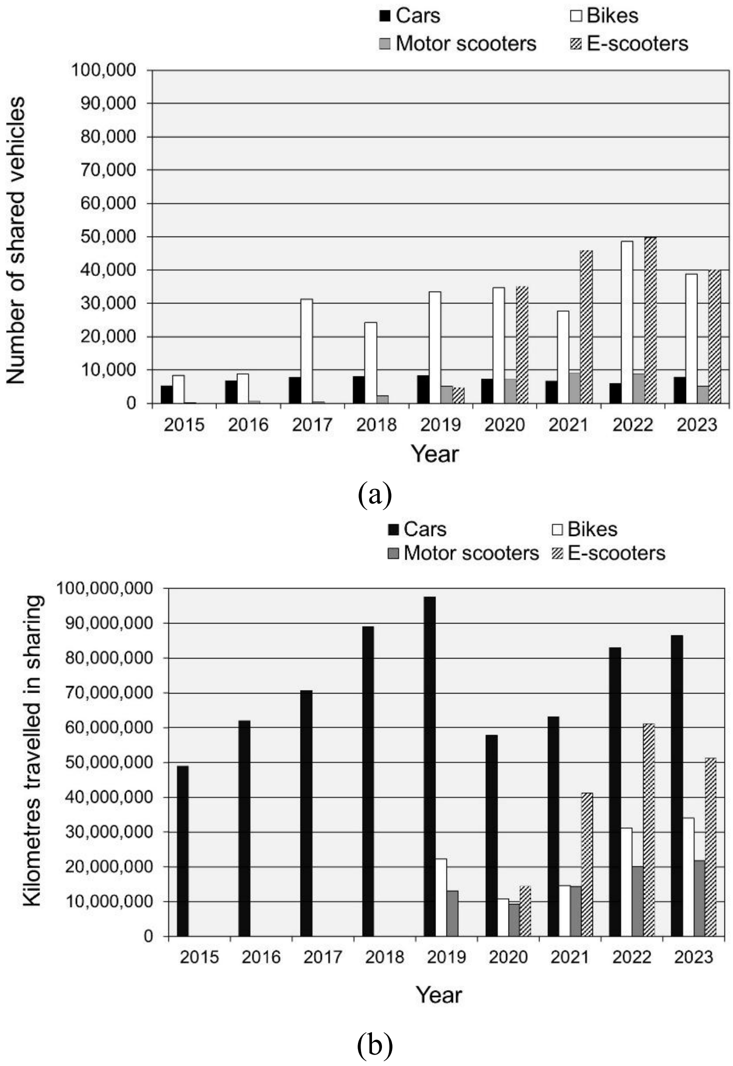
2.2. Trends in Shared Mobility

Shared mobility is transforming traditional transportation into a more innovative and environmentally friendly model [16]. Bike-sharing, car-sharing, carpooling, scooter-sharing, and on-demand services improve efficiency, decrease dependence on private vehicles, and promote conservation and equity through shared use rather than ownership [17].

Bike-sharing services include: 1) Station-based systems – comprising low-tech options, some outdated but still functional, which rely on codes or keys at georeferenced stations – and dock-based systems where bikes are secured in racks and accessed with magnetic cards; 2) Free-floating fleets accessible anywhere within the area; 3) GPS-based systems that reserve or unlock bikes via an app; and 4) Peer-to-peer sharing offered by individuals through specialized platforms. Car-sharing allows users to rent vehicles for trips, promoting cost-sharing and reducing ownership burdens by treating cars as temporary, consumable assets [17]. Types of car-sharing include 1) Station-based services with fixed pickup and return stations; 2) Free-floating services, allowing users to pick up and return cars within the operational area; and 3) Peer-to-peer sharing, where private owners share their cars via a platform without involving rental companies. Carpooling involves informal arrangements where individuals share a vehicle on the same route, with drivers providing the car and passengers sharing fuel and travel costs, with instant carpooling via platforms and apps being the most common [17]. Scooter-sharing services, like bike-sharing, involve renting scooters for travel within the service area and typically include a helmet stored in the scooter. On-demand transportation services – such as taxis and modern apps like Uber – enable users to book shared trips quickly via smartphones [17]. All sharing mobility services possess key characteristics that enhance effectiveness and user experience [18]. Modern mobility services prioritize shared transportation, operating alongside or after private vehicles like public transit and taxis. Using digital platforms and GPS, they connect drivers and passengers for on-demand, flexible, and scalable options, helping to reduce urban congestion and CO_2 emissions. Fig. 6 shows the supply and demand trends for shared mobility in Italy from 2015 to 2023, including the number of vehicles for car-sharing, bike-sharing, motor scooters, and e-scooter sharing (Fig. 6a), as well as mileage data (Fig. 6b).

Notably, e-scooter sharing services began in 2019, saw significant growth until 2022, and experienced a decline in 2023 [19].

In 2023, shared mobility in Italy totalled nearly 200 million kilometres travelled, a 45% rise since 2021 in the post-COVID period (see Fig. 6b). A further 7% increase is projected for 2024 based on first-quarter data [19]. The vehicle composition in 2023 included bikes (14%), e-bikes (28%), motor scooters (5%), e-scooters (44%), electric cars (3%), and gasoline cars (6%), reflecting a shifting landscape in shared mobility trends [19].



(a)

(b)

Fig. 6. Trends of supply and demand for shared mobility in Italy:
(a) Number of shared vehicles, (b) Kilometres travelled in sharing.
Note: car-sharing and bike-sharing services include both free-floating and station-based options
Source: data elaborated from the authors from [19]

Fig. 7 shows the supply and demand trends for car-sharing and bike-sharing in Italy (2015-2023), focusing on free-floating (FF) and station-based (SB) models. The number of FF car-sharing services is increasing, while SB car-sharing decreased by 27% in 2023 compared to 2022 and by 17% compared to 2021 (Fig. 7a). Since 2020, the number of vehicles in FF car-sharing has been recovering, whereas the vehicle count in SB car-sharing has remained stable at around 1,200 vehicles (Fig. 7b).

SB car-sharing achieved approximately 300,000 rentals in each of the last two years, despite a slight reduction in FF car-sharing during the same period (Fig. 7c). Meanwhile, distances travelled by FF car-sharing increased by 52% in 2023 compared to 2020, reaching about 78 million kilometres in 2023, demonstrating greater resilience to the effects of the pandemic (Fig. 7d) [19].

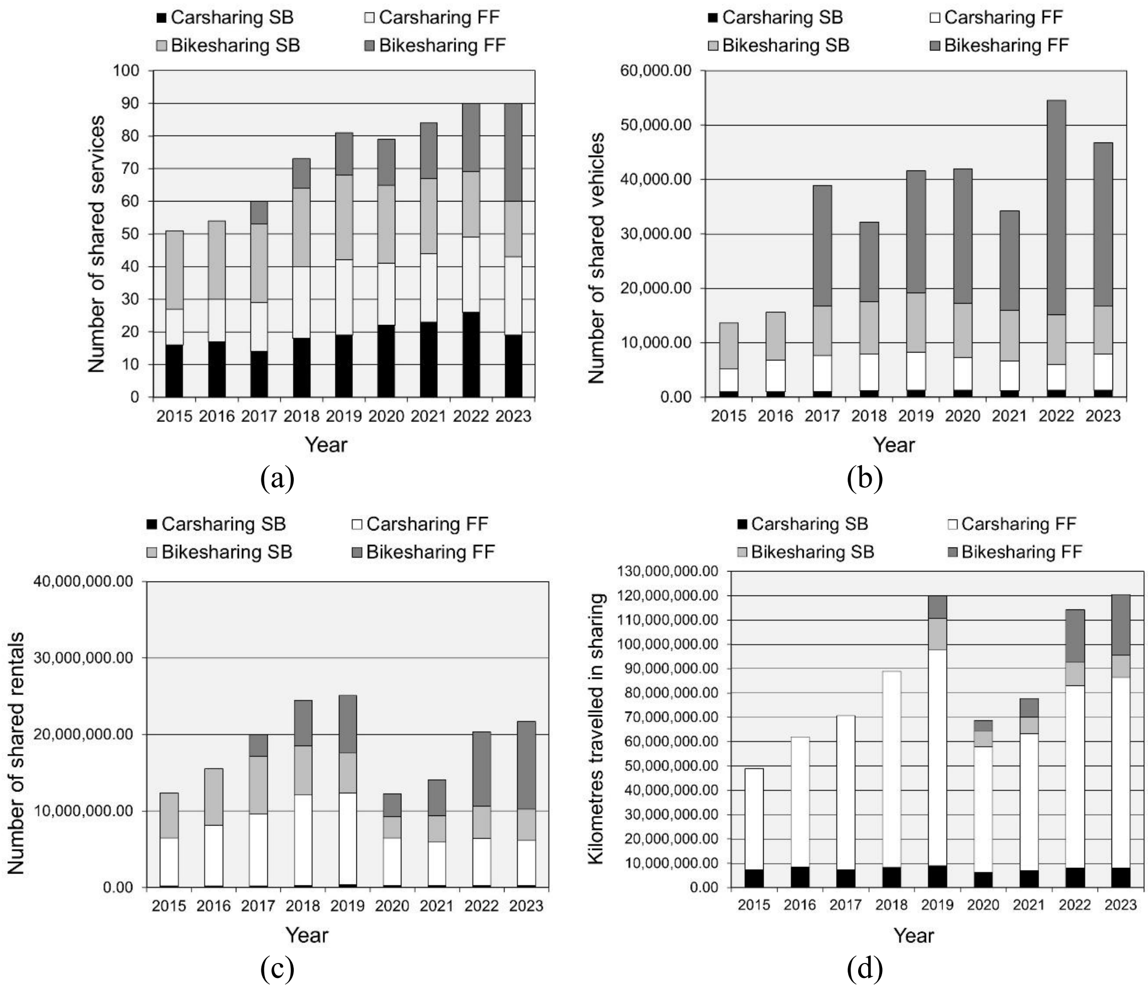


Fig. 7. Trends of supply and demand for car-sharing e bike-sharing in Italy: (a) Number of shared services, (b) Number of shared vehicles, (c) Rentals and (d) kilometres travelled.
Note: Shared services include free-floating (FF) and station-based (SB) models
Source: data elaborated by authors from [19]

The data shows that FF bike-sharing services increased by 76% in 2023 compared to 2021, while SB services declined by 26% over the same period (Fig. 7a). The number of bikes in SB services remained stable during the period shown in Fig. 7b. In contrast, bikes in FF services decreased by 26% in 2023 compared to 2022, mainly due to fleet downsizing in major cities like Rome and Milan. The supply level in 2023 is expected to be maintained through 2024 [19]. Electric bikes constitute 62% of Italy's shared bicycle fleet in FF services, driven by the adoption of hourly and daily rental options [19]. Demand for bike-sharing, particularly in rentals, grew significantly between 2022 and 2023 for FF services, with further growth forecasted (Fig. 7c) [19]. Additionally, distances travelled increased by 15% in 2023 compared to the previous year, totalling around 25 million kilometres in FF bike-sharing (Fig. 7d).

A questionnaire was distributed to over 10,000 shared mobility users via app pop-ups, newsletters, and social media to assess perceptions of shared mobility as public transportation [19]. The survey was designed to mask its objectives and ensure anonymity, encouraging genuine responses about the benefits of these services and potential shifting usage preferences. The main feedback showed that three out of four users expressed positive opinions about the development of available shared mobility services. Car sharing received only 42% positive responses, lagging behind other services. Additionally, over 80% of users indicated that the closure of shared mobility services in their city would greatly impact their mobility habits. On financial support for vehicle-sharing services, 63% of users favoured it, 24% agreed with conditions, while only 7% opposed public funding. Data on on-demand transport services showed that over 600,000 passengers were transported in 2023 [19]. Service offerings increased significantly, especially in northern regions, tailored to specific contexts and addressing local mobility needs with both seasonal and year-round options.

2.3. Trends in Zero-Crash Mobility

Road safety is a shared responsibility among all road users and professionals. Frequent crashes result in loss of life and property damage, impacting community safety. Zero-Crash mobility refers to a transportation system or approach aimed at eliminating road traffic crashes and fatalities. The goal is to create a safer mobility environment where advanced safety technologies, intelligent infrastructure, and comprehensive safety strategies protect all road users like drivers, passengers, pedestrians, and cyclists [20,21]. Achieving this requires balancing the components of the road system and their interactions within natural and built environments, as illustrated in Fig. 8.

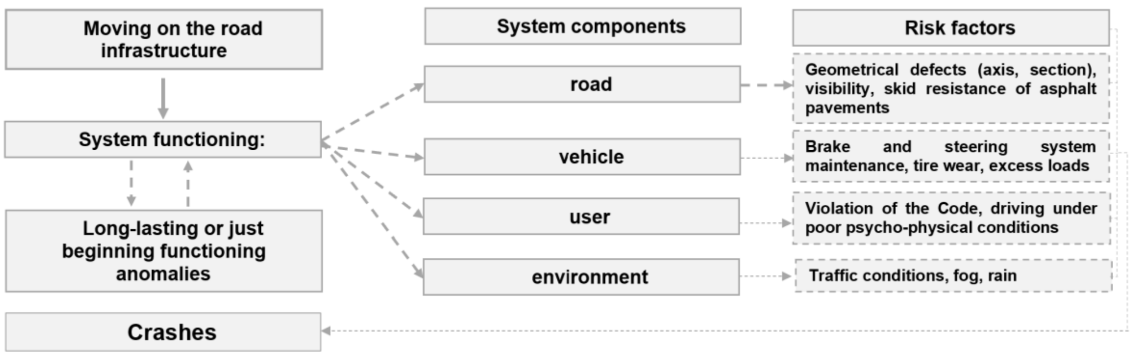


Fig. 8. Framework for understanding the functionality of the road safety system

Effective road design should be clear and intuitive, with suitable slopes and materials that encourage safe vehicle speeds and smooth traffic flow [20]. While improved safety generally reduces crashes and their severity, managing road safety remains complex due to the unpredictable nature of crashes. In this context, Fig. 9 outlines the key aspects essential for achieving zero-crash mobility.

Engineering measures and countermeasures significantly impact road safety, which depends on the quality of road infrastructure and its link to crash frequency. Security pertains to users' personal feelings of safety and perceptions of infrastructure reliability. Although safety and security are related, the focus is on assessing road safety across different infrastructure segments and intersections to identify effective interventions that enhance overall safety [21].

In Italy, a road crash is defined according to the 1968 Vienna Convention [22] as an event involving at least one vehicle – stationary or moving—on a traffic-accessible road resulting in injuries or fatalities within 30 days.

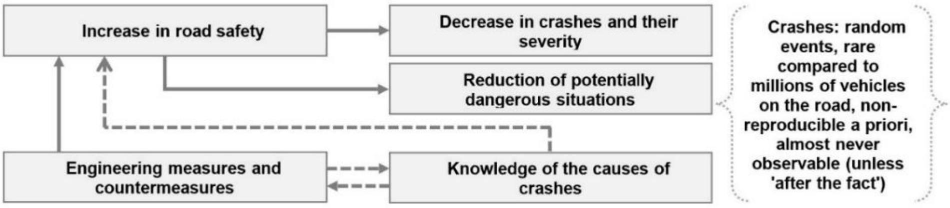


Fig. 9. The logical pathway of zero-crash mobility.

Data are collected nationally and officially recorded by law enforcement. This definition serves as a benchmark for comparing crash data to the first six months of 2019, which is the reference year for the European Commission's 2030 goal [21]. Compared to 2019, Italy has globally experienced a decline in road crashes (4.0%), injuries (8.0%), and fatalities (~7%), reflecting progress towards safer mobility.

Preliminary data for the first half of 2024 show a slight increase in road crashes causing injuries compared to the same period in 2023, with crashes (+0.9%), injuries (+0.5%), and fatalities within thirty days (+4.0%) [22]. This trend suggests that Italy is moving away from European road safety targets, underscoring ongoing challenges in road safety management and the need for effective interventions. In the first half of 2024, highway fatalities decreased by 14.0% compared to the same period in 2023, while fatalities on urban and rural roads increased by 8.0% and 1.0%, respectively. Compared to the first half of 2019, highway fatalities declined significantly by 32.0%, rural road fatalities decreased modestly by 4.0%, but urban road fatalities rose slightly by 1.0% [22]. However, complete official data for 2024 are needed for a definitive analysis.

Data for the first four months of 2024 indicates a 3% increase in vehicle kilometres travelled on highways compared to 2023, driven mainly by a 4% rise in heavy vehicle traffic and a 3% increase in light vehicle volumes [21,22]. In the first half of 2024, new car registrations increased by about 5%, and motorcycle registrations rose by 6% compared to the same period in 2023. However, compared to 2019, new car registrations declined by 16.5%, while motorcycle registrations increased significantly by 47.5%. Provisional data for January to June 2024 indicates that 73% of crashes occurred on urban roads, while rural roads have the highest fatality rate at 47%. On highways, crashes and fatalities represented 6% and 8%, respectively [22]. Data on crashes involving personal injuries related to shared micromobility in Italy has also been collected from insurance company reports and law enforcement, including user-reported events [22]. Notably, crashes were recorded even without formal reports or hospitalizations. In 2023, there were 637 recorded crashes, including one fatal e-scooter crash in Rome. The incidence of crashes associated with shared micromobility services appears to be decreasing, likely due to increased user familiarity, with higher rates observed during the initial months of service. Fig. 10 shows crashes per 100,000 km in Italy for 2021–2023 [19].

Preliminary data reveal contrasting trends between crashes and shared micromobility usage. To meet Europe's 2030 road safety goals, Italy needs a comprehensive approach that leverages big data for detailed analysis and targeted interventions [21].

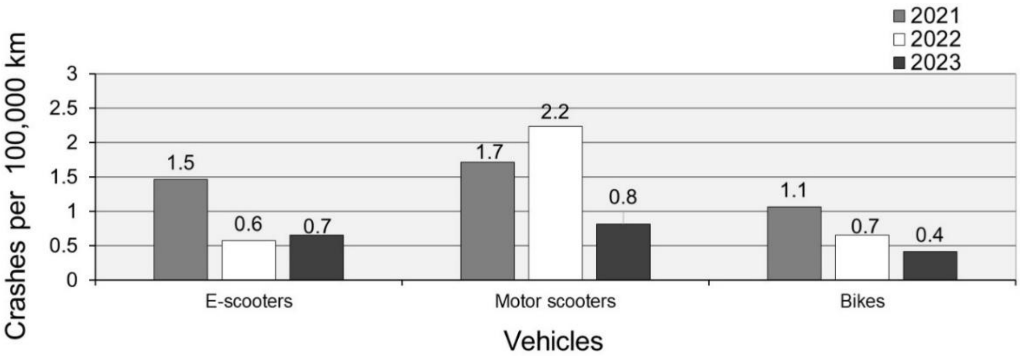


Fig. 10. Crashes in shared micromobility services per 100,000 km in 2021-2023
Source: data elaborated by the authors from [19]

3. INVESTIGATION THROUGH A SURVEY INTERVIEW FOR THE ELDERLY: WHAT DO THEY KNOW ABOUT SUSTAINABLE AND SMART MOBILITY?

Mobility trends in Italy are increasingly centred on sustainable and smart solutions to enhance transportation and residents' quality of life. Understanding the perceptions of diverse groups, especially the elderly, is essential for developing inclusive policies. Community surveys can provide valuable insights into their knowledge, attitudes, and experiences regarding sustainable mobility and related concepts. This initial investigation aims to promote inclusivity by listening to user groups that may be marginalized during the digital transition, with ongoing improvements envisaged.

3.1. Explaining the Survey Methodology

Recognizing that the survey interview was in its prototype phase, the authors conducted the research action following specific steps as follows:

1. The first step involved designing a structured survey interview that addressed key aspects of sustainable and smart mobility. The prototype questionnaire consisted of 16 closed-ended questions, with the first five providing informational content. These included demographic questions to contextualize the data, such as age, educational qualifications, gender, cultural identity, and a question about smart cities to assess participants' understanding of the concept, expressed in English (see Table 1). Other questions addressed concepts such as smart mobility, smart roads, shared mobility, road infrastructure, autonomous vehicles and willingness to use them, car-sharing services, connected and automated mobility, low-emission cars, and micromobility. Each question provided a minimum of three alternative options to guide participants' responses (see Table 2). The final question concerns participants' preferences regarding the mode of questionnaire administration (face-to-face interview or email) to understand their inclinations. Gathering feedback on participants' preferred delivery methods can facilitate a more personalized and accessible research approach, ultimately enhancing the effectiveness of the surveys and enabling the optimization of data collection methods for future studies.

2. The second step involved selecting the pilot sample. It was decided to limit the administration of the questionnaire to 30 older adults living in urban areas in Sicily, Italy. Half of the participants would reside in a metropolitan city with a population exceeding 600,000 but below 700,000, while the other half would live in a town with a population of approximately 50,000; population classes were based on official data as of January 1, 2024 [23]). Understanding participants' diverse backgrounds reveals disparities in mobility knowledge and access, with older adults in urban areas experiencing different challenges compared to those in rural areas, where transportation options are often limited. None of the respondents were engineers or worked in the engineering field, which resulted in a limited number of interviews during this phase.
3. The third phase involved conducting face-to-face interviews using the prototype questionnaire consisting of 16 closed-end questions (see Tables 1,2), with 30 participants over the age of 60 years old who voluntarily agreed to participate. Participants were assured of anonymity and informed that data would be used solely for informational purposes. Researchers directly engaged with them, clarifying the questionnaire and objectives, and encouraged sharing experiences on urban mobility to identify knowledge barriers and gather insights into older adults' challenges and opinions.
4. After administering the questionnaire, the fourth step involved processing the collected data to ensure accuracy and reliability. Quality checks were conducted to identify inconsistencies or errors. The data were then coded and organized into a database to facilitate the analysis; all information was handled anonymously for privacy reasons, based on the exclusively informational purpose of the research.
   Key findings from elderly respondents will be presented in the next section.

Tab. 1

The preliminary questions (PQ1 to PQ5) and the alternative answers

No	Questions	Alternative answers
PQ.1	How old are you?	a. Between 60 and 65. b. Over 65 and under 75. c. Over 75.
PQ.2	What is your educational qualification?	a. High school diploma*. b. Master's degree. c. PhD. d. I prefer not to say.
PQ.3	What is your gender?	a. Male. b. Female. c. I prefer not to say.
PQ.4	How do you identify your origin?	a. I am Italian. b. I am European. c. I prefer not to say.
PQ.5	Have you ever heard of Smart Cities?	a. Yes, many times. If yes, please specify (news on TV, radio, documentaries, books, internet) b. No. c. I don't know.

* In the case of a middle school diploma (msd), the answers will also be reported as a separate category

Tab. 2

The closed-end questions (Q1 to Q11) and the alternative answers

No	Questions	Alternative answers
Q.1	What does smart mobility mean?	a. Smart mobility represents an intelligent and eco-sustainable transportation approach that uses digital technologies to optimize mobility. b. Smart mobility is fast mobility with small-displacement cars. c. Smart mobility is represented by motorcycles, helicopters, and motorboats.
Q.2	What does Smart Road mean?	a. A smart road is a fast-flowing road. b. Smart roads, or intelligent roads, are road infrastructures equipped with advanced technologies to monitor traffic, enhance safety, and promote sustainability. c. A small-sized car, such as a city car.
Q.3	How would you define shared mobility?	a. Sharing mobility is a form of transportation exclusively for private vehicles purchased in installments. b. A transportation method that uses only public transport and intercity and metropolitan trains. c. Sharing mobility allows for the sharing of vehicles and routes, making transportation more interactive and efficient, while also reducing expenses and consumption associated with owning a vehicle. Examples include car-sharing and bike-sharing.
Q.4	What comes to mind when you think of road infrastructure?	a. The materials used to create a stable and durable road surface. b. In the context of land transportation, road infrastructure refers to the collection of road networks and roads. c. The construction of skyscrapers.
Q.5	What is an autonomous vehicle?	a. An autonomous vehicle is a car capable of sensing road conditions and driving without human intervention. b. A vehicle that belongs to a single owner. c. A vehicle designed exclusively for the transportation of heavy goods and hazardous materials.
Q.6	Are you willing to use an autonomous vehicle?	a. Yes. b. No. c. Maybe.
Q.7	What is a car-sharing service?	a. A support service for the purchase of zero-kilometre vehicles. b. Car sharing is a service that allows you to rent vehicles for short periods, sharing the costs and facilitating booking through an app or website. c. A travel agency that organizes long-distance car tours.
Q.8	What does connected automated	a. Connected and automated mobility is synonymous with cooperative mobility in sharing data and resources to promote congestion.

	mobility mean?	b. Connected mobility uses technologies for real-time communication, while automated mobility employs autonomous vehicles. c. A transportation method based solely on bicycles.
Q.9	What is a low-emission vehicle?	a. A vehicle powered by gas or bi-fuel, electric, or hybrid engines. b. A vehicle that can operate only on solar energy. c. A vehicle that consumes more fuel than traditional models.
Q.10	What comes to mind when you hear the word “micromobilit y”?	a. Light vehicles for short trips in the city, such as e-scooters. b. Light air transport. c. Large cars designed for large families.
Q.11	Would you have preferred to receive the questionnaire via email?	a. Yes. b. No. c. I prefer not to answer

4. THE RESULTS AND THEIR ANALYSIS

This section highlights key findings from elderly respondents regarding their perceptions and experiences with sustainable and smart mobility. Fig. 11 displays responses to preliminary questions PQ.1,2,3,4 in Table 1.

The data on age (PQ.1) helped characterize the sample, revealing that 53% of respondents are aged between 65 and 75. This information is useful for analyzing age-related effects on understanding and knowledge of contemporary mobility and sustainability issues. Additionally, PQ.2 explored participants' education levels with four options: (a) high school diploma, (b) master’s degree, (c) doctorate, and (d) no answer. This data aims to assess the potential correlation between education and awareness of the discussed topics. The results showed that 40% of respondents hold a high school diploma, 33% have a master's degree, none have a PhD, and 7% chose not to disclose their education level (but 20% possess only a middle school diploma). Regarding gender (PQ.3), participants were asked to identify their gender, selecting from male (40%), female (57%), or no answer for the remaining respondents. This information was used to analyze potential differences in experience related to the discussed themes. In response to question PQ.4, 90% indicated they are Italian, and 10% stated they are European. The origin, or cultural identity, of participants, through three options by identifying as (a) Italian, (b) European, or (c) choosing not to indicate their origin, can support the characterization of the socio-cultural context for the responses given thereafter. Question PQ.5 assessed participants' familiarity with Smart Cities, revealing that 20% had frequently heard about the concept through TV or documentaries, although three of them did not specify their sources. One participant mentioned learning about it from "work," despite no engineers or industry professionals being involved in the survey. Conversely, 67% had never heard of smart cities, 10% responded "I don't know," and the remaining participants did not answer.

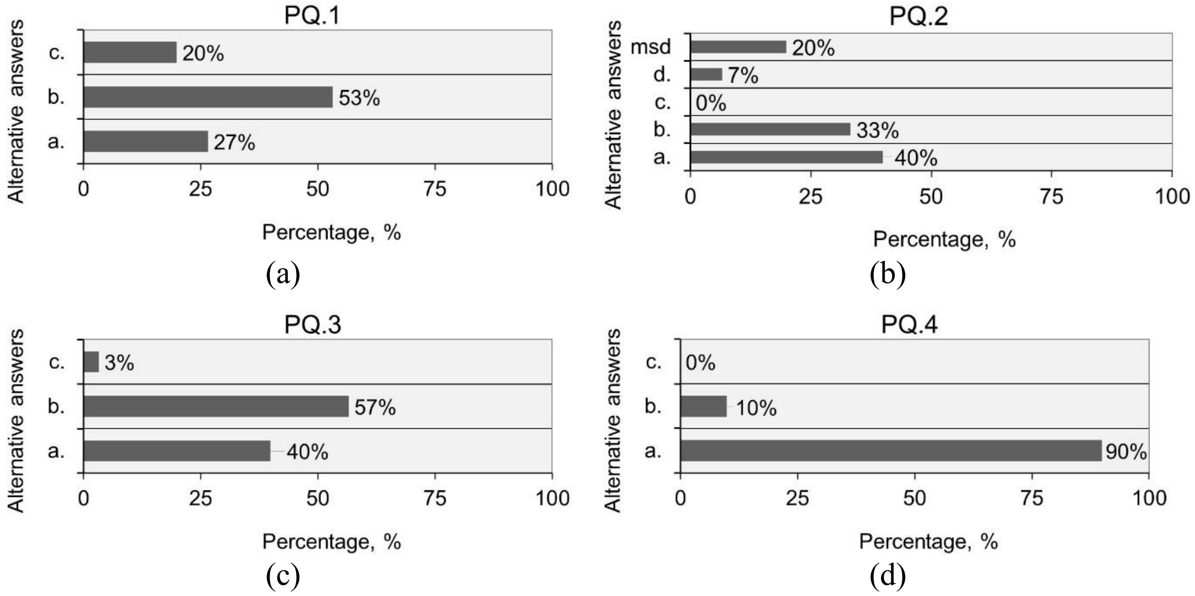


Fig. 11. The respondents' answers to the preliminary questions in Table 1 are as follows: (a) PQ.1 pertains to age, (b) PQ.2 concerns education level, (c) PQ.3 relates to gender, (d) PQ.4 addresses cultural identity. Note: Items a, b, c, and d (where present) are detailed in Table 1; "msd" stands for middle school diploma

Fig. 12 presents the most significant results related to questions from Table 2 (e.g., Q.1, Q.2, Q.4, Q.5, Q.8, and Q.9). For brevity, the remaining questions and their corresponding answers will be described and discussed only briefly.

In response to the question about the meaning of smart mobility (Q.1), 83% of respondents recognized it as an intelligent and eco-sustainable transportation approach that uses digital technologies to optimize mobility. Conversely, 17% associated smart mobility with speed and small-displacement cars, potentially due to a lack of familiarity with related English terms or expressions, which are generally considered part of the current vocabulary by experts (see Fig. 12a). All the interviewees exclude that smart mobility is represented by motorcycles, helicopters, and motorboats. In response to Q.2 (see Fig. 12b), around 27% mistakenly linked the smart road concept to a fast-flowing road as highways, while around 67% appropriately associated it with road infrastructures that utilize advanced technologies for traffic monitoring, safety enhancement, and sustainability, potentially influenced by the attribute 'intelligent' present in the answer choices (see Table 2). The remaining respondents were evenly split between choosing a small-sized car, such as a city car, as an alternative answer, and selecting no suitable options. Regarding the definition of sharing mobility in response to Q.3 in Table 2, 80% of respondents agreed on the correct answer (c), which is that sharing mobility allows for the sharing of vehicles (such as cars and bikes) and routes, making transportation more interactive and efficient while also reducing expenses and consumption associated with owning a vehicle. However, one respondent, unsure, also attributed the concept of sharing mobility to the first option in Table 1 (i.e., sharing mobility as a form of transportation exclusively for private vehicles purchased in installments). The remaining respondents were evenly split among the other two options.

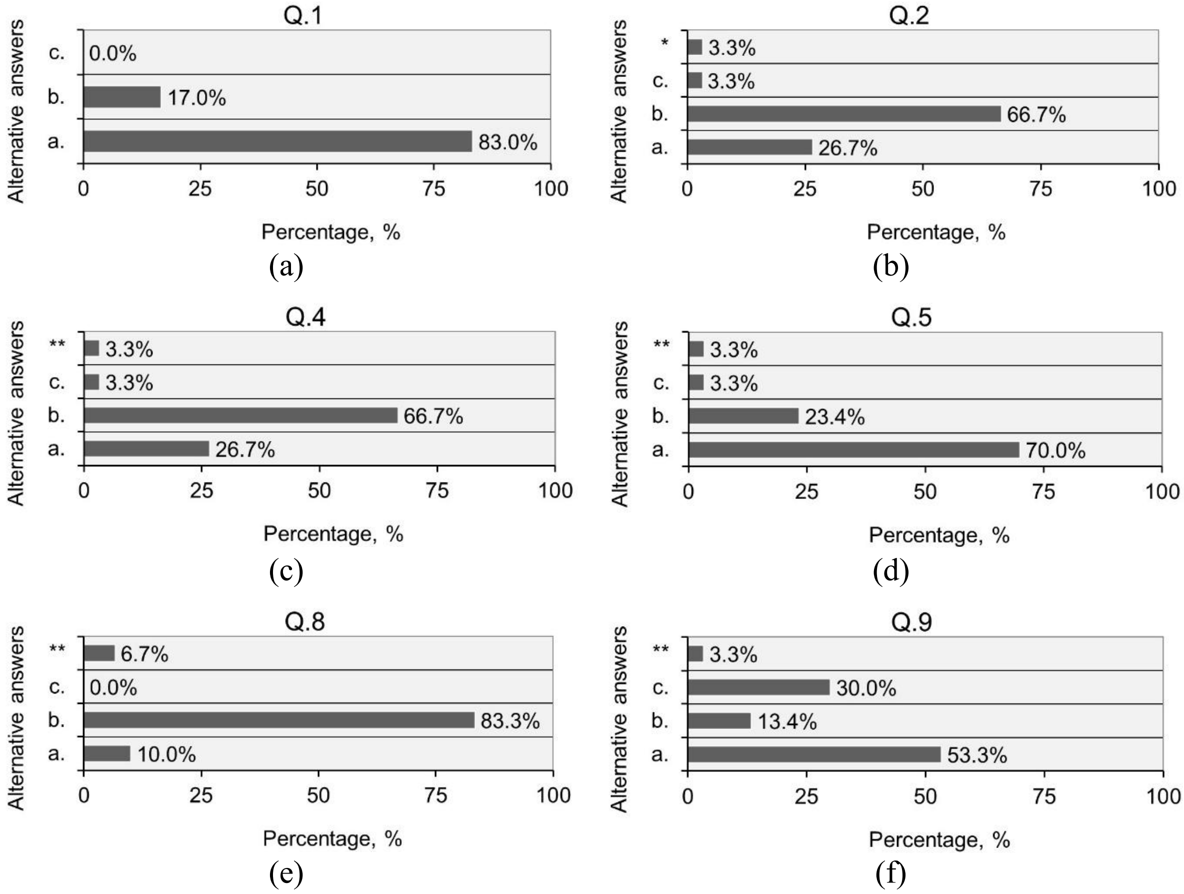


Fig. 12. The answers provided by the respondents to the questions in Table 2: (a) Q.1 pertains to smart mobility, (b) Q.2 pertains to smart roads, (c) Q.4 pertains to road infrastructure, (d) Q.5 pertains to autonomous vehicles, (e) Q.8 pertains to connected automated mobility, and (f) Q.9 pertains to low-emission vehicles. Note: Items a, b, and c are detailed in Table 2; (*) indicates that the respondents do not find answers among the options provided, while (**) indicates no answer was given

Regarding the responses to the question Q.4 (see Fig. 12c) about "road infrastructure", they reveal important insights into how people perceive the concept. Most respondents (67%) associated road infrastructure with the road networks and roads within the context of land transportation. This suggests that the concept primarily evokes the idea of connectivity and the organizational structure of transport systems, highlighting their role in promoting travel and commerce. On the other hand, around 27% of the responses linked the term to the materials used for creating stable and durable road surfaces. This indicates an awareness of the technical aspects of road construction, acknowledging that the quality of materials is crucial for the longevity and safety of roadways. It is also noteworthy that two respondents associated road infrastructure with both options (i.e., a and b in Fig. 12c), reflecting a more comprehensive understanding of the topic that encompasses both the physical elements and the broader network of routes. The exclusion of skyscrapers (see Q.4, option c in Table 2) in their associations highlights a clear delineation between structures and infrastructure (i.e., only one respondent selected option c for Q.4 in Table 2). Respondents likely view road infrastructure as distinct from building construction, focusing on transportation rather than urban architecture. In turn, the fact that one respondent did not provide an answer could suggest either a lack of familiarity with the topic or ambiguity in the understanding of road infrastructure, indicating that public knowledge on this subject may vary, which ideally it should not.

Regarding the question, 'What is an autonomous vehicle?' (Q.5), Fig. 12d shows that 70% know that an autonomous vehicle is a car capable of sensing road conditions and driving without human intervention; additionally, 23% imagined that it is a vehicle that belongs to a single owner; one respondent associated it with a vehicle designed exclusively for the transportation of heavy goods and hazardous materials, while one respondent did not answer this question. However, 57% were not willing to use an autonomous vehicle, while the remaining respondents were equally divided between being willing to test an autonomous vehicle and expressing uncertainty (see Q.6 in Table 2). The high percentage of respondents recognizing autonomous vehicles as self-driving suggests growing awareness of advanced technologies. However, the reluctance to use them (57%) may stem from safety concerns, mistrust in technology, or lack of understanding about their reliability. The varied perceptions, from ownership to specific use cases, highlight a need for better public information and outreach to address misconceptions and enhance acceptance of autonomous vehicles.

Confirming the understanding of shared mobility from Q.3, in Q.7 in Table 2, 57% of respondents associated the concept of car-sharing services with option (b), which involves renting vehicles for short periods, sharing the costs, and facilitating bookings through an app or website. Meanwhile, 37% associated it with "a support service for the purchase of zero-kilometre vehicles", while the remaining respondents did not answer. Furthermore, concerning Q.8 in Fig. 12e about connected and automated mobility, 83% answered the question indicating that connected mobility uses technologies for real-time communication, while automated mobility employs autonomous vehicles. Meanwhile, 10% incorrectly attributed it to means of promoting congestion, and only two respondents did not answer. Appropriately, none associated it with bikes. The understanding of connected mobility emphasizes awareness of technology's role in communication, while misattributions to congestion reflect a possible lack of comprehensive knowledge. The absence of bike associations may indicate overlooked alternatives in mobility solutions.

Regarding Q.9 in Fig. 12f, 16 respondents stated that a low-emission vehicle is powered by gas or bi-fuel, electric, or hybrid engines (option "a" in Table 2), while only 4 indicated that it is a vehicle that can operate solely on solar energy (option "b" in Table 2). Nine respondents incorrectly identified it as a vehicle that consumes more fuel than traditional models (option "c" in Table 2), and one respondent did not answer. The varied responses to Q.9 indicate a general awareness of low-emission technologies, but misconceptions about solar energy and fuel consumption persist, highlighting the need for improved education on sustainable vehicle options.

Regarding Q.10 in Table 2, 93% of respondents linked micromobility to light vehicles for short city trips, such as e-scooters, showing strong awareness of modern urban transport options, while the remaining respondents did not provide an answer. About 73% were not willing to receive the questionnaire via email, while the remaining respondents were evenly split between giving a positive answer and choosing not to answer (see Q.11 in Table 2). The reluctance to participate via email suggests potential privacy concerns or preferences for different communication methods, highlighting the need for varied engagement strategies. Despite the small sample size, the insights offered are valuable, emphasizing the importance of effective communication about infrastructure development to better engage the public and assess the social impact of novel technologies integrated in transport services and road design. Future efforts should expand the sample to identify broader relationships and involve experts, as well as explore other methods to reach the target respondents.

5. CONCLUSIONS

Starting from data-driven trend analysis, road infrastructure is crucial for sustainable urban mobility, requiring investments in public transport, bicycle lanes, and pedestrian areas to reduce congestion and pollution. Incorporating smart technologies enhances traffic management and safety, while multimodal solutions – combining transit, cycling, walking, and eco-friendly fuels – improve accessibility and urban quality of life. Prioritizing pedestrian-friendly infrastructure and supporting emerging technologies like autonomous vehicles and ridesharing promote cleaner air and digital communities. As Italy's mobility concepts evolve, inclusive policies that consider diverse groups, especially the elderly, are essential to assess their social impact. Engaging older adults through surveys provides valuable insights into their awareness, attitudes, and experiences, ensuring their active participation and preventing marginalization in sustainable and smart mobility initiatives.

Do the Elderly Know It's Sustainable Mobility? This study sheds light on elderly respondents' perceptions of sustainable and smart mobility. Most participants were aged 65-75, with many holding only a high school diploma, suggesting potential links between age, education, and understanding of modern mobility concepts. Given the level of education of the respondents and the number of correct answers, the understanding of the topic is quite good. While 83% recognized smart mobility as environmentally friendly and digitally enhanced, misconceptions still existed, such as associating it with speed or limited terminology familiarity. Knowledge about road infrastructure, autonomous vehicles, and connected mobility varied; some correctly identified key features, but gaps remained, like linking traffic congestion to connected mobility or misunderstanding low-emission vehicle capabilities. A notable 57% were hesitant to use autonomous vehicles, mainly due to safety and trust concerns, highlighting the need for better public education. The high awareness of micromobility (93%) indicates openness to urban solutions. However, reluctance to engage via email underscores privacy concerns, emphasizing the importance of diverse communication channels for effective outreach.

Despite the small sample and provisional nature of the questionnaire, these findings emphasize the critical importance of implementing targeted communication and education strategies to improve understanding and acceptance of sustainable and smart mobility. Developing inclusive policies is essential to ensure that innovative mobility solutions address the diverse needs of all groups, especially vulnerable populations. Such policies help prevent marginalization, promote social equity, and foster greater societal participation.

Future research involving larger, more diverse samples and expert input in questionnaire design will support the development of comprehensive, culturally sensitive outreach strategies. Promoting inclusivity strengthens social cohesion and guarantees that sustainable mobility benefits everyone, contributing to more resilient and equitable urban environments.

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