

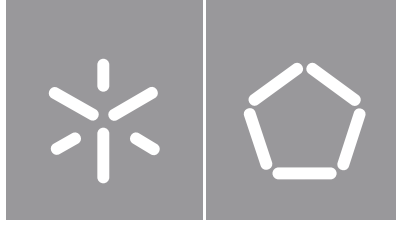


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Impacts of Shared E-scooters on Urban Transportation Systems

Universidade do Minho
Escola de Engenharia





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Impacts of Shared E-scooters on Urban Transportation Systems

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Trabalho efetuado sob a orientação do

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STATEMENT OF INTEGRITY

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Impactos de Trotinetes Elétricas Partilhadas no Sistema de Transporte Urbano

Resumo

O recente aumento significativo no uso de trotinetes elétricas partilhadas nas cidades levantou preocupações entre cidadãos, políticos e planeadores urbanos, nomeadamente no que se refere ao impacto na segurança e no funcionamento dos sistemas de transporte e mobilidade urbana, assim como na utilização dos espaços e infraestruturas viárias urbanas.

Neste contexto, este estudo tem como principal objetivo compreender e avaliar os impactos no sistema de transportes urbanos, com vista ao desenvolvimento de ferramentas de planeamento e regulação mais eficazes para tornar o uso deste modo de transporte mais seguro e sustentável. Para este efeito, a investigação avalia os principais motivadores, determinantes e barreiras associados ao uso das trotinetes partilhadas.

Para atingir esses objetivos, foram realizados dois inquéritos na cidade de Braga, no Norte de Portugal. O primeiro consistiu num inquérito de preferência revelada, destinado a determinar os principais fatores que influenciam o uso de trotinetes partilhadas, traçar o perfil sociodemográfico dos seus utilizadores e identificar os principais atributos que podem incentivar o uso deste modo de transporte. Numa segunda fase, foram conduzidos dois inquéritos de preferência declarada para avaliar o contributo deste modo para a sustentabilidade do sistema de mobilidade, nomeadamente como uma alternativa mais sustentável ao automóvel em viagens pendulares e de lazer.

Os resultados indicam que o perfil dos utilizadores é maioritariamente composto por jovens adultos do sexo masculino e com um salário semelhante à média para a cidade. As vias dedicadas, o estacionamento e as zonas exclusivas para circulação de trotinetes surgem como os principais fatores determinantes para a sua utilização, especialmente entre mulheres. No caso das viagens pendulares, as trotinetes partilhadas não conseguem promover uma transferência modal dos automóveis para este modo, sendo o transporte público frequentemente uma opção mais eficiente. Já em relação às viagens de lazer, as trotinetes podem ser vistas como uma alternativa potencial ao carro, abrangendo um perfil mais diversificado de utilizadores, especialmente se houver infraestrutura dedicada e se forem oferecidos incentivos financeiros (como vouchers) aos utilizadores, particularmente os de rendimentos mais baixos.

Palavras-chave: impacto das trotinetes partilhadas; micromobilidade partilhada; mobilidade urbana sustentável; planeamento para trotinetes partilhadas; trotinete partilhada.

Impacts of Shared E-scooters on Urban Transportation Systems

Abstract

The recent rise in shared e-scooter usage has raised concerns among citizens, policymakers, and city planners regarding its impact on the safety and the synergy of urban transportation systems, as well as the usage of urban space and the available road infrastructure.

In this context, this research aims to understand and evaluate the impacts of shared e-scooters on urban transportation systems, with a focus on developing tools, planning, and regulation strategies to harness the potential benefits of shared e-scooter usage. By making it more efficient, safe, and sustainable, shared e-scooters could significantly improve urban transportation. Thus, this research evaluates the main drivers/motivations and barriers associated with the usage of this mode of transportation.

To achieve these goals, two survey methods were deployed in Braga, North of Portugal. Firstly, a revealed preference survey is deployed to delineate the primary factors that affect shared e-scooter usage, identify the sociodemographic profile of the users, and identify the primary attributes that can lead to using shared e-scooters. Then, two stated choice experiments are deployed to assess how shared e-scooters can contribute to the sustainability of urban mobility, namely as a more sustainable option than cars for commuting and leisure trips.

The results indicate that the shared e-scooter user profile is mainly composed of young male adults with a salary similar to the city average. Dedicated lanes, parking spots, and exclusive areas for e-scooters appear to be the main determining factors for their use, especially among women. In the case of commuting, shared scooters cannot promote a modal shift from cars, with public transportation often being a more efficient option. However, in relation to leisure travel, shared e-scooters can be seen as a potential alternative to cars, reaching a more diverse user profile, especially if there is dedicated infrastructure and if financial incentives, such as vouchers, are offered to users and potential users, particularly those with lower incomes. This suggests that financial incentives could be a key solution to increasing e-scooter usage.

Keywords: shared micromobility; shared e-scooters; shared e-scooter impacts; shared e-scooter planning; sustainable urban mobility.

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To my nephews Davi José and Arthur Custódio

Chapter I. Introduction

This chapter provides a general overview of the thesis, and it is divided into five main subsections. Section I.1. presents the theoretical framework for developing the thesis. Section I.2. presents the motivation for selecting the research field of shared micromobility in cities. Section I.3 introduces the objectives of the thesis. Section I.4. presents the hypothesis and research questions to be answered by the thesis research work. Section I.5. introduces the structure of the thesis.

I.1. Context

Sustainable urban mobility planning is believed to be a critical factor in achieving a cleaner, greener, and more innovative future for all. The prioritization of public transportation, walking, cycling, and zero-emission solutions for urban fleets, as well as new digital solutions and services, will put the transportation sector on track to cutting its emissions by 90% by 2050 (European Commission, 2021a). Thus, to make transportation more sustainable, appropriate conditions need to be created for a higher uptake of greener alternatives that are safe, competitive, and affordable, including the subsequent mobility patterns created in recent years, such as shared solutions facilitated by the creation of the “sharing economy” and digital advancements (European Commission, 2020c).

The concept of the “sharing economy,” which enables the sharing of a diverse range of goods and services through the availability of various online information systems (Hamari et al., 2015), came to life to fulfill environmental, economic, and social needs to reduce the ownership of goods and consequently reducing the need for their production and the production of waste (Cohen & Shaheen, 2016a). This specific new

form of sharing is present in many sectors, including lodging (e.g., Airbnb), labor (e.g., TaskRabbit, Handy), equipment (e.g., EquipmentShare), food (e.g., Nommery), and transportation (e.g., Lyft, Uber, Gira) (S. Shaheen et al., 2020).

One of the motivations for the sharing economy or collaborative consumption is that it provides economic benefits to users, such as travel cost savings, facilitating access to resources, and free riding (Hamari et al., 2015). On the other hand, participation in the sharing economy is usually expected to be highly ecologically sustainable (Prothero et al., 2011). The sharing economy is suggested to be used to foster a sustainable marketplace (Phipps et al., 2013) that “optimizes the environmental, social, and economic consequences of consumption to meet the needs of both current and future generations” (Luchs et al., 2011, p. 2).

According to the United Kingdom Department for Transportation (2019), while public transportation remains a fundamental form of shared mobility, new models based on shared use or vehicle ownership are rising. Digital platforms increasingly enable these models and align with shifts toward a sharing economy in other sectors. Shared mobility includes various service models and modes of transportation, such as car sharing, ridesharing, bike-sharing, scooter sharing, ride-sourcing, and alternative public transportation services that have transformative effects on urban mobility and local planning (Castellanos et al., 2022; Cohen & Shaheen, 2016a).

The evolution in technology and the change in consumption patterns allowed the introduction of some new ways of displacement in cities that generated positive outcomes. One example is the bike-sharing programs worldwide, which bring several benefits, such as travel time saving, connections with public transportation systems, improved personal health, better air quality, and a decrease in noise pollution (S. A. Shaheen et al., 2013; Todd et al., 2021).

The shared mobility service has a transformative impact on many major cities worldwide by enhancing transportation accessibility while reducing personal vehicle ownership and driving among users (FHWA, 2018). This impact has several independent synergies that affect the work of planners and civic leaders, such as transportation and circulation, zoning, land use, growth management, urban design, housing, economic development and environmental policy, conservation, and climate action (Cohen & Shaheen, 2016a).

These impacts in urban areas started with the expansion of bicycle infrastructure that accompanied the first wave of micromobility and led to opportunities for the current flux of dockless bicycles and e-scooters (National League of Cities, 2019). E-scooters themselves are not new, as they were an active part of transportation in the 1910s-40s; what is new is the shared ability to access e-scooters using personal smartphone devices and the evolution of electric batteries that now power them (Six, 2019).

In the United States, shared micromobility tools began to arrive in cities in 2010 (NACTO, 2019). In Europe, Paris pioneered one of the first city bike schemes, the “Vélib”, and projected it onto the global stage. The system was successful and inspired similar global schemes, such as Milan in 2008, London in 2010, and even New York City in 2013 (World Economic Forum, 2019a).

Bike-sharing services, especially dockless or free-floating ones, where users can park their bicycles wherever the ride ends, have seen an abrupt increase in popularity (Richter, 2018). Data from the World Economic Forum (2019b) shows that in 2015, there were 700,000 public-use bicycles in the world, while in 2016, the number reached 2,294,600. China has the highest number of public-use bicycle programs, followed by France, Italy, the United States, Germany, and Spain.

E-scooter sharing was first introduced in the United States. These self-service, free-floating rental services started to proliferate in Europe after the arrival of the first providers in Paris in the summer of 2018 (6t-bureau de recherche, 2019). The number of shared e-scooters in Europe doubled between 2021 and 2022. By the end of 2022, there were 700,560 e-scooters in Europe compared to the 285,000 e-scooters available in 2021 (Pinheiro, 2023).

However, one major problem in expanding shared e-scooter services is the lack of regulation surrounding this “new” mode of transportation. Recently, cities worldwide have been working on shared e-scooter trials and pilot programs to regulate their usage better. In the United States of America, Chicago performed a shared e-scooter pilot in 2019 to understand how the service could be better used when implemented to boost mobility and reduce inequality among users (City of Chicago, 2020).

In the European context, France conducted a nationwide e-scooter survey to understand better how, where, and when people ride shared e-scooters (6t-bureau de recherche, 2019a); however, the service was shut down for popular demand in September of 2023. London established e-scooter trials to support

a green restart of local travel and help mitigate public transportation capacity due to COVID-19 pandemic restrictions (Department for Transportation & Transportation for London, 2020).

Even if pilot programs have been developed, more is still needed to know how shared e-scooters could affect the urban transportation system. This approach to acknowledging the effects of shared e-scooters in cities can lead to the adjustment of the service to increase its positive impacts on the urban transportation systems and the sustainability of the urban environment. However, further studies must be conducted on this matter to allow the creation and establishment of a sound and systemic regulation for shared e-scooters, which is still a gap in the deployment and massive usage of this mode of transportation in cities.

I.2. Motivation

One of the main concerns in urban planning is how to manage the transportation systems to accommodate the best mobility options that meet the population's needs, decrease traffic congestion and air pollution, and allow low-income communities access to safe, comfortable, and efficient public transportation. With the introduction of new technologies (electric-powered vehicles) and new consumption patterns (sharing economy), cities have been looking forward to integrating new modes of transportation to increase the versatility and efficiency of urban mobility.

Considering the relevance of the above, shared e-scooter systems were chosen as the research theme to be studied and understood in urban environments. The goal is to determine how this mode could contribute to a more sustainable mobility option in urban centers. Thus, after a preliminary evaluation of the bibliography available, it was possible to identify the need for further studies to assess the impacts of shared e-scooter systems in cities once the addition of this new mode of transportation has been causing some dilemmas associated with how they should be managed to bring the best solutions to help mobility, the environment in urban centers.

Cities all around the world, such as Chicago, San Francisco, São Paulo, Lisbon, and Braga, have seen the quick rise of shared e-scooter use in their streets, as it comes with several problems that can be overcome by proper planning and policymaking (Petzhold & Pasqual, 2019; San Francisco Municipal Transportation Agency - SFMTA, 2020). The issue is that there is no consensus on managing e-scooter-sharing systems in cities. Often, cities allow the implementation of these services without fully

understanding the impacts they will cause on the transportation system and public space, which leads to the banning of the service right after they are established.

Thus, the primary motivation of the thesis is to complement and further study the many current possibilities available to establish shared e-scooter services in cities. The focus will be on understanding users' and potential users' perceptions and how the sociodemographic characteristics of the population can affect the choice to use shared e-scooters.

I.3. Objectives

This thesis aims to identify the impacts of shared e-scooters in urban transportation systems, considering the determinants of their usage and how different attributes influence their choice of daily rides. It also compares and contrasts the use of shared bicycles and shared e-scooters in cities to understand what features unite and separate them as modes of transportation in cities. A case study of the town of Braga was used for this.

The primary challenge is to develop a methodology to treat the available information to determine the characteristics of shared e-scooter use and how the implementation of this service is managed in urban planning. The second challenge is finding the optimal interface to analyze, compare, and contrast the shared e-scooters and shared bicycles to determine whether one is better for public use and a sustainable city strategy.

The specific objectives of this research work are thus listed as follows:

- This research examines how implementing shared e-scooter services in cities can contribute to diversifying the mobility options available to the population. Using available data, it will be possible to determine people's main points of interest in using shared e-scooters, where they feel more vulnerable, where they usually ride their e-scooters, how users evaluate the service, and identify its best and worst features;
- This research investigates the immediate problems caused by shared e-scooters in urban mobility and public space;
- This research investigates the potential to change the modal share in cities, i.e., the probability of shifting trips from other modes, such as individual vehicles, to the usage of shared e-scooters

and other sustainable modes of transportation. It also evaluates its contribution to reducing traffic congestion and decarbonizing the cities;

- This research evaluates the environmental and social benefits of shifting modes of transportation to shared e-scooters in cities;
- This research assesses whether shared bicycles and shared e-scooters can complement each other in cities or if the availability of both services can cause competition.

I.4. Hypothesis and research questions

Since there is still yet to be a consensus on the key factors influencing shared e-scooter planning and implementation in cities, more studies are needed to prove that this can be a safe and sustainable transportation option. Therefore, this research author has been conducting research on this matter since 2020, culminating in publishing six scientific papers in international journals as the main author, with the contribution and oversight of the supervisors of this thesis. Thus, this thesis comprises a miscellaneous work already published and further studies submitted for peer review.

In addition, due to the period when the research was conducted (between 2020 and 2024), amidst the mobility restrictions of the COVID-19 pandemic, this subject was also identified as a possible influence on the usage of shared e-scooters. Thus, it was included in the research questions presented below.

Considering the context of the shared e-scooter implementation in cities, as well as the lack of consensus on its impacts in cities, the following hypothesis and research questions were formulated:

The research hypothesis proposed for the thesis is:

“A shared e-scooter system can be a main driver of sustainable mobility for short city trips if considering the proper planning and infrastructure needed to promote a safe and comfortable ride, which can mitigate its negative impacts on urban transportation systems.”

The main research questions of this research work are:

- RQ1 – How did the COVID-19 pandemic influence the usage of shared e-scooters?

The scope of this research question is to understand the differences in shared e-scooter usage in the pre- and post-pandemic context, the usage of shared e-scooters during the pandemic in some specific contexts, and what happened in Braga during this period. This research question is further investigated in Chapter II of this research.

The following published paper helps to answer RQ1:

Dias, G., Arsenio, E., & Ribeiro, P. (2021). The Role of Shared E-scooter Systems in Urban Sustainability and Resilience during the COVID-19 Mobility Restrictions. Sustainability (Switzerland), 13(13). <https://doi.org/10.3390/su13137084>

- **RQ2 – What are the main drivers/determinants of shared e-scooter usage for commute and leisure trips?**

This research question aims to understand the main motivations and drawbacks of shared e-scooter usage. In addition, it targets the assessment of how different attributes affect the choice of shared e-scooters for daily trips. Research question two is further investigated in Chapter IV of this research.

The following published papers help to answer RQ2:

Dias, G., Ribeiro, P., & Arsenio, E. (2023). Determinants of shared e-scooters usage in the city of Braga: Results from a mobility survey and trip data analysis. Transportation Research Procedia, 72, 4002–4009. <https://doi.org/10.1016/j.trpro.2023.11.379>

Dias, G., Ribeiro, P., & Arsenio, E. (2024). Perceptions of shared e-scooters service among university students in Braga, Portugal. Transportation Engineering, 16(April 2023), 100231. <https://doi.org/10.1016/j.treng.2024.100231>

- **RQ3 – How do transportation planning and traffic management influence the safe usage of shared e-scooters?**

This research question intends to understand that shared e-scooters need specific planning measures to be widely used so the population feels safe and comfortable using them. The results presented in Chapter IV of this research are used to answer this research question.

The following published paper helps to answer RQ3:

Dias, G., Ribeiro, P., & Arsenio, E. (2024). Determinants of shared e-scooter usage and their policy implications. Findings from a survey in Braga, Portugal. European Transportation Research Review, 16(1). <https://doi.org/10.1186/s12544-024-00642-4>

- **RQ4 – What are the impacts of shared e-scooter usage on the sustainability of the transportation system?**

The target of RQ4 is to understand the modal shift shared e-scooters can promote and the possible environmental benefits of replacing vehicle trips with shared e-scooters. Chapter IV of this research investigates the answer to this research question.

The following published papers help to answer RQ4:

Dias, G., Arsenio, E., & Ribeiro, P. (2021). The Role of Shared E-scooter Systems in Urban Sustainability and Resilience during the COVID-19 Mobility Restrictions. Sustainability (Switzerland), 13(13). <https://doi.org/10.3390/su13137084>

Dias, G., Ribeiro, P., & Arsenio, E. (2023). Shared E-Scooters and the Promotion of Equity across Urban Public Spaces – A Case Study in Braga, Portugal. Applied Sciences, 13(3653). <https://doi.org/10.3390/app13063653>

- **RQ5 – Are shared e-scooters more competitive than shared e-bikes for short and medium-distance trips?**

RQ5 intends to understand the choice of shared e-scooters and e-bikes in Braga and compare how each mode of transportation is chosen. The interaction of these two modes is presented in Chapter IV of this research.

The following paper helps to answer RQ5:

Dias, G., Ribeiro, P., & Arsenio, E. (2024). Are shared e-bikes disruptive of established shared e-scooter services? A case study of Braga, Portugal. Lecture Notes in Mobility (Proceedings of TRA2024), Springer: in process of publication.

I.5. Structure of the thesis

The thesis is composed of five main chapters and is organized as follows:

Chapter I is the introduction of the thesis, offering a comprehensive research outline. It presents the theoretical framework and main motivations for selecting shared micromobility as the theme for this research. Then, the objectives of the thesis are outlined, as well as the hypothesis and the research questions. Additionally, it presents the structure of the thesis document.

Chapter II focuses on the literature review and the theoretical support for the theme explored. This chapter presents the concepts of micromobility and shared micromobility and the cities' take-up on shared e-scooter services worldwide. Then, the profile of shared e-scooter riders and the main problems caused in the towns by exploiting this mode of transportation without any prior planning will be presented. The chapter concludes by extending the review to the usage of shared e-scooters for improving sustainability in cities, the impacts of the COVID-19 pandemic on urban mobility, and the role of shared e-scooters in the towns during this period. The information presented in this chapter helps to answer RQ1 regarding the influence of the pandemic on shared e-scooter usage.

Chapter III introduces the methodology used for the thesis. It provides an overview of the two survey models used to collect data on the determinants of shared e-scooter usage in Braga, as well as how the choice of modes of transportation is affected by different attributes. Therefore, a review of Revealed Preference (RP) surveys and the tools used to process the data collected in this part of the research are presented. In addition, the stated choice (SC) method and the steps to formulate a stated choice experiment are presented. Then, Multinomial Logit (MNL) models will be introduced and used to model the data retrieved from the SC experiment.

Chapter IV presents the results of the RP and SC surveys collected in Braga's case study. It starts characterizing the case study site and explaining the outline of the surveys deployed in the city. The RP survey collected data on the main determinants of shared e-scooter usage in Braga and the primary needs

Chapter I – Introduction

of users and potential users of this mode of transportation. The results from the RP survey are used to answer RQ2, RQ3, and RQ4. They were also used as a basis to determine the main attributes of the SC experiment. Next, this chapter outlines the structure of the SC experiment conducted in Braga and presents the questionnaire results, which address RQ2, RQ3, RQ4, and RQ5.

Chapter V serves as the conclusion section of the thesis. In this part, all the work will be summarized, and the overall conclusion of the research will be delineated. In addition, possible policy recommendations for implementing shared e-scooter services in cities will be proposed, followed by a critical analysis of the research and its limitations. Moreover, this chapter offers suggestions for future research on micromobility, shared micromobility, and shared e-scooters.

Chapter II. State of the Art

This chapter aims to provide a comprehensive literature review on introducing shared micromobility modes in urban areas and their interaction with existing transportation systems. Since shared e-scooters are a recent addition to urban mobility, the chapter also focuses on profiling their users and addressing the issues of insufficient planning in their deployment. The positive outcomes of shared e-scooters in cities are also presented, such as their impacts on urban sustainability and their role during the COVID-19 pandemic.

This chapter includes the collection of information published in the following scientific paper, which is part of a Special Issue named “Ensuring Sustainable Development at the Light of New Mobility Trends and Challenges”:

Dias, G., Arsenio, E., & Ribeiro, P. (2021). The Role of Shared E-scooter Systems in Urban Sustainability and Resilience during the COVID-19 Mobility Restrictions. Sustainability (Switzerland), 13(13). <https://doi.org/10.3390/su13137084>

II.1. Background

II.1.1. The concept of micromobility, shared micromobility, and active transportation

Micromobility is defined as any transportation via very light vehicles (Dutta, 2019); in other words, the International Transportation Forum - ITF (2020) defines micromobility as any transportation through

vehicles that weigh up to 350kg and reach a maximum speed of 45km/h, being all of them human or electrically powered (Figure 1). NACTO (2019b) states that micromobility is a term that catches several small modes of transportation that are fully or partially human-powered, such as station-based bike-share (including e-bikes), dockless bike-share (including e-bikes) and scooter share. These modes increase routes' flexibility and help improve the efficiency of the “last mile” traveled, which is the least efficient part of the journey, and comprises up to 28% of the total cost of moving goods (urban logistics) and is responsible to consume much time and effort from the individual on the move (Arcadis, 2019).

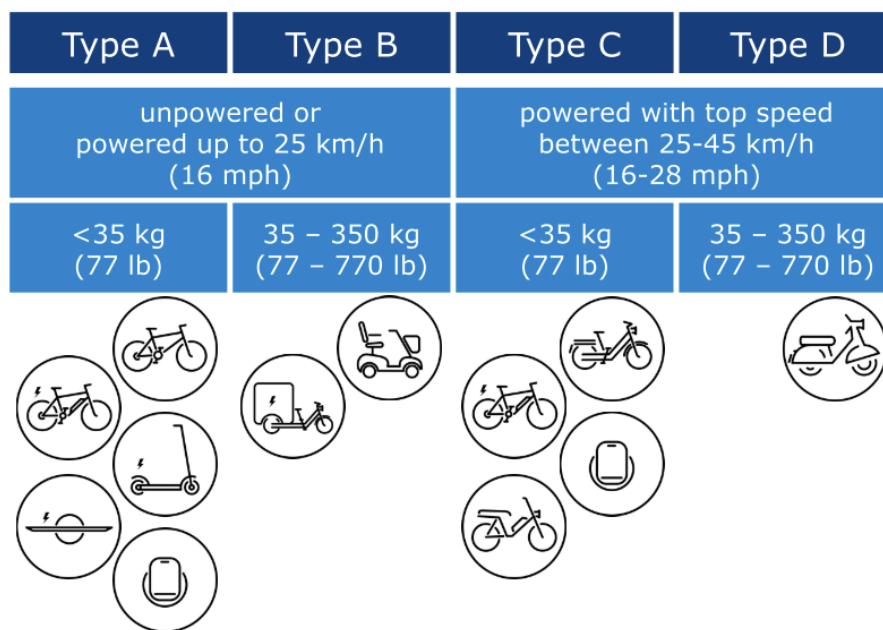


Figure 1: Micromobility definition and classification (ITF, 2020)

Shared Micromobility is an innovative transportation strategy that gives users short-term access to a mode of transportation on a needed basis. Shared micromobility includes various service models and modes of transportation that meet the diverse needs of travelers (S. Shaheen et al., 2020). “These vehicles are generally rented through a mobile app or kiosk, are picked up and dropped off in the public right-of-way, and are meant for short point-to-point trips” (NACTO, 2019a, p. 5). They are usually provided by companies that offer residents and tourists convenient and flexible transportation options while lowering greenhouse gas emissions (GHG) by endorsing shared electric and pedal-powered transit tools (Six, 2019).

Micromobility trends are rapidly adapting (Six, 2019). In the United States in 2018, non-electric dockless bikes have largely exited North American cities as e-bikes and e-scooters have emerged (NACTO, 2019b).

E-bikes constituted about 8% of U.S.A. trips in 2018, and over 90% were dockless (NACTO, 2019b). Dockless forms of micromobility rose to about 56% of all trips in 2018 (NACTO, 2019b). More recent data shows that in 2022, 130 million trips were made by shared e-scooters and e-bikes in the U.S.A. and Canada (Nacto, 2023). In Europe, from 2022 to 2023, there was an increase of 1% in shared micromobility ridership despite marginally fewer vehicles on the streets (-2%) (Maxwell, Krieg, Venkatesh, et al., 2023).

In addition, active transportation, represented by micromobility (e.g., bicycles) and walking, offers numerous health and environmental benefits. Research has shown that active transportation can significantly improve public health by increasing physical activity levels and reducing the risk of chronic diseases such as cardiovascular disease, diabetes, and obesity. For instance, a systematic review of health impact assessments (HIA) found that the health benefits of increased physical activity from walking and cycling far outweigh the risks associated with traffic incidents and air pollution exposure (Mueller et al., 2015). Also, populations relying heavily on active transportation enjoy better health and increased longevity, suggesting that active transportation can address significant public health challenges like climate change, air pollution, and physical inactivity (Alessio et al., 2021).

Moreover, active transportation is not only beneficial for individual health but also for the environment. By reducing reliance on gasoline-powered vehicles, active transportation helps decrease greenhouse gas emissions and other pollutants, mitigating global climate change (Alessio et al., 2021). Policies promoting active transportation in European cities have shown potential health benefits, including reductions in all-cause mortality and carbon dioxide emissions (Rojas-Rueda et al., 2016). These findings underscore the importance of integrating health perspectives into transport policies to promote active transportation and its associated benefits.

II.1.2. Bike sharing

The bike-sharing system has emerged as one of the fastest-growing transportation innovations in many cities (S. Shaheen et al., 2020). Today, there are more than 1,900 systems in 92 countries of every continent, which comprises a fleet of around 9 million shared bicycles (PBSC Urban Solutions, 2022). They come in a variety of forms, such as dock-based systems (allow users to pick up and return bikes from IT-enabled docks or stations), dockless or GPS-based systems, low-cost systems (users sign up online and then receive a text or e-mail with a code to open the bike's lock) and the peer-to-peer bike-

sharing (allows users to rent or borrow bikes hourly or daily from individuals or bike rental shops) (Kou & Cai, 2021; Shared-Use Mobility Center, 2015).

The bike-sharing evolution comes from generations, starting with free bikes called “white bikes” in the 1960s, followed by the generation of coin-deposit systems, the third generation was information technology-based, and the fourth generation of demand-responsive and multimodal systems (S. Shaheen et al., 2010). The fourth generation is built upon the technology of third-generation systems by implementing enhanced features to support user metrics, such as flexible, solar-powered docking stations or “dockless” bicycles (Cohen & Shaheen, 2016b).

Besides creating a large cycling population, helping decrease air pollutants and GHG emissions, as well as improving public health, bike-sharing programs have reduced traffic congestion since cycling can lead to 45% less car traffic and faster public transportation (ECF, 2018). Shaheen et al. (2020) say that public bike-sharing in large cities takes riders off crowded buses while bike-sharing in smaller cities improves access/egress from bus lines.

Regarding introducing e-bikes in the context of shared micromobility, a study by NACTO (2019c) shows that people tend to choose e-bikes over conventional bicycles when available. The study says that in the U.S.A. cities, the vehicles with the highest use frequency (measured by rides/vehicle/day) are e-bikes. Cities that added e-bikes to their station-based fleets report that, on average, e-bikes are used twice as much as pedal bicycles (NACTO, 2019b).

In the Asian market, bicycles became popular and experienced exponential growth in China in the 1980s and 1990s (Mateo-Babiano et al., 2017). However, after the mid-1990s, bicycle use declined due to economic growth and increasing urbanization. In 2005, the first bicycle-sharing program in China was launched, and by 2015, dockless bicycle systems emerged in the country (S. Li et al., 2023). The country has been relying on shared bicycle schemes to decrease traffic and reduce GHG emissions. The success of shared bicycle usage represented a contribution of EUR 30 trillion to the country's economy in 2017 (Ferrari et al., 2024).

In Europe, cities are implementing and enlarging their bicycle-sharing systems to become carbon-neutral and comply with the urban mobility frameworks proposed by the European Commission (Figure 2). A

benchmarking with 148 European cities showed that Paris, Bordeaux, Antwerp, Toulouse, and Lyon were the top five cities with the most trips made by shared bicycles (daily trips per 1,000 inhabitants). It was also estimated that 1.7 million trips are made daily on shared bicycles and around 600 million trips per year in the studied cities (Cycling Industries Europe, 2023).



Figure 2: Bike-sharing in Europe (own author)

In the Portuguese case, the Lisbon bike-sharing service “Gira, Bicicletas de Lisboa” started in 2017 with ten dock stations and 90 bicycles, 2/3 composed of e-bikes. According to EMEL (2018), in 2017, there was an average usage of 2.36 trips/bicycle/day in Lisbon, and in 2018, they reached the number of 2.91 trips/bicycle/day. Also, the number of annual passes to use the system has increased from 491 in September 2017 to 4,838 in February 2018, representing an increase of about 900% in less than six months (EMEL, 2018). Currently, Lisbon residents can use their monthly public transportation pass to access “Gira” bicycles. Until 2023, more than 10 million trips were made by Gira bicycles and e-bikes in Lisbon; on average, 7,360 trips are made daily, representing an increase of 5% compared to 2022 (EMEL, 2023).

Other Portuguese cities that have implemented bike-sharing systems include Figueira da Foz, where forty e-bikes and twenty-five conventional bicycles are available in seven stations around the city; since its introduction, more than 200,000 km have been traveled, and more than 64,000 trips have been made (Município de Figueira da Foz, 2023). In Torres Vedras, the bicycle-sharing system called “Agostinhas” has been active since 2013 and currently counts twenty stations and twenty-six bicycles available for the population (Município de Torres Vedras, 2024).

More recently, a bicycle-sharing system was implemented in the “Comunidade Intermunicipal do Médio Tejo,” where sixty-eight bicycle stations are available in eleven municipalities, including Alcanena, Constância, Entroncamento, Ferreira do Zêzere, Mação, Ourém, Sertão, Tomar, Torres Novas, Vila de Rei, and Vila Nova de Barquinha. In these towns, 250 electric bicycles are available, and only in the first month of availability have the systems already reached more than 1,500 people who subscribed to the app (CIM Médio Tejo, 2024).

Another essential feature of bike-sharing programs is the possibility of connection to public transportation services, which helps in the first and last mile of the journey. As a means to promote the integration of bicycles and public transportation, Wang & Chen (2020) state that there is a statistically significant and positive increase in shared bicycle usage when their availability near bus stops and subway entrances is promoted.

II.1.3. E-scooter sharing

The e-scooter-sharing service was first introduced in the United States in 2017 and has increased worldwide as a mobility trend. In Europe, an example of the spread of this system is Paris, where the first provider of self-service, free-floating e-scooter rental service was introduced in 2018 (6t-bureau de recherche, 2019c). As of early June 2019, the French capital hosted 12 free-floating scooter services. However, Parisians voted in 2023 to ban shared e-scooters from the city starting in September of the same year (Giuffrida, 2023) due to the high number of accidents involving this mode of transportation.

Yet, the dockless e-scooter service model has taken off and witnessed aggressive growth in its early years (Figure 3). Several US-based scooter-sharing companies have reached unicorn status at lightning speeds as big investors pour millions of dollars into this business (CB Insights, 2019). Moreover, about 70% of Americans living in major urban areas and current shared e-scooter users worldwide view e-scooters positively. The positive perception is primarily due to their ability to expand transportation options, enable a car-free lifestyle, provide a convenient replacement for short car trips, and complement public transportation (Populus, 2018a; Pourfalamatoun et al., 2023).



Figure 3: Shared e-scooters in Europe (own author)

In Asia, shared e-scooters have been gaining traction as a viable solution for short-distance public transportation trips because of their excessive indirectness, multiple transfers, and long access walking distances, mainly in urban areas. In Singapore, e-scooter-sharing services have been identified as an effective last-mile solution that complements public transportation services for longer journeys. In the Asian market, factors such as fare and walking distances significantly influence the choice between shared e-scooters and traditional public transportation modes (Cao et al., 2021a)

However, some cities still consider shared e-scooters dangerous, with the case of Paris, which banned shared e-scooters from its streets in 2023. While many feared that other towns would follow this example, it has not happened, except for Madrid, which is banning shared e-scooters in October of 2024. Different cities have opted for cuts to fleet sizes rather than bans; this is the case of Berlin, which cut up to 6,000 shared e-scooters from the fleet, and Brussels, which opted to cut 12,000 e-scooters from the city in 2023 (Maxwell, Krieg, & Corbett, 2023). The opposite happened in Eastern Europe, where fleets have grown 33% in the same period.

Guaquelin (2019) and Cao et al. (2021a) say that in France, like the U.S.A. and Singapore, the primary users of e-scooters are males with high income, with an average revenue of EUR 2,500/month in the

U.S.A. versus an average revenue of EUR 2,202/month in Paris. However, a couple of differences can be found, as in Paris, 42% of the users were tourists, which lowers the importance of the shared e-scooter as an alternative for commuting. Students are over-represented despite the high price of the service. Companies usually charge a EUR 1.0 fee to unlock the e-scooter and more than EUR 0.15 per minute traveled.

According to 6t-bureau de recherche (2019c), 58% of e-scooter users in France are wealthy local executives and students who use e-scooters in their city. The following 33% are foreign visitors, and the last 9% are French visitors who use e-scooters outside their town.

The main motivations for using the services are related to leisure and the fun aspects of the e-scooters that make a ride pleasant, the time people can save in traffic by using this mode of transportation, and the possibility of taking door-to-door trips (Laa & Leth, 2020a). On the other hand, the main obstacles are price, feeling unsafe, and exposure to poor weather (Hardt & Bogenberger, 2017a).

Research from NACTO (2019b) shows that people use e-scooters in U.S.A. cities mainly for recreation and exercise, to go to and from work, to connect to public transportation, and for social reasons. In addition, a survey conducted in Germany (Hardt & Bogenberger, 2019) shows that e-scooters were used mainly for commuting, leisure, and business trips within the city. These trip purposes represent a chance to establish e-scooters as an alternative to cars since commuting and leisure trips are still dominated by car usage. In Singapore, e-scooters are primarily used to replace traditional public transportation modes that do not meet people's needs (Cao et al., 2021a)

However, the modal shift in trips can also represent changes in people's walking and bicycling patterns. Chang, Miranda-Moreno, Clewlow, & Lijun Sun (2019) show that in a survey deployed in the U.S.A., more than half of the respondents said that e-scooter sharing essentially replaces walking and cycling. Moreover, 46% of respondents stated that they would have walked or cycled if a shared e-scooter had not been available for their last trip (A. Chang et al., 2019).

In France, a survey showed that 44% of local users would have walked to take their last trip instead of using a free-floating e-scooter. 30% would have used public transportation, but only 6% have taken fewer urban transportation options since they started using e-scooters. Moreover, 23% of these trips are

intermodal, which combines the e-scooter with another mode of transportation, such as public transportation for 66% and walking for 19% (Polis, 2019).

Trips made by e-scooters have their limitations. This mode of transportation could perform better in hilly areas or brick-line streets; it needs to be improved for lousy weather, and riders need somewhere to stow groceries or other belongings (Schellong et al., 2019a). E-scooter use can also cause difficulties for pedestrians on sidewalks. Several studies have reported that e-scooters disrupted pedestrian travel and blocked pedestrian right-of-way (Fang et al., 2018; Radavoi & Potter, 2019).

II.2. Worldwide use of shared e-scooters

The advent of shared e-scooter schemes in 2017 changed how people commute in many cities worldwide, such as Madrid, San Diego, Santa Monica, and Portland. To exemplify, in 2012 and 2013, 2% of the population over the age of 18 in metropolitan areas were members of carsharing services (Populus, 2018b), while in less than one year of availability in some cities, e-scooter sharing has experienced an average adoption rate of 3.6% as measures by the percentage of people who have used these services (Populus, 2018c). Nearly 90% of the micromobility investments were going to shared e-scooter companies in the core of Asia, Europe, and North America, representing approximately more than EUR 8 billion from 2018 to 2022 (Heineke et al., 2022).

In the United States of America, by August 2020, 145 e-scooter-sharing schemes were serving around 40 cities across the country (U.S. Department of Transportation, 2020a). The number of e-scooter schemes increased through 2019, then declined by almost 40% from 2019 to 2020 due to the Covid-19 pandemic restrictions. In 2018, there were 82 e-scooter systems throughout the USA, while in 2019, 115 systems were seen, and in 2020, only around 40 remained (U.S. Department of Transportation, 2020a). After the pandemic of COVID-19, in 2022, dockless e-scooter trips dropped by 10% due to the end of operations of some companies in the North American market, which made people take 58.5 million trips on dockless shared e-scooters in 2022, compared to 65 million in 2021 (Nacto, 2023). Some cities that provide e-scooter sharing services in the U.S.A. and the companies running them can be found in Table 1.

Table 1: Shared e-scooter services in the U.S.A. by 2020 (U.S. Department of Transportation, 2020b)

City	Companies Operating (by 2020)
San Francisco, CA	Spin, Scoot
San Diego, CA	Bird, Spin, Lyft, Wheels
Los Angeles, CA	Bird, Jump, Lyft, Spin, Sherpa, Wheels
Long Beach, CA	Bird, Lime, Gruv, Razor
Santa Monica, CA	Bird, Lyft
Freemont, CA	Hopr
Portland, OR	Spin, Razor, Lime, Bird
Boise, ID	Lime, Bird, Spin
Bozeman, MT	Blink Rides
Salt Lake City, UT	Bird, Lime, Spin, Razor
Ogden, UT	Lime
Farmington, UT	Spin
Denver, CO	Lyft, Razor, Spin, Bird, Lime
Tucson, AZ	Razor (Pilot)
Tempe, AZ	Razor
Austin, TX	Bird, Lime, Spin, Wheels
Corpus Christ, TX	Blue Duck
San Antonio, TX	Bird, Razor
Dallas, TX	Lime, Bird, Wheels
Plano, TX	Boaz Bikes, Razor
Oklahoma City, OK	Lime
Stillwater, OK	Bird, Lime
Kansas City, KS	RideKC scooter, Bird, Spin
Wichita, KS	Spin, Voeride
Minneapolis, MN	Bird, Lyft
St. Paul, MN	Lime
Detroit, MI	Bird, Spin
Ann Arbor, MI	Spin
Lansing, MI	Gotcha
Nashville, TN	Lime
Atlanta, GA	Bird, Spin, Helbiz, Veoride
Tampa, FL	Spin, Bird, Lime
Fort Pierce, FL	Zagster
Orlando, FL	Wheels
Charlotte, NC	Bird, Lime, Spin
Blacksburg, VA	Spin
Virginia Beach, VA	Bird, Lime, Veoride, Spin
Washington, D.C.	Jump, Lyft, Skip, Spin
Baltimore, MD	Lime, Spin
Providence, RI	Veoride, Spin

While in 2020, only around 40 cities in the U.S.A. provided shared e-scooter services, by 2022, there were 286 shared e-scooter services across the U.S.A. However, this also represents a decrease from the

peak number of 311 systems in 2021. Figure 4 shows the sizes of shared e-scooter services in North America by 2022.

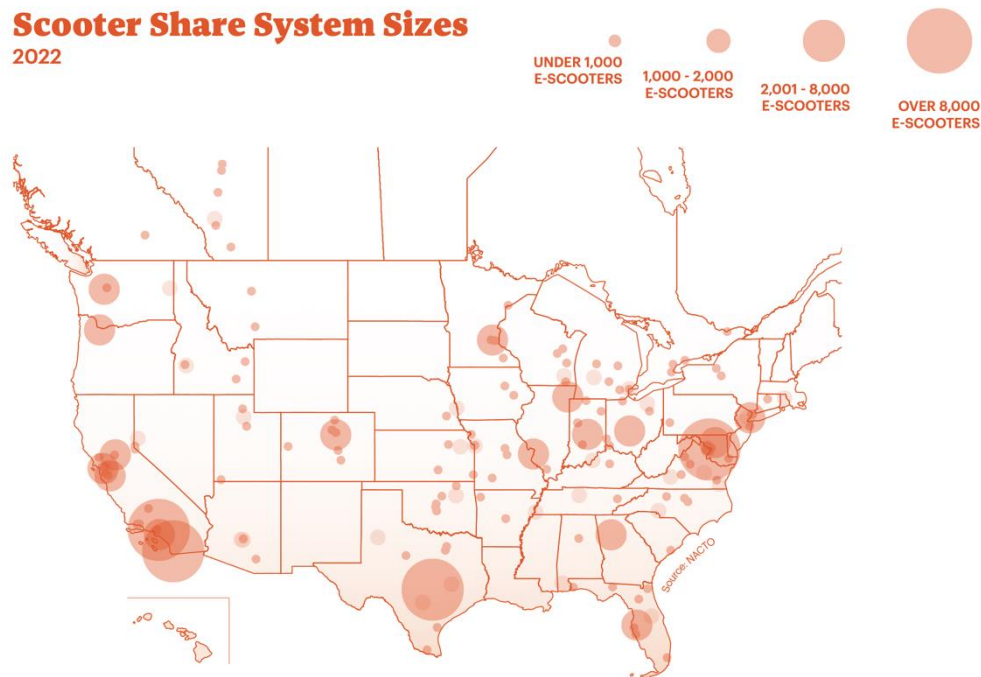


Figure 4: Shared e-scooter systems size in North America by 2022 (NACTO, 2022)

Despite the quick rise of the service in many North American cities and the growth in shared e-scooter usage in the years preceding the COVID-19 pandemic, the current state of availability shows a decrease in the number of vehicles present in cities, which has affected the number of trips generated. Following this pattern, European cities face the same trend regarding shared e-scooter availability and usage in their towns.

In several European cities, many e-scooters and free-floating bicycle schemes have been rolled out, and 2019 can be considered the year of the shared e-scooter (van Wijnendaele, 2019). The early days of shared e-scooters in Europe show that in Brussels, for example, there were around 3000 free-floating e-scooters and bicycles by 2019, and the e-scooters are mainly used for 2 km to 3 km trips (van Wijnendaele, 2019). In Paris, more than 20,000 shared e-scooters (Crellin, 2019) used to be rented daily for commuting during the weekday for a 19-minute trip (6t-bureau de recherche, 2019b). This massive adoption of shared e-scooters is also promoted by enlarging internet access, allowing people to rent the e-scooters through mobile apps and share their experience through user-generated content (UGC) (Owusu et al., 2016).

A survey in Europe showed that among countries with shared e-scooter systems (Austria, Belgium, Czech Republic, Denmark, Germany, Greece, Finland, France, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Serbia, Spain, Sweden, and Switzerland) there is a pattern in the number of shared e-scooters per resident in different countries, such as Denmark, Norway, Sweden and Germany (Table 2) (Kamphuis & van Schagen, 2020). Even if the global number of shared e-scooters differs in distinct contexts, it usually represents a similar ratio of vehicles per inhabitant.

Table 2: Availability of shared e-scooters in different European countries (Kamphuis & van Schagen, 2020)

Location	Number of shared e-scooters	Shared e-scooters per resident
Denmark	7,000	1/1000
Norway	11,000	2/1000
Sweden	17,000	2/1000
Germany	50,000	0.6/1000

In other countries, only the estimate of shared e-scooters in a town or city was possible, such as Thessaloniki city (Greece) with more than 100 shared e-scooters (e-scooter per resident: 1/1000), Lisbon (Portugal) with around 4,000 shared e-scooters (e-scooter per resident: 8/1000), and Stockholm (Sweden) with around 9,000 shared e-scooters (e-scooter per resident: 9/1000) (Kamphuis & van Schagen, 2020).

Some companies that dominate the market also influence the spread of shared e-scooter services in Europe. Table 3 shows data from three companies that provide shared e-scooter services in Europe and the cities where the offer is present by 2021.

Table 3: Shared e-scooter services in Europe (Bird, 2021; Bolt, 2021; Lime, 2021)

E-scooter company	Country	Cities
Bolt	Czech Republic	Boskovice, Brno, Frydek-Mistek, Mladá Boleslav, Olomouc, Pardubice, Prague
	Estonia	Parnu, Talin, Tartu
Bolt	France	Bordeaux
	Croatia	Osijek, Rijeka
	Lithuania	Kaunas, Klaipeda, Panevezys, Vilnius
	Latvia	Daugavpils, Jelgava, Liepaja, Riga, Valmiera
	Malta	Malta
	Norway	Bergen, Fredrikstad, Lillestrom, Oslo

E-scooter company	Country	Cities
Bolt	Poland	Bialystok, Gdansk, Gdynia, Katowice, Krakow, Lublin, Poznan, Silesia, Sopot, Trojmiasto, Warsaw, Wroclaw
	Portugal	Braga, Lisbon,
	Romania	Bucharest, Cluj-Napoca, Constanta, Galati,
	Sweden	Gothenburg, Stockholm
Lime	Austria	Vienna
	Belgium	Brussels
	Bulgaria	Sofia
	Czech Republic	Brno, Pilsen, Prague
	Denmark	Copenhagen
	Finland	Helsinki
	France	Lyon, Toulouse
	Germany	Berlin, Bonn, Brunswick, Cologne, Dortmund, Dresden, Dusseldorf, Essen, Frankfurt, Hamburg, Hannover, Karlsruhe, Munich, Nuremberg, Ruhrpott, Stuttgart
	Greece	Chania, Rethymno, Thessaloniki
	Hungary	Balaton, Budapest
	Italy	Milan, Rimini, Rome, Turin, Verona
	Norway	Oslo
	Poland	Krakow, Poznan, Tricity, Warsaw, Wroclaw
	Portugal	Lisbon
	Romania	Bucharest, Cluj-Napoca
	Spain	Barcelona, Madrid, Malaga, Seville
	Sweden	Gothenburg, Malmo, Stockholm
	United Kingdom	London, Milton Keynes
Bird	Austria	Vienna
	Belgium	Antwerp, Brussels
	France	Bordeaux, Bretigny-sur-Orge, Marseille, Orange, Villemonble, Viry-Chatillon
	Germany	Berlin, Chemnitz, Cologne, Darmstadt, Dortmund, Dusseldorf, Erfurt, Frankfurt, Gelsenkirchen, Gottingen, Hamburg, Hannover, Heidelberg, Heilbronn, Karlsruhe, Kassel, Ludwigshafen, Munich, Neckarsulm, Neu-Ulm, Oldenburg, Pforzheim, Regensburg, Reutlingen, Rostock, Troisdorf, Ulm, Wurzburg
Bird	Italy	Aprilia, Firenze, Milano, Palermo, Pesaro, Rimini, Rome, Torino, Verona, Viareggio
	Norway	Bergen, Oslo
	Portugal	Braga, Lisbon, Porto
	Spain	Madrid, Malaga, Terragona, Zaragoza
	Sweden	Gothenburg, Stockholm
	Switzerland	Basel, Winterthur, Zurich
	UK	Canterbury, Redditch

The data from Table 3 shows that more than 18 European countries offer a shared e-scooter service by 2021, reaching big and small cities in different countries. By 2023, 91 cities in Europe offered shared e-scooter services (less four than in 2022), with a fleet size of approximately 514,000 e-scooters, representing 64% of the shared vehicles fleet in Europe (Maxwell, Krieg, Venkatesh, et al., 2023). Even with the high number of shared e-scooters in the urban fleet, their presence has shrunk since 2022, the same as in the U.S.A. Figure 5 shows Europe's shared e-scooter fleet difference between 2022 and 2023.



Figure 5: Shared e-scooter fleet in Europe in comparison to 2022 (Maxwell, Krieg, & Corbett, 2023)

In one year, Eastern Europe experienced a high rise in the shared e-scooter fleet. At the same time, southern Europe was affected by a 33% decrease in the same year, followed by France and Benelux, primarily due to the ban on shared e-scooter usage in Paris. The differences in the fleets of shared e-scooters in the U.S.A. and Europe show that after an exponential rise in usage and fleet during the first years of operation, shared e-scooters have experienced a decrease in availability and use worldwide. The decline can be attributed to companies struggling to cope with market competition and some bans that occurred in some cities, such as Paris and Madrid.

The Asian-Pacific market for shared e-scooters has been growing in recent years; however, data on usage and information on the patterns of geographic vehicle distribution are still scarce. This is the world's third biggest shared e-scooter market, only behind Europe and North America, representing a 10% market share.

The number of users of shared e-scooters in Asia is expected to continue growing in the following years, reaching 19.25 million by 2029. The projected penetration of 0.3% in 2024 is expected to rise to 0.4% by 2029 (Statista, 2023). Even if the market's growth is projected for the following years, shared e-

scooters are still banned in most parts of China, for example. In 2024, a trial was proposed in Suzhou, China to introduce 10,000 shared e-scooters and e-bikes by the end of the year, aiming to demonstrate the safety and potential of shared micromobility through the controlling context of a trial (Musa, 2024).

II.3. Usage and users' profile of shared e-scooters

Temporal, sociodemographic, and built-environment variables have influenced the usage of shared e-scooters in cities. However, the profile of the population exposed to shared e-scooter services highly influences the usage of this mode of transportation. Hence, understanding the relationship between the usage of shared e-scooters and the sociodemographic characteristics of the population can be crucial to establishing e-scooters as a mode of transportation (Nikiforiadis et al., 2021).

Therefore, some researchers have indicated that shared e-scooters are more used in areas with more employment rates between residents and where bicycle infrastructure is higher (Mehzabin Tuli et al., 2021). Mixed-use regions have the most minor portion of non-recreational trips. In contrast, downtown areas have the highest usage of shared e-scooters for non-recreational trips and institutional-oriented mixed-type regions (Liu et al., 2020). Shared e-scooters also reach their peak usage in the middle of the day or the evenings for trips focused on recreation and educational usage (Dibaj et al., 2021).

Besides, the presence of commercial regions, along with an encouraging environment for active transportation (e.g., walking and cycling), and the proximity to public transportation stations and hubs were also correlated with high usage of shared e-scooters, which can suggest that this mode of transportation can be associated positively with sustainable development (Hosseinzadeh et al., 2021a; Latinopoulos et al., 2021).

In addition, the presence of shared e-scooters near and on university campuses, combined with the ability to appreciate the ease of use of this “new” mode of transportation, the availability of smartphones, and online payments, make university students the main adopting group of shared e-scooter services around the world (Fistola et al., 2022).

Students and other specific groups of users have been reported to be constantly using shared e-scooters. In Paris, for example, shared e-scooter users used to be 18 to 29-year-old males with a high educational level. They can be students or executives significantly wealthier than the general French population (6t-

bureau de recherche, 2019c; Christoforou et al., 2021a; Latinopoulos et al., 2021). Similar results were obtained in Vienna, Austria, where most e-scooter users are young to middle-aged, highly educated men (Laa & Leth, 2020b). Table 4 presents the sociodemographic characteristics of users in cities in Europe and America to draw a profile of the public covered by shared e-scooter services.

Table 4: Sociodemographic profile of shared e-scooter users (Bielirski & Ważna, 2020; Jiao & Bai, 2020; Laa & Leth, 2020a; Mitra & Hess, 2021; Pazzini et al., 2022; Reck & Axhausen, 2021)

Location	Profile				
	Gender	Age	Education status	Occupation	Income level
Vienna, Austria	Male	26-35 years old	High	Student/employed	-
Thessaloniki, Greece	Male	18-27 years old	-	-	Medium income
Zurich, Switzerland	Female	21-30 years old	High	Employed	High income
Trondheim, Norway	Male	18-35 years old	-	-	-
Gdansk/Gdynia/Sopot, Poland	Male	31 years old	-	Student/employed	Medium income
Great Golden Horseshoe, Canada*	Male	25-40 years old	High	-	-
Chicago, USA	Male	25-34 years old	High	-	High income
Austin, USA	Male	-	High	-	Low income

*Intention to use shared e-scooters

Users of shared e-scooters are usually young men with high educational levels and medium to high incomes; only in Zurich, Switzerland, are women the most predominant gender amongst users. This illustrates the possible gender, age, and income disparities promoted in cities when this new mode of transportation is introduced. The locations where shared e-scooters are deployed can also stimulate these differences. They are usually available in downtown areas, business districts, and near a university campus, which can influence the type of public that has access to this mode of transportation.

Moreover, the main sociodemographic aspects that affect the usage of shared e-scooters in cities include gender, age, family size, employment status, educational status, and family monthly income. Table 5 shows some recent research that surveyed shared e-scooter users to identify the sociodemographic reasons for using or not using the service.

Table 5: References that identify sociodemographic reasons to use shared e-scooters (6t-bureau de recherche, 2019a; Blazanin et al., 2022; Y. Guo & Zhang, 2021a; Laa & Leth, 2020a; Mitra & Hess, 2021; Nikiforiadis et al., 2021)

Source	Sociodemographic characteristic					
	Gender	Age	Family size	Employment status	Educational status	Family income
6-t bureaux of recherche, 2019	X	X	X	X	X	
Laa & Leth, 2020	X	X	n/a	n/a	X	X
Mitra & Hess, 2021	X	X	X			
Guo & Zhang, 2021	X	n/a	n/a	n/a	n/a	n/a
Nikiforiadis et al., 2021	X	X	n/a	n/a	n/a	
Blazanin et al., 2022	X	n/a	n/a	n/a	x	n/a

*The “X” mark on the sociodemographic characteristics means that the study found a statistical correlation between the characteristic and the usage of shared e-scooters. In contrast, the lack of any mark indicates otherwise. The “n/a” means that the source did not consider that determinant in their study.

Gender, age, and family size are essential in shared e-scooter usage when only users are surveyed. Employment status and family income are not always determinants of service usage. In addition, some psychographic characteristics may affect shared e-scooter usage behavior, such as the person’s identification with a spirit of adventure and belief that they do not live a traditional life (Fuchs et al., 2021).

II.4. Problems regarding shared e-scooter usage

The introduction of e-scooter-sharing services in cities, combined with the lack of clear legislation for users and proper infrastructure for journeys, has resulted in a rise in injuries related to this new mode of transportation. According to Choron & Sakran (2019), the e-scooter (with only a flat piece of metal between two small rubber tires) and the high speeds left riders extremely vulnerable to traumatic injury on roadways.

According to Nikolaj et al. (2019), in Copenhagen, most e-scooter rider injured patients were between 18 and 25 years old, and their trauma was mainly related to failing off the scooter (93.8%), followed by the ones who collided with an object (2.8%). For non-riders, the average age of the patients was 75 years old, with the trauma mainly caused by the hit of an e-scooter and by tripping over a discarded e-scooter. More than 385 accidents involving e-scooters were reported in Spain in 2021; from that, eighteen people died (AMT, 2022). Also, a study conducted by Sikka, Vila, Stratton, Ghassemi, & Pourmand (2019) in the

United States reported that of 249 patients who presented to the emergency department with e-scooter-related injuries, 8.4% were pedestrians.

One of the safety components that could help prevent head injuries, which, according to Badeau et al. (2019), are among the most commonly related to e-scooter use, would be using helmets by e-scooter riders. Although there is no common sense on the subject, users are not obligated to use safety gear by the authorities or companies providing the service. In other words, no rules or policies obligate e-scooter users to use helmets, for example (AMT, 2022), and regulation is not transparent for riders on where to use e-scooters (e.g., roadway, cycle lanes), which corroborated the decrease in safety and increase in accidents and trauma.

Due to data on shared e-scooter accidents and their proliferation on streets, mostly parked on sidewalks, many vehicles suffered from vandalism (Figure 6). Only in one month of operating in Oakland, California, U.S.A., nearly one hundred shared e-scooters were encountered floating on the local river. In addition, many e-scooters have been broken or stolen in cities worldwide.



Figure 6: Shared e-scooter dumped in a river (own author)

Vandalism also helps shorten the lifecycle of a shared e-scooter, another problem of this mode of transportation. When shared e-scooters started being deployed on streets, the average service life was only three months, which decreased their sustainability. In addition, the decrease in environmental benefits of this mode of transportation is accentuated when they are not constantly used, which decreases their lifecycle assessment, the energy source for their charging is polluting and the times they are collected and redistributed in cities, usually carried by combustion vehicles (Reis et al., 2023a).

Moreover, the unregulated proliferation of e-scooters has also led to various urban management challenges. Issues such as traffic rules, public safety, parking regulations, and liability concerns have emerged as significant problems for city management (Feng et al., 2021). The lack of clear legislation and difficulty categorizing e-scooters as either a bicycle or vehicles further complicates their integration into urban transportation systems (Pazzini et al., 2022). This ambiguity makes it challenging for local governments to develop appropriate policies and infrastructure to support safe and efficient e-scooter use.

II.5. Shared e-scooter regulation

Shared e-scooter regulation differs between cities and countries. In the United States, for example, shared e-scooter services are allowed in thirty-eight states, while in ten states, it is not street-legal. In Phoenix, Arizona, and Chicago, Illinois, riders must operate shared e-scooters in the roadway, and riding on sidewalks is prohibited. The former encourages helmet usage but does not require it, while the latter requests the use in every e-scooter ride (City of Chicago, 2022; City of Phoenix, 2023).

In Paris, even with strict regulations, the service was shut down in the Fall of 2023. In this city, riders could only circulate alone on an e-scooter on cycle lanes. They must circulate on roads with a 50 km/h speed limit if these were unavailable. If the shared micro vehicle is parked on the sidewalk, riders must pay a fine of EUR 49 (République Française, 2022).

London experienced a period of trial of shared e-scooters before implementing the regulation. In this case, only shared e-scooters are allowed on the streets, meaning private e-scooter usage is illegal. The shared ones can only circulate at up to 25 km/h. They must be operated by eighteen or older riders with a full or provisional driving license (Transportation for London, 2020).

In Portugal, the Authority for Mobility and Transportations (AMT) has recently launched specific guidelines for regulating shared micromobility. Currently, e-scooters are subject to the same legislation as bicycles. Thus, they cannot circulate on sidewalks or exceed the speed of 25 km/h, and a helmet is recommended but optional (AMT, 2022). Table 6 shows a compilation of regulations in some different locations that were the results of the trials (e.g., Chicago, Phoenix, London), experience of usage (e.g., Paris), and a collection of standards already used in other contexts (e.g., Portugal).

Table 6: Regulation for shared e-scooters in different locations (AMT, 2022; City of Chicago, 2022; City of Phoenix, 2023; République Française, 2022; Transportation for London, 2022)

Location	Type of infrastructure	Minimum age	Parking	Maximum speed	Helmet
Chicago, USA	Roadway and cycle lane	18 years old or 16 with parental consent	Public right-of-way (cannot block fire hydrants, or bus stops)	25 km/h	Mandatory
Phoenix, USA	Roadway	18 years old	In designated parking spots	25 km/h	Recommended
Paris, France*	Cycle lanes or roads with a speed limit of 50 km/h	12 years old	-	25 km/h	Recommended
London, UK	Roadway and cycle lanes	18 years old with a driver's license	-	25 km/h	Recommended
Portugal**	Roadway and cycle lanes	-	In designated parking spots	25 km/h	Recommended

*Not in use since Paris banned shared e-scooters

**According to the most recent guidelines for the future regulation of shared e-scooters

Although these are the most common regulations applied in different locations, some specificities are found, such as the restricted area where shared e-scooters are available in Phoenix, U.S.A., the need for riders to yield for pedestrians in Chicago, USA, and the recommendation to use light-colored or fluorescent clothing while riding a shared e-scooter in London (City of Chicago, 2020; City of Phoenix, 2023; Transport for London, 2020).

II.6. Impacts of shared e-scooters on sustainability

Shared e-scooter systems gained popularity as they came to life as a promise to be an environmentally friendly mode of transportation (Holm Moller & Simlett, 2020) since their usage can result in several benefits, such as the increase of community cohesion, possible reduction of traffic congestion (for short-

distance trips), and lower emission levels, therefore contributing to improving air quality (Boglietti et al., 2021). The usage of shared micromobility options in cities, including shared e-scooters, has been pointed out by the European Commission as an opportunity to decarbonize the transportation sector and reduce GHG emission goals for the transportation sector in the following years since it does not pollute the atmosphere while being ridden (European Commission, 2021b).

However, the current lifespan of e-scooters has raised concerns about their direct environmental benefits (Hollingsworth et al., 2019). Still, the increase of the lifespan of e-scooters by 9.5 months can be an asset to make them a green choice for urban mobility (Moreau et al., 2020), which can be translated into a higher mileage achieved by each e-scooter, which could represent a drop of up to 76% of their carbon footprint (de Bortoli & Christoforou, 2020). For shared e-scooters, 76% of the total CO_{2eq} is related to the material extraction and production stages, and 23% represents the collection and distribution operation (Reis et al., 2023b). Therefore, the recycling strategies for end-of-life material could reduce those impacts by up to 50% in CO_{2eq} emissions.

Besides, shared e-scooter systems, as an electric-powered mode of transportation, can help to reduce the emission of pollutant gases to the atmosphere if they are used to replace fossil-fueled vehicle trips (Fong & Mcdermott, 2019). Data from Lime (2019) shows that only in Paris, in more than one year, e-scooter rides replaced 1.2 million motor vehicle trips and kept more than 330 tons of CO₂ from being emitted into the atmosphere. However, the use of shared e-scooters can generate three different activities that pollute the environment, such as the pickup and drop-off of charged e-scooters by fossil-fueled vehicles, the displacement of e-scooters by pollutant vehicles when some repair is needed, and battery charging when the required electricity is generated by polluting resources (Johnston, 2019). However, these pollutant trips generated by the e-scooter services can be replaced with greener options if municipalities and provider companies apply proper planning strategies and policies (Fenton, 2017). Also, the energy to charge the batteries of the e-scooters can come from renewable sources to enhance the sustainability of this mode of transportation, such as solar-powered charging systems (Muneer et al., 2011; Şengül & Mostofi, 2021).

In addition, the pollution impacts associated with shared e-scooters are highly associated with the materials used, the manufacturing procedure, and the automotive use for e-scooter collection and charging (Hollingsworth et al., 2019). To help increase the sustainability ratio of this mode of

transportation, some strategies need to be taken, such as increasing the lifespan of e-scooters, the reduction of collection and redistribution of e-scooters by using more efficient vehicles, as well as making less frequent battery charges (Bortoli, 2020; Hollingsworth et al., 2019; Reis et al., 2023b). In the case where a shared e-scooter lifespan could increase to 6,500 km, a reduction of about 28% in GHG emissions could be achieved, while a lifespan increase to 10,000 km could lead to an emission reduction of 46% (EU Urban Mobility Observatory, 2023).

As a result of investments to develop shared-scooter service and lifespan, in Munich, Germany, shared e-scooters are seen as a benefit to the environment, as they have low energy consumption, produce less noise and fewer air pollutants, as well as help overcome congested, exhausted streets and over-crowded parking spaces by substituting cars. The data from the pilot program in Munich shows that shared e-scooters could cover up to 60% of daily trips by replacing cars, especially the ones for commuting and leisure purposes. Also, up to 50% of all trips in Munich are suitable for an e-scooter (Hardt & Bogenberger, 2017b).

Despite the possible complaints from dwellers about pedestrian safety and the impact of the emerging shared e-scooters on European urban public spaces. They are believed to help cities ease problems with traffic, emissions, and parking (Hardt & Bogenberger, 2019; Zagorskas & Burinskienė, 2019). A survey conducted in Brussels showed that 25% of the respondents said that one of the reasons for them to use shared e-scooters was to lower the air pollution in the city (Moreau et al., 2020), which can translate into a positive effect on human footprint, especially if shared e-scooter trips replace private car trips (C. C. Chang et al., 2016). Besides, using micromobility in urban logistics to replace traditional combustion engine vehicles has been demonstrated to have environmental and social effectiveness (Nocerino et al., 2016).

If considering the social benefits of shared e-scooter usage, it was deployed in cities as a beacon of hope to reduce the gender gap in transportation use, as women would feel safer on e-scooters because they are smaller in comparison to other modes of transportation (International Transportation Forum - ITF, 2020) and are more easily ridden on sidewalks; along with the possibility of wearing skirts and dresses that make it easier to stand on an e-scooter than on a bicycle. Women are also more distance-sensitive and are less likely to bike long distances, and both e-bikes and e-scooters enable everyone to travel greater distances easily (CB Insights, 2019). However, recent literature has shown that women feel unsafe on

shared e-scooters and constantly avoid this mode of transportation (Campisi et al., 2021; Gauquelin, 2019).

Furthermore, new micromobility solutions such as shared e-scooters can help cities develop policies to incentivize the equitable spatial deployment of micro-vehicles (Caspi et al., 2020; Clewlow et al., 2018). One possibility could be creating programs and policies to distribute shared e-scooters in cities considering undeserved developments and focusing on portions of the city with the highest social impact (Hosseinzadeh et al., 2021b; Olabi et al., 2023). Lee et al. (2021) also point out that low-income people prefer shared e-scooter services for first-mile and last-mile trips. Still, governments should take particular action to promote a policy reducing the fares of shared e-scooters and fare integration systems, allowing for multiple modes of public transportation. Thus, disadvantaged groups could be integrated to the group of shared e-scooter users and gain in accessibility compared to the rest of the population (Abouelela et al., 2024).

For economic purposes, shared scooters primary motivation for usage can be seen as travel time savings followed by playfulness and money savings (Christoforou et al., 2021a), as they are cheaper than hailing a ride-share vehicle (Schellong et al., 2019b). For urban drivers on short-distance trips, shared e-scooters would be a more cost-effective alternative to car ownership (Smith & Schwieterman, 2018). However, even if shared e-scooters can be more affordable than car ownership and ride-hailing services, one of the main drawbacks for its usage is still the price of the trip. Thus, some cities have required that shared e-scooter companies address equity issues by supplying a specific number of e-scooters in underserved areas and offering a low-income fare for the resident population (McQueen et al., 2021).

Also, the business model for shared e-scooter deployment and their economic sustainability emphasizes functionality over ownership. It incorporates practices such as increasing e-scooter lifecycles, recycling, and using renewable energy to enhance sustainability. However, shared e-scooter services still face challenges in economic sustainability, requiring careful consideration of business operations and policies to mitigate adverse impacts (Sundqvist-Andberg et al., 2021).

The number of trips generated, which translates into profit for e-scooter companies, and the span of the vehicle's lifecycle can lead the business to profitability, as well as environmental advancements, through

the longer usage of e-scooters. These are some of the aspects that contribute to making shared e-scooters economically sustainable.

Table 7 shows a collection of references that approach the three aspects of sustainability in shared e-scooter usage to shed light on how this service can be used in urban environments to achieve more sustainable mobility.

Table 7: Sustainability in shared e-scooter usage

Reference	Sustainability Aspect			Methodology
	Environmental	Social	Economic	
Chang et al., 2016	X			LCA
Clewlöw et al., 2018		X		Geospatial analysis
Populus, 2018		X		Geospatial analysis
Zagorskas and Burinskienė, 2019	X			Review
Smith and Schwieterman, 2019	X		X	Geospatial analysis
Hollingsworth et al., 2019	X			LCA
Schellong et al., 2019			X	Review
Hardt and Bogenberger, 2019	X			Pilot study
Fong and Mcdermott, 2019	X			Review
Moreau et al., 2020	X			LCA
Gössling, 2020	X		X	Review
Caspi et al., 2020		X		Geospatial analysis
Holm Møller and Simlett, 2020	X			Review
Bortoli, 2020	X			LCA/Survey
Christoforou et al., 2021	X		X	Survey
Hosseinzadeh et al., 2021		X		Review
Lee et al., 2021		X		Survey
Almannaa et al., 2021		X	X	Survey

The environmental effects of shared e-scooter usage are still the main research subject in recent literature. In contrast, its social and economic effects are still understudied. On the other hand, geospatial analysis, Life Cycle Assessment (LCA), and discussions/revisions are the main methods used to describe the impact of shared e-scooters on cities. Impact assessment and attitudinal studies are needed to deepen the studies on this matter.

II.7. Impacts of the COVID-19 pandemic on urban mobility and the role of shared e-scooters

In the first quarter of 2020, a virus started spreading worldwide, resulting in lockdowns, reduced displacements, and social distancing. At that time, shared e-scooters had been deployed in cities for nearly two years. Therefore, it was unknown what would happen to this mode of transportation amid the changes in travel behavior on all continents. Hence, the assessment of the usage or not usage of shared e-scooters during the pandemic became a subject of interest for this research since, in times of uncertainty, this “new” mode of transportation could not have returned to cities after the mobility restrictions were lifted.

Before the COVID-19 pandemic started, 52% of Europeans used a car as their primary mode of transportation for daily trips, while only 1% used a shared bicycle or e-scooter (European Commission, 2020a). This pandemic induced several behavioral changes that disrupted urban mobility, including avoiding crowded spaces, such as public transportation (Kakimoto et al., 2020). Therefore, it was of utmost importance to understand the role of shared e-scooters in urban mobility during the pandemic and how urban mobility could change after the restrictions were lifted.

To stop the spread of COVID-19, people started avoiding crowded public transportation in many cities worldwide (De Vos, 2020), culminating in historic low passenger demand for public transportation use (Governors Highway Safety Association, 2020). To bypass the shift from public transportation to individual vehicles, cities worldwide joined forces to invest in infrastructure to increase micromobility usage, primarily to address daily mobility needs among commuters.

In order to increase micromobility usage, many countries adopted specific policies, including financial support, for the relaunch of transportation through more sustainable modes, which included an investment of EUR 100 million in Italy to incentivize the transition to sustainable solutions, such as electric vehicles, e-bikes, and e-scooters, as well as the possibility for e-scooters to become part of the public transportation supply (Lozzi et al., 2020).

To boost micromobility usage during the pandemic of COVID-19, Rotterdam, Netherlands, partnered with micromobility providers, such as Donkey Republic, Felyx, Check, Go Sharing, and Rotterdam Ahoy, to

ensure that 1,500 shared bicycles and more than 1,500 shared e-scooters were available in more than 25 public transit hubs throughout the city (RET, n.d.).

Milan, Italy, invested in the Lazzaretto and Isola pilot projects to create more protected and accessible roads for everyone. The municipality offers new public spaces for adults and children. It encourages travel by foot/bicycle/e-scooter for urban displacements through a diversified, complementary, alternative offer to public transportation and private cars. The municipality aims to free up public space by temporarily pedestrianizing some roads, widening sidewalks and connections with existing cycle paths, implementing new tactical urban planning interventions, and installing outdoor areas (Comune di Milano, 2020).

In Rome, drastic measures were taken by the capital municipality to reduce dependence on personal automobiles. E-scooter operators such as Bird supported this effort by promoting micromobility as an everyday alternative to cars, allowing for social distancing (Bird, 2020). The e-scooter provider Lyft, with its program Lyftup, started offering free 30-minute rides for first respondents, the transit workforce, and healthcare providers in Denver, Colorado; Los Angeles, California; the Washington, D. C. area; San Diego, California; and Santa Monica, California. This program is in addition to bicycle share programs offering free membership for critical workers on networks that Lyft operates, including City Bike (New York), Divvy (Chicago), Bluebikes (Boston area), and Bay Wheels (SF Bay Area) (Lyft, 2020). In Europe, the shared e-scooter company Bird equipped Red Cross volunteers with a donated fleet of Bird e-scooters to enable more accessible transportation around urban neighborhoods (Bird, n.d.) so they could provide healthcare assistance to those in need.

Other than that, to evaluate and study the resilience of alternative mobility systems such as public transportation, bicycles, and e-scooters during the COVID-19 pandemic, shared micromobility companies such as Bird, Spin, Biketown Spin, and TriMet are sharing their survey data on riders' habits, preferences, and attitudes towards various shared modes of transportation with researchers (Goddard, 2020). Data from this study shows that almost 90% of respondents said they do not avoid taking shared e-scooter trips because of COVID-19; also, nearly 20% of respondents said they replaced public transportation trips with e-scooter trips during the pandemic (Cherry et al., 2020).

Furthermore, this mode of transportation could promote well-being and sustainable and safe transportation for people who need it the most when the pandemic started. This leads to the advantages

of having shared systems in cities to help decrease the need for “traditional” modes of transportation (Hamad Almannaa et al., 2021), such as vehicles and public transportation, which became an unsafe option during the COVID-19 pandemic. In many cities, shared e-scooter services also played an essential role in not letting people rely only on cars to avoid public transportation, consequently increasing urban mobility and environmental problems related to the massive usage of private vehicles.

However, some cities worldwide opted for shutting down the shared e-scooter services in order to discourage urban trips. Braga, Portugal was one of these cities, where shared e-scooters were collected from the streets and riders could not use this vehicle to displace, which resulted in an increase in car usage to avoid public transportation. Therefore, more information on the impacts of the COVID-19 pandemic on shared e-scooter usage in Braga will be presented in the case study section (Chapter IV).

II.8. Synthesis of main considerations

Micromobility and its shared form are seen as an opportunity to increase the quality of life in cities by achieving environmental goals and decreasing traffic congestion and noise. Shared bicycle services have been around for a long time in cities, contributing to the eminent benefits brought by its usage and the knowledge on how it should be used and ridden to promote safe and sustainable mobility.

Shared e-scooters, on the other hand, were first deployed in cities in 2017. At first, this new mode of transportation was revealed to be an opportunity for cities to invest in a clean, fast, economically viable, equitable, and fun way of displacement. However, the shortcoming of shared e-scooters was the increase in the number of accidents involving not only riders but also pedestrians, the expansion of e-scooters “flooding” sidewalks and disrupting pedestrians’ right-of-way, as well as the unknown benefits for the environment in its current business model.

The unplanned deployment of shared e-scooters displayed the differences between what was considered this mode of transportation and what it is in cities. Wealthy, well-educated men are the primary users of this mode of transportation in downtown areas, near business districts, and university campuses. However, cities' commitment to improving mobility showed that pilot programs and trials could disrupt the negative impacts caused by shared e-scooters, by testing procedures and measuring how they can affect the safe and sustainable usage of this mode of transportation.

The primary outcomes from the pilots and trials show that shared e-scooter companies and authorities need to work together to offer a sustainable, safe, equitable, and economically viable service for the population. Firstly, the rules for where shared e-scooters must be ridden must be clear, even if they differ depending on the location. Secondly, the recharging of batteries and the collection of e-scooters need to be done by non-polluting modes of transport, and the available fleet must be offered not only downtown but also in underprivileged communities with special discounts that allow people access to the service.

The positive outcomes from shared e-scooter deployment in cities can also be felt in disruptive events like the COVID-19 pandemic. Subsection II.7 brings information to answer RQ 1 concerning the usage of this mode of transportation to promote safe and inclusive mobility to respond to the rejection for crowded public transportation options worldwide.

When the pandemic spread and essential workers needed to make their journeys to their job sites every day, shared e-scooters were used as an alternative to public transport and the massive usage of private vehicles. If no other sustainable option were available for the population, the choice of the car would have been more prominent.

Shared e-scooters were essential in providing a sustainable transportation option when they were available for essential workers in many cities. The discounts offered, the dedicated infrastructure that was available through pop-up cycle lanes that became effective after the mobility restrictions were revoked, and the programs to boost this mode of transportation through the cooperation of companies and governments made it possible to take people from public transportation where the virus could spread quickly, to a better option than the car.

However, this was only the case in some cities. In Braga, the case study of this thesis, the shared e-scooter service was completely shut down during the pandemic to prevent people from making their daily journeys. The city also did not benefit from special programs for first respondents and essential workers to use e-scooters, and it lost the opportunity to create pop-up cycle lanes that could have been transformed into permanent infrastructure for micromobility. This decision to ban e-scooters during the pandemic could have caused an increase in car usage since the mobility restrictions were lifted in the country once people got used to using cars more often and declined public transportation usage.

Chapter III. Research Methodology

This chapter presents the methodology used to conduct the research developed in this thesis. This research comprises a literature review presented in Chapter II and is used to complement the information presented in the case study (Chapter IV) to create two survey methods. These survey methods were deployed to assess the main determinants of shared e-scooter usage in the case study of Braga and how different attributes influence the choice of sustainable modes of transportation for commutes and leisure trips. Therefore, the methodology used to deploy the first survey is presented in section III.1, where the Revealed Preference (RP) survey is disclosed, and the statistical approach used to analyze the data retrieved from this survey is shown. Next, section III.2 presents the stated choice (SC) methodology related to the second set of surveys deployed to assess the likelihood of replacing a car with a sustainable mode of transportation in urban trips. The collection of the results from the case study, added to the information from the literature review, is used to draw policy recommendations for implementing shared e-scooters in cities. Figure 7 shows an illustration of the methodology used.

The methodological approach starts with deploying a Revealed Preference (RP) survey to gather information on the main determinants of shared e-scooter usage, its main drivers, and the primary needs to boost it. The latter is used to compose the stated choice experiments for commute and leisure trips that are used to assess the impacts of shared e-scooters on sustainability, the influence of transportation planning on shared e-scooter usage, the main determinants for it, and the competitiveness of shared e-scooters and e-bikes.

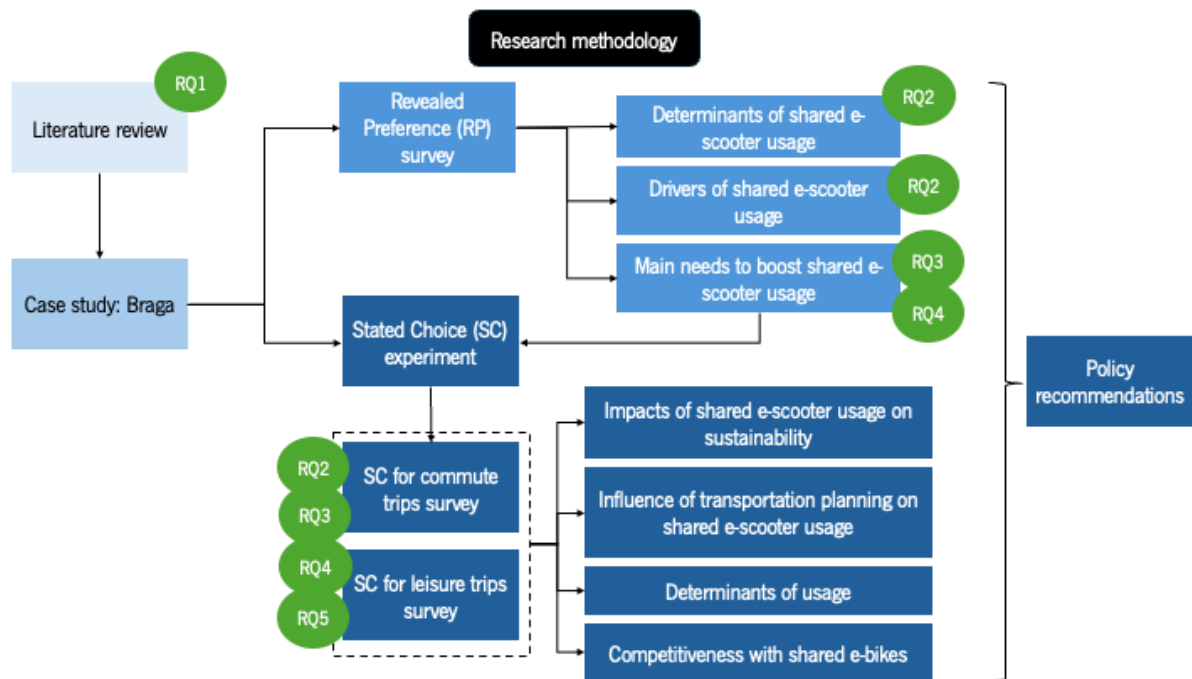


Figure 7: Methodology used for the research

III.1. Revealed preference (RP)

Revealed preference (RP) has long been a fundamental approach in mobility planning, providing a robust framework for understanding and predicting consumer behavior. This approach posits that individuals' true preferences can be inferred from their observable choices rather than relying solely on self-reported preferences or stated intentions (Fischhoff et al., 1978). Revealed preference techniques have gained traction as a valuable tool for researchers and policymakers, allowing them to delve deeper into the complex drivers of consumer decision-making.

Therefore, Revealed Preference (RP) surveys are used to report the actual behavior of travelers; thus, the data retrieved does not suffer from hypothetical biases (Rudloff & Straub, 2021). The revealed preference theory developed by Samuelson (1948) suggests that an individual's true preferences can be best indicated by their choices or actions. Therefore, RP choices are partly governed by different agents, such as beliefs and desires (Holmes, 2022).

One of the primary advantages of revealed preference surveys is their ability to capture actual behavior, thereby reducing the hypothetical bias often associated with stated choice surveys. Hypothetical bias occurs when there is a discrepancy between what people say they will do and what they do. A study on blood donation preferences found that stated intentions significantly overestimated actual donation

frequencies. Researchers could adjust their models by incorporating revealed preference data and reducing this overestimation, leading to more accurate predictions (de Corte et al., 2021).

Furthermore, combining revealed and stated choice data can provide a more comprehensive understanding of consumer behavior. This approach leverages the strengths of both methods: the real-world accuracy of revealed preferences and the flexibility of stated choice to explore hypothetical scenarios. For example, in travel behavior, revealed preference data from actual travel patterns can be combined with stated choice data from surveys about hypothetical travel scenarios, such as the introduction of autonomous vehicles. This combined approach allows for more robust modeling and forecasting of future travel behaviors (Yu & Jayakrishnan, 2018).

One of the critical applications of revealed preference surveys is the study of the mode of transportation choice. Researchers have used this approach to understand how individuals select their mode of transportation, such as car, bus, or train, based on their observed travel behavior (D. Basu et al., 2018). For example, a Mumbai, India study used a revealed preference survey to capture information on individuals' travel patterns, socio-economic characteristics, and attitudes. It then employed structural equation modeling to analyze the factors influencing their decision to share cab rides (Shah et al., 2020).

Besides, RP surveys are often used in transportation to identify attributes for stated choice (SC) experiments. Bottero, Bravi, Caprioli, & Dell (2023) describe the usage of RP surveys to collect information from respondents on the features they value the most on a subject; then, this data is used to design the alternatives included in the SC experiment.

Interestingly, recent research has explored the potential limitations of revealed preference techniques, highlighting the need for a more nuanced understanding of their underlying assumptions and methodological considerations. For example, studies have shown that consumers may employ different cognitive strategies when evaluating new products, which standard preference measurement techniques must better capture (Scheibehenne et al., 2015).

The steps for creating the RP survey for this research, as well as the statistical treatment for the data collected are presented and explained in details in Chapter IV, when the case study and the survey structure is presented.

III.2. Stated choice (SC)

III.2.1. Preferences and the nature of economic valuation

Hensher et al. (2005a) state that individuals are born traders. They consciously or subconsciously make decisions by comparing alternatives and selecting an action called a choice outcome. In a population of individuals, there is a large amount of variability in the reasoning underlying decisions they make, often referred to as heterogeneity. The challenge for researchers is to find ways of observing and measuring this variability, maximizing the amount of measured variability (or observed heterogeneity) and minimizing the amount of unmeasured variability (or unobserved heterogeneity). Thus, the primary outcome for a choice experiment is to capture such information through data collection and to state that any information not captured in the data (be it known but not measured or simply unknown) is still relevant to an individual's choice and must somehow be included in the effort to explain choice behavior.

Moreover, to deal with real market choices, there are several compelling reasons why researchers should be interested in stated choice (SC) data, which involve choice responses from the same economic agents but evoked in hypothetical markets (Louviere et al., 2000; Ortúzar & Willumsen, 2008), which are:

- Organizations need to estimate demand for new products with new attributes or features. Since the late 1960s, companies have relied on SC data to address this need and have the best information about the market response to new products they can afford;
- Explanatory variables are highly collinear in the marketplace. As markets mature and more closely satisfy the assumptions of free competition, the attributes of products should become more negatively correlated, becoming perfectly correlated in the limit;
- New variables explain choices: as product categories grow and mature, new product features are introduced, and the latest designs supplant obsolete ones. Thus, designing SC experiments to provide insights into the likely market response to such new features is often essential;
- Observational data cannot satisfy model assumptions and contain statistical assumptions hidden in actual data: all empirical data contain chance relationships, which may mitigate against the development of reliable and valid inferences and predictions. A significant advantage of SC data is that it can be designed to eliminate or significantly reduce such problems;
- Observational data are time-consuming and expensive to collect. For new product introductions, very long observation periods may be required to model changes in trial and repeat rates accurately. SC data are frequently much less expensive to obtain and usually can be collected

much faster, although SC panels may involve the same lengthy observation periods as revealed preference panels;

- The product is not traded in the real market: Many products, such as environmental and public goods (e.g., freeways), are not traded in real economic markets. Yet society and its organizations often require that they be valued and their costs and benefits calculated. Consequently, some researchers have come to rely on SC theory and methods to address such problems.

The involvement of hypothetical markets and economic agents creates a strong connection between economic efficiency and what happens in markets. Economic efficiency rests on the theories of welfare economics. It is a theorem of welfare economics that, in any equilibrium state of a competitive economy, resources are allocated so that no further gains of economic efficiency are possible. Also, in a perfectly competitive economy, people increase economic efficiency when acting according to their preferences. By acting according to their preferences, a person maximizes benefits for themselves, but their actions toward others must also be considered (Bateman et al., 2002).

Considering that the allocation of resources among private consumption goods is generally determined through markets, the valuation methods used to guide decision-making should underwrite the allocations of resources generated by markets wherever it is uncontroversial that markets should be relied on (Bateman et al., 2002).

Hence, through the ultimate interest in predicting aggregate demand, the researcher must explicitly treat the differences in decision-making processes among individuals. To illustrate this, Ben-Akiva & Lerman (2000) consider that the car travel cost variable in a choice experiment depends on the type of car used and the local fuel price. Moreover, the extent to which the commuter is willing to pay the higher travel cost of a vehicle may depend on this individual's income. Therefore, the characteristics of the decision-maker are used to capture some of this heterogeneity, and decision-maker characteristics such as income, gender, and age become an essential part of the problem.

The attractiveness of an alternative is evaluated in terms of a vector of attributes. In microeconomic consumer theory, an alternative is just a vector of quantities of the commodities; this vector of "attributes" reduces to the amounts (e.g., kilometers of car travel, kilometers of bicycle travel). However, when alternatives are described by their attributes, it is much more natural to work directly with a general

characterization of each alternative by its attributes rather than just the associated quantities (Ben-Akiva & Lerman, 2000).

III.2.2. Stated choice application in transportation

Stated choice models can be used to analyze and predict travel decisions according to some problem-related attributes, such as path length, travel cost, transit-specific characteristics, and other (e.g., level of congestion, number of stop signs, surface quality, and scenery) (Ben-Akiva & Bierlaire, 1999). Therefore, transportation applications of stated choice experiments have been used since the early 1960s (Kocur et al., 1982; Lisco, 1967; Louviere & Kocur, 1983; Warner, 1962) across a varied set of applications, such as the assessment of mode choice and route choice behavior (Ahmad & Al-Fagih, 2024; Arsenio et al., 2018), road traffic externalities (Ortúzar & Rizzi, 2007), and value of time (Fayyaz et al., 2021; Z. Li et al., 2020).

To predict the switching behavior for different modes of transportation, a survey of stated choices can be used to gather information on whether respondents would use a newly planned mode of transportation. In this case, the respondents are presented with planned or potential future changes in the transportation system and asked if and how they intend to modify their current choices in response to a change (Ben-Akiva & Morikawa, 1990a).

Usually, in stated choice experiments used to test the likelihood of using a new mode of transportation alternative, respondents are faced with different scenarios in which they have to choose between a new service and the mode of transportation they currently use based on the attributes of those modes (Petrik et al., 2016). To date, the influences of several transportation-related attributes have been investigated, such as trip characteristics, travel time, the combination of in-vehicle time and cost, and the value of travel time (Masoumi, 2019).

In addition to the capability of stated choice experiments to extend evaluations beyond observed attribute levels, revealed preference data can be combined with stated choice data. The joint utilization of both data should enrich the modeling explanatory power and further the understanding of choice behavior. In particular, stated choice data can be used effectively to enhance the predictive capability of a base-revealed preference model, especially where the market share for a new alternative is being evaluated (Hensher, 1994). Therefore, both methods (i.e., RP and SC) are used in the thesis.

III.2.3. Processes to prepare a stated choice experiment

III.2.3.1. Experimental design

The foundation of any SC experiment is an experimental design. An experiment defined in scientific terms involves the observation of the effect upon one variable, a response variable, given the manipulation of the levels of one or more other variables. The manipulation of the levels of the variables does not occur randomly.

A designed experiment is, therefore, a way of manipulating attributes and their levels to permit rigorous testing of specific hypotheses of interest. In the general case of SC models, the hypotheses of interest typically concern terms in utility and choice models. More generally, the term “design” refers to the science of planning in advance exactly which observations to take and how to take them to permit the best possible inferences from the data regarding the hypotheses of research interest. The design aspect deals with planning the experiment so that as many influences as possible can be ruled out (Louviere et al., 2000). Each attribute level is referred to as a treatment. Combinations of attributes, each with unique levels, are called treatment combinations. Treatment combinations thus describe the profile of the alternatives within the choice set.

Figure 8 summarizes the process used to generate stated choice experiments. This process begins with refining the problem to ensure a deep understanding of what the research hopes to achieve by completion. This experimental design process was used as a backbone to develop the stated choice experiment for this thesis.

The first two stages of the process consist of refining the understanding of behavioral aspects of the problem as they relate to decision-makers. After the completion of these stages, the experimental design may be generated. Following the generation of the experimental design, the attributes must be selected, and once they are chosen, the first manipulations can be performed to produce the response stimuli. While several forms of response stimuli are available, the “choice” is to be considered. Then, the choice sets are constructed to be used in the survey. The final stage of the experimental design process is to build the survey by inserting the choice sets as appropriate into different versions and inserting any other questions that may need to be answered (e.g., revealed preference questions and sociodemographic questions).

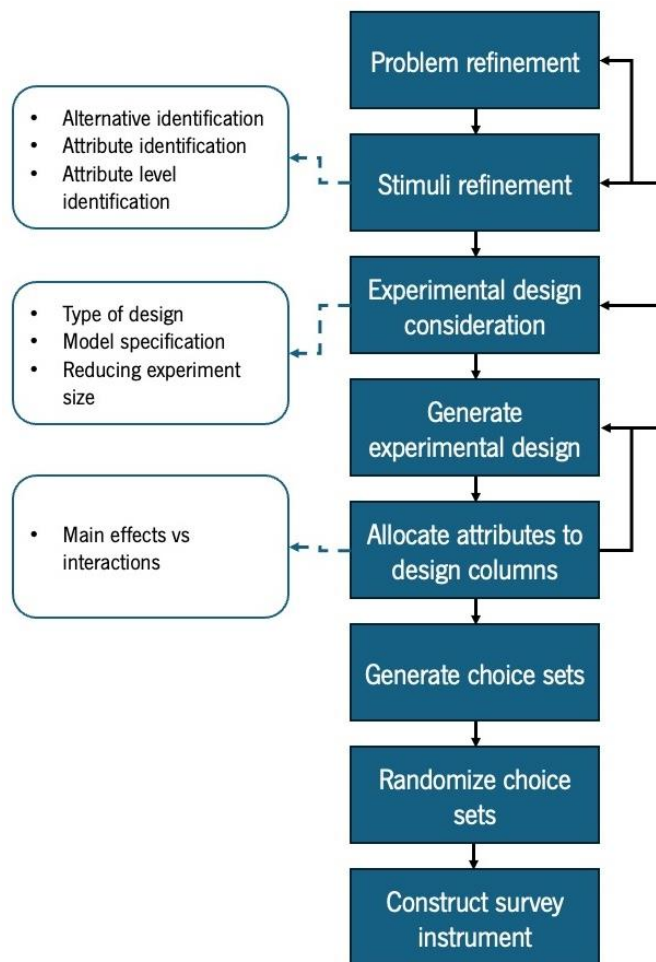


Figure 8: The experimental design process (edited from Hensher et al., 2005)

1. Problem definition refinement

This stage is composed of developing research questions that need to be answered by the SC experiment. These questions should allow the decision of the approach to be taken. Also, the generation of hypotheses sharpens the questions requested to be answered about the population under study.

2. Stimuli refinement

This stage comprises alternative identification and refinement. The first step involves defining the universal but finite alternatives available to decision-makers within the studied context. Every possible alternative should be identified to meet global utility maximization. Step two consists of selecting options from the list.

After identifying the list of alternatives to be studied, the attributes and attribute levels can be determined. Each alternative may incorporate a mix of familiar and different attributes, and even if two alternatives have the exact attributes, the levels of those attributes may differ from alternative to alternative.

3. Experimental design consideration

Having identified the alternatives, attributes, the number of attribute levels, and the attribute-level labels, the decision on the design to be used must be taken. This includes a full factorial design section, enumerating all possible treatment combinations or a factorial orthogonal design. The decision on the labeling or not of alternatives (i.e., labeled or unlabeled experiments). The possible blocking of the design if the number of scenarios created in the design is too large for respondents to answer appropriately.

4. Generate the experimental design

Some aspects need to be considered when generating the experimental design, such as whether a design based on main effects only is to be generated or whether a design based on main effects plus selected interactions is required. Researchers usually use software to assist with this task; some of the most used are SPSS or Ngene.

5. Allocate attributes to design columns, generate choice sets, and construct survey instrument

If a main effects design is required for the experiment, the allocation of attributes and the generation of the experimental design are conducted simultaneously. However, if the main effects and selected interactions are of interest, then the generation of the design is separated from the allocation of the attributes to the design columns. In this case, the attributes must be allocated to design columns, and the attribute levels must be coded using orthogonal codes.

After the attributes are allocated to the design columns, the treatment combinations on the orthogonal coding can generate the choice sets. These choice sets are then used to construct the survey and the situation cards presented to respondents.

III.2.3.2. Full factorial design

Full factorial designs are considered the most comprehensive type of choice experiment design since they consider each possible choice situation. In this case, each respondent faces all possible choice situations

and is asked to select one of the alternatives. Full factorial designs guarantee that all attribute effects of interest are genuinely independent and that the main interaction effects are considered (Louviere et al., 2000).

However, the number of situations generated (i.e., scenarios) for the respondents to choose from can become large as the total number of alternatives, attributes, and attribute levels increase. The number of choice situations in the full factorial design can be calculated using Equation 1 (ChoiceMetrics, 2021a).

$$S^{ff} = \prod_{j=1}^J \prod_{k=1}^{K_j} l_{jk} \quad (1)$$

Where:

- S^{ff} = total number of choice situations;
- J = alternatives;
- K = attributes of the alternatives;
- l = levels within the attributes.

Because each decision maker is presented with each choice situation in a full factorial design, the workload for the respondent becomes excessively large in all but the smallest experiments (Hensher et al., 2005a). In addition, as the number of choice situations presented to a respondent increases, the amount of effort the respondent puts into analyzing the alternatives and selecting the most favorable alternative has been found to decrease (Louviere et al., 2000). One possibility for reducing the number of choice situations presented to each respondent is to divide the choice situations among the respondents instead of assigning all situations to all respondents. However, this can lead to biased outcomes (ChoiceMetrics, 2021a). Another option for limiting the number of treatment situations presented to each respondent is to systematically select the most critical situations for producing the desired statistical results, and one of the options is the fractional factorial or orthogonal designs.

III.2.3.3. Fractional factorial/orthogonal design

Researchers commonly employ orthogonal coding to label attribute levels when constructing an orthogonal fractional factorial choice experiment. This coding approach simplifies the creation of the

experimental design. Orthogonal coding ensures that the sum of each column of attribute levels equals zero. For instance, conventionally assigned values would be 1 and -1 when dealing with an attribute having two levels. Similarly, the labels would be 1, 0, and -1 for an attribute with three levels. Notably, it exclusively utilizes odd numbers, avoiding using the number 5 because orthogonal coding relies on balanced and orthogonal arrays designed to ensure that all levels of each factor are equally represented and that the factors are uncorrelated.

Creating an orthogonal fractional factorial design through orthogonal coding can be laborious (ChoiceMetrics, 2021a). A minimum of six choice situations must be included to meet the requirements of attribute balance and degrees of freedom. However, the minimum number of choice situations may vary significantly based on the number of alternatives, attributes, and attribute levels incorporated into the experimental design (Louviere et al., 2000). When the number of choice situations is high, a technique called blocking is employed to reduce the survey burden on respondents. This method splits the design into smaller, non-orthogonal designs while ensuring that the sum of these designs maintains orthogonality (Hensher et al., 2005a).

Recent advancements in stated choice experimental design theory, particularly the introduction and refinement of efficient stated choice designs, have brought attention to several limitations of the orthogonal fractional factorial method. Maintaining orthogonality within the dataset when creating choice models is atypical for several reasons (ChoiceMetrics, 2021a). Firstly, orthogonality is compromised when data is missing for any choice situations. If blocking is employed and a respondent fails to complete their choice task, the entire dataset's orthogonality is jeopardized (Louviere et al., 2000). Secondly, the transition from design codes to orthogonal codes can result in a loss of orthogonality (ChoiceMetrics, 2021a).

However, ChoiceMetrics (2021a) acknowledges that orthogonal design is ease of construction or acquisition, whether through software packages or academic literature, which facilitates their widespread use. Also, the historical impetus behind the prevalence of orthogonal designs in studies related to stated choice (SC) stems from the experimental design literature's historical focus on linear models, particularly linear regression models. In such models, orthogonality serves two critical purposes: (a) preventing multicollinearity and (b) minimizing parameter estimate variances, which are derived from the variance-covariance (VC) matrix of the model (Equation 2).

$$VC = \sigma^2[X'X]^{-1} \quad (2)$$

Where:

- σ^2 = the model variance;
- X = the matrix of attribute levels in the design or in the data to be used in the estimation.

Controlling for the model variance, which serves as a mere scaling factor, the variance-covariance (VC) matrix elements in linear regression models are minimized when the design matrix (X matrix) is orthogonal. Opting for a design that minimizes the VC matrix elements offers two distinct advantages. Firstly, such a design yields the minor possible standard errors (i.e., square roots of the variances), thereby maximizing the t-ratios derived from the model. Secondly, an orthogonal design (or dataset) ensures zero-off diagonals in the VC matrix, effectively disentangling parameter estimates and mitigating multicollinearity.

Orthogonal designs, particularly in the context of linear models, satisfy the two essential criteria for effective experimental design outlined in the introduction. Firstly, they facilitate the independent assessment of each attribute's impact on the dependent variable. Secondly, they enhance the design's statistical power to detect significant relationships (as reflected in t-ratios) at any given sample size. This means that the different attributes used are combined in the design so that the attribute's effects can be estimated independently of the others, and that the attributes are uncorrelated, allowing for a clear and unbiased estimation of each attribute's impact on the choice made by respondents.

III.2.4. Building stated choice experiments from revealed preference data

Recent literature has highlighted the potential enhancement of choice experiment realism by constructing alternatives based on existing situations (Starmer, 2000). Using a reference alternative may yield more meaningful disaggregated data, as participants can contextualize the choice task using their existing memory (Rose & Bliemer, 2004).

The recommended approach involves using both data sources, namely revealed preference and stated choice data, which allows one to exploit their advantages and overcome their limitations (Ben-Akiva & Morikawa, 1990b; Louviere et al., 2000). A methodology adopted by Cherchi & Ortúzar (2002) focuses on retrieving revealed preference in the early stages of the stated choice experiment's development to

gather better information on people's attitudes towards a particular mode of transportation. These authors conducted an RP survey to obtain data on actual choices and select a reference trip using a customized SC design.

This approach offers the advantage of presenting attributes and attribute levels that align more closely with respondents' expectations, thereby creating more realistic choice scenarios (Hensher et al., 2005a). When designing a pivoted stated choice experiment, careful consideration of the attribute levels used for pivoting is essential, as they significantly impact the situations/scenarios presented to respondents and the usability of the resulting data.

According to Rose & Bliemer (2004), a promising approach for constructing a stated choice experiment is to base its design on revealed preference data. In this method, respondents participate in an initial survey phase that collects revealed preference (RP) data. Subsequently, this RP data is utilized to create a stated choice experiment in the second phase. From a statistical perspective, this two-phase approach is commendable because it generates a data-specific design by minimizing values within the attribute-value-cost (AVC) matrix using the same dataset employed for model estimation (Rose & Bliemer, 2004).

III.3. Theoretical framework

According to Ortúzar et al. (2008), the random utility theory is the most common theoretical framework for generating discrete choice models. This theory assumes that individuals belong to a homogeneous population, act rationally, and possess perfect information. This means that they always choose to be in a situation that maximizes their net personal utility subject to legal, social, physical, and budgetary (in time and money) constraints.

In this theory, a given individual is supplied with attributes to face different choice sets according to the available alternatives and the vectors (levels) of attributes. It is then assumed that one's choice set is predetermined, implying that the effect of constraints has already been taken care of and does not affect the selection process among the available alternatives.

Each respondent's option is associated with a net utility for the individual. The researcher does not have complete information about all the elements the respondents (choice makers) considered. Therefore, the utility is assumed to be represented by two components:

- A measurable, systematic, or representative part V_{jq} , which is a function of the measured attributes X ;
- A random part ϵ_{jq} reflects each individual's peculiarities and particular tastes, together with any measurement or observational errors made by the researcher.

Therefore, the random utility theory can be formulated according to equation 3.

$$U_{jq} = V_{jq} + \epsilon_{jq} \quad (3)$$

The random utility theory formulation allows two apparent illogicalities to be explained: that two individuals with the same attributes and facing the same choice set may select different options, and that some individuals may not always select the best alternative

III.4. Logit model

Logit models are a fundamental tool in statistical analysis and are convenient for modeling binary and multinomial outcome variables. These models estimate the probability of a given event based on one or more predictor variables.

Multinomial and Mixed logit models represent an advanced extension of the basic logit model, allowing for random heterogeneity in the population. This means the model can account for variations in preferences or behaviors not captured by observed variables. These models are instrumental in discrete choice modeling, where they can incorporate both revealed preference and stated choice data (Hensher & Greene, 2003).

Another variant, nested logit models, is designed to handle situations where choices can be grouped into a hierarchical structure. These models are advantageous in scenarios where alternatives can be naturally grouped based on attributes, such as flight itineraries grouped by departure time and number of stops. Despite their utility, nested logit models can be computationally intensive, especially when dealing with large datasets (Carrasco & De Dios Ortuzar, 2002). Recent advancements have focused on developing more efficient estimation methods for large-scale applications.

In addition to these specific models, various specification tests are available for logit models. These tests can be used to check for omitted variables and heteroskedasticity, ensuring that the model is correctly specified. Lagrange Multiplier tests, for example, can be computed inexpensively and help identify potential issues in the model (Davidson & Mackinnon, 1984).

Logit models and their extensions offer powerful tools for modeling binary outcomes and discrete choices. This model was chosen because the coefficients in a logit model can be interpreted as the change in the odds of the dependent variable for a one-unit change in the predictor variables; they are computationally simpler and faster to estimate, more widely used and understood in different fields, and often more robust to deviations from the underlying assumptions compared to other models.

III.4.1. Binary logit model

Binary logit models are a fundamental tool in statistical analysis, particularly useful for modeling binary response variables. These models are a type of regression model where the dependent variable is binary, taking on values of 0 or 1. The primary goal of binary logit models is to estimate the probability that a given observation falls into one of the two categories based on one or more predictor variables.

The basic form of a binary logit model involves the logistic function, which ensures that the predicted probabilities lie between 0 and 1. The logistic function is defined as equation 4 (Ben-Akiva & Lerman, 2000):

$$P_n(1) = \frac{1}{1 + e^{-\mu V_n}} \quad (4)$$

One of the critical advantages of binary logit models is their ability to handle non-linear relationships between the dependent and independent variables. This is particularly useful when the relationship between variables is often complex and not strictly linear (Cramer, 1998). However, interpreting the coefficients in a logit model can be more complex than linear models. The coefficients represent the change in the log odds of the dependent variable for a one-unit change in the predictor variable. This can be transformed into odds ratios, which are easier to interpret but should be used cautiously, especially when comparing different studies or models (Norton & Dowd, 2018).

Extensions of the binary logit model include the bivariate binary logit (BBL) model, which handles two correlated binary responses. This model is advantageous when dealing with data that can be represented in a 2x2 contingency table and follows a multinomial distribution. The BBL model uses maximum likelihood estimation and provides robust hypothesis testing methods (Purhadi & Fathurahman, 2021). Another extension is the dynamic logit model, which incorporates time-dependent covariates and can handle repeated measurements of binary responses. This model is helpful for longitudinal data analysis, where the same subjects are observed under different conditions over time (Zheng & Sutradhar, 2018). Despite their widespread use, binary logit models have limitations. For instance, they can be sensitive to unbalanced samples, where the frequency of one outcome is much lower than the other. This imbalance can lead to biased prediction probabilities and affect the model's performance. Partial remedies, such as adjusting the model fit or using alternative diagnostics, can somewhat mitigate these issues (Cramer, 1998).

Moreover, binary logit models are a versatile and powerful tool for analyzing binary response data. They offer flexibility in modeling complex relationships and can be extended to handle correlated responses and repeated measurements. However, careful consideration must be given to interpreting coefficients and handling unbalanced samples to ensure accurate and meaningful results.

III.4.2. Multinomial logit model (MNL)

Multinomial logit models (MNLs) are powerful statistical tools for predicting outcomes where the dependent variable consists of multiple non-ordinary categories. These models are instrumental in marketing, health economics, industrial organization, and transportation, where researchers need to analyze choices among numerous alternatives. The MNL uses a maximum likelihood estimator to handle situations with several categories, making it a versatile method for various applications. The formulation of this method considers a universal set of alternatives composed of multiple modes in an individual subset, which defines a restricted set of options for a particular decision-maker. The general expression for MNL models is presented in equation 5 (Ben-Akiva & Lerman, 2000):

$$P(i|C_n) = \frac{e^{\mu V_{in}}}{\sum_{j \in C_n} e^{\mu V_{jn}}} \quad (5)$$

Where:

- The utility for the decision-maker in a mode is $U_{in} = V_{in} + \varepsilon_{in}$;
- $P(i|C_n)$: the probability of the decision maker choosing a mode of transportation;
- The numerator is the utility of mode for the decision-maker, and the denominator is the summation of the utilities for all alternative modes for a decision-maker;
- The disturbances μ are distributed in independent and identical forms.

In this case, the model satisfies the axiom of independence of irrelevant alternatives. Therefore, where any two alternatives have a non-zero probability of being chosen, the ratio of one probability over the other is unaffected by the presence or absence of any additional alternative in the choice set (Luce & Suppes, 1965; Ortúzar & Willumsen, 2008)

One of the key advantages of the multinomial logit model is its ability to incorporate continuous and discrete individual heterogeneity, depending on the model specification. This is achieved by allowing the parameters to vary randomly over individuals according to a chosen distribution, which can be constant, discrete, or a mixture of both. For instance, the Biogeme software (Bierlaire, 2023) supports the estimation of various multinomial logit models, including the mixed multinomial logit, the scale heterogeneity multinomial logit, and the generalized multinomial logit. These models can be estimated using either the maximum likelihood estimator or the maximum simulated likelihood estimator, providing flexibility and robustness in handling different types of data (Sarrias & Daziano, 2017).

However, the application of multinomial logit models is not without challenges. One significant issue is the interpretation of results. Researchers often face difficulties interpreting the model coefficients due to the independence of irrelevant alternative assumptions. This assumption implies that the relative odds of choosing between any two alternatives are unaffected by the presence of other alternatives. To address this, guidelines and practical steps have been developed to aid in analyzing and interpreting MNL results. These include intuitive graphical representations of predicted probabilities and marginal effects, which are crucial for interpreting and communicating results (Wulff, 2015).

Moreover, multinomial logit models are versatile and powerful tools for analyzing choices among multiple alternatives. They can handle continuous and discrete individual heterogeneity, provide intuitive interpretations of results, and be extended to account for scale and coefficient heterogeneity. Despite the

challenges in high-dimensional settings, advancements in estimation techniques and variable selection methods continue to enhance the applicability and robustness of these models in various fields.

III.4.2.1. Maximum likelihood

The maximum likelihood estimation (MLE) method is a cornerstone in applying multinomial logit (MNL) models, which are widely used for modeling categorical response variables. MLE is particularly advantageous because it provides a consistent and efficient means of estimating the parameters of these models, even in complex settings. Equation 6 gives the mathematical representation for the calculation of the maximum likelihood in the Biogeme software:

$$L(\beta) = \ln L^*(\beta) = \sum_{n=1}^N \ln P(y_n | X_n, \beta) = \sum_{n=1}^N \left(\sum_{i \in C_n} y_{in} \ln P(i | C_n) \right) \quad (6)$$

Where:

- $y_{in}=1$ if n chose alternative i , 0 otherwise.

In Biogeme, the maximum likelihood estimation (MLE) is used to estimate the parameters of discrete choice models. The Log-Likelihood Function measures how well the model with a given set of parameters explains the observed data (Bierlaire, 2023).

III.4.2.2. Rho-square

To determine the optimal model design, assessing the overall goodness of fit of the estimated model in relation to the collected data is essential. A common approach for evaluating how well a discrete choice model aligns with the data involves using a statistical metric known as the likelihood ratio index, also called rho-square. This index allows the comparison of the performance of the model with estimated parameters against two reference scenarios: one with all null parameters (equivalent to having no model, where all modes share the same distribution) and another with only the specific constants of the alternatives (comparable to the model based on market distributions from the sample used). The rho-square for the null model is calculated using equation 7, and the rho-square for the initial model is calculated using equation 8:

$$\rho^2 = 1 - \frac{\mathcal{L}^*}{\mathcal{L}^0} \quad (7)$$

$$\rho^2 = 1 - \frac{\mathcal{L}^*}{\mathcal{L}^i} \quad (8)$$

In economics or stated choice experiments, the variability of the model can be explained by using different rho-squared values. However, as practical modeling guidance, a value of 0.2 can be considered excellent for the models.

III.5. Synthesis of main considerations

Two survey methods were chosen to gather information on the determinants of shared e-scooter usage and the effects of attributes on the choice of sustainable modes of transportation in Braga. Revealed preference and stated choice surveys have been used in the transportation sector in order to assess people's willingness to shift modes of transportation, as well as understand how different attributes affect mode choice.

These two survey methods were selected for this thesis to complement its information and retrieve the current state of data, as well as the choice for hypothetical scenarios. Firstly, the revealed preference survey was deployed in Braga to collect data on the main motivations and drawbacks of using or not using shared e-scooters in Braga, as well as the perspectives of users and non-users about this mode of transport. This information was used to create two stated choice experiments.

The first experiment comprises choice sets with multiple transportation options, which explains the usage of the MNL model to design the utility of the choices presented to the respondents. The second experiment comprises a binary choice between transportation modes, which corroborates the choice of a binary logit model to delineate the choices according to the attributes presented.

The choice of the RP and SC methods for this thesis is based on the best practices for surveying users of different modes of transportation in cities to acknowledge the main observed features that define the usage or not usage of a specific transportation option. Since the choice is often dependent of different

attributes, the RP survey was used to acknowledge the primary attributes in the city of Braga that would indicate decision-making for shared e-scooters. This information was used to compose the SC experiment.

Chapter IV. Case Study: City of Braga

This chapter presents the case study where the proposed methodology was deployed. The city of Braga was selected for the case study because the researcher is allocated at the campus of the University of Minho in the referred city, and it has an established shared e-scooter service running with two different companies; also, no studies had been conducted to support the introduction of this micromobility mode in the city. For a short time, it also offered free-floating shared e-bikes to the population. Also, the Municipality of Braga provided data on using the shared micromobility services.

Thus, the chapter is divided into four parts: 1) the characterization of the study site, where the background information about Braga is presented, as well as the state of the shared e-scooter and e-bike service is introduced, 2) the construction of the RP survey, its deployment, and results, 3) the design, deployment, and results of the SC experiment for commute trips are presented, and 4) the design, deployment, and results of the SC experiment for leisure trips are displayed.

This chapter is composed of the results published in the following scientific papers:

Dias, G., Arsenio, E., & Ribeiro, P. (2021). The Role of Shared E-scooter Systems in Urban Sustainability and Resilience during the COVID-19 Mobility Restrictions. Sustainability (Switzerland), 13(13). <https://doi.org/10.3390/su13137084>

Dias, G., Ribeiro, P., & Arsenio, E. (2023). Determinants of shared e-scooters usage in the city of Braga: Results from a mobility survey and trip data analysis. Transportation Research Procedia, 72, 4002–4009. <https://doi.org/10.1016/j.trpro.2023.11.379>

Dias, G., Ribeiro, P., & Arsenio, E. (2023). Shared E-Scooters and the Promotion of Equity across Urban Public Spaces – A Case Study in Braga, Portugal. Applied Sciences, 13(3653). <https://doi.org/10.3390/app13063653>

Dias, G., Ribeiro, P., & Arsenio, E. (2024). Perceptions of shared e-scooters service among university students in Braga, Portugal. Transportation Engineering, 16(April 2023), 100231. <https://doi.org/10.1016/j.treng.2024.100231>

Dias, G., Ribeiro, P., & Arsenio, E. (2024). Determinants of shared e-scooter usage and their policy implications. Findings from a survey in Braga, Portugal. European Transportation Research Review, 16(1). <https://doi.org/10.1186/s12544-024-00642-4>

Dias, G., Ribeiro, P., & Arsenio, E. (2024). Are shared e-bikes disruptive of established shared e-scooter services? A case study of Braga, Portugal. Lecture Notes in Mobility (Proceedings of TRA2024), Springer: in process of publication.

IV.1. Characterization of the city of Braga

With more than 2,000 years of history, Braga is considered one of Portugal's most relevant cities, considering its population and economic diversity. In 2012, the city was elected as the European Youth Capital and received the European Capital of Sport title in 2018. In 2017, it joined the Creative Cities UNESCO group in the Media Arts category; more recently, in 2019, it was included in the list of European Best Destinations. In 2023, Braga was among the top three exporter cities in Portugal, reaching EUR 2,833 million, representing 3.65% of the Portuguese exports.

IV.1.1. Location and demographics

Braga is a municipality located in the North (NUTS II) of Portugal in the subregion of Cávado (NUTS III) (Figure 9). It has more than 190,000 inhabitants in an area of 183 km², representing a population density

of 1053.94 inhabitants per km² (Instituto Nacional de Estatística, 2022a). The population is distributed in 37 parishes (i.e., the minor municipal administrative division) (Figure 10).

The city of Braga borders the municipalities of Vila Verde and Amares in the north, the city of Póvoa do Lanhoso in the northeast and east, and the municipalities of Guimarães and Vila Nova de Famalicão in the south and southwest, and the city of Barcelos in the west.

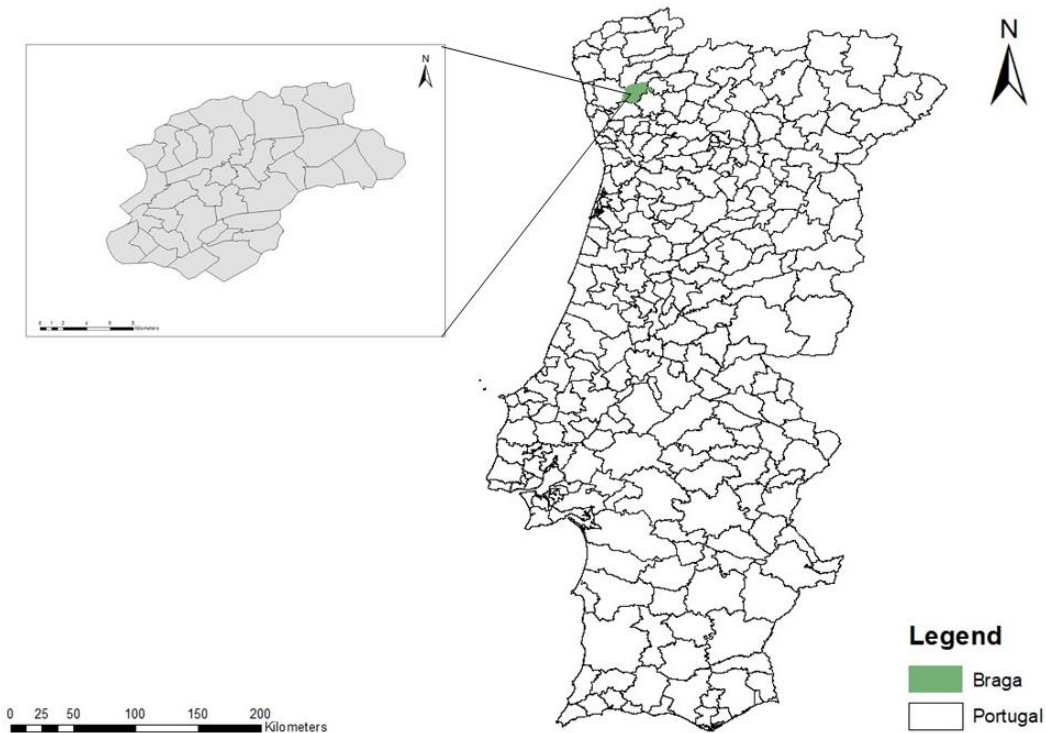


Figure 9: Location of the study site (own author)

According to data from INE (2022a), Braga is the Portuguese city with the highest population increase in recent years. This is now the youngest city in the country, with more than 60,000 inhabitants who are up to 29 years old. Immigration, the presence of higher education centers, such as the University of Minho, and research hubs, such as the International Iberian Nanotechnology Laboratory - INL can stimulate the presence of younger people in the city, which contributes to the diversification of the economy and the development of advanced services, as well as the promotion of vital infrastructure to stimulate cultural events, e.g., theaters and museums (MPT, 2018a).



Figure 10: Braga divided into parishes (CMB, 2020)

IV.1.2. Main traffic-generating hubs

Considering all the daily trips made in Braga and the main modes of transportation used in the town, it is also essential to evaluate the main places that generate these trips. This way, traffic can be reallocated, or the foremost option to reach those places can be restructured to accommodate more sustainable alternatives that do not harm the environment and decrease the possibility of traffic congestion.

The main traffic generators in Braga are categorized into five main sections (Município de Braga, 2015), which are:

- Administration, justice, and social security;
- Education;
- Health;
- Heritage and Cultural promotion;
- Sports.

Most of the traffic-generating hubs in Braga are located in the city's downtown area (*Figure 11*). The Study for Mobility and Traffic Management of Braga (MPT, 2018a) shows that the main facilities intended for justice and social security are located near or in the downtown area, which generates congestion in this part of the city. The educational hubs are also primarily local in the city's central area. This culminates in a high level of individual vehicles circulating during peak hours as parents drop off or pick up their children in one of the 155 educational facilities in the city, and, in some cases, they do it breaking some traffic laws. Shopping areas and culture hubs are also primarily located in downtown Braga, which even burdens the traffic in this city area. On the other hand, sports and health centers are distributed in different areas of the city, and the hospitals and clinics are located in several parishes.

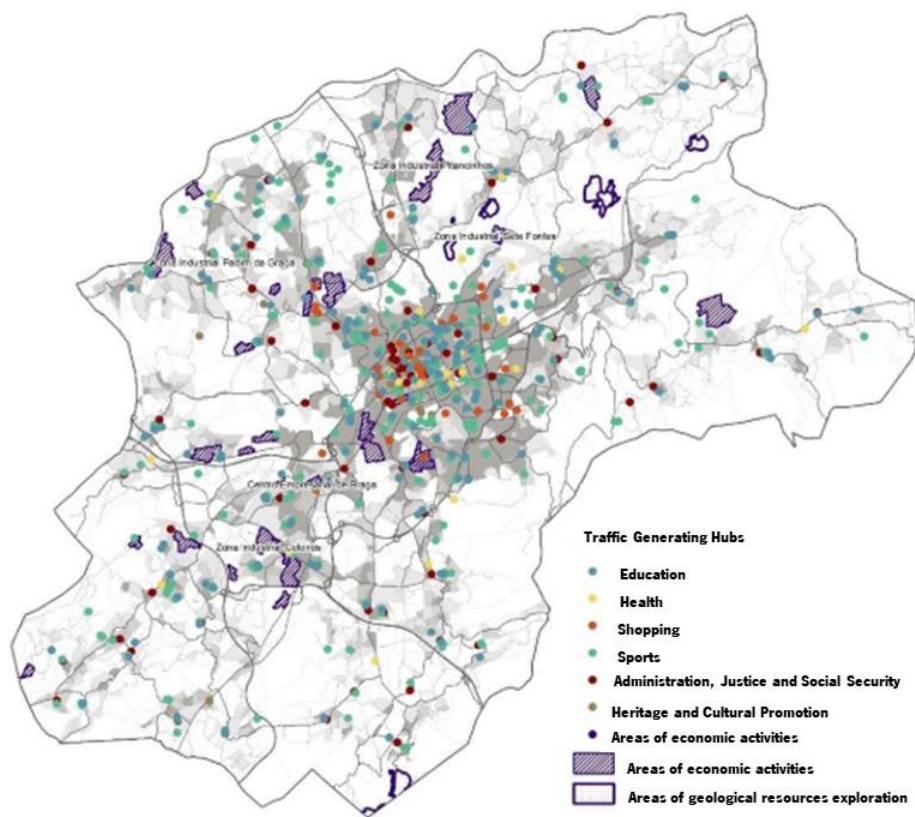


Figure 11: Spatial location of the main traffic-generating hubs (MPT, 2018b)

The following sections present how diverse modes of transportation are used in the city of Braga. Even if the car is still the predominant mode chosen by the residents, there is still room to introduce more bicycle infrastructure, more accessibility to public transport, and new and versatile modes of transportation in cities, such as shared bicycle services and shared e-scooter services.

IV.1.3. Urban mobility in Braga

IV.1.3.1. Daily trips and modal share

In Braga, 113,902 commuting trips are generated daily, 61.5% within the municipality. 78,321 trips are made mainly by working individuals (68.8%), followed by trips made by students, representing 31.8% of the displacements (Instituto Nacional de Estatística, 2022a). The most common modes of transportation used in these trips are cars (70%), followed by walking (16%) and bus (10%). This tendency to use individual vehicles has been growing in Braga compared to data from the 2011 Census, and a decrease in trips by foot and public transportation has also been noticed (Figure 12).

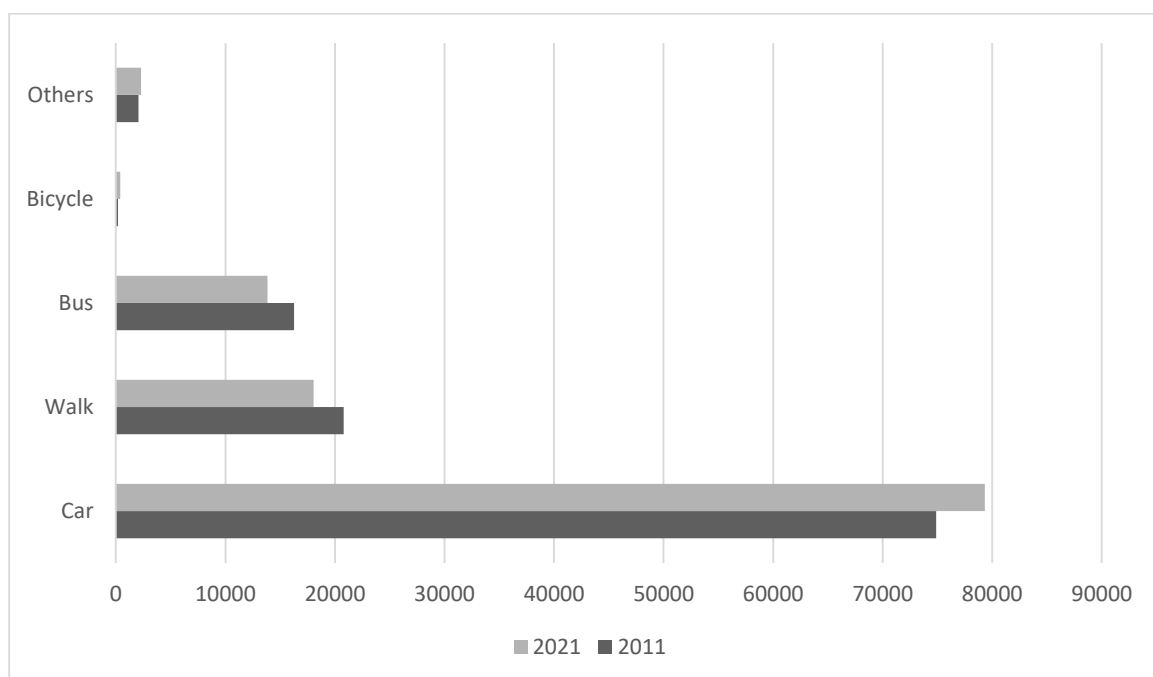


Figure 12: Modal share in Braga in 2011 and 2021

The distribution of the commutes within the municipality of Braga shows that the parishes with higher commute rates are located in the central area of the city and are São Vitor (Northeast of Braga), the parish union of Nogueira, Fraião, and Lamações (Northeast of Braga), and the parish union of Real, Dume, and Semelhe (Northwest of Braga). These three parishes have a daily commuter share of 16.8%, 8.5%, and 7.6%, respectively. On the other hand, the parishes with a smaller number of daily commuters are Lamas (0.5%) (South of Braga), Espinho (0.5%) (East of Braga), and parish union of Santa Lucrécia de Algeriz and Navarra (0.5%) (North of Braga), located in the periphery of Braga.

IV.1.3.2. Time spent on daily trips

According to data from Instituto Nacional de Estatística (2022a), Braga's average commute time is 17.6 minutes, lower than the national average for 2021 (19.9 min). Table 8 shows the percentage of commuter trips by the time spent in some cities in Braga.

Table 8: Commuter trips by duration

Town	Duration of commute trips				
	Up to 15 min	16 – 30 min	31 – 60 min	61 – 90 min	More than 90 min
Braga	66,197	34,366	10,848	1,496	995

Most commuter trips in Braga last up to 15 minutes (58.1%), which means that a large portion of those trips would be suitable for active modes of transportation (e.g., walking, bicycle). The change in modal share for short trips would represent a decrease in car usage and a chance for Braga to shift its current massive car usage in town.

IV.1.3.3. Presence of active modes of transportation

The city of Braga has been working in the last few years to promote walkability in the city by expanding its pedestrian zone (Figure 13). These pedestrian zones were created in 1995, with the pedestrianization of the city center's main streets, including Republic Square and Souto Street (Silva, 2017). It has more than 20,000 m² of area exclusively for pedestrian use (Souza & Dias, 2020). Figure 14 and Figure 15 show the changes in the urban built environment since the introduction of pedestrian zones in Braga, which shows that the city of Braga, throughout time, has been working to promote better and greener ways of transportation for its population. This is also reflected in better usage of active modes in Braga compared to other municipalities, such as Porto, Coimbra, Aveiro, and Faro (MPT, 2018a).



Figure 13: Pedestrian zone in Braga (own author)



Figure 14: Republic Square in Braga in 1940 (left) and 2018 (right)



Figure 15: Liberty Avenue in Braga in 2000 (left) and 2018 (right)

However, it is also important to note that the suitable conditions for pedestrian use in Braga are only constant in some of its territory. In Braga's city center, for example, the pavements, their color, and the continuity of the walkways are well maintained. At the same time, the connected pathways suffer from discontinuation of the width and length of walkways (Rahaman et al., 2010). Studies from MPT (2018a) show that in other areas of the city, such as the city's traditional consolidated area and areas of linear shaping, pedestrian mobility is classified as low because it shows a lack of elements and needs improvements in the quality of the built environment.

Bicycle infrastructure in Braga is also a recurring theme among urban mobility discussions. According to Meireles & Ribeiro (2020), the local government has been assuming the need to offer citizens adequate infrastructure to enable active mobility to achieve the sustainable mobility goals from the National Strategy for Active Mobility, which culminated in the creation of 22km of cycling routes along with parking facilities to promote multimodality.

The bicycle network in Braga is presented in different ways. There is an infrastructure shared with pedestrians along with the extension of the Este River, called eco via. Cycle paths are present in distinct areas of the city, and there are signed shared roads. Figure 16 shows the current cycle network in the city of Braga.

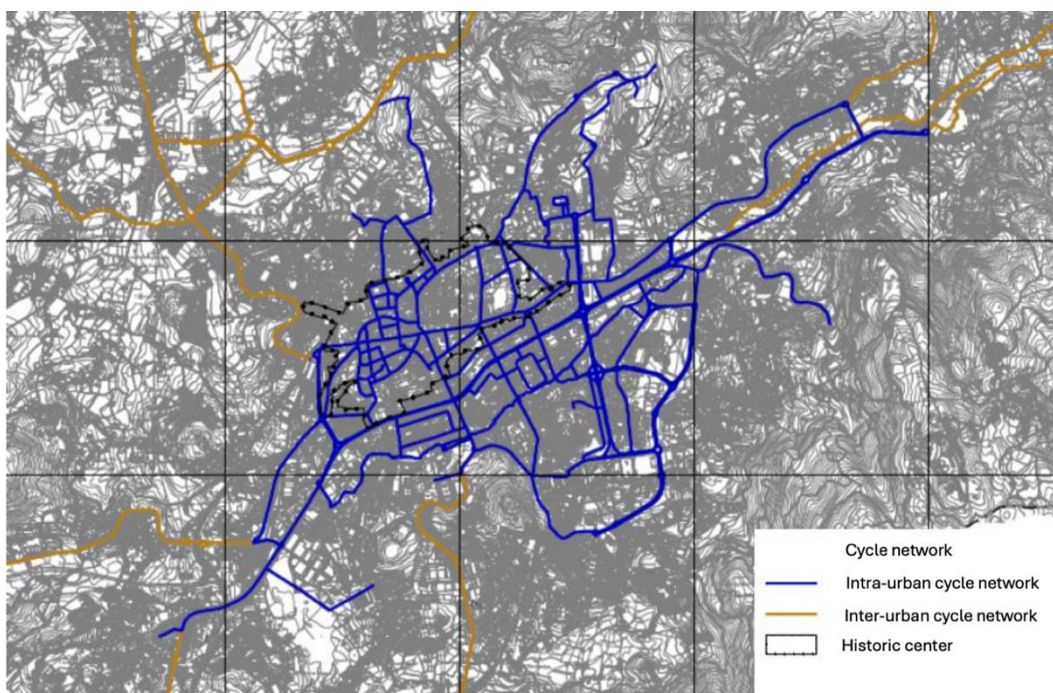


Figure 16: Bicycle infrastructure network (MPT, 2019)

The Municipality of Braga states in its Municipal Master Plan that the city needs to reach a modal share of 10% for bicycle use by improving cyclists' safety, developing and keeping the cycle network connected and attractive, providing parking facilities for bicycles, and identifying partners to create educational plans for bicycle use (Município de Braga, 2015).

Yet another measure that promotes the increase in safety for the most vulnerable in Braga's urban mobility (bicyclists and pedestrians) is the creation of 30km/h zones. According to data from Portugal 2020 (2019), the constraint on speed must be implemented in residential areas with high economic activity or in the surrounding areas of schools. The project includes the creation of crosswalks with tactile floors, traffic calming measures, installations of access ramps, and widening sidewalks. Figure 17 shows the location of Braga's existing and future 30km/h zones.

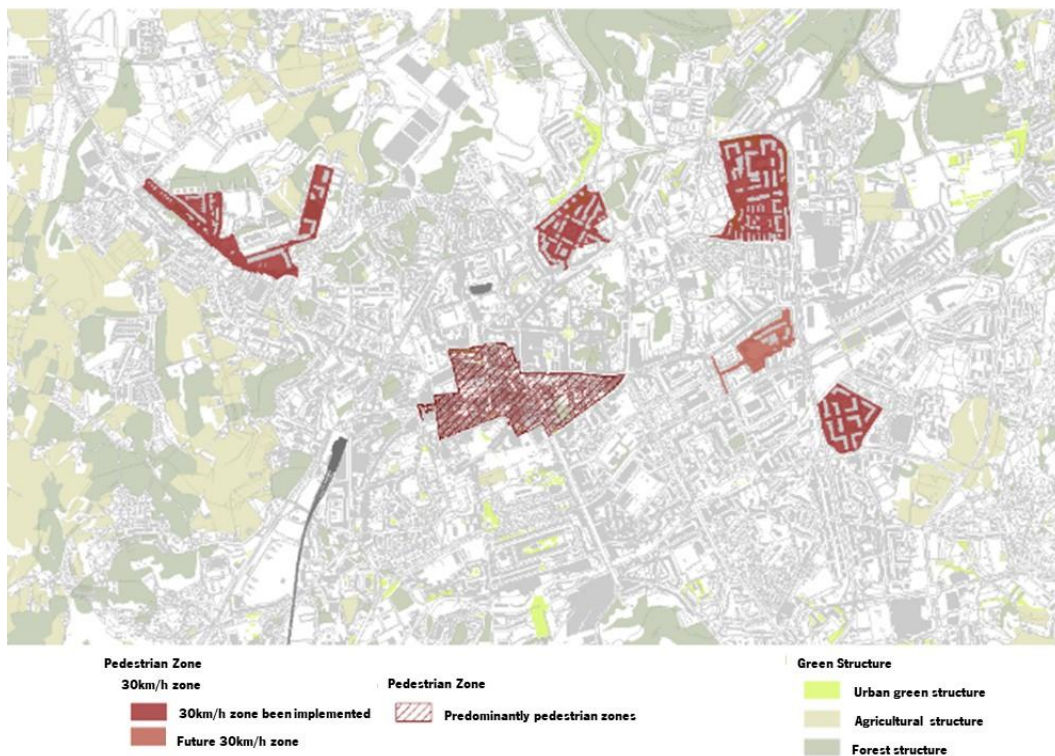


Figure 17: Areas where 30km/h zones will be implemented (MPT, 2019)

In addition to walking and cycling in Braga, the city has also worked to establish a shared e-scooter service as a new mode of transportation to help ease traffic congestion, pollution, and noise problems. The Municipality holds the shared e-scooters as a promise to improve mobility in Braga, even if some constraints are reported in this mode of transport.

IV.1.4. Shared e-scooters in Braga

The e-scooter-sharing service started operating in Braga on August 19th, 2019, with only one company providing the service. This company started its operation with about 80 e-scooters distributed around the city center, with expected expansion in the short term. Later, two other companies began to provide the same service in the following months of the same year. However, only two companies remain offering the service in the city and currently make available 379 shared e-scooters for the population. The e-scooters were available in 25 different parking spaces allocated within the city center area (City of Braga, 2019) at the beginning. Still, currently, there are more than 50 parking spaces available near malls and educational institutions to stimulate the usage of the service by students (Figure 18). These parking spots were converted from car parking spaces to accommodate bicycles and e-scooters (Figure 19).

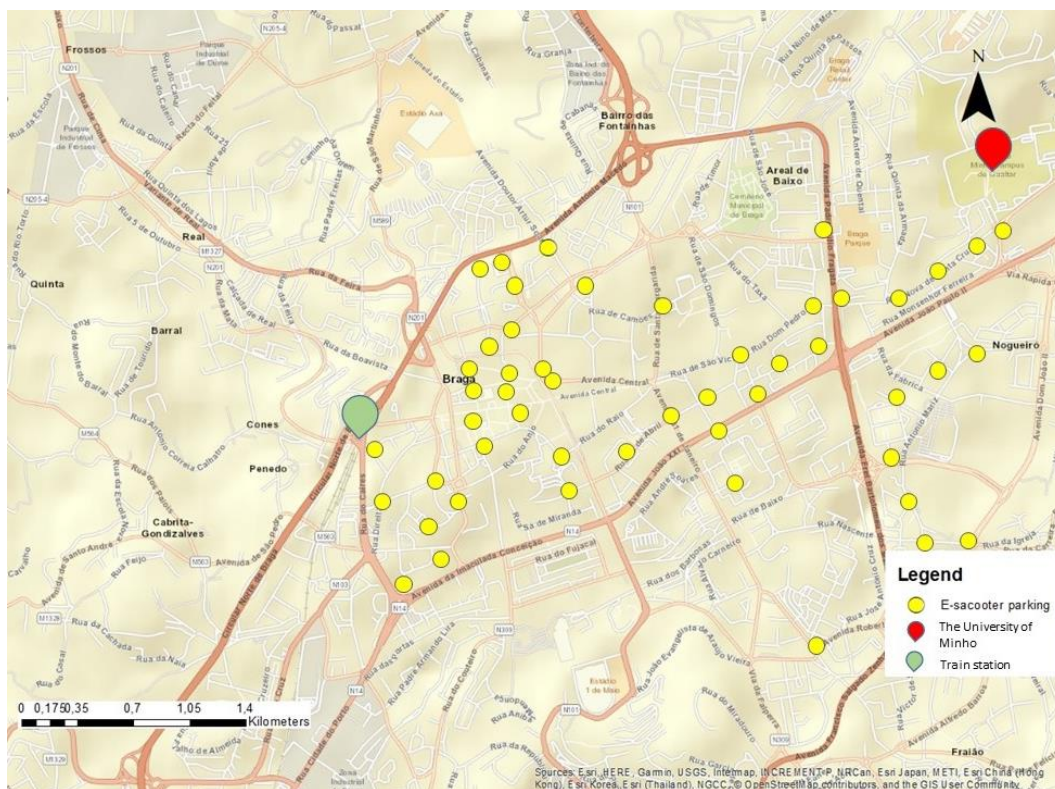


Figure 18: Location of shared e-scooter parking spots (own author)



Figure 19: Micromobility parking spots (own author)

Although riders don't need to park their shared e-scooters in the parking spots, decreasing the number of e-scooters parked on sidewalks blocking the walkways is a great asset. Besides the parking spots, the City of Braga also created a “red zone” –seen in the companies’ app - where the maximum speed of the e-scooter must be reduced, and the wheels are blocked when the rider reaches a “no-circulation zone”. These areas were created to increase the safety of the e-scooter users and the pedestrians circulating there. This “no-circulation” zone covers some critical streets of the city, such as Dom Diogo de Sousa Street, Souto Street, Dom Paio Mendes Street, Dom Gonalo Pereira Street, Rossio da S , Miseric rdia Street,  a de Queir s Street, Dr. Justino Cuz street, Francisco Sanches Street, S. Marcos Street, Liberdade Avenue, Dr. Gonalo Sampaio Street. The map in Figure 20 covers the city of Braga with the “red zones” printed in “red”, and it is essential to point out that besides the streets, a large part of the city center of Braga is covered with these constraints.

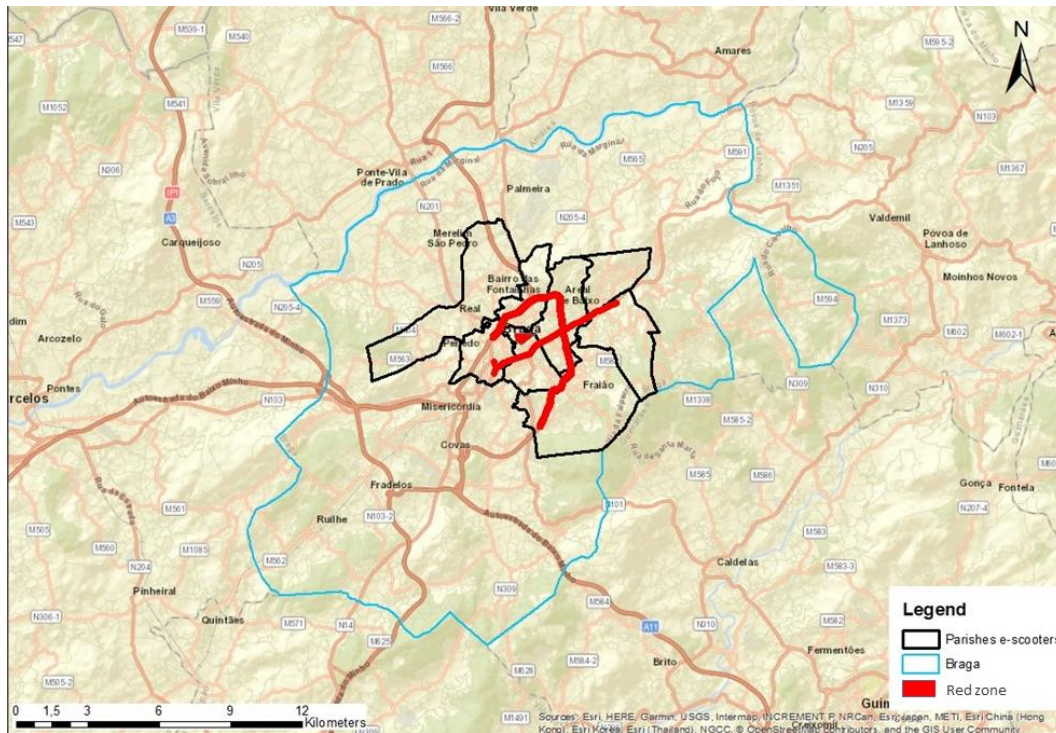


Figure 20: Red zone for shared e-scooter usage (own author)

Moreover, some rules were established by the Municipality (City of Braga, 2019) to be followed by the companies that provide the service once it can help increase the users' safety. The rules are as follows:

- The company needs to make e-scooters available in the designated locations (dedicated parking spots) under the authorizations and monitoring of the Municipality of Braga;
- Safeguard that the equipment is maintained and safe for users;
- Provide users with information about operations, road safety, and usage rules. At registration, all information on good practices for use and circulation on public roads and parking rules will be given;
- Ensure that the equipment does not pose a danger to other road users. The company must remove or relocate shared e-scooters parked in inappropriate places on its initiative and whenever requested;
- Inform users about authorized stopping places;
- Distribute e-scooters in all locations and regularly;
- Apply mandatory checkout mechanisms in the app when riders reach the “red zones”, where vulnerable users recognize more sensitivity.

IV.1.4.1. Pre-pandemic usage of shared e-scooters in Braga

The shared e-scooter service was offered in Braga before the COVID-19 pandemic started. Data from August until December 2019 shows that, in this period, 174 e-scooters were operating in the city by the end of October. These e-scooters made an average of 4,000 trips per month, and according to the data retrieved, from August to October, e-scooters made more daily trips. In November and December of the same year, the average number of trips per e-scooter decreased to 0.8, which can be justified as in these months, the temperatures decrease, the days are shorter, and it starts raining more often in Braga. In addition, the weekends and hours between 5 p.m. and 7 p.m. were when e-scooters were more solicited, representing that e-scooters were more used for leisure activities. Table 9 shows the metrics for shared e-scooter trips in the second half of 2019 in Braga.

Table 9: E-scooter usage in Braga in the second half of 2019

Metric	Month of 2019				
	August	September	October	November	December
Number of e-scooters	46	110	174	103	98
Number of trips	1746	7,159	6,843	2,439	2,549
Number of trips per e-scooter	1.26	2.17	1.31	0.8	0.8
Number of trips (average/day)	58	239	228	81	82
Number of km traveled	4,624	14,924	11,770	4,004	4,076
Most solicited weekday	Sunday	Sunday	Saturday	Saturday	Tuesday
Most solicited hour of the day	6 p.m.	5 p.m.	7 p.m.	6 p.m.	5 p.m.

At the end of the five months after the implementation of the service, shared e-scooters have made more than 20,000 trips and traveled more than 40,000 km. According to data from the company, more than 95% of the users in this period were locals, and they took trips mainly during the evening, between 5 p.m. and 6 p.m. The geographic sprawl of trips changed during these months. When the service started operations in October, people would start and finish their trips in the central area of Braga (i.e., the historic center), while in the last months of the year, people would take further trips to different areas of the city, namely near Braga Parque mall and the University of Minho campus. Moreover, the only pre-pandemic data available for Braga comprises the second half of 2019, and there is no consistent data from the beginning of 2020.

IV.1.4.2. Impacts of the COVID-19 pandemic on the shared e-scooters in Braga

With the spread of COVID-19 in Europe, Portugal started a lockdown on 18 March 2020. The government took several measures, including allowing residents to circulate on the streets only for a few reasons, including grocery shopping, health care, assisting vulnerable people, and exercising (Republica Portuguesa, 2020).

In Braga, with the state of lockdown, the shared e-scooter service was suspended until people could walk freely on the streets, which happened at the beginning of 2021. Since then, three different companies have resumed their services to the population. Starting in April 2021, the city offered about 500 shared e-scooters. For the service to be resumed, some measures were taken to try to reduce the negative impact of this mode of transportation in the city, such as the control of the speed, as e-scooters cannot run at speeds higher than 25 km/h in order not to disturb and to harm people's accessibility to public spaces. In addition, e-scooters must be allocated in specific parking spots distributed within the city, where companies must ensure their correct parking (Agência Lusa, 2021).

Besides, companies started offering price reductions to increase the use of this mode of transportation in the city. One of the companies provided the service with a free e-scooter unlock and only EUR 0.05 per minute traveled. While the other started offering 15-minute trips for only EUR 1.0 and some trip packs to be used for one month or 90 days with a price reduction.

These measures increased the usage of shared e-scooters in Braga in the following months. The companies that deployed their e-scooters on the streets of Braga saw the success of this mode of transportation, as reported in the increased number of trips presented in the following section.

IV.1.4.3. The current shared e-scooter service in Braga

Currently, the two companies that offer the service in Braga have applications that allow users to unlock and ride their e-scooters throughout the city. The apps also provide the location of the specific parking spots for e-scooters and the exact location of the e-scooters for rent. Figure 21 shows the parishes where shared e-scooters are available.

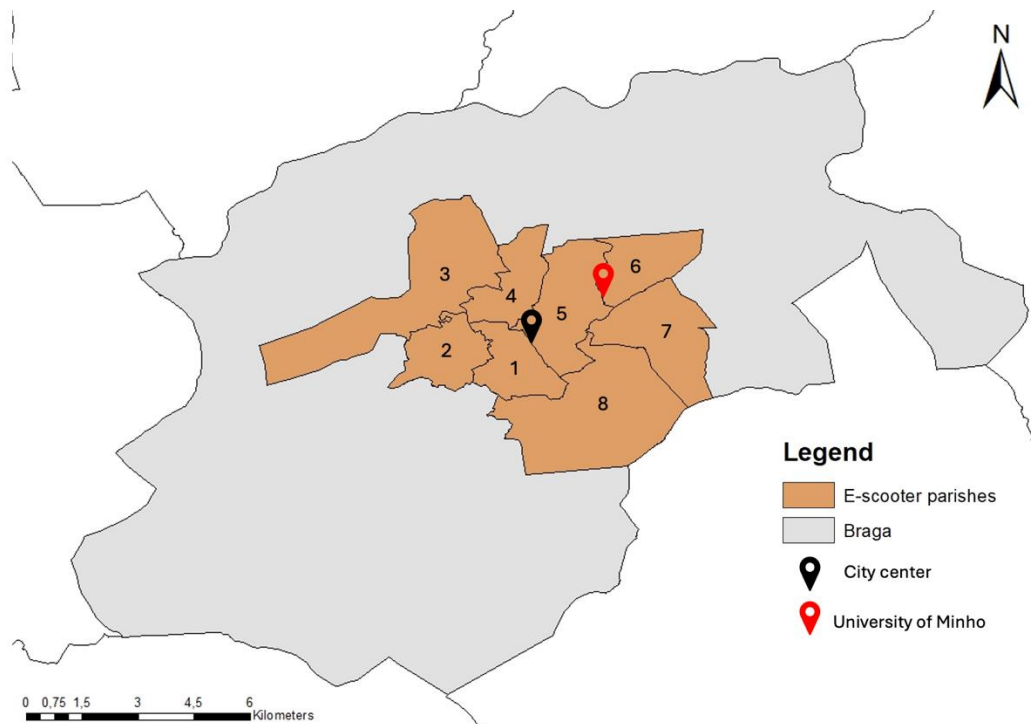


Figure 21: Area served by shared e-scooters (own author)

The area where shared e-scooters are available through the companies' application covers eight parishes in the city. The parishes and their respective population are (Figure 21): (1) Parishes union of São José de São Lázaro e São João do Souto (14,791 inhabitants); (2) Parishes union of Maximinos, Sé, and Cidade (15,087 inhabitants); (3) Parishes union of Real, Dume, and Semelhe (13,682 inhabitants); (4) São Vicente (13,974 inhabitants); (5) São Victor (32,876 inhabitants); (6) Gualtar (6,761 inhabitants); (7) Parishes union of Nogueiró and Tenões (5,946 inhabitants); (8) Parishes union of Nogueira, Fraião, and Lamações (15,015 inhabitants). The resident population in the area served by shared e-scooters corresponds to more than 60% of the total population of the municipality of Braga.

The prices charged for the rides depend on each e-scooter provider and have changed over time. One of the companies only charges for the minutes traveled, which costs EUR 0.21 per minute, yet this company offers subscription packs for riders, such as a two-day pass that costs EUR 3.50, a weekly pass that costs EUR 6.50, and a monthly pass that costs EUR 20.0. The other company charges EUR 1.0 to unlock the e-scooter and more EUR 0.15 for each minute traveled; it also offers a two-day pass for EUR 2.99, a three-day pass for EUR 11.99, and a monthly pass for EUR 29.99.

After the rider unlocks the e-scooter in one of the parishes where the service is available, rides to their destination, and pays for the trips, they have to take a photo of the used e-scooter to demonstrate that it is parked in one of the dedicated parking spots or that it is parked close to the walls on a sidewalk and is not obstructing pedestrians' right-of-way. When all these steps are done, the trip can be concluded.

IV.1.4.4. Shared e-scooter trip data

The two shared e-scooter companies that offer the service in Braga currently provide 362 vehicles. These vehicles have a device rotation of 1.21 trips per e-scooter per day. Throughout the forty months of the data availability of shared e-scooters in Braga, from April 2021 (when the service resumed after the COVID-19 pandemic) until July 2024 (the last month of available data), the fleet size varied from 143 vehicles in September 2021 to 832 in May 2023. Figure 22 shows the shared e-scooter fleet size variation throughout time in Braga.

The fleet curve in Braga follows the same path observed in Europe and worldwide. The fleet increased from 2021 until 2023, when fleet availability peaked. Since then, the number of vehicles available to the population has been dropping. Even if the number of companies providing the service is constant, they have chosen to offer fewer e-scooters. One of the companies holds 2/3 of the vehicles available, while the other holds only 1/3 of them.

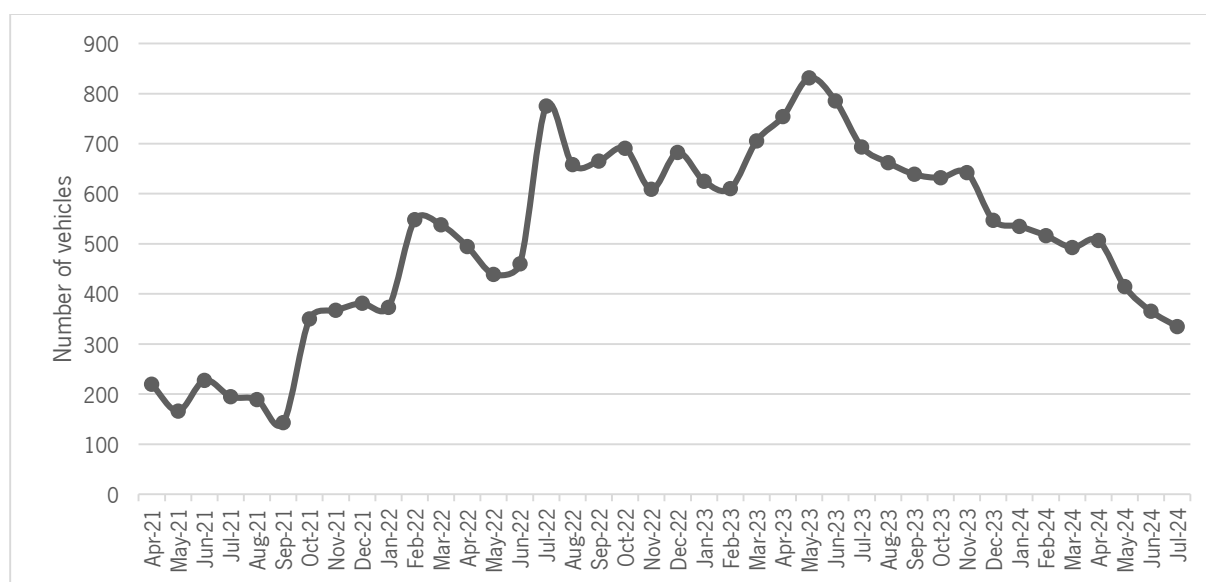


Figure 22: Fleet size of shared e-scooters

Because of the decrease in vehicle availability, the number of trips generated by shared e-scooters in Braga has dropped since the second half of 2023. The highest number of trips generated in Braga was 48,791, which occurred only in August 2022. Conversely, the fewest trips by shared e-scooters were made in January of the same year, when only 11,396 trips were generated. Figure 23 shows the number of monthly trips in shared e-scooters in Braga.

Regarding the number of trips made in the same period when the availability of shared e-scooters started to drop in Braga, which started in August 2023, an average of 16,220 trips were generated monthly until July 2024. This is a considerable trip drop compared to the former 12 months (from August 2022 until July 2023), when 22,836 trips were made on average every month.

The data suggest that the shared e-scooter service has experienced considerable growth in usage in Braga since its implementation until June of 2023. From April 2021 until the second half of 2022, the number of trips generated grew exponentially. The only exception is the winter months, from December until February, when the rainfall in Braga increases and shared e-scooter ridership is compromised. This weather outcome is experienced in all years of available data for shared e-scooters in Braga.

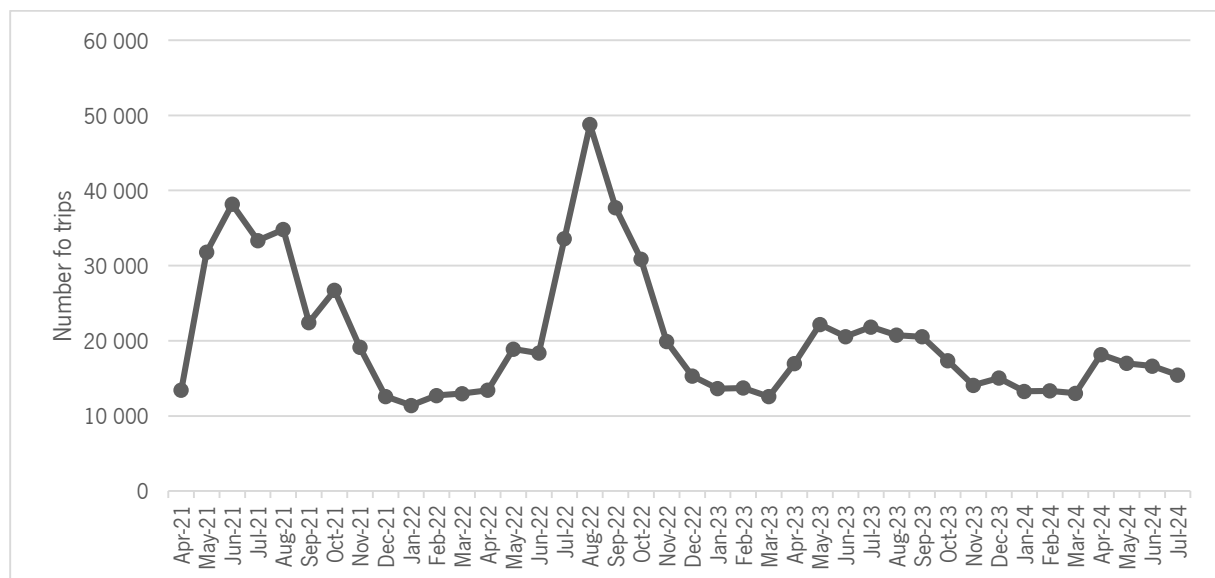


Figure 23: Number of trips of shared e-scooters

Two other metrics available for shared e-scooters in Braga are the distance traveled and the trip duration (Figure 24), which are interconnected. Since shared e-scooters are seen as an opportunity for a modal shift in short-distance trips, it is crucial that the distance traveled and the trip duration are evaluated. In

the last 12 months (from August 2023 to July 2024), shared e-scooters have traveled on average 1,5 km. The highest average distance traveled was experienced in April 2021 when shared e-scooters would travel 1.8 km in Braga. In contrast, February 2022 was the month with the lowest average trip duration, 1.3 km.

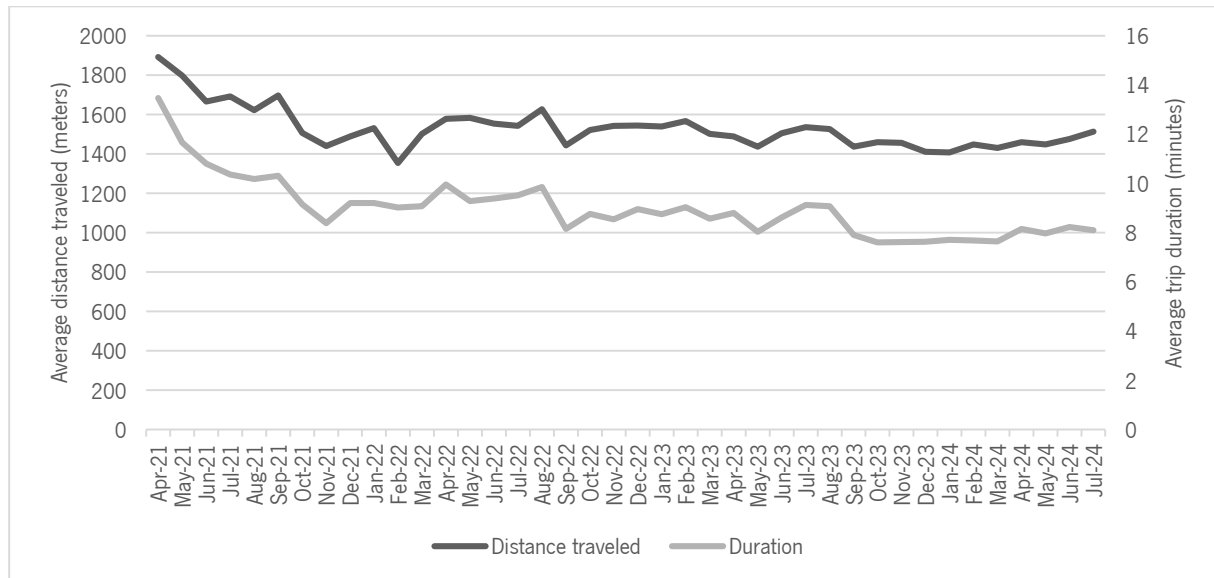


Figure 24: Distance traveled and trip duration of shared e-scooters

Considering that, on average, shared e-scooters make 1.5 km long trips in Braga (average for the forty months of available data), the average trip duration for the same period is 9 minutes. This can be translated into an average of 6 minutes per kilometer traveled in shared e-scooters in Braga. Estimating that a shared e-scooter can reach up to 25 km/h in Braga; in 6 minutes, a rider can travel 2.5 km. However, the current state of the data points that, on average, a rider travels at a speed of 10 km/h in a shared e-scooter in Braga. A collection of the e-scooter trip data information from 2021 to 2024 is presented in Table 10.

Table 10: Average results per year for shared e-scooter trips

Trip characteristic (average)	2021	2022	2023	2024*
Fleet size	249	578	678	452
Trips	25,819	22,828	17,436	15,266
Distance traveled (meters)	1,644	1,526	1,488	1,454
Trip duration (minutes)	10	9	8	8

*First semester

The highest average fleet size of shared e-scooters in Braga was 2023, following an increase from the previous years. In 2021, even with a smaller average fleet, the average number of trips rose compared to the following years; however, 2022 is the second-best year for shared e-scooter trips in Braga, mostly corroborated by the high peak of trips in August. The first year of shared e-scooters after the pandemic also shows the highest average distance traveled and average duration of trips.

Considering the spatial distribution of the trips, most started and ended in the same parish, São Victor, Braga's most populated and dense parish, located in the city center. Also, shared e-scooters in Braga are most used during the week, reaching a peak of usage on Friday. The most solicited part of the day is the evening, with a peak in trip generation at 6 p.m.

IV.1.5. Shared e-bike trip data

Unlike shared e-scooters, which have had a consolidated presence in Braga for the last few years, the free-floating shared e-bike service debuted in September 2022 to celebrate European Mobility Week. Only one company deployed the service, which provided 51 e-bikes in the city center of Braga. Despite the investment in the service, it only lasted ten months in the city.

The fleet size of shared e-bikes is reduced compared to the e-scooter fleet. The shared e-bike service peaked in April 2023 with 54 vehicles available and the least number of vehicles in March 2023 (26 vehicles). Differently from the shared e-scooter case, where the fleet size grew in the following months after the deployment, the shared e-bike fleet decreased in the following months after the deployment, reached a peak almost in the same period as the e-scooter fleet, and declined again before its cease. Figure 25 shows the trajectory of the shared e-bike fleet in Braga.

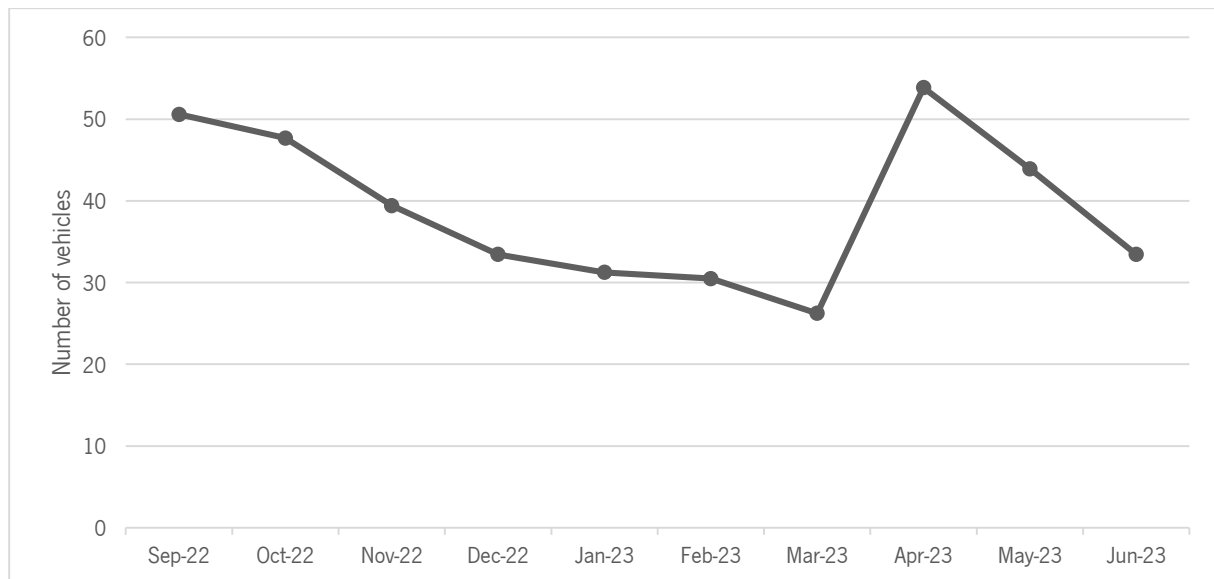


Figure 25: Fleet size of shared e-bikes

As a possible consequence of the low availability in Braga, the number of trips generated by shared e-bikes was also low. Figure 26 shows an increase in the number of trips in the first month of deployment of this service, which peaked in October 2022, with 638 trips being made. Yet, in June 2023, it only reached 102 shared e-bike rides. The average number of monthly trips in shared e-bikes was 260 for the ten months of availability.

Shared e-bikes in Braga were also used for short-distance trips. On average, the bikes were only ridden for 1.0 km in the ten months of availability. The highest average distance traveled was reached in June 2023, the last month of operations, when shared e-bikes rode an average of 1.7 km (Figure 27).

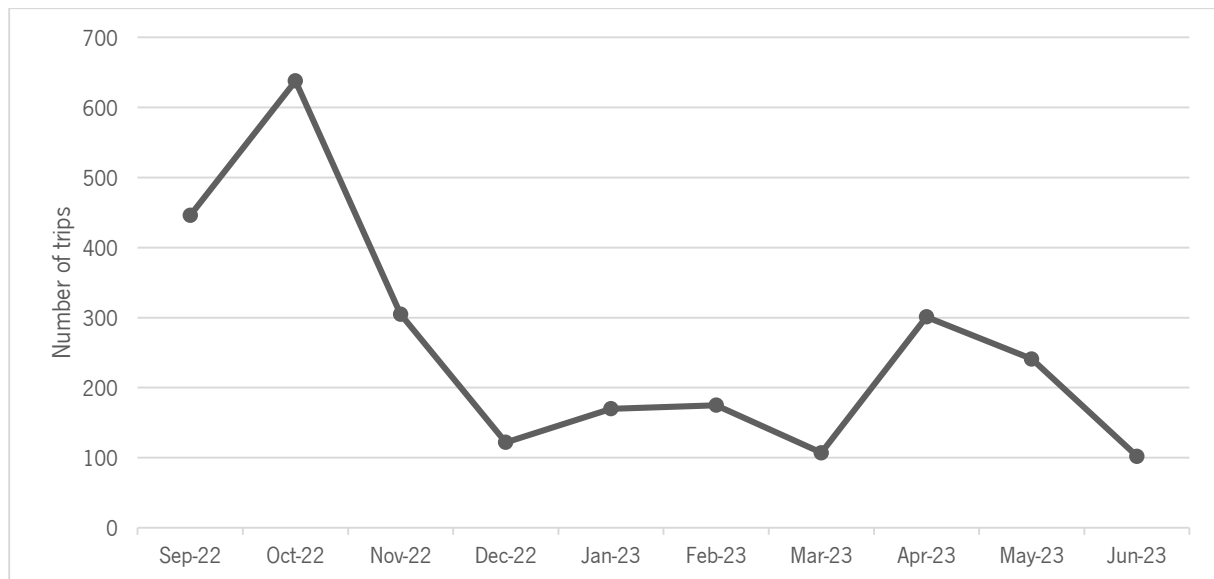


Figure 26: Number of trips in shared e-bikes

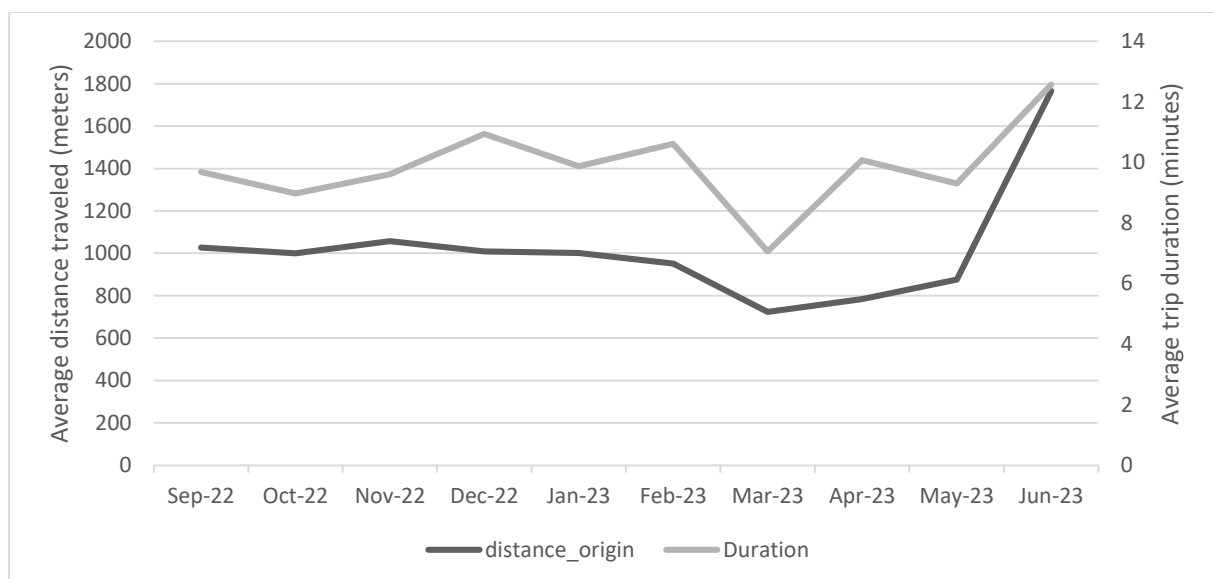


Figure 27: Distance traveled and trip duration of shared e-bikes

Shared e-bike riders spent an average of 10 minutes traveling an average of 1.0 km per trip in Braga. Figure 25 shows that the highest duration of trips occurred in June 2023 since this month also presented the highest distance traveled. In the other months, the duration of the trips remained almost constant, with a considerable drop in March 2023, when the average duration of trips was 7 minutes. It is essential to mention that the distance traveled, the duration of trips, and even the number of trips show a slight increase in the months when the number of shared e-bikes increases.

Following the same pattern as shared e-scooters, the trips made by shared e-bikes had similar origins and destinations. Most trips started and ended in São Victor parish, the city's most populated and dense area. Shared e-bikes were most solicited on Fridays and the weekend.

IV.1.6. Interaction between shared e-scooters and e-bikes

To check the interaction between shared e-scooters and shared e-bikes, 273 days from September 2022 to May 2023 are evaluated since both services ran in the city this period.

Within this period, 185,355 trips were reported by shared e-scooters and shared e-bikes in the city. The highest number of trips were made by e-scooters (182,850), while only 2,505 trips were made by e-bikes. The number of trips shows an increase in e-scooter and e-bike rides during the months of higher solar exposure and less rainfall, which are September, October, April, and May. However, during the colder and rainy months of November until mid-March, these modes of transportation face a decline in the number of rides.

Even if the usage pattern throughout this timeframe seems similar for e-bikes and e-scooters, the number of trips made by each mode is different. E-scooters represent over 97% of shared micromobility trips during the ten months. These patterns can represent that e-scooters have more acceptance among users of shared micromobility in Braga or that residents are more used to this mode once it has been available to the population since 2019.

Another difference in e-scooter and e-bike usage in Braga is related to the characteristics of the trips regarding the distance traveled by each mode and the duration of these trips. Table 11 shows the descriptive statistics for the number of trips made by shared e-scooters and shared e-bikes during the ten months. The data used to compose the table comprises all trips generated during this period.

Table 11: Descriptive statistics of shared e-bike and e-scooter trips

	Shared e-bike (N=2,505)		Shared e-scooter (N=182,850)	
	Distance traveled (m)	Trip duration (min)	Distance traveled (m)	Trip duration (min)
Mean	972.5	9.8	1508.1	8.6
Std. Dev	502.9	4.1	94.4	1.0
Min.	118.5	1.7	1302.9	6.7
Max.	3269.83	25.7	1822.1	11.6

The average distance traveled by e-scooters is higher than the ones made by e-bikes. However, e-bikes take longer to reach their destination. Even though shared e-scooters are used more often than e-bikes, the trips made by e-bikes usually reach further distances in longer journeys. Figure 28 shows the percentage of trips made per day of the week for shared e-scooters and shared e-bikes. These trips are made mainly on the weekends, with the most used days being Friday, Saturday, and Sunday, with a slight peak also on Tuesday. The e-scooter usage presents an almost even utilization rate during the week, reaching the peak of trip numbers on Friday.

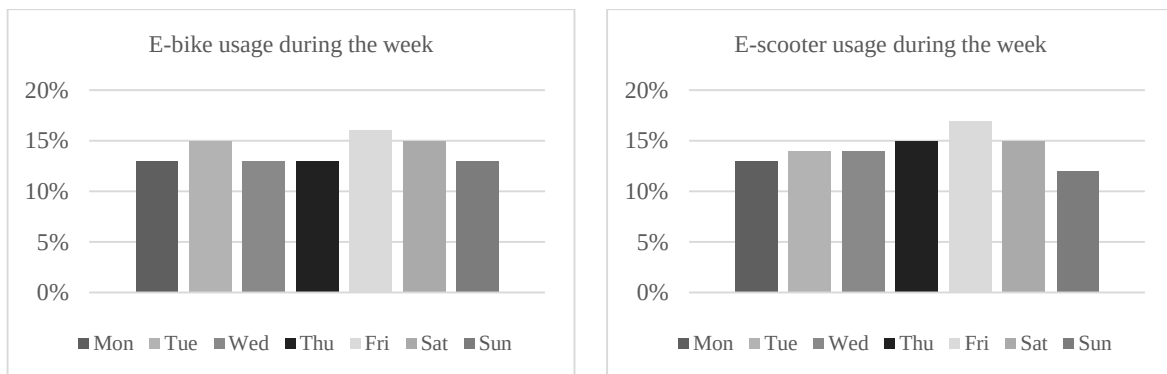


Figure 28: Percentage of shared e-bike and e-scooter trips during the week

When comparing the main areas of usage for shared micromobility in the city, it is possible to identify that e-bikes and e-scooters are used relatively in the same regions of the city, with particular attention to the darker colors in Figure 29, which represent the most populated parishes that comprise the most significant number of services for the population, such as the shopping mall, school districts, the University of Minho campus and city facilities. The darkest color represents São Victor parish, the most populated and dense in the city.

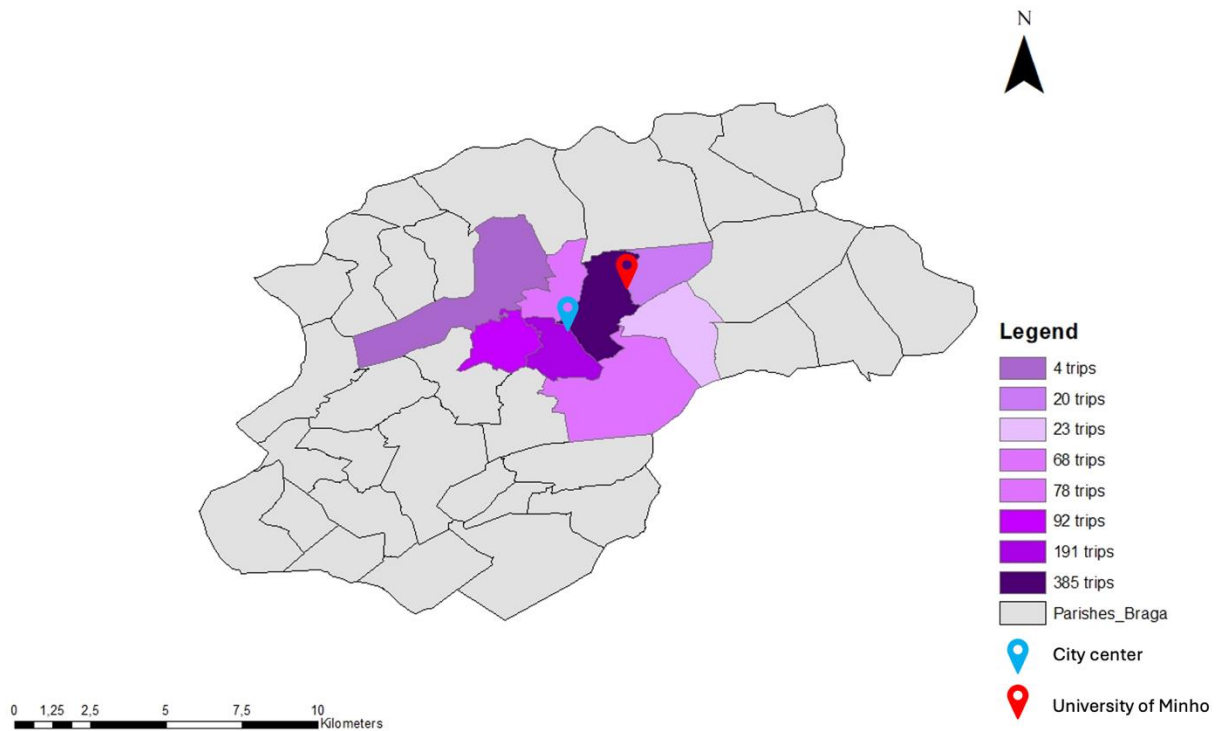


Figure 29: Shared e-bikes and e-scooters main area of usage (own author)

In Braga, the implementation of shared e-scooters occurred before the implementation of the shared e-bike service, which is not common, since bicycle sharing services have been around for longer. The early rise of the former contributed to familiarizing the general population with this mode.

The trip data shows an excessive disadvantage of e-bikes when considering the number of trips studied. This can be due to the early familiarization of e-scooters. Another reason that can cause an advantage of e-scooter usage over e-bikes is the trip's price. While e-scooters can reach the lower cost of only EUR 0.21 per minute traveled, e-bikes used to cost EUR 1.0 to be unlocked, plus EUR 0.18 per minute traveled. This also confirms the role of deploying mode choice experiments in the city.

The need for dedicated infrastructure can be another crucial factor in determining the lack of competitiveness between e-bikes and e-scooters. This is because in the area of the city where most micromobility trips are made, cycle lanes are almost non-existent, and the streets are narrow and paved with cobblestones. Therefore, e-scooters would have priority usage since they are easier to ride on the sidewalk, even though it is legally forbidden in Portugal.

In Braga, both modes are present and used in the same area of the city, representing that they are accessed in the same locations. When comparing the usage throughout the week, patterns remain similar since both micromobility modes present higher ridership rates on Fridays.

Furthermore, shared e-scooters and e-bikes in Braga can coexist and provide mobility options for short-distance trips. In Braga, to balance the usage of both micromobility modes, more efforts needed to be made to minimize price differences among them and to provide equal opportunities for people to ride safely (i.e., provision of dedicated infrastructure) so the population could be familiarized with e-scooters as well as e-bikes and use them according to their mobility needs.

IV.2. Revealed preference (RP) survey

This sub-section displays the objectives of the administered survey, the methodology used, and the data collection. In addition, the results are presented in two blocks: 1) results from the survey administered with the population sample and 2) results from the survey administered with the university students sample.

IV.2.1. Objectives of the RP survey

The main objective of the Revealed Preference survey deployed in Braga is to identify the main attributes (i.e., motivations and barriers) for shared e-scooters in Braga that can be used to create the SP experiment. Also, the RP survey is used to identify the users' and non-users perceptions of shared e-scooters, the profile of the users and potential users of the service in Braga, the main determinants of shared e-scooter usage in Braga, and the possible planning strategy that needs to be taken into consideration to promote a safe usage of this mode of transport. Therefore, the results of the RP survey are closely related to the following research questions:

- RQ2: What are the main drivers/determinants of shared e-scooter usage for commute and leisure trips?
- RQ3: How do transportation planning and traffic management influence the safe usage of shared e-scooters?
- RQ4: What are the impacts of shared e-scooter usage on the sustainability of the transportation system?

IV.2.2. Methodology of the RP survey

The RP survey was developed to extract information from users and non-users of Braga's shared e-scooter service. The online Google Forms survey (Appendix A) was disseminated from 24 January to 10 July 2022 in downtown Braga, in the vicinity of shared e-scooter stations that comprise the main traffic generators in the city, near school districts, as well as the University of Minho campus (i.e., students and staff). The survey administration was divided into two approaches: collecting data from a sample from the general population of the city and a sample from the university student body. The choice to collect data specifically for the latter group is due to previous research showing that shared e-scooters are used mainly by younger

people (Y. Guo & Zhang, 2021b; McKenzie, 2019), and heavy e-scooter traffic is expected to occur in downtown and university campus areas (Caspi et al., 2020; Huo et al., 2021).

As people were still highly concerned about the contamination from COVID-19 in the first half of 2022, the survey was disseminated with focus on the two needed samples. The survey was disseminated through e-mail, institutional e-mail and on campus through a QR code for the university students. For the general population of Braga, the survey QR code near the city center was propagated near shopping malls and school districts targeting students and parents, so people could respond to the survey on their cellphones and avoid close contact with the researcher (Figure 30).



Figure 30: QR Code flyer used to disseminate the RP survey

A stratified random sampling method was employed to target current users of shared e-scooters and potential service users. The survey incorporated multiple question types, including single-choice, multiple-choice, and Likert-type scales. These questions explored vital aspects, such as the main factors not to use shared e-scooters in Braga (for non-users), the main motivations to use this mode of transportation (for current users), and what they would like to see improved in the provision of the service to increase its usage.

IV.2.2.1. Structure of the RP survey and sampling

The same survey structure was used to collect data from the general and university student populations. Firstly, the respondents had to answer whether or not they use the shared e-scooter service in Braga. Then, if the answer was negative (potential users of shared e-scooters in the future), the respondents were forwarded to a selection of questions regarding the main factors for them not to use the service and if they were willing to start using shared e-scooters if the current perceived negative factors were solved.

If the respondents use the service, they were asked questions regarding their primary motivations for using this mode of transportation and how they use the micro vehicle and the service across the municipality (e.g., origin-destination, frequency). In the end, all respondents were asked sociodemographic questions. Thus, to better identify the profile of the population and their point of view on the shared e-scooter service, the structure of the survey is as shown in Figure 31.

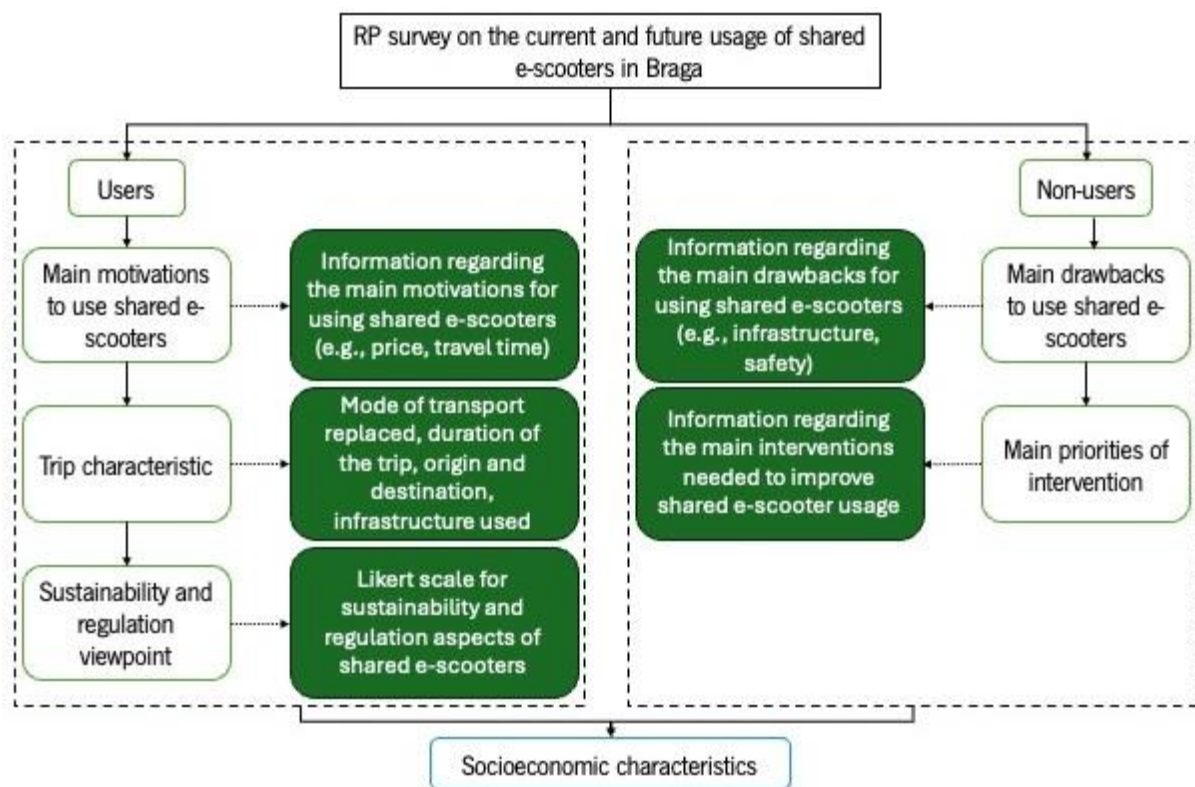


Figure 31: Structure of the RP survey

For the general population sample, the data collection resulted in 541 answers for the survey, but 108 had to be discarded due to inconsistent answers (e.g., surveys that were left partially blank or when single-

answer questions received more than one answer), which resulted in 433 (N = 433) valid answers to estimate the results. For the university student sample, 376 valid answers were collected.

The sample size for both respondent categories (i.e., general population and university students) was calculated using valid approaches in designing and conducting survey research (Ayaz et al., 2021; Cochran, 1977) (equation 8). To statistically representative of the population of Braga at a 95% confidence level (margin of error of 5%), a population of 193,324 people who live in the city (Instituto Nacional de Estatística, 2022b) was considered, a z-score of 1.96 (Kelley, 2007; Krejcie & Morgan, 1970), and 40% male population. It is essential to mention that from the 433 valid answers, 78 represent current users of shared e-scooters in Braga. In contrast, 355 represent potential users (i.e., people who do not use shared e-scooters but could start using the service if some improvements were made).

To statistically represent the university student population at the University of Minho at a 95% confidence level and 5% margin of error, a population of 15,350 students in the University of Minho campus in Braga was used, considering a z-score of 1.96, and 40% male population.

$$Sample\ size = \left(\frac{\frac{z^2 * p(1 - p)}{e^2}}{1 + \left(\frac{z^2 * p(1 - p)}{e^2 N} \right)} \right) \quad (8)$$

Where:

- e – desired level of precision, the margin of error;
- p – the fraction of the population (as percentage);
- z – the z-score.

IV.2.2.2. Statistical treatment of results

To determine whether the use or non-use of shared e-scooters in Braga and the sociodemographic characteristics of the sample are independent (unrelated), Pearson's chi-square tests (equation 9) were performed to correlate the data for the general population and university student sample. This test is used because the collected data is categorical, meaning it is divided into categories and does not fall within a parametric or continuous data group.

$$X^2 = \sum \frac{(O - E)^2}{E} \quad (9)$$

Where:

- X^2 – is the chi-square test statistic;
- Σ is the summation operator;
- O is the observed frequency;
- E is the expected frequency.

In addition, since university students constitute a large portion of shared e-scooter users (Nikiforiadis et al., 2023a), and the younger population is more open to shifting modes of transportation due to their sustainability features, only the university student sample data was used to assess the correlation between the perception of sustainability of shared e-scooters and their sociodemographic characteristics. The Mann-Whitney test (equation 10) and the Kruskal-Wallis H test (equation 11) were performed (Pestana & Gageiro, 2014).

$$U = n_1 n_2 + \frac{n_1(n_1 + 1)}{2} - R_1 \quad (10)$$

Where:

- n_1 – sample size one;
- n_2 – sample size two;
- R_1 – rank of the sample size.

$$H = \frac{12}{n(n + 1)} \sum_j^k \frac{R_j^2}{n_j} - 3(n + 1) \quad (11)$$

Where:

- n – total number of observations;
- k – number of groups that are being compared;
- R_j – is the sum of ranks for group j ;
- n_j – number of observations in each group.

IV.2.3. Results from the RP survey for the general population sample

IV.2.3.1. Profile of the respondents

The sample size comprises 433 answers, of which 47.8% are male and 49.4% are female. Respondents belong primarily to the age range of twenty to twenty-four years old (38.3%), but all ages were represented in the data collection. Regarding the educational background of the respondents, 54% finished high school, and 27% have a bachelor's degree, which are the most prominent educational stages. When inquired about their employment status, 70.7% said they are students, and 26.8% are employed and have family monthly incomes from EUR 1,001 to EUR 1,500. Table 12 shows the profile of the respondents by category.

Table 12: Sample description for the RP survey (general population)

Category	Subcategory	N Sample	% Sample	% Braga
Gender	Female	214	49.4%	52.4%
	Male	207	47.4%	47.6%
	Other	2	0.5%	-
	Prefer not to say	10	2.3%	-
Age	Up to 19 years old	115	26.6%	19.3%
	20-24 years old	166	38.3%	5.9%
	25-29 years old	33	7.6%	5.9%
	30-34 years old	29	6.7%	6.1%
	35-39 years old	30	6.9%	7.1%
	40-44 years old	15	3.5%	7.9%
	45-49 years old	9	2.1%	7.8%
	50-54 years old	19	4.4%	7.6%
	55-59 years old	12	2.8%	7.4%
	Above 60 years old	5	1.1%	24.7%
Education	Up to secondary education	241	55.8%	63.7%
	Bachelor's or equivalent	130	30.1%	16.8%
	Master's degree	51	11.8%	5.6%
	Doctoral degree	10	2.3%	1.0%
Occupation	Students	306	70.7%	7.8%
	Employee	116	26.8%	46.8%
	Employer	5	1.2%	5.6%
	Unemployed	6	1.4%	3.9%
Family size	1 person	43	9.9%	7.3%
	2 people	56	12.9%	11.4%
	3 or more people	120	77.2%	18.6%
Household monthly income	Up to EUR 665	17	6.0%	
	EUR 666 – EUR 1000	45	15.8%	
	EUR 1001 – EUR 1500	83	29.2%	

Category	Subcategory	N Sample	% Sample	% Braga
Household monthly income	EUR 1501 – EUR 2000	54	19%	
	EUR 2001 – EUR 2500	38	13.4%	
	EUR 2501 – EUR 3000	17	6.0%	
	EUR 3001 – EUR 3500	14	4.9%	
	EUR 3501 – EUR 4000	8	2.8%	
	Above 4000	8	2.8%	
The main mode of transportation	Walking	113	26.1%	15.8%
	Private car	165	38.1%	69.7%
	Public transport	108	24.9%	10.3%
	Micromobility (bicycle or e-scooter)	47	10.9%	0.9%

The sample's sociodemographic characteristics are mostly aligned with the described population of Braga. However, there are specific deviations that can be explained considering the results of previous studies. The high number of respondents who are young adults (age between 20 and 24 years old) is due to the fact that the primary users of shared e-scooter systems in cities are in this age range (Christoforou et al., 2021b; Laa & Leth, 2020a; Nikiforiadis et al., 2021). This is the main reason for their expressive participation in the survey; therefore, their contribution is considered very important and statistically representative of the e-scooter market. Also, most of the respondents' occupation in the sample is to study (70.7%), whereas in Braga, most of the population is employed adults commuting to work (46.8%). This deviation is related to the primary age of respondents of the questionnaire, who are in the schooling range.

In addition, the profiles of the users and potential users were compared. Current users of the service in Braga are male (67.95%), students (74.36%) that are between 20 to 34 years old (55.13%), and have family monthly incomes between EUR 1,000 to EUR 1,500 (19.23%). When considering current and potential users, it is possible to infer that the proportion of males and females using shared e-scooters would be balanced. In this category, the age range with the most representativeness is between 20 years old and 34 years old. Most respondents are students or are employed and have a medium to high family monthly income.

Since one of the survey's objectives was to investigate shared e-scooter acceptance among the Braga population and how sociodemographic characteristics can affect their usage, it was essential to see that, from all answers, more than 80% of respondents said they do not use shared e-scooters but would be willing to do so if improvements were made in the provision of the shared e-scooter service.

IV.2.3.2. Primary motivations for using shared e-scooters

In Braga, respondents who use shared e-scooters were asked about their primary motivations for using the service. They could choose between nine options related to the trip's comfort, improvements on the displacement, and environmental benefits. According to Figure 32, shared e-scooters are used because they provide a pleasant trip for riders, followed by the possibility of reaching the destination quickly on this mode of transport. The third most chosen alternative was the low physical effort they offer, which can harm the usage of this mode of transportation compared to walking or riding a bicycle.

Figure 32 also reveals that the discounts often offered by shared e-scooter providers do not motivate e-scooter usage. These discounts usually comprise free e-scooter unlocks and free ride minutes. Figure 33 shows the discount provided by a shared e-scooter company in Braga. This is in addition to the fact that the price of the service is also not considered a motivation for its usage.

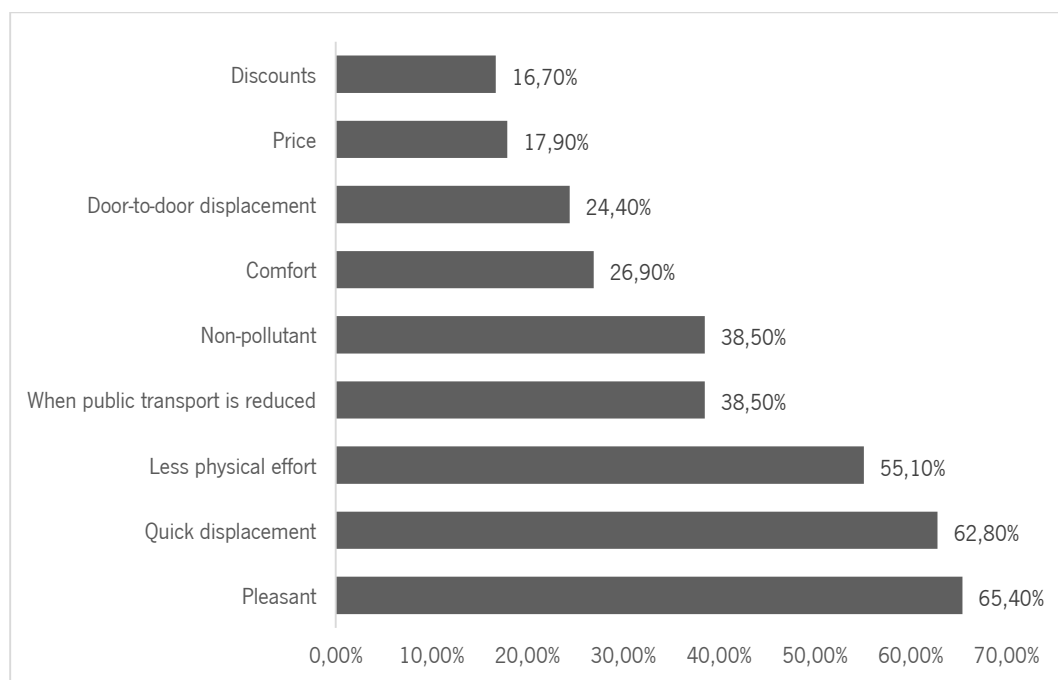


Figure 32: Motivations for shared e-scooter usage



Figure 33: Discount offered by a shared e-scooter company (own author)

The availability of micro vehicles late at night, early in the morning, and on weekends, when public transportation is reduced, also motivates people to ride shared e-scooters. Thus, this mode of transportation can be an asset to complement public transport. The possibility of making a trip in an environmentally friendly vehicle also motivates riders to use shared e-scooters.

Men consider shared e-scooters more pleasant to ride than women do. Still, women revealed that they would use this mode more frequently to reduce physical effort on trips and in situations where public transportation is not available or reduced. The choice to ride an e-scooter due to its non-air pollutant aspect was a constant influential factor across all sociodemographic groups.

IV.2.3.3. Main trip characteristics according to users

Users of shared e-scooters tend to walk between 5min and 9min (47.4%) to find an available e-scooter to start their micromobility trip. These trips are usually made in the afternoon (38.5%) and evening (29.5%) during the week. In contrast, most respondents reported not using shared e-scooters on the weekends (46.2%), and 28.2% reported using them in the afternoon.

Even though shared e-scooters are not used extensively in the morning, respondents said that the primary origin for their first shared e-scooter trip of the day is their home/place of living (48.7%), and the origin for their last shared e-scooter trip of the day is their workplace or school/university (38.5%). This could represent the usage of shared e-scooters for commuting.

When asked if they would use shared e-scooters combined with public transport, respondents said that if the price/ticket were combined between both modes, they would be willing to use shared e-scooters to improve the last/first mile of the public transportation trip.

IV.2.3.4. The main modes of transportation replaced by shared e-scooters

Shared e-scooter riders were also asked which mode of transportation they usually replace when they use e-scooters (Figure 34). In this question, they could choose between public transportation, private car, bicycle, taxi or ride-hailing service (e.g., Uber, Bolt), personal e-scooter, and walking.

Walking is the most popular mode of transportation, but it has been replaced by shared e-scooters, which can contribute to the population's lack of physical activity. Even if both modes (i.e., walking and shared e-scooters) do not emit GHG while being used, the electrical assistance in the standing scooters contributes to the reduction in movement from the rider, which can be a health-related problem in the future. On the other hand, private cars take the second largest share of trips, replaced by shared e-scooters, which can be translated into good environmental impacts on the community.

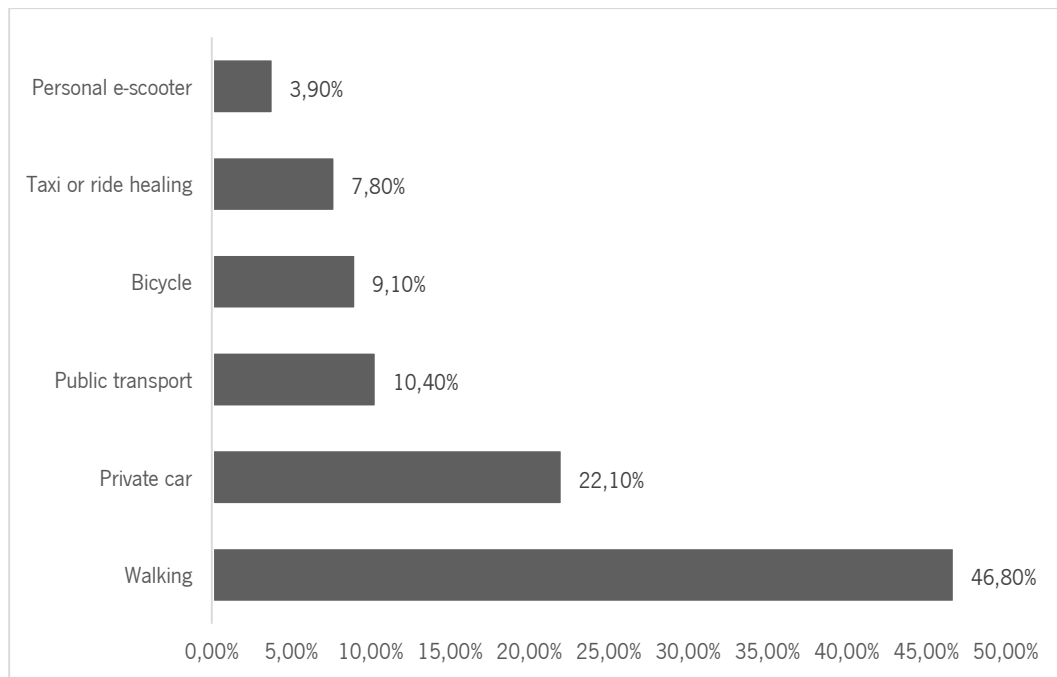


Figure 34: Modes of transportation replaced by shared e-scooters

The bus and the bicycle are also cited as the third and fourth most replaced modes of transportation by shared e-scooters. Therefore, shared e-scooters can substitute already sustainable modes of transport.

IV.2.3.5. Intervention to continue using shared e-scooters

Even though this group of respondents already uses shared e-scooters, they were also asked about the main intervention priorities so they would be willing to continue using the service. This question was also present in the non-users' survey so the views of users and non-users could be compared.

For users, the primary intervention needed is the implementation of dedicated channels (e.g., cycle lanes) (62.8%), followed by the offer of dedicated parking spots (46.2%) and the presence of zoning in the area where shared e-scooters are available (43.6%). Figure 35 shows the results for the primary interventions chosen by users of shared e-scooters.

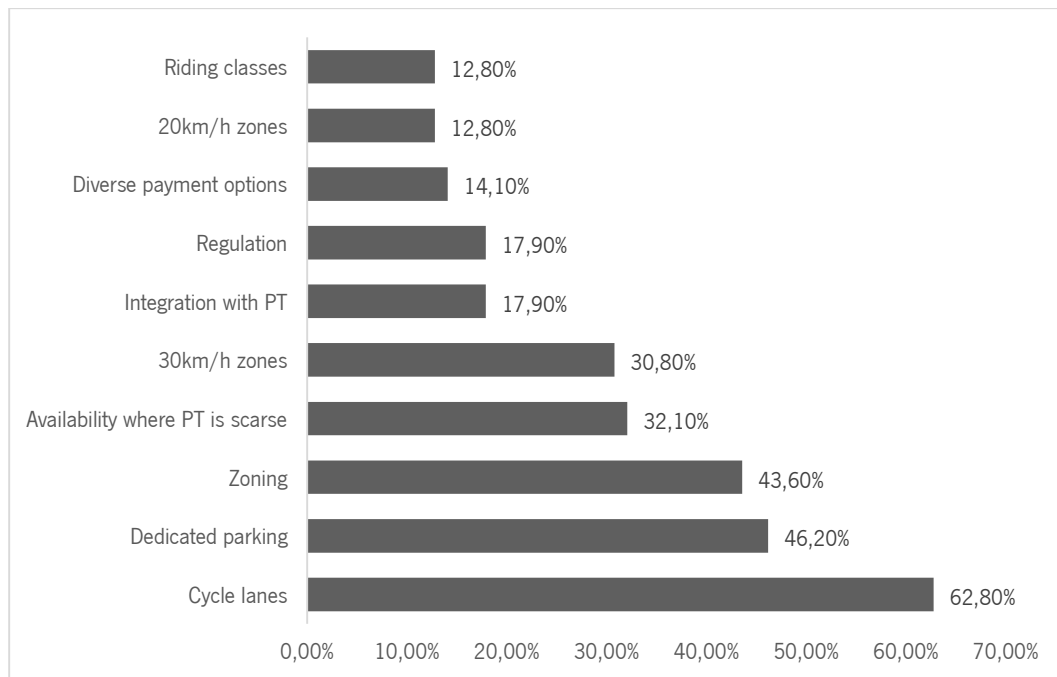


Figure 35: Intervention for users to continue using shared e-scooters

As it was expected, the offer of riding lessons was the least chosen option by shared e-scooter users. However, even if they are familiar with riding shared e-scooters, the provision of safety infrastructures is still a concern since the most chosen options are related to the increase in the protection and safety of an e-scooter rider (e.g., cycle lanes, dedicated parking, zoning).

Shared e-scooter users would also appreciate the availability of this mode of transportation where public transportation is scarce. In Braga, the bus service (the only public transportation option available) is reduced in some parishes distant from downtown. This could contribute to the spread of other sustainable transportation options for the population.

Users also appreciate the creation of low-speed zones. However, there is a distinction between implementing a 30km/h zone and a 20km/h zone. In most cases, users prefer that the speed be reduced to 30km/h, and this can be due to their already experience riding an e-scooter and consequently having more confidence in the traffic.

IV.2.3.6. The main factors for not using shared e-scooters

The non-users of shared e-scooters could also report the main reasons for not using them in Braga. In a multiple-choice question, they could choose among infrastructure and weather-related options. Yet, the

most chosen factor for not using shared e-scooters was the lack of safety (34.6%) and the preference for using other modes of transport, such as the car (33.2%) and the bus (29.3%). Figure 36 shows the choices for the factors for not using shared e-scooters.

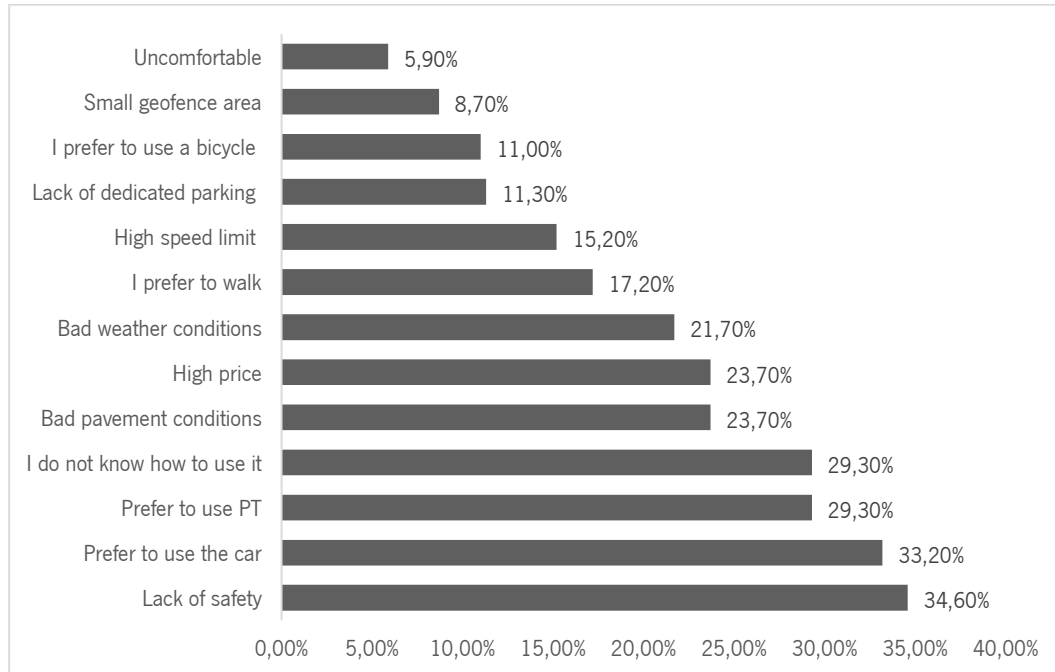


Figure 36: Main factors for not using shared e-scooters

Another critical issue that needs to be addressed regarding the factor that negatively affects the usage of shared e-scooters in Braga is that people need to learn how to use the service or ride an e-scooter. In a car-centric country, such as Portugal, where people have access to learn how to drive a car when they are eighteen years old, but they do not have the same opportunity to learn how to ride a micro vehicle, such as a bicycle and an e-scooter, it is improbable that they even consider these modes as a valid transportation option for their daily trips. Therefore, this could also cause a low preference for bicycle use (11.0%).

The current pavement conditions in Braga also disrupt the usage of shared e-scooters. The pavement's poor condition increases the trip's discomfort since it is a vehicle with little or sometimes no suspension system that allows a smooth ride. In addition, the high prices of the service can be a drawback from the usage since the usual cost of EUR 1.0 to unlock the vehicle plus EUR 0.15 per kilometer traveled can make the trip more expensive than a single bus ticket (EUR 1.55 in Braga) or even a ride healing (e.g., Uber, Bolt).

Another aspect highly considered by non-users is the weather conditions. Braga is known for experiencing heavy rain during late fall and winter, which contributes to the unwillingness to use a mode of transportation that provides no weather protection for the rider. The city of Braga experiences more than 114 days of rain during the year ($p > 1\text{mm}$) and more than 48 days during the year with precipitation of more than 10mm (IPMA, 2010). Thus, usage of shared e-scooters during rainy months can be decreased.

It is also reported that women suffer more than men due to the lack of road safety in riding this mode of transport. In addition, with the advancement of the age of respondents, one feels more unsafe being on the road on a shared e-scooter. Despite this micro vehicle, the preference for a car is also more prominent for women than men. In addition, the increase in family income is proportional to the preference for using a car instead of a shared e-scooter. The contrary is found with the preference for public transportation over e-scooters since the preference for PT decreases as the family income increases.

Women are also more affected by the lack of knowledge about how to use a shared e-scooter than men, and as the educational level of the respondents increases, the knowledge of how to ride e-scooters increases. Price affects usage on all academic levels almost equally, affecting more men than women.

IV.2.3.7. The primary interventions to start using shared e-scooter

In addition to the main factor preventing shared e-scooter usage, respondents were also asked about the interventions they find relevant to allow shared e-scooter usage. The primary choice is related to providing infrastructure that allows a safe ride, which is the implementation of cycle lanes since shared e-scooters would have a dedicated channel to be ridden on. This would reduce the interaction with cars and pedestrians when they are erroneously ridden on sidewalks. Figure 37 shows the selected interventions.

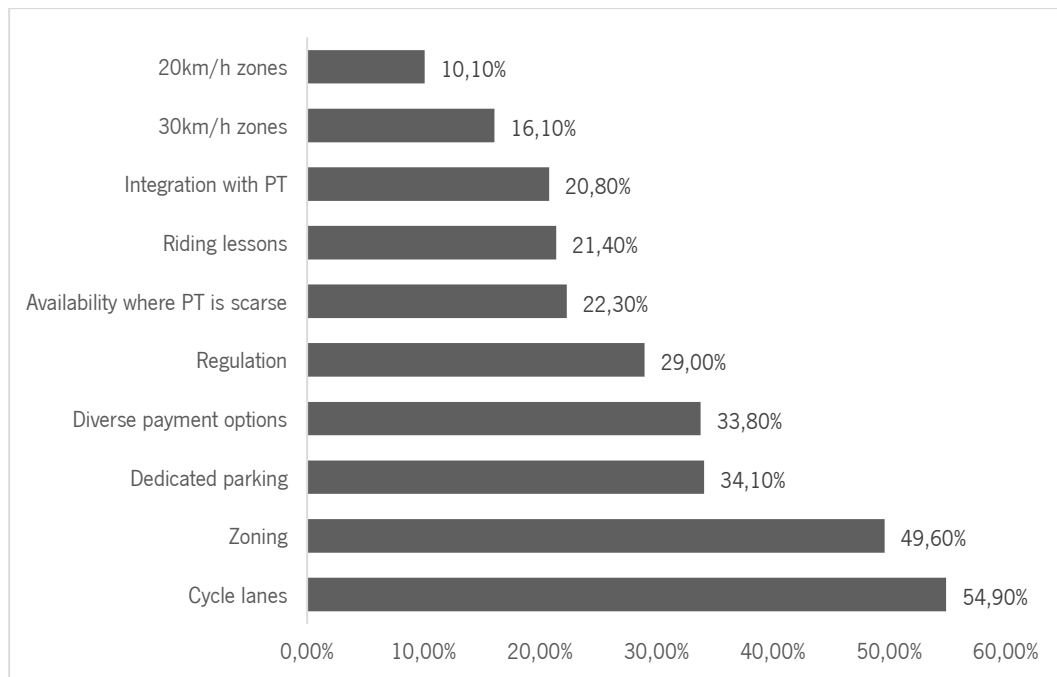


Figure 37: Main interventions for non-users to start using shared e-scooters

Non-users of shared e-scooters are also seeking to improve safety in their trips. The three most selected options were the implementation of cycle lanes (54.9%), provision of zoning (49.6%), and dedicated parking (34.1%). This aligns with the answers provided by service users, as well.

While the availability of diverse payment options is an intervention needed for non-users, this was one of the least chosen options by users of the service. Riding lessons is another contrast between users and non-users; while this was the least chosen option by users, riding lessons still play an essential role for non-users. This situation can be induced by the fact that one of the main reasons people do not use shared e-scooters is that they do not know how to ride them.

The integration of shared e-scooters with public transportation has almost the same percentage of choice between users (17.9%) and non-users (20.8%), indicating that the two groups value almost the same degree the possibility of using shared e-scooters in the first/last mile traveled, which could increase the catchment area of the bus stops.

IV.2.3.8. Main determinants of shared e-scooter usage

After analyzing the primary motivations for using shared e-scooters, their main drawbacks, and the sample profile, it was possible to audit the main determinants for using this service. The determinants are related

to the sociodemographic characteristics of the population, such as gender, age range, educational stage, employment status, family size, family monthly income, parish of origin of most of the trips, parish of destination of most of the trips, and the mode of transportation used daily. The results from the statistical correlation between the use or not use of shared e-scooters (yes or no) and the sociodemographic characteristics can be seen in Table 13.

Table 13: Pearson's chi-square for the determinants of shared e-scooter usage

Utilization determinant	Use of shared e-scooters (yes or no)			
	Pearson chi-square	Df	Fisher's exact test	p
Gender	15.698	1	<0.001	<0.001
Age	7.367	9	0.751	0.602
Educational stage	1.401	3	0.702	0.707
Employment status	1.725	3	0.722	0.668
Family size	2.113	4	0.677	0.718
Family monthly income	3.353	8	0.919	0.919
Parish of origin	26.020	1	<0.001	<0.001
Parish of destination	1.581	1	0.271	0.271
Mode of transportation	37.979	3	<0.001	<0.001

There is evidence of a significant statistical association between the utilization of shared e-scooters and the respondents' gender. This is because there is a lack of women's participation in shared e-scooter usage in Braga (critical $z = -4.0$), while men are overrepresented (critical $z = 4.0$), meaning that the adjusted residuals for women are lower than expected and higher than expected for men. Thus, gender is likely to influence the willingness to use the service because it is reported that women suffer more than men due to the lack of road safety when riding this mode of transport.

The parish of origin of the trips also represents a significant statistical association with the use or not use of shared e-scooters. Thus, if a person lives in the central area of the city, where shared e-scooter services are available, the probability of using this mode of transportation for daily trips is higher than people who live in peripheral areas. The critical z for this correlation is -5.1 , which is related to the uneven distribution of the e-scooter service in Braga since this mode of transportation is only available downtown and in its immediate surroundings.

Respondents' primary mode of transportation also influences their use or non-use of shared e-scooters. People tend not to use the service if they have access to a car (critical $z = 2.5$, meaning that the adjusted

residual for this mode of transportation is higher than expected for non-users of shared e-scooters) or public transportation (critical $z = 3.9$, meaning that the adjusted residual for this mode of transportation is higher than expected for non-users of shared e-scooters). On the other hand, people tend to use shared e-scooters if they need to walk (critical $z = 4.7$, meaning that the adjusted residual for this mode of transportation is higher than expected for users of shared e-scooters).

However, shared e-scooters can act as a mode of transportation that attends to the needs of people from multiple family sizes, incomes, employment statuses, and educational stages since there is no evidence of a significant statistical association between using or not using e-scooters and these determinants.

Respondents tend to use shared e-scooters regardless of their family's monthly income. This can be influenced by the fact that most respondents are students who depend on their parents' incomes to pay for transportation options. Also, most respondents earn more than EUR 1,501, which is higher than the average income in Braga, which is EUR 1,146 (Instituto Nacional de Estatística, 2022a).

In addition, the employment status of the population shows no significant statistical association with the use or not use of shared e-scooters in Braga, which shows that students, employees, unemployed people, and self-employed people have the same willingness to use this mode of transport, which is also in line with the work of Mitra & Hess (2021).

IV.2.3.9. Representativeness of different sociodemographic groups in shared e-scooter usage

This section correlates the sociodemographic profiles of users and potential users (i.e., non-users who would start using shared e-scooters if the service were improved) with the sociodemographic profile of the population in Braga (Instituto Nacional de Estatística, 2022b). For this, the chi-square goodness of fit is used to determine whether the sociodemographic characteristics of users and potential users are similar to the sociodemographic characteristics of the population of Braga. The aim is to assess whether the general population is represented in the service's usage.

Among current users ($N = 78$), statistical observations show that shared e-scooters do not provide equity services for the diverse population of Braga (Table 14). Regarding gender differences, women are underrepresented compared to men since the data distribution from shared e-scooter users is not consistent with the distribution of the data from the 2021 census. In this case, a higher representation of

women was expected among service users, as the number of observations from the survey for women ($N = 23$) was lower than expected to represent the population of Braga ($N = 39.8$).

Table 14: Chi-square goodness of fit test for shared e-scooter users ($N = 78$)

Sociodemographic characteristics	Chi-square Goodness of Fit	Df	p
Gender	14.932	1	<0.05
Age	98.288	3	<0.05
Educational level	18.016	2	<0.05
Employment status	122.855	1	<0.05

The correlation of education level shows that people with higher education are overrepresented, while people with lower educational levels are underrepresented. In this case, the number of observations of respondents who completed their undergraduate studies ($N = 27$) was higher than expected to represent the population of Braga ($N = 14$). In comparison, the number of observations for people who have completed their high school degree ($N = 42$) is lower than the number of observations expected for the population of Braga ($N = 58$).

The professional status of the population is also another aspect of inequity among shared e-scooter users. Students are the most prominent group of people served (observed $N = 58$, expected $N = 17.4$), while unemployed people (i.e., people with reduced economic means) are left behind.

When potential users are added to the total sample in Braga ($N = 433$), the representation of the general population in the usage of shared e-scooters somewhat changes, but this mode of transportation is still deficient in enabling equitable service across the population (Table 15). Interestingly, if potential users start riding shared e-scooters in Braga, gender differences will decrease as more women begin riding this micro vehicle. Considering the improvement in gender representativeness, men and women would have shares of almost 50% in usage, as the number of observations for men is $N = 207$, and the expected number of observations to represent the population of Braga would be $N = 200.4$. The number of observations for women is $N = 214$, and the expected number of observations for this gender in Braga would be $N = 220.4$.

Table 15: Chi-square goodness of fit test for shared e-scooter users and potential users ($N = 433$)

Sociodemographic characteristics	Chi-square Goodness of Fit	Df	p
Gender	0.415	1	0.519

Sociodemographic characteristics	Chi-square Goodness of Fit	Df	p
Age	431.799	3	<0.05
Educational level	70.225	2	<0.05
Employment status	639.346	3	<0.05

However, shared e-scooters would continue providing an inequitable service across all other socioeconomic groups surveyed. Regarding the age of users, people from 20 to 34 would still be overrepresented since the number of observations for this group is $N = 228$, and the expected number of observations in Braga would be $N = 77.6$. People 35 years old and above are underrepresented because the expected number of observations for Braga would be $N = 100.1$, and the actual number of observations was $N = 54$.

In this scenario, users' educational levels continue to over represent people with high academic levels, mainly people who graduated from the university and pursued a master's or doctoral degree. Respondents who concluded their undergraduate studies have a number of observations of $N = 130$, and people with master's or doctoral degrees have a number of observations of $N = 61$, while the expected number of observations for Braga would be $N = 76.8$ and $N = 37.4$, respectively.

Shared e-scooters still underserve people at an economic disadvantage or unemployment, while students are the most prominent users. In this case, the observed number of unemployed people is $N = 6$, and the expected number of observations for the population of Braga would be $N = 18.2$.

It is essential to mention that the increase in potential users is due to some expected changes in providing shared e-scooters in Braga. Nevertheless, more efforts need to be made to increase equity issues through other measures, such as the ones mentioned by respondents of the survey, which includes the implementation of more dedicated infrastructure (e.g., cycle lanes), which could influence road safety perception, as well as the creation of specific zones where shared e-scooters, and micromobility in general, have priority over cars, and implement other payment methods other than credit cards.

IV.2.4. Results from the RP survey for the university student sample

To better understand how young users perceive shared e-scooter services, the same survey was deployed in Braga in the spring of 2022 among university students. The survey's main objectives are to assess the

perception of sustainability of shared e-scooter services among university students and how regulation could affect this type of user's usage of this service.

IV.2.4.1. Profile of the respondents

The total number of answers retrieved from the survey is 376, and the prevailing age range of the respondents is from 20 to 24 years of age. Of all enquired students, 58% are female, 39% are male, and 3% preferred not to say their gender. Their average family monthly income ranges between EUR 1,000 to EUR 1,500, corresponding to the average monthly income of families in Portugal (Instituto Nacional de Estatística, 2022a). The respondents' main modes of transportation are private cars (36%), public transportation (35%), and walking (27%). The profile of the respondents and the student body of the University of Minho in Braga can be seen in Table 16.

Table 16: Sample description for university students

Category	Subcategory	N Sample	% Sample	% University
Gender	Female	218	57.8%	60.1%
	Male	146	38.7%	39.9%
	Other	2	0.5%	-
	Prefer not to say	11	2.9%	-
Age	Up to 19 years old	148	39%	26%
	20-24 years old	181	48%	45%
	25-29 years old	21	5.6%	12%
	30-34 years old	12	3.2%	5%
	35-39 years old	6	1.6%	4%
	40-44 years old	4	1.1%	3%
	45-49 years old	1	0.1%	2%
	50-54 years old	3	0.8%	1%
	55-59 years old	0	0%	1%
	Above 60 years old	1	0.3%	0%
	Up to EUR 665	17	4.5%	-
Household monthly income	EUR 666 – EUR 1000	38	10.1%	-
	EUR 1001 – EUR 1500	66	17.5%	-
	EUR 1501 – EUR 2000	36	9.5%	-
	EUR 2001 – EUR 2500	28	7.4%	-
	EUR 2501 – EUR 3000	15	4.0%	-
	EUR 3001 – EUR 3500	7	1.9%	-
	EUR 3501 – EUR 4000	3	0.8%	-
	Above 4000	6	1.6%	-
The main mode of transportation	Walking	103	27.3%	-
	Private car	135	35.8%	-
	Public transport	130	34.5%	-

Category	Subcategory	N Sample	% Sample	% University
The main mode of transportation	Micromobility (bicycle or e-scooter)	4	1.1%	-

The sample of 376 students statistically represents the wider University population (N = 15,350). However, data on household income and the main mode of transportation used by students were not available. Moreover, the sample used in this research work is aligned to represent the gender and age distribution of the University's student body evenly.

IV.2.4.2. University students' perception on shared e-scooter usage and sustainability

Of all survey respondents in Braga, 86% do not use the service, while only 14% use shared e-scooters regularly. The main reasons for using or not using shared e-scooters in Braga (Figure 38) show that students prefer to displace in other modes of transport, such as public transportation and private cars. Also, the need for knowledge on using a shared e-scooter (digital unlock system, online payment option, how to ride the vehicle) and insecurity on the road lead young students to avoid this shared micro vehicle.

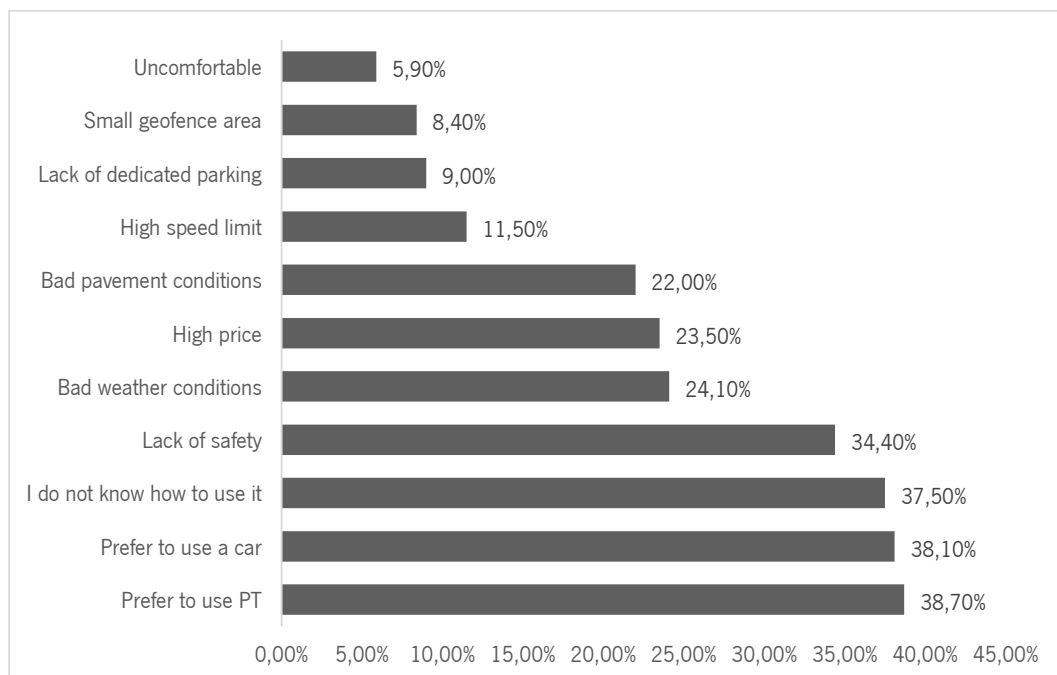


Figure 38: Main reason for university students to not use shared e-scooters

Moreover, Pearson's chi-square tests were performed to acknowledge how the main reasons for not using shared e-scooters are affected by different socioeconomic groups. The results presented in Table 17 show a statistical correlation between the gender of the non-user and the feeling of lack of road safety, as well

as the prevention of shared e-scooter usage due to not knowing how to use the vehicle. It is possible to say that young women do not use shared e-scooters because they feel unsafe due to the lack of dedicated infrastructure and do not know how to use an e-scooter compared to men (Table 18).

Table 17: Chi-square test between the main reasons for not using shared e-scooters and sociodemographic characteristics of non-user university students

Sociodemographic characteristics	Reason for not using e-scooter	Statistical results			
		Pearson chi-square	Df	Fisher's exact test	p
Gender	Prefer to use PT	1.366	1	0.275	0.243
	Prefer to use a car	0.495	1	0.542	0.482
	I do not know how to use it	22.631	1	0.000	0.000
	Lack of safety	3.826	1	0.033	0.050
Age	Prefer to use PT	13.769	8	0.061	0.056
	Prefer to use a car	9.526	8	0.321	0.280
	I do not know how to use it	11.424	8	0.134	0.145
	Lack of safety	12.329	8	0.085	0.106
Family monthly income	Prefer to use PT	9.059	8	0.338	0.342
	Prefer to use a car	6.168	8	0.583	0.648
	I do not know how to use it	3.174	8	0.928	0.932
	Lack of safety	7.555	8	0.495	0.494
Mode of transport	Prefer to use PT	73.174	5	0.000	0.000
	Prefer to use a car	50.138	5	0.000	0.000
	I do not know how to use it	6.897	5	0.226	0.206
	Lack of safety	4.003	5	0.642	0.573

Table 18: Critical z for gender considering reasons for university students not to use shared e-scooters

Reason for not using e-scooter		Gender	
		Male	Female
Lack of safety	Observed	30	76
	Expected	37.8	68.2
	Critical z	-2.0	2.0
Do not know how to use it	Observed	21	92
	Expected	41.3	72.7
	Critical z	-4.8	4.8

On the other hand, the fun aspect of the shared e-scooters and the possibility of making a quick ride (i.e., e-scooters enabling fast access to activities, places, and destinations) are the two main reasons students

use this mode of transport. The possibility of making less physical effort in trips is also appealing, as well as the usage of shared e-scooters when public transportation frequency is reduced on weekends and late at night (Figure 39).

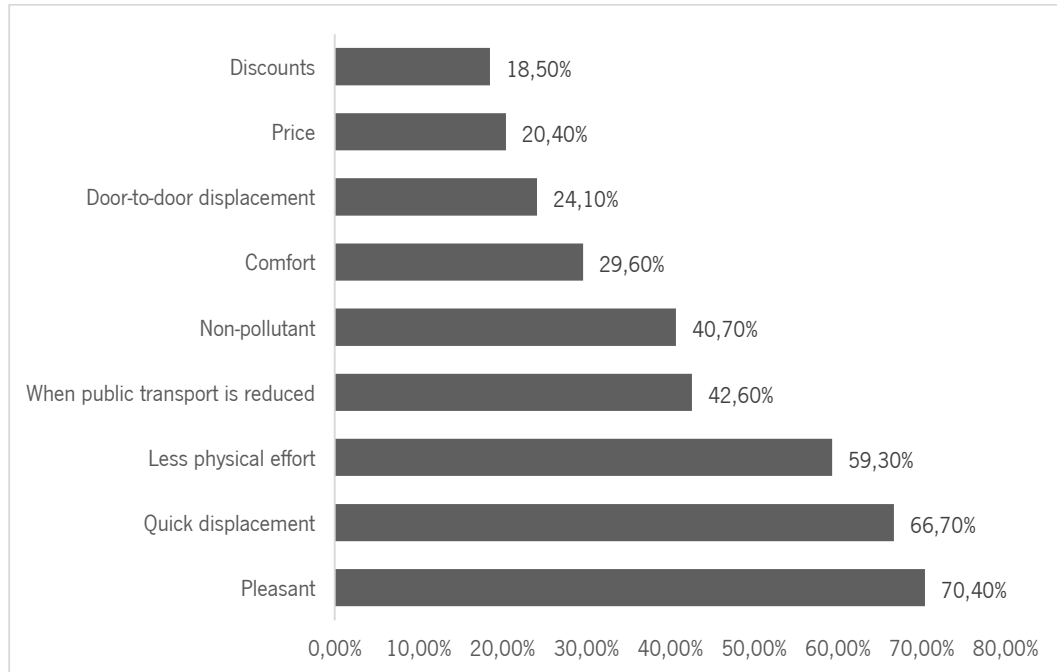


Figure 39: Main reasons for university students to use shared e-scooters

Users and non-users also reported that some changes need to be made in providing shared e-scooter services in Braga. Zoning of the city (creation of areas where micromobility and active mobility have priority over cars), implementation of more dedicated infrastructure (e.g., cycle lanes), and creation of more parking spots for e-scooters would make non-users start using the service (70%), as well as keep the current users (85%).

When asked about the sustainability of the shared e-scooter service, more than 98% of respondents said they consider shared e-scooters a sustainable mode of transport. Students in Braga stated that they believe this mode of transportation can help in decreasing the emission of greenhouse gasses into the atmosphere (83%), support the promotion of resilient urban mobility (85%), as well as the sustainable usage of urban public spaces (65%). On the other hand, respondents said they believe that shared e-scooters do not help in promoting gender equity (52%), as well as equity among different sociodemographic groups (35%). The sustainability perception data were correlated with the

socioeconomic characteristics of respondents to assess how answers are affected by the respondent's situation. Table 19 shows the results from the Mann-Whitney and H Kruskal-Wallis tests performed.

Table 19: Statistical correlation between perception of sustainability and sociodemographic characteristics of university students

Sociodemographic characteristic	Type of test		Df	p
	Mann-Whitney	H Kruskal-Wallis		
Gender	157.5	-	-	0.003
Age	-	2.925	3	0.403
Family monthly income	-	4.441	7	0.731
Mode of transportation	-	8.381	7	0.300

Gender affects respondents' perception of the sustainability of shared e-scooters. This relates to the gender differences in green consumption since women are more concerned with the ecological impacts of the products and services they purchase and use, and it is extended to young ages as well (Zhao et al., 2021). On the other hand, age, monthly income, and the current mode of transportation used by respondents do not affect their sustainability perception of shared e-scooters. The perception of sustainability goes through the social, environmental, and economic spheres. Respondents believe that gender equity and social issues are not solved or decreased by implementing shared e-scooters.

IV.2.4.3. University students' perception of shared e-scooter regulation

In the next part of the survey, respondents had to evaluate how regulation could improve shared e-scooter usage in Braga. Respondents stated that the presence of areas where micromobility and active mobility have priority over cars could highly improve shared e-scooter usage. Circulation in coexistence zones (i.e., where priority is given to pedestrians and micro vehicles) (59%), as well as the circulation in areas with controlled speed for cars (44%), are seen as the main infrastructural changes that could lead to the increase in shared e-scooter usage in Braga. On the other hand, measures to restrain shared e-scooters from only circulating in cycle lanes are perceived as a factor that would make dwellers stop using the service (54%).

Respondents also evaluated regulations that involved the behavior of riders. The restriction on the usage of cellphones and earphones while riding an e-scooter (43%), as well as the stipulation of only one person on the e-scooter at a time (34%), are perceived as measures that would improve shared e-scooter usage. However, helmet usage (46%) and the controlled speed of 25 km/h for all vehicles on roads (35%) are

perceived not to affect the usage. Then, it is possible to infer that for respondents, improving the regulations that directly enhance safety in the urban environment, such as zoning and giving priority to micro vehicles, are perceived by respondents to improve shared e-scooter usage since the lack of road safety is still one of the main factors leading to the avoidance of this mode of transportation in Braga.

IV.3. Stated choice experiment for commute trips

IV.3.1. Objectives of the SC experiment for commute trips

The experiment's main objective in Braga is to identify the main factors that can influence the modal shift to e-scooters in commuting trips and the expected sustainability results associated with the promotion of shared micromobility (e.g., contribute to the decarbonization of the urban mobility through reducing car travel for short trips). This objective is closely related to the following research questions of the Ph.D. research:

- RQ2: What are the drivers/determinants of shared e-scooter usage for commute and leisure trips?
- RQ3: How do transportation planning and traffic management influence the safe usage of shared e-scooters?
- RQ4: What are the impacts of shared e-scooter usage on the sustainability of the transportation system?
- RQ5: Are e-scooters more competitive than shared bicycles for short and medium-distance trips?

The results from the stated choice experiment acknowledge the possible modal shift in Braga from cars to shared e-scooters, which can be translated into environmental benefits, namely the reduction air pollutants and GHG emissions to the atmosphere. In addition, the bike-sharing program in Braga is also compared in the experiment, which can give insights into the willingness to use this mode or shared e-scooters for daily commutes.

IV.3.2. Main attributes for micromobility usage in stated choice experiments: a review of related works

Stated choice has been used as an analytical procedure in studies of travel choice. It typically predefines the characteristics of alternatives in the choice set. It seeks behavioral responses from travelers' behavior to produce empirical models for predicting travel choices and deriving travel attributes' shadow prices and values (Hensher et al., 1988). Therefore, SC experiments aim to determine the independence of different variables (i.e., attributes) on some observed outcomes (Rose & Bliemer, 2009).

According to Hensher, Rose, & Greene (2005b), an essential part of creating an SC experiment is identifying and refining a list of possible alternatives (i.e., attributes) relevant to the studied context. These attributes or alternatives can be extracted from the literature or observation (data collected in the RP

survey), which is the case of this thesis. The following review presents the main attributes used in stated choice experiments regarding micromobility usage in recent literature. It regards the usage of bicycles, e-bikes, e-scooters, and their respective shared services.

Most stated choice experiments regarding micromobility usage are related to bicycles and e-bikes. Campbell, Cherry, Ryerson, Jones, & Campbell (2014) studied respondents' willingness to switch modes to shared bicycles and e-bikes in Beijing, China. For this SC experiment, 623 adults were presented with eighteen hypothetical choices whose attributes were precipitation, temperature, air quality, congestion, presence of bike lanes, shared bicycle travel cost, and shared e-bike travel cost. In addition, to refine the answers, sociodemographic data were extracted from respondents, such as gender, age, higher education indicator, environmental concern indicator, and income level.

Two years later, Campbell, Cherry, Ryerson, and Yang (2016a) deployed another SC experiment in Beijing, China, to identify the factors influencing the choice to switch from an existing mode of transportation to bike sharing or e-bike sharing. In this case, the attributes presented to the 623 adults surveyed were precipitation, temperature, air quality, congestion, bike lanes, license plate number restriction, shared bicycle cost, and shared e-bike cost.

Lin, Wang, & Feng (2017) compared bicycles, buses, and walking in Taipei, Taiwan, to identify the relationship between shared bicycle pricing and their usage as a transfer mode from the metro. In this case, 372 metro passengers leaving or entering stations for home-based work trips were asked to choose between four different hypothetical choices that considered attributes such as the cost of the trip, trip distance, trip mode, bus service, and the existence of a bicycle facility.

Another SC experiment that tested the choice of a mode of transportation for short-distance trips (less than 2km) in a heavily polluted city was deployed by Li & Kamargianni (2018) to the population of Taiyuan, China. The attributes used to compare different modes of transportation (e.g., private car, e-bike, bus, car sharing, bike sharing, and walking) were travel time, cost, presence of parking space, parking cost, walking time to and from public transportation stations, bus frequency, and mobile app availability.

Focusing on the relevance of micromobility usage by university students and staff, Orozco-Fontalvo, Arévalo-Támara, Guerrero-Barbosa, & Gutiérrez-Torres (2018) deployed an SC experiment to identify the

variables that influence modal choice on trips respondents make to and from the University by bicycle. In this experiment, respondents had seven different hypothetical choices that comprised the following attributes: car travel time, bicycle travel time, cost, and presence of dedicated infrastructure.

In Belgium, Adnan, Altaf, Bellemans, Yasar, & Shakshuki (2019) used stated choice to identify the willingness to use a shared bicycle for the last mile of journeys through the rail. The experiment had nine different hypothetical choices with attributes regarding the cost of the trip, travel time, trip distance, presence of segregated bike lanes, rainfall, availability of other modes, temperature, and bicycle parking at the destination.

In order to better understand mode choice when micromobility services are available, namely shared bicycles, Li & Kamargianni (2019), Masoumi (2019), and Politis, Fyrogenis, Papadopoulos, Nikolaidou, & Verani (2020) deployed SC experiments in China, Greece, and the Middle East, respectively. The attributes used in the experiment were travel time, cost, walking time, parking availability and cost, bus availability, and mobile app usage.

To test the choice of a micromobility mode if there is a public transportation strike in London, UK, Manca, Sivakumar, & Polak (2019) deployed an SC experiment to compare shared taxi services, docked bike-sharing services, and dockless bike-sharing services. Civil engineering students from two different universities were given twelve hypothetical choices, each with attributes such as in-vehicle time or cycling time, cost, walking time, and weather conditions.

Since 2021, shared e-scooters have also been introduced in stated choice experiments regarding the usage of micromobility in cities. Studies from Baek, Lee, Chung, & Kim (2021), (Awad-Núñez, Julio, Gomez, Moya-Gómez, & Sastre González (2021), van Kuijk, de Almeida Correia, van Oort, & van Arem (2022), McQueen & Clifton (2022), Nikiforiadis et al. (2023b) and Yan, Zhao, Broaddus, Johnson, & Srinivasan (2023) surveyed students and public transportation users in the USA, Europe, and Asia to identify their willingness to use of this mode of transportation for last-mile trips connected to public transport. The attributes in the choice experiments focused on the travel time, cost, waiting time for public transport, public transportation frequency, walking time, and the extra cost promoted by using a new mode of transportation for the last mile traveled. In addition, Hong, Jang, & Lee (2023) used stated choice

to identify a specific mode choice for the last mile after parking a car in a shared parking lot. The attributes used were travel time, cost, shared micromobility availability at departure, and weather conditions.

The case studied by Cao, Zhang, Chua, Yu, & Zhao (2021b) comprises the usage of shared e-scooters to replace short-distance public transportation trips in Singapore, where public transportation users face several stops and transfers to make short displacements. In this case, students, white-collar workers, and tourists faced hypothetical choices with attributes such as public transportation stops, public transportation transfers, public transportation access within walking distance, public transportation fare, public transportation travel time, e-scooter travel time, and e-scooter fare.

In Paris, Gioldasis, Christoforou, & Seidowsky (2021) studied the impacts of specific human factors that influence shared e-scooter riding. For this stated choice experiment, users of shared e-scooter services faced hypothetical choice scenarios comprising attributes such as mode choice criteria (i.e., comfort, safety, cost), e-scooter use frequency, use frequency for strolling, and the primary motivation for using the service (i.e., leisure activities, services, commute, visit family)

Then, Krauss, Krail, & Axhausen (2022) deployed a stated choice experiment in Germany to identify the willingness to use shared micromobility modes (e.g., shared bicycles, shared e-scooters) for short or medium-distance leisure trips. The attributes were the length of the trip, travel time, access time, egress time, availability of the shared micro vehicle, and cost. In addition, a synthesis of the main attributes used in all foremost studies is presented in Table 20.

Besides the attributes used in stated choice experiments that value micromobility and shared micromobility as a way to complement trips as a last-mile option and the willingness to shift from current modes of transportation, some latent variables and sociodemographic information are also considered. Latent variables are regarded as further opportunities to enhance the behavioral realism of shared micromobility choices. They are represented by attitudes and perceptions on mode-choice decisions (W. Li & Kamargianni, 2019), while sociodemographic data from respondents are an essential source of explanation for the choices, as well as a way to check whether the sample collected matches known characteristics of the population of interest (Hensher et al., 2005b).

The main latent variables used in the twenty references used in this section regard the respondents' perspective on micromobility safety, management, the newness of this mode of transport, the possible positive environmental outcomes from the usage of micromobility, flexibility, convenience for short trips, operation of the micro vehicle or the app to unlock and pay for the service, trip purpose, experience using shared micromobility (e.g., involvement in accidents, smartphone usage while riding), physical activity promoted by micromobility, and traffic safety.

Besides the latent variables, all studies collected sociodemographic information from respondents. This information regards their gender, age, employment status, monthly income, educational level, if they have a mobile data plan, car ownership, bicycle ownership, possession of a driver's license, possession of a public transportation card or monthly pass, frequency of micromobility usage, and general state of health.

Table 20: Main attributes used in SC experiments for micromobility

Authors	Year	Type of Micro vehicle	Context	Attributes								
				Travel time	Cost	Availability	Weather condition	Parking	Parking cost	Dedicated infrastructure	Walking time	
Campbell et al.	2014	Shared bike, shared e-bike	Factors influencing the switch from the respondent's preferred mode to a new hypothetical mode		X		X					
Campbell et al.	2016	Shared bike, shared e-bike	Factors influencing the choice to switch from a current mode of transportation to bike sharing		X		X				X	
Lin, Wang & Feng	2017	Shared bikes	Relationship between shared bike pricing and usage as a transfer mode from metro	X	X						X	
Li & Kamargianni	2018	Shared bikes	Choice of a mode of transportation in short-distance trips in heavily air-polluted cities	X	X				X	X		X
Orozco-Fontalvo et al.	2018	Shared bikes	Identification of variables that influence inhabitant's modal choice and their perception of the trips they make by bicycle	X	X						X	
Adnan et al.	2019	Shared bikes	Factors influencing the usage of shared bicycles for the last mile of journeys through the rail	X	X	X	X	X			X	
Li & Kamargianni	2019	Shared bikes	Mode choice behavior on shared mobility services	X	X				X	X		X
Manca, Sivakumar & Polak	2019	Shared bikes	Choice of shared bikes if there is a public transportation strike	X	X		X					X
Masoumi	2019	Shared bikes	Explain the causality of urban travel mode choice			X					X	
Politis et al.	2020	Shared bikes	Mode choice between current mode and shared bicycle	X	X							X
Cao et al.	2021	Shared e-scooters	To what extent shared e-scooters can replace short-distance trips made by public transport	X	X							X

Authors	Year	Type of Micro vehicle	Context	Attributes								
				Travel time	Cost	Availability	Weather condition	Parking	Parking cost	Dedicated infrastructure	Walking time	
Baek, Lee & Kim	2021	Shared e-scooters	How people value shared e-scooters as a last-mile mode of transportation	X	X							X
Gioldasis, Christoforou & Seidowsky	2021	Shared e-scooters	Impacts of specific human factors on e-scooter riding		X							
Awad-Núñez et al.	2021	Shared bikes, shared e-scooters	Respondent's willingness to use and pay for public transportation and shared e-scooters given a set of Covid-19 safety measures			X						
van Kuijk et al.	2022	Shared bikes, shared e-scooters	Preference for shared modes as first and last mile connection in local public transport	X	X							
Krauss, Krail & Axhausen	2022	Shared bike, shared e-scooter	Willingness to use shared modes for short or medium-distance leisure trips	X	X	X			X			
McQueen & Clifton	2022	Shared e-scooters	Willingness to take multimodal (PT and e-scooter) trips to the university	X	X					X		
Hong, Jang & Lee	2023	Shared bikes, shared e-scooters	Mode choice for the last mile after parking a car in a shared parking lot	X	X	X	X					
Nikiforiadis et al.	2023	Shared e-scooters	Willingness to use shared e-scooters for intermodal trips	X	X							
Yan et al.	2023	Shared e-scooters	Enhancement of public transportation by e-scoot and ride option	X	X							

IV.3.3. Stated choice design for commute trips

The data collected in the literature review on stated choice experiments regarding the usage of micromobility in cities, as well as the results from the revealed preference survey in Braga, allows better analysis and refinement of the structure and the attributes that can be used in the SC experiment in Braga for shared e-scooters.

IV.3.3.1. Context for the stated choice experiment for commute trips

In order to increase the respondents' familiarity with the context of the stated choice experiment, a well-known route in Braga was chosen. This route is where respondents can experience the changes in their commute according to the attributes and attribute levels of the experiment.

The route connects Braga's train station and the University of Minho. It is 4.5 km long and composed of Caires Street, Conde Dom Henrique Avenue, Imaculada Conceição Avenue, João XXI Avenue, and João Paulo II Avenue (Figure 40).

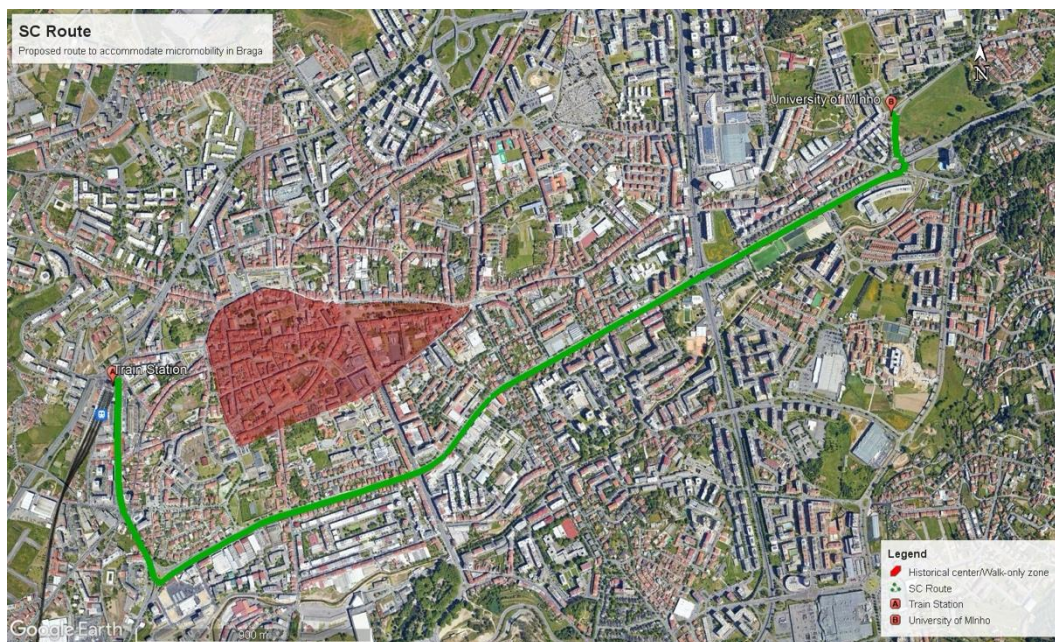


Figure 40: The selected route for the stated choice experiment for commute trips (own author)

This route was also chosen because it has the potential to be a direct connection from the train station to the University of Minho by micromobility. Currently, shared e-scooters and shared e-bikes have restrictions on using this route due to the high speeds allowed for cars. The geofence strategy allows

shared micromobility vehicles to reach the maximum speed of 6 km/h on the streets that compose the route selected.

The possibility of creating a green route in this very same location would allow residents to be displaced safely from two important trip generator hubs in Braga. This would also contribute to generating equity in this area's public space since the redistribution allows different types of users to use it.

The context of the experiment also regards the adoption of a BUS lane (Bus Rapid Transit – BRT) to increase the realism of the choice experiment since the city of Braga has plans to implement a rapid bus lane that connects the two hubs studied here, namely the train station and the University of Minho.

The current state of the route prioritizes private vehicles for displacements. Imaculada Conceição Avenue, João XXI Avenue, and João Paulo II Avenue have five to six car lanes, with no dedicated infrastructure for buses or micromobility. In addition, there is a lack of accessibility on the route since pedestrians can only cross the roads using overpasses and tunnels (Figure 41).



Figure 41: Current state of João Paulo II Avenue (own author)

Thus, the creation of a green route for micromobility and the implementation of a BUS lane in the route selected to connect the train station to the University of Minho would allow for a better distribution of

public space and the support for the use of more sustainable modes of transport, therefore reducing the modal share of private cars in the city of Braga.

IV.3.3.2. Alternatives, attributes, and attribute levels

To compare the likelihood of using different modes of transportation in Braga, namely private cars, buses, shared e-scooters, and shared e-bikes, some attributes are selected to constitute the stated choice experiment. Travel time and the cost of the trip are crucial elements that need to be considered in this type of experiment. The following attribute selected is the availability of dedicated infrastructure (Adnan et al., 2019; Campbell et al., 2016b; Lin et al., 2017; Masoumi, 2019; Orozco-Fontalvo et al., 2018), which is corroborated by the results from the revealed preference survey with non-users of the services since the implementation of cycle lanes and zoning is likely to increase the number of potential users of shared e-scooters in the future in Braga.

In addition to the increased safety for shared micromobility users promoted by the implementation of dedicated infrastructure and zoning, employing intelligent sensors in the micro vehicle would be an asset to detect and inform riders of dangerous riding contexts. The technology for Dangerous Riding Detection (DRD) has already been implemented in Canada, Australia, and the United Kingdom, where e-scooters have this newly developed technology that allows high accuracy location, rapid geofence detection, and an array of multi-function sensors that detect unsafe behavior. The sensors monitor real-time dangerous habits for riders, such as sidewalk riding, aggressive swerving, skidding, tandem riding, and curb jumping (Onag, 2021a) (Figure 42).

The implementation of an obstacle detection system in shared e-scooters and e-bikes in Braga, as it has been made in the countries mentioned above, would improve the awareness of riders for the most common dangers that provoke injuries among the users of this mode of transportation (Nikolaj et al., 2019; Ragot-Court et al., 2021)

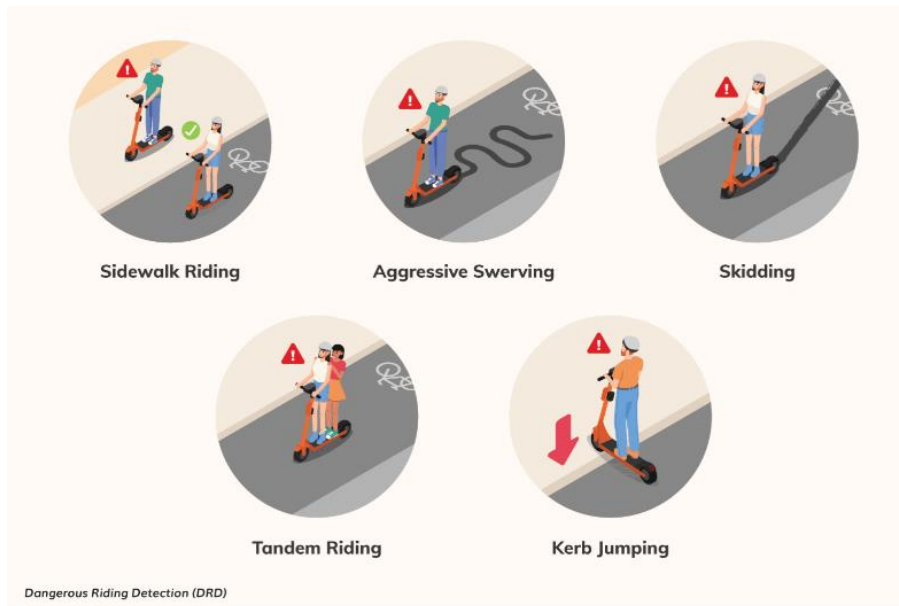


Figure 42: Dangerous riding sensors in e-scooters (Onag, 2021b)

In addition, the provision of onboard Wi-Fi in buses is seen as a technological advancement that increases the quality of the service provided to the population (Rupprecht Consult (editor), 2019). This technology has already been used in some cities, such as Oxford, to support urban mobility principles (Department for Transport, 2020). Wi-Fi as an attribute in stated choice experiments has already been used to access users' preferences for bus services, according to studies performed by Chalak, Al-Naghi, Irani, & Abou-Zeid (2016).

Therefore, the stated choice experiment deployed in Braga is composed of four different attributes that are relevant according to the literature and the data collected in Braga through the revealed preference survey, and they are:

- Travel time;
- Travel cost;
- Presence of dedicated infrastructure;
- Presence of technology (i.e., the presence of Wi-Fi in buses and the presence of DRD technology in shared e-scooters and e-bikes).

The four attributes mentioned above were used in four alternatives to provide the population with a realistic stated choice experiment. Each attribute has two or three different levels of attributes, as they encompass the current situation of the modes of transportation and other hypothetical situations. The

trips were considered to be 4.5 km long, which comprises the distance between the Braga's train station and the University of Minho campus in Gualtar.

- Car

For this Stated Choice experiment, the travel time and cost of current commute trips are considered the same as those of private cars. The trip in a private vehicle between the train station and the University of Minho campus in the selected route takes 8 minutes using Google Maps (© Google) and costs 3.50 EUR. The cost of the private car trip is measured according to the reference for a Volkswagen Golf 1.0, estimated to be EUR 0.83 per km traveled, which was also used in the study by Gössling, Kees, & Litman (2022). The cost per kilometer traveled comprises private costs (e.g., vehicle depreciation, operating costs, fixed costs, repairs, and maintenance) and social costs (e.g., health costs, infrastructure, subsidies, and environmental costs). The price of the reference level is estimated to be the cost of a 4.5 km long trip, which comprises the route selected for the stated choice experiment.

- Bus

The travel time for a bus to depart from the train station and arrive at the University of Minho through the selected route is 15 minutes on Google Maps (© Google), a base level for the experiment. Then, level 3, which represents the optimal condition for the bus to travel between the train station and the University of Minho, counts for the travel time in a dedicated infrastructure on an arterial road (Hook & Wright, 2017). Level 2 represents a mid-point between the most extended trip versus the quickest trip scenario.

The base scenario for the bus trip cost represents the pre-paid single-trip ticket, which costs EUR 0.75 in Braga. Level 2 represents the daily cost of bus usage for adults who pay for the monthly bus pass, which means a decrease in the trip cost for the stated choice scenario (TUB, 2023). The last level for this attribute presents the bus fare with no cost for the population to incorporate the Sustainable and Smart Mobility Strategy launched by the European Commission (European Commission, 2020b) as well as the new trend of free public transportation already taking place in Luxembourg, Malta, Hasselt (Belgium), Tallinn (Estonia), Dunkirk (France), and Cascais and other cities in Portugal.

Technology in buses refers to providing Wi-Fi service to the population. In this case, there are only two attribute levels: the existence or nonexistence of Wi-Fi in the bus.

- Shared e-scooter

Braga's average travel time to travel 4.5 km on a shared e-scooter is 25 minutes (according to the shared e-scooter trip data from 2022), representing this attribute's base level. Level 3 represents the time needed for an e-scooter to travel the selected route in a dedicated infrastructure with a 25 km/h speed (highest allowed speed for shared e-scooters in Braga), and level 2 is an average of the two mentioned levels with a rounding on the number to be easier for respondents understanding.

The price per trip corresponds to EUR 0.50 to unlock the vehicle plus EUR 0.18 per minute traveled, representing the weighted mean of the prices to ride the e-scooters in the two companies that offer the service in Braga, considering that the prices charged are different. The cost is weighted in that more than 70% of the trips in 2022 were made by one of the companies' vehicles and only 30% by the other company. The prices for the three levels represent the correlation to the three levels of travel time, since the cost of the shared e-scooter trip is counted per minutes traveled, and the values are rounded to facilitate the respondents' perception of the scenarios.

Dedicated infrastructure is also related to shared e-scooter usage since it can promote this mode of transportation and, therefore, stimulate modal shifts. The base level represents the current state of the route, which is the absence of dedicated infrastructure. Level 2 represents the possibility of having half of the itinerary covered with dedicated infrastructure, and level 3 represents the totality of the itinerary covered with dedicated infrastructure.

The presence of obstacle detectors is also evaluated to increase riders' safety and reduce the possibility of injuries. These can be present or not in shared e-scooters to warn users of nearby pedestrians, skidding, and aggressive swerving.

- Shared e-bike

Shared e-bikes present in Braga could reach speeds of up to 25 km/h. Therefore, for the sake of the experiment, the current travel time of shared e-bikes is considered the same as that of shared e-scooters. For levels 2 and 3, the decrease in travel time follows the same rate as the ones for shared e-scooters.

The cost of the trip on a shared e-bike is expected to be equivalent to the shared e-scooter. However, for shared e-bike trips, an advantage is given to the rider since, in Braga, there was a gamification program

that offers prizes to residents who use bicycles called BICIFICATION, a project co-funded by the European Union. Incorporating the “voucher” awarded to the user into the e-bike cost can give a perspective on the influence of gamification projects in supporting the advancement of micromobility modes in Braga.

The presence of dedicated infrastructure and an obstacle detector follow the same prerogatives as for shared e-scooters.

1. Summary of alternatives, attributes, and attribute levels

Table 21 summarizes the attributes and attribute levels described in the previous sections. Level 1 presents the data for the current state of the displacement in the route selected for the experiment, while levels 2 and 3 present created scenarios for the sake of the experiment.

The numbers represented between parentheses are the differences between the current travel time and travel cost (i.e., reference to the private car trip). To increase respondents' perception of the stated choice experiment, they are presented with the differences in travel time and cost to the current trip in the selected route.

Table 21: Attributes and levels of attributes for the stated choice experiment for commute trips

Attribute	Level	Mode of transport			
		Private car	Bus	Shared e-scooter	Shared e-bike
Travel time (min)	1	8	15 (+7)	25 (+17)	25 (+17)
	2		12 (+4)	15 (+7)	15 (+7)
	3		9 (+1)	10 (+2)	10 (+2)
Travel cost (EUR)	1	3.5	0.75 (-2.75)	5 (+1.5)	5 (+1.5)
	2		0.50 (-3)	3.5 (Same)	3.5 + Voucher (Same)
	3		0 (Free)	2 (-1.5)	2 + Voucher (-1.5)
Presence of dedicated infrastructure	1	-	None	0%	0%
	2	-	BUS lane	50%	50%
	3	-	-	100%	100%
Presence of technology	1	-	-No	No	No
	2	-	-Yes	Yes	Yes

The levels of attributes consider that specific actions are taken to improve modes other than cars in Braga, such as implementing dedicated infrastructure for buses, which translated into the BUS lane where this type of vehicle has priority. In addition, cycle paths can also be implemented to improve trips by

shared e-scooters and e-bikes because, according to the Portuguese Road legislation, bicycles and e-scooters should be ridden on cycle paths (Republica Portuguesa, 2020).

IV.3.3.3. Experimental design

The experimental design for the SC experiment was created using the software Ngene (ChoiceMetrics, 2021b). The design considered the four attributes and attribute levels selected for this experiment. The interaction in the above software resulted in 36 scenarios to assure orthogonality. However, as 36 is an excessive number of scenarios to be evaluated by respondents, they were divided into three blocks of 12 scenarios. Although the 12 scenarios presented for each respondent are not orthogonal among themselves, the 36 scenarios altogether are, and they will be used to estimate the logit model for data reduction.

IV.3.3.4. Pilot survey

The pilot survey refers to testing the questionnaire on a small sample of respondents to identify and correct potential problems. The pilot survey for the current stated choice experiment was conducted between October 12th and October 18th, 2023, with a sample of 50 respondents (Bateman et al., 2002b) ranging in age between 18 and 65, 46% of whom were male.

During the pilot, it was possible to detect that respondents could understand all the questions presented correctly and that, in some specific cases, it was necessary to explain what they should do to select the best mode of transportation according to the scenarios shown.

Moreover, minor changes were made in the survey to increase readability and the understanding of the questionnaire for all respondents, namely rewriting some sentences to improve respondents' understanding. These changes were made regarding respondents' comments during the pilot survey.

In addition, to improve the quality of data collection and minimize any problems understanding the content of the survey, the researcher decided to conduct face-to-face interviews, which allow probing and clarification, higher response rates, and greater sample control (Bateman et al., 2002).

IV.3.3.5. Structure of the SC survey for commute trips

This SC survey aims to identify the possible modal shift for sustainable modes of transportation in commute (Appendix B) trips. The survey started by introducing the research objectives to respondents and asking for their consent to answer the questions (Figure 43). The online Qualtrics survey was disseminated from 1 December 2023 to 12 April 2024 in downtown Braga, near the University of Minho campus, shopping malls and city parks.



Início

Estudo de Preferências de Mobilidade em Braga (viagens casa-trabalho/escola)

O presente estudo é desenvolvido no âmbito da investigação de doutoramento em Engenharia Civil entre a Universidade do Minho e o LNEC, e o seu principal objetivo é identificar os principais fatores que podem influenciar **alterações nos padrões de mobilidade para modos mais sustentáveis em viagens pendulares de curta distância em Braga.**

As opções de mobilidade sustentável consideradas para este estudo são: trotinete elétrica partilhada, bicicleta elétrica partilhada e autocarro elétrico.



Para mais informações sobre a mobilidade em Braga, clique [aqui](#).

O estudo é de responsabilidade de Gabriel Dias (id8651@alunos.uminho.pt), que pode ser contactado para esclarecer qualquer dúvida ou partilhar algum comentário.

Todas as informações coletadas pela sua participação voluntária serão tratadas de forma anónima e serão utilizadas exclusivamente para fins científicos.

Declaro ter compreendido os objetivos do estudo e aceito preencher o questionário de forma anónima, pelo que:

☐ Sim, aceito participar do estudo
☐ Não, não aceito participar do estudo

Figure 43: SC survey for commute trips (first page)

The first part of the survey collected RP information about the number of cars in the household, whether the person uses the bus service in Braga regularly or not, whether they have the monthly bus pass,

whether they have already used the shared e-scooter or e-bike service in Braga, and how likely they are to use these services connected to public transportation to fight climate change.

The second part of the survey was composed of the SC experiment. In this part, the context of the situations presented was explained, as well as the attributes respondents would face when selecting the most suitable mode of transportation for their trips based on the information presented in the cards (Figure 44). Each respondent would face twelve scenarios to choose a preferred mode of transport.

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

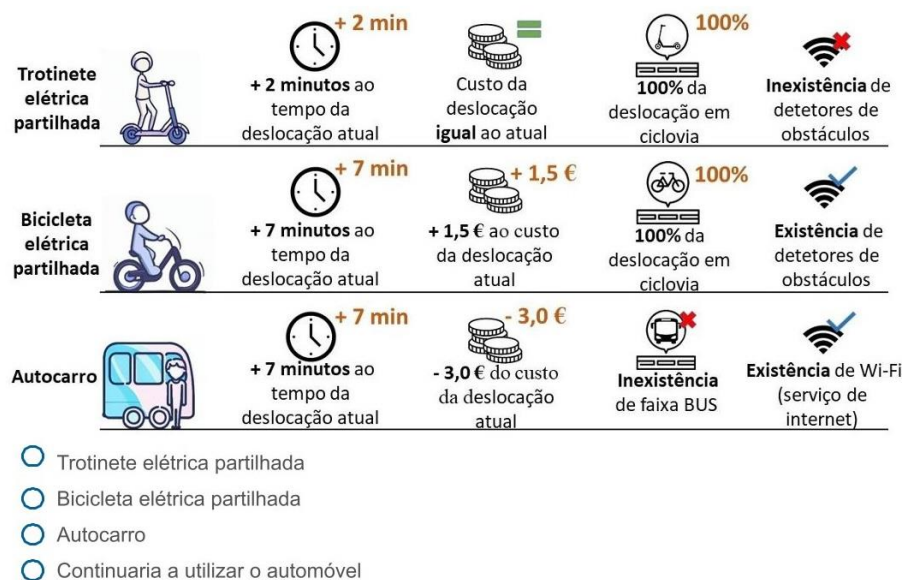


Figure 44: Example of a card presented to respondents for commute trips

Next, a sociodemographic questionnaire was presented, where respondents had to state their gender, age, professional situation (e.g., student, worker, employer), education status, monthly household income, and number of people in the household.

IV.3.4. Results from the SC experiment for commute trips

A multinomial logit (MNL) model was specified to estimate Braga's discrete choice model for commute trips. The estimation is based on the random utility maximization framework, where every respondent n of each choice task t would only choose alternative i with utility U_{int} , when $U_{int} > U_{jnt}$, $j \neq i$.

This research used the Biogeme package to estimate the models. Biogeme is a Python package written in Python and C++ that relies on the Pandas library for data management (Bierlaire, 2023). In all estimated models, the “car” and the “bus” were defined as the reference alternatives. The model with alternative-specific constants reflects the inertia effect and provided the best fit to the data. The reference scenario considering alternative-specific constants for the car and bus was reported with the highest rho square (0.201) for the model. All tables with results from the model present the maximum likelihood estimation for the model ($\mathcal{L}$), as well as the rho-square results for the model (ρ^{-2}).

The sample comprised 425 valid answers (5,100 observations) that represents the population of Braga considering a 95% confidence level and 5% margin of error. The respondents were required to be 18 years old and older and use the car as the primary mode of transportation for commute trips; therefore, the data for the population of Braga corresponds to the population that are above that age. The description of the sample can be found in Table 22.

Table 22: Sample description of the SC experiment for commute trips

Category	Subcategory	N Sample	% Sample	% Braga*
Gender	Female	217	51.1%	52.4%
	Male	203	47.8%	47.6%
	Other	2	0.4%	-
	Prefer not to say	3	0.7%	-
Age	Up to 24 years old	70	16.5%	11.4%
	25-39 years old	177	41.6%	19.2%
	40-54 years old	144	33.9%	23.6%
	55-64 years old	30	7.1%	13.9%
	Above 65 years old	4	0.9%	18.2%
Education	Up to secondary education	113	26.5%	63.7%
	Technical course	26	6.1%	0.2%
	Bachelor's or equivalent	178	41.9%	39.9%
	Master's degree	97	22.8%	5.6%
Occupation	Doctoral degree	11	2.6%	1.0%
	Students	76	17.9%	9.4%
	Employee	312	73.4%	56.8%
	Employer	19	4.5%	5.8%
	Unemployed	16	3.8%	4.7%
Family size	1 person	54	12.7%	19.5%
	2 people	117	27.5%	30.5%
	3 people	114	26.8%	24.5%
	4 people	109	25.6%	19.1%
	More than 4 people	31	7.3%	6.4%

Category	Subcategory	N Sample	% Sample	% Braga*
Household monthly income	Up to EUR 760	13	3.1%	-
	EUR 761 – EUR 1000	54	12.7%	-
	EUR 1001 – EUR 1500	106	24.9%	-
	EUR 1501 – EUR 2000	68	16.0%	-
	EUR 2001 – EUR 2500	49	11.5%	-
Household monthly income	Above EUR 2501	80	18.8%	-

*Population of Braga considering the minimum age of 18 years old (minimum age to have a driver's license and to rent an e-scooter or e-bike)

The respondents also stated that 41.6% of their households have two cars. Also, 59.1% of the respondents never use the buses in Braga, and 83.1% do not have a monthly public transportation pass. Regarding the previous usage of shared micromobility, 76% of respondents said they never used an e-scooter in Braga. In comparison, almost all respondents (97.2%) said they had not used an e-bike in the city.

The overall choice for modes of transportation in the scenarios presented showed that the preferred sustainable mode to replace the car in Braga would be the bus. Shared micromobility is still not preferred in relation to the vehicle. Figure 45 shows the modes of transportation in the stated choice experiment for commute trips in Braga.

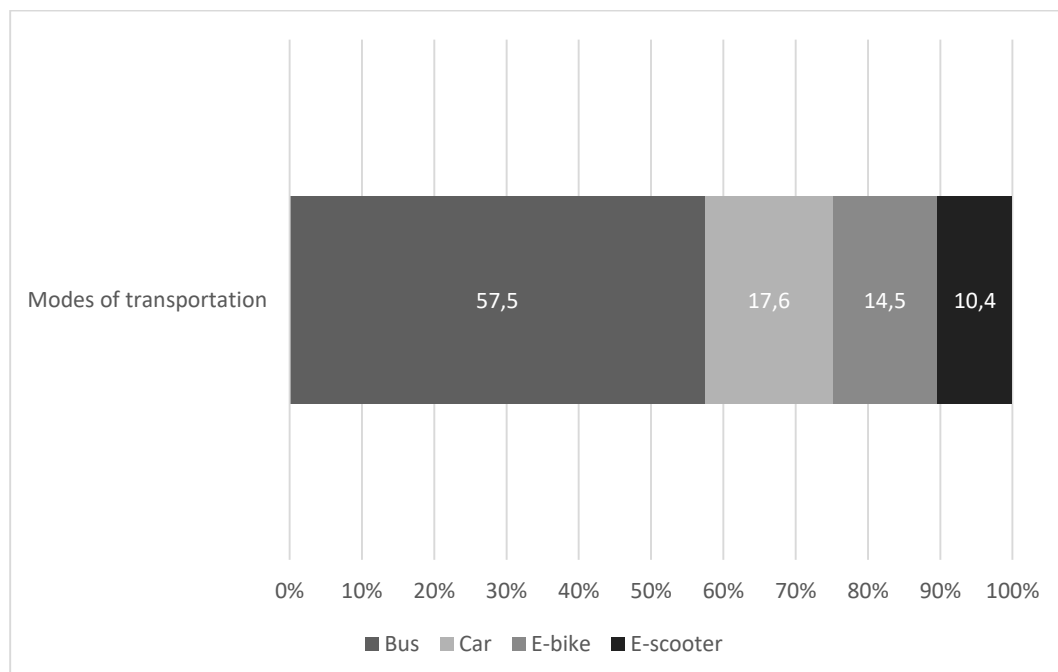


Figure 45: Choice of modes of transportation in the SC experiment for commute trips

It is possible that the bus is the preferred mode of transportation chosen by the respondents to switch from the car to achieve sustainable mobility in Braga. The bus even surpassed the statical preference to continue using the vehicle, which would not be expected due to decision inertia, which is the tendency to repeat the same previous choices (i.e., using a car) regardless of the outcome (Jung et al., 2019). Table 23 also shows the preference for buses over cars and the effects of attributes in choosing a mode of transportation in Braga.

Table 23: Base logit model for the commute SC experiment

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_BUS	1.009	0.080	12.55	0.0
ASC_CAR	-0.517	0.065	-7.89	2.88e-15
B_COST	-0.085	0.023	-3.60	3.08e-04
B_INFRA	0.004	0.000	10.22	0.0
B_TECH	0.112	0.042	2.66	7.74e-03
B_TIME	-0.076	0.005	-14.65	0.0
<i>Summary statistics</i>				
Number of observations = 5100				
$\mathcal{L}(\mathbf{O}) = -7070.101$				
$\mathcal{L}(\hat{\beta}) = -5647.564$				
$\rho^{-2} = 0.201$				

For estimation purposes and considering that using the model with the alternative-specific constants to cars and buses gave the highest rho-square values, the alternative-specific constants for e-scooters and e-bikes were normalized to zero. The estimated values for the alternative-specific constants ASC_CAR and ASC_BUS show that all else being equal, there is a preference for the bus concerning the other modes of transportation available (i.e., car, e-bike, e-scooter). As expected, both the travel time and the cost coefficients have negative signs. The higher the travel time or the cost of an alternative, the lower the related utility. The positive estimate of the infrastructure and technology coefficient (B_INFRA and B_TECH) indicates that the utility is higher when more infrastructure and technology are offered.

Next, sociodemographic characteristics are added to the investigation results to capture the heterogeneity of preferences in the population. Table 24 shows the results, considering a dummy variable (SENIOR) that identifies people who are 40 years old or older. This age frame for SENIOR was selected following the pilot results, which showed that people over 40 would preferably choose the bus in all scenarios. The base age category in the model specification was considered to be from 18 to 39.

Table 24: Logit model with the sociodemographic characteristic age

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_BUS	0.811	0.084	9.62	0.0
ASC_CAR	-0.523	0.065	-7.96	1.7e-15
B_COST	-0.085	0.023	-3.63	0.0
B_INFRA	0.004	0.0	10.3	0.0
B_SENIOR	-0.479	0.059	-8.05	8.88e-16
B_TECH	0.114	0.042	2.7	0.006
B_TIME	-0.076	0.005	-14.7	0.0
<i>Summary statistics</i>				
Number of observations = 5100				
$\mathcal{L}(\mathbf{0}) = -7070.101$				
$\mathcal{L}(\hat{\beta}) = -5614.35$				
$\rho^{-2} = 0.206$				

The estimation results for this model show a negative sign of the age coefficient (dummy variable SENIOR), reflecting that people over 40 are less likely to use shared micromobility in Braga compared to younger people. This aligns with the expectations that older people would not be willing to shift to micromobility due to the lack of experience in riding these two vehicles and the perceived high lack of safety in a two-wheeled vehicle.

The influence of the respondents' gender was also tested in the SC experiment model for commute trips in Braga. Table 25 presents the results considering a dummy variable, FEMALE, describing people who identify themselves as female. The base gender category in the model specification was considered to be the male one.

Table 25: Logit model with the sociodemographic characteristic gender

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_BUS	0.712	0.086	8.24	2.22e-16
ASC_CAR	-0.45	0.068	-6.54	6.26e-11
B_COST	-0.088	0.023	-3.76	0.0
B_FEMALE	-0.409	0.057	-7.09	1.38e-12
B_INFRA	0.002	0.0	5.34	9.19e-18
B_TECH	0.114	0.042	2.71	0.0
B_TIME	-0.073	0.005	-14.4	0.0
<i>Summary statistics</i>				
Number of observations = 5040				
$\mathcal{L}(\mathbf{0}) = -6986.924$				

Summary statistics

$$\mathcal{L}(\hat{\beta}) = -5622.743$$

$$\rho^{-2} = 0.195$$

The negative sign of the gender coefficient (referring to the FEMALE dummy variable) reflects a rejection from females towards shared e-scooters and e-bikes in Braga. This finding is aligned with the expectation considering the RP results for the city, dictated probably by safety reasons concerning these shared modes of transport, and since women usually are responsible for carrying children to school and grocery shopping, which are two activities that are enabled by modes of transportation that can carry only one person at a time, and do not have space to carry shopping bags (UN Women, 2019).

The possession of a bus monthly pass was also tested in the model to assess its effect in the usage or not usage of shared micromobility in Braga. Table 26 shows the results of the model considering a dummy variable (BPASS) determining respondents that own a bus monthly pass in Braga (i.e., TUB pass).

Table 26: Logit model with the characteristic of possession of a bus monthly pass

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_BUS	1.03	0.087	11.8	0.0
ASC_CAR	-0.476	0.068	-6.98	3.02e-12
B_BPASS	-0.152	0.055	-2.75	0.006
B_COST	-0.085	0.024	-3.53	0.0
B_INFRA	0.004	0.0	10.2	0.0
B_TECH	0.112	0.043	2.61	0.0
B_TIME	-0.077	0.005	-14.6	0.0

Summary statistics

Number of observations = 5100

$$\mathcal{L}(\mathbf{0}) = -7273.872$$

$$\mathcal{L}(\hat{\beta}) = -5697.455$$

$$\rho^{-2} = 0.217$$

The estimation results for this model show a negative sign of the pass coefficient (referring to the BPASS dummy variable), which indicates that people who own a bus monthly pass in Braga are less likely to choose shared e-scooters and e-bikes for commuting compared to people who do not own a bus monthly pass. This seems to be a plausible conclusion since bus pass owners prefer to take the bus instead of incurring extra costs when using other modes of transport.

The respondents' professions were also tested in the model to assess how this variable affects the choice of shared micro vehicles in Braga. For this, a dummy variable EMPLOYER and a dummy variable STUDENT were considered. In this model, the base category considered was to be an employee. Table 27 highlights the results from the interaction of the dummy variables in the model.

Table 27: Logit model with the sociodemographic characteristic profession

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_BUS	0.99	0.081	12.1	0
ASC_CAR	-0.519	0.065	-7.91	2.44e-15
B_COST	-0.085	0.023	-3.61	0.0
B_EMPLOYER	0.314	0.137	2.28	0.022
B_INFRA	0.004	0.0	10.2	0.0
B_STUDENT	-0.19	0.076	-2.5	0.012
B_TECH	0.113	0.042	2.68	0.007
B_TIME	-0.076	0.005	-14.7	0.0
<i>Summary statistics</i>				
Number of observations = 5100				
$\mathcal{L}(\mathbf{O}) = -7070.101$				
$\mathcal{L}(\hat{\beta}) = -5641.243$				
$\rho^{-2} = 0.202$				

The positive sign of the profession coefficient for the dummy variable EMPLOYER shows this group is more likely to use shared e-bikes and shared e-scooters in Braga than employees. This result contributes to the literature confirming the usage of shared micromobility, mainly shared e-scooters, by businesspeople who usually work in the city's central areas. On the other hand, the negative sign of the profession-related coefficient estimate referring to the dummy variable STUDENT reveals that this stratification is less likely to use shared e-bikes and shared e-scooters for commute trips (compared to employees), meaning they prefer other modes of transportation to go to classes. This can be related to the latest measures taken by the Municipality, and the public enterprise that provides buses in Braga, which started providing free monthly bus passes for students of all ages in Braga.

Next, the education status of the respondents was tested in the model to capture the heterogeneity of taste across different categories. For this, five dummy variables were used: a dummy variable (DOC) to identify people who have a doctoral degree, a dummy variable (HIGH) to identify people who finished high school, a dummy variable (MAST) to identify people who completed their master's degree, a dummy variable (MID) identifying people who have finished middle school, and a dummy variable (TECHNI)

identifying people who have accomplished a technical course. In this model, the base educational status category in the specification was considered to be the bachelor's degree. Table 28 presents the results from the model with these dummy variables.

Table 28: Logit model with the sociodemographic characteristic educational status

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_BUS	0.913	0.087	10.5	0.0
ASC_CAR	-0.523	0.065	-7.96	1.78e-15
B_COST	-0.085	0.023	-3.61	0.0
B_DOC	-0.638	0.203	-3.14	0.001
B_HIGH	-0.33	0.073	-4.49	6.99e-06
B_INFRA	0.004	0.0	10.3	0.0
B_MAST	-0.147	0.074	-1.97	0.049
B_MID	-0.042	0.305	-0.137	0.891
B_TECH	0.113	0.042	2.67	0.007
B_TECHNI	0.62	0.127	4.9	9.74e-07
B_TIME	-0.076	0.005	-14.7	0.0
<i>Summary statistics</i>				
Number of observations = 5100				
$\mathcal{L}(\mathbf{0}) = -7070.101$				
$\mathcal{L}(\hat{\beta}) = -5613.222$				
$\rho^{-2} = 0.206$				

For commute trips in Braga, it is possible to infer that people with a technical course are more likely to use shared micromobility modes compared to people with a bachelor's degree since the parameters estimate for this dummy variable presents a positive sign. Nevertheless, people with a doctorate, master's degree, high school, and middle school are less likely to use a shared e-bike or shared e-scooter for their commute trips in comparison to people with a bachelor's degree; the negative signs in the parameter estimate for these dummy variables attest to this.

When the family size is investigated to capture its heterogeneity effects in the population, four dummy variables are used: dummy variable (ONE) for a unipersonal family, dummy variable (THREE) for families with three people, dummy variable (FOUR) for families of four people, and dummy variable (MORE) for families with more than four people. In this model, the base category is a family with two people. Table 29 presents the results from the model with family-size dummy variables.

Table 29: Logit model with the sociodemographic characteristic family size

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_BUS	0.871	0.092	9.4	0.0
ASC_CAR	-0.519	0.065	-7.91	2.66e-15
B_COST	-0.085	0.023	-3.6	0.0
B_FOUR	-0.085	0.079	-1.08	0.28
B_INFRA	0.004	0.0	10.2	0.0
B_MORE	-0.252	0.12	-2.1	0.035
B_ONE	-0.088	0.098	-0.903	0.367
B_TECH	0.112	0.042	2.65	0.008
B_THREE	-0.329	0.078	-4.2	2.66e-05
B_TIME	-0.076	0.005	-14.6	0.0
<i>Summary statistics</i>				
Number of observations = 5100				
$\mathcal{L}(\mathbf{O}) = -7070.101$				
$\mathcal{L}(\hat{\beta}) = -5637.358$				
$\rho^{-2} = 0.203$				

It is possible to infer that, due to the negative signs for dummy variables ONE, THREE, FOUR, and MORE, people in these family sizes are less likely to use shared micromobility to commute in Braga compared to families with two people. It would be expected that people in bigger families would not prefer to use shared micromobility because commute trips, in this case, could involve multiple stops (e.g., a stop at school to leave children). Therefore, a shared micro vehicle would not be a suitable option. However, in Braga, people from small families (i.e., one person) would also be less likely to ride shared e-scooters and e-bikes than people in families with two people.

The last sociodemographic characteristic tested to capture the heterogeneity of taste in the population is the family monthly income of the respondents. In this case, a dummy variable (INCOME) was used to identify family monthly incomes higher than EUR 1,251, which represents a higher income than the average for the city of Braga, which is EUR 1,146 (Instituto Nacional de Estatística, 2022a). Table 30 presents the results from the model considering the dummy variable INCOME.

Table 30: Logit model with the sociodemographic characteristic family income

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_BUS	0.755	0.090	8.31	0.0
ASC_CAR	-0.553	0.07	-7.9	2.89e-15

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
B_COST	-0.088	0.024	-3.56	0.0
B_INCOME	-0.356	0.062	-5.74	9.56e-09
B_INFRA	0.004	0.0	9.94	0.0
B_TECH	0.081	0.044	1.82	0.069
B_TIME	-0.078	0.005	-14.1	0.0
<i>Summary statistics</i>				
Number of observations = 4440				
$\mathcal{L}(\mathbf{0}) = -6155.147$				
$\mathcal{L}(\hat{\beta}) = -4952.082$				
$\rho^{-2} = 0.195$				

The negative sign of the income coefficient (referring to the INCOME dummy variable) reflects that people with higher income tend to be less likely to choose shared micromobility to make their commutes compared to people with income lower than EUR 1,250. It seems a reasonable conclusion, dictated probably by the fact that higher income people would prefer to continue using their private cars to commute due to comfort reasons. When the income increases, there is a preference to continue using the vehicle, or if the mode of transportation needs to be replaced, the bus is chosen.

After the test of the sociodemographic characteristics of the sample in the model to understand how they affect the preference for micromobility and sustainable modes of transportation in Braga for commuting trips, the incremental effects of the models were compiled in Table 31.

Table 31: Incremental effects for the choice of micromobility in the commute SC experiment

Variable/Description of the interaction effect		Expected sign* (+) or (-)	Incremental effect is statistically significant	Model represents a statistical improvement
Age	Age of the respondent (senior)	✓ (-)	No	Yes
Gender	Gender of respondent (female)	✓ (-)	No	Yes
Pass	Possession of a bus pass	✓ (-)	No	Yes
Profession	Student	✗ (+)	No	Yes
	Employer	✓ (+)	Yes	
Degree	Middle school	✓ (-)	No	Yes
	High school	✗ (+)	No	
	Technical course	✓ (+)	Yes	

Variable/Description of the interaction effect		Expected sign* (+) or (-)	Incremental effect is statistically significant	Model represents a statistical improvement
Degree	Masters	✓ (-)	No	Yes
	Doctorate	✓ (-)	No	
Family size	One person	✗ (+)	No	Yes
	Three persons	✓ (-)	No	
	Four persons	✓ (-)	No	
	More than five persons	✓ (-)	No	
Income	Above 1251 EUR	✓ (-)	No	Yes

*(Ghasri et al., 2024; Nigro et al., 2024; Nikiforiadis et al., 2024)

In Braga, the effects of sociodemographic characteristics align with the available literature for commute trips. Even though students, people with high school degrees, and single-person families were expected to prefer shared micromobility, the other factors followed the expected results.

The age of the respondents (80% being 25 years old or older) also plays a key role in shared micromobility choice since it is expected that with the increase in the age of the respondents, the preference for these modes of transportation will decrease. Thus, even if the person has a high school degree, which does not mean that the person is young and live by themselves (single-person family), it does not reflect in a higher preference for commuting in shared e-scooters or e-bikes.

However, the preference for the bus as a sustainable option for commuters is also a great advantage for the city to invest in this mode of transportation to promote modal shifts. In more than 50% of cases, people would choose the bus instead of any other mode of transportation if better traffic conditions and comfort were available for the riders.

If only shared micromobility is regarded, it is seen that e-bikes overpass e-scooters in preference by respondents. Even if Braga shared e-bikes are unavailable, people would prefer this mode to e-scooters. These research findings indicate that e-bikes are preferred in relation to e-scooters for commute trips if they are available and safe conditions for riding are provided.

IV.4. Stated choice experiment for leisure trips

IV.4.1. Objectives of the SC experiment for leisure trips

The stated choice experiment for leisure trips aims to assess how different attributes can affect the choice of sustainable modes of transportation in Braga for this type of trip. The literature has evaluated the determinants of shared e-scooter usage and their implications for commuting. However, since one of the main reasons for using shared e-scooters is that they are fun and pleasant, people tend to use them for leisure trips.

Therefore, the possible modal shift from cars to sustainable modes of transport, such as shared e-scooters, e-bikes, and walking, must be studied. This stated choice experiment evaluates how different attributes in the built environment can affect the modal shift from cars. Unlike the stated choice experiment for commute trips, the experiment for leisure trips considers that the modal shift occurs in short-distance trips, for walking, shared e-scooter, or shared e-bikes compared with the car. In this case, the bus alternative was substituted for walking, since short-distance trips are considered that can be made by this mode of transportation. This stated choice experiment is closely related to the following research questions:

- RQ2: What are the main drivers/determinants of shared e-scooter usage for commute and leisure trips?
- RQ3: How do transportation planning and traffic management influence the safe usage of shared e-scooters?
- RQ4: What are the impacts of shared e-scooter usage on the sustainability of the transportation system?
- RQ5: Are shared e-scooters more competitive than shared e-bikes for short and medium-distance trips?

IV.4.2. Walking as a mode of transportation

Of all journeys made daily in European Union countries, 20-40% travel by bicycle or on foot (European Commission, 2023). The average length of walking trips varies from just under 1 km to 2.8 km. However, the extent of coverage of short trips may differ from country to country (European Commission, 2023). Walking is a way of traveling used mainly for two purposes: short trips to specific destinations such as

shops when there is a probability not to carry too much weight, and leisure trips where the walking in itself is the purpose (Hydén et al., 1999).

Walkways or sidewalks must comply with certain levels of service in order to promote walkability in cities. Thus, good walking networks should comply with five different standards, which are (Transport for London, 2005):

- **Connectivity:** walking routes should connect different areas with key “attractors,” such as public transportation stops, schools, work, and leisure destinations. These routes should connect at the local and district levels, forming a comprehensive network;
- **Convivial:** walking routes should be pleasant and allow social interaction between people, including other road users. They should be safe and inviting, with diverse activity and continuous ground-level interest;
- **Conspicuous:** routes should be clear and legible, if necessary, with the help of signposting and waymarking;
- **Comfortable:** walking should be enjoyed through high-quality pavement surfaces, attractive landscape design and architecture, and as much freedom as possible from the noise and the fumes, and harassment arising from proximity to motor traffic. Opportunities for rest and shelter should be provided;
- **Convenient:** routes should be direct and designed for the convenience of those on foot. This should apply to all users, including those whose mobility is impaired. Road crossing opportunities should be provided as of right and located following desired lines.

Sidewalks should also be able to accommodate varied uses. Their design should provide the space required for various types of pedestrian activities, which can impact the placement of urban furniture or even the pedestrian circulation capacity. Some of the aspects that need to be considered when planning a walking route are i) the proximity to shops – wider width to accommodate pedestrians with shopping bags; ii) the weather – usage of umbrellas that would require more personal space for each pedestrian; iii) luggage, stroller – routes that accommodate the luggage or stroller used by pedestrians; iv) proximity to older adults housing – wider width to accommodate personal mobility devices (Gomes et al., 2020).

The context where the sidewalk is inserted is a crucial figure in establishing its complexity and layout. The design of the facades of buildings, as well as their heights and architectural details, should contribute to

breaking down the scale and rhythm of the block, therefore making walking distances feel shorter (Global Designing Cities Initiative, 2007). Another relevant opportunity that needs to be considered is incorporating trees in sidewalks. Greenery should be provided on streets surrounding parks, large boulevards, central urban areas, and local neighborhoods (Global Designing Cities Initiative, 2007).

The minimum width for sidewalks should also be planned considering the existence of pedestrians in the infrastructure and urban furniture. The effective width corresponds to the space for pedestrians to move around and carry out activities (Seco, Macedo, & Pires da Costa, 2008). Figure 46 illustrates the definition of the effective width of sidewalks.

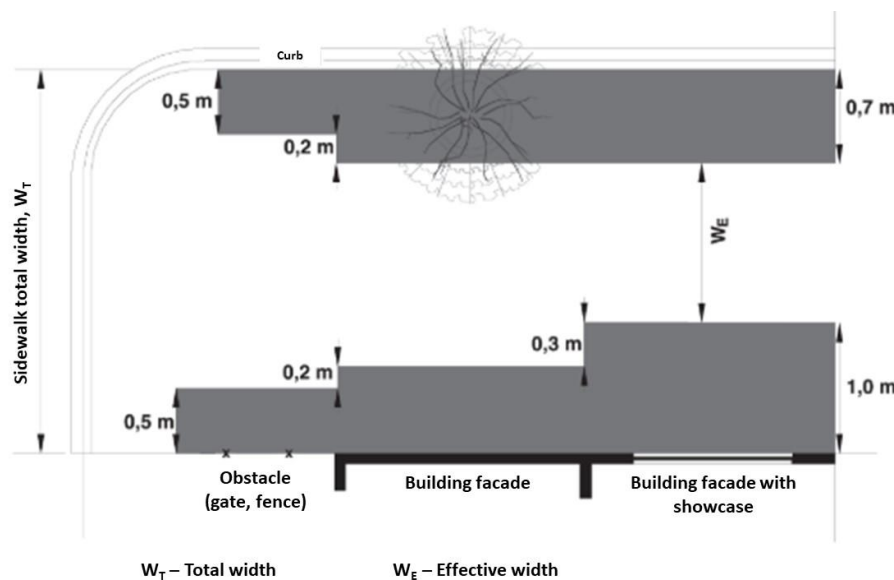


Figure 46: Definition of effective width for sidewalks (Seco, Macedo, da Costa, et al., 2008)

In addition, providing more comfortable sidewalks can increase the number of trips made by walking, particularly in areas with mixed land uses (Federal Highway Administration - FHWA, 2023). The creation of attractive and inviting sidewalks can have the potential to be socially inclusive if they are accessible; they can also increase the general autonomy and safety of the population and stimulate active commutes (dos Santos et al., 2019). Therefore, investing in quality walking infrastructure can represent gains in economic and health benefits (Arsenio & Ribeiro, 2015).

IV.4.3. Main attributes for walking in urban environments in stated choice and revealed preference: a review of related works

Walkability is defined and enabled in cities by the influence of several attributes related to the built environment: the physical support of all activities, services, and infrastructure in urban spaces (Fonseca, Ribeiro, et al., 2022). Therefore, it is of utmost importance to reference the main attributes of the built environment that can affect the willingness to walk in cities for both commuter and leisure trips.

Early studies from Greenwald & Boarnet (2001) assessed how land use characteristics affect walkability in Portland, Oregon, USA. A revealed preference survey and GIS information were used to determine non-work walking trip preferences, which showed that areas with mixed land use positively influence the number of non-working short-distance walking trips generated in the city.

Another study performed in Hong Kong, China, and New York City, USA (Z. Guo & Loo, 2013) estimated the relationship between walking and the environment, focusing on the test of the feasibility of route choice modeling based on pedestrians' walking behavior. In both contexts, pedestrians ranked length of the trip, personal safety, and familiarity as the top three attributes; Hong Kong pedestrians ranked safety as the number one priority, but New Yorkers cared most about walking distances.

In order to understand pedestrians' preferences in Singapore, Erath, Eggermond, Ordonez, & Axhausen (2015) used GIS information, as well as an SC experiment, to identify that pedestrians choose their routes based on the shortest path or because they are already familiarized with the route they take. What impacts walking satisfaction most is the feeling of safety on the road and the attractiveness of the route (i.e., when pedestrians report seeing something interesting in their journeys). Pedestrians also reported that sidewalks could be improved if more coverage was implemented, which includes the presence of trees, and if sidewalks were widened.

Furthermore, regarding the scarcity of empirical evidence on the relationship between the design of the street and how it is experienced by pedestrians, Kasraian et al. (2021) focused on quantifying pedestrians' perception of walkability through a stated choice survey using a dynamic 3D representation of various street designs in Toronto, Canada. Results show that pedestrians prefer walking on sidewalks near public transportation or cycle lanes. In addition, sidewalks have a better environment/attractiveness (e.g., outdoor dining) and have trees on the way, even if it represents the narrowing of the sidewalk.

Still using a stated choice survey to determine sidewalks' physical characteristics and users' perceptions, Bellizzi, Forciniti, and Mazzulla (2021) designed a questionnaire focusing on university students and their perceptions of sidewalk attributes. The study's outcomes suggest that for the young population, the attractiveness of the environment where the sidewalk is placed is the most critical attribute to improve walkability, followed by the overall condition of the sidewalk's pavement.

Three other selected studies performed stated choice surveys in Boston, USA (R. Basu & Sevtsuk, 2022), Queensland, Australia (N. Basu et al., 2023), and Hong Kong, China (Liang et al., 2023). All three found routes in suitable environments (i.e., mixed land use, presence of restaurants and shops). Bostonians also prefer shorter routes that are more exposed to greenery and where they have more exposure to the sky (i.e., streets with lower building edges). While Queensland residents also value safety when choosing their walking route, Hong Kong residents seek walking routes with continuity, where the paths are more comprehensive, and crossing is on ground level.

Other studies used revealed preference data to assess the relationship between urban attributes and the willingness to walk. The results show that having sidewalks with enough space to accommodate a comfortable journey is a crucial aspect of improving walkability (Abdeldayem et al., 2023; Bokharaei & Nasar, 2023). In addition to the width of the sidewalk, the attractiveness of the environment (i.e., the presence of green areas and amenities) is also a factor in attracting pedestrians to specific routes in Madrid (López-Lambas et al., 2021).

Another essential factor enabling walking in urban environments is the quality and infrastructure of pedestrian crossings. In this sense, Mfinanga (2014) studied pedestrians' preferences for environmental and infrastructural attributes of crosswalks in Tanzania. The assessment concluded that crosswalks on level ground are the preferred type, as less effort would be required to cross, followed by raised rather than underground crossings. Regarding controlling the speed of vehicles approaching crosswalks, pedestrians trust traffic calming measures to control oncoming cars.

Regarding the Portuguese context, studies performed in Lisbon (Barros et al., 2015) and Porto (Fonseca, Papageorgiou, et al., 2022) show that in the former city, the feeling of safety (i.e., streets with good lighting and less motorized traffic) is fundamental for people to choose their walking route. Also, trees and wide sidewalks corroborate the willingness to walk. In Porto, urban ambiance, pedestrian

infrastructure, connectivity, and access to community facilities were the most rated attributes to improve walkability, and this is translated into the need for wide sidewalks in areas with mixed land use where people can have access to other modes of transport, such as public transport, as well as city facilities, such as educational, recreational and cultural poles.

Lastly, it is possible to infer from the studies presented above that the attractiveness of the environment (e.g., shops and showcases, outdoor dining) where the walkway is placed is one of the most valued attributes to increase walkability. All studies that included the presence of greenery and trees in their surveys also reported that pedestrians value this feature as a way to improve the comfort of the journey, as well as the perception of the shortening of the route where trees are available. In addition, the width of the sidewalk is another factor that influences walkability in cities. The summary of the main attributes of sidewalk usage can be found in Table 32.

Table 32: Main attributes for walking in urban environments

Authors	Year	Data type	Context	Attributes								
				Trip distance	Safety	Environment	Crossings on level	Greenery	Width	Traffic/ speed	Sidewalk conditions	continuity
Greenwald & Boarnet	2001	RP, GIS	Measuring the degree to which land use characteristics influence pedestrian travel behavior	X		X						
Guo & Loo	2013	RP, GIS	Quantify the perceived utility of the pedestrian environment through pedestrian behavior	X	X	X						
Mfinanga	2014	SP	Determination of pedestrians' preferences of environmental and infrastructural attributes of crosswalks		X		X					
Barros, Martinez & Viegas	2015	SP	Assess which factors that influence walking		X		X	X	X	X		
Erath et al.	2015	SP, GIS	Assess determinants for walking to develop planning tools for walkability	X		X		X	X			
Kasraian et al.	2021	SP	Develop evidence-based design tools to improve pedestrian experience			X		X		X		
Bellizzi, Forciniti & Mazzulla	2021	SP	Preferences of young pedestrians			X						X
López-Lambas, Sánchez & Alonso	2021	RP	Identify the factors that influence people when walking			X						

Authors	Year	Data type	Context	Attributes							
				Trip distance	Safety	Environment	Crossings on level	Greenery	Width	Traffic/speed	Sidewalk conditions/continuity
Fonseca et al.	2022	RP	Identify attributes that are the main determinants of walkability		X	X					X
Basu & Sevtsuk	2022	SP, GIS	Sensitivity of pedestrians to attributes	X		X		X	X		
Liang et al.	2023	SP	Recognition of the importance of street-level facility attributes and pedestrian responses to it			X	X		X		X
Abdeldayem et al.	2023	RP, GIS	Specify the relationship between design parameters and walkability						X		
Bokharaei & Nasar	2023	RP	Test the effects of street characteristics on perceived walkability						X		
Basu et al.	2023	SP	Identification of the significance of route attributes that influence pedestrians' preferences			X				X	

IV.4.4. Stated choice design for leisure trips

The Household Mobility Survey (Instituto Nacional de Estatística, 2001) states that, in Braga, on workdays, 7.1% of the trips are for leisure activities, while on weekends, leisure trips have a share of 23.2% of all trips, and 6.3% of the trips are for shopping purposes. These trips are made mainly by car with a low occupancy rate, which means that, on average, 70% of the vehicles only carry one person, and 23% carry the driver and one passenger.

In Braga, 58.6% of the trips made within the municipality take up to 15 minutes (MPT, 2018c). Central areas of the city, namely the parishes of São José de São Lázaro e São João do Souto, São Vicente, and São Victor, hold the preponderance in the generation of trips, which are mostly short-distance within parishes. The most significant volume flows observed within and between these parishes all occur over short distances (less than 4 km in a linear route), which means that displacements in the municipality of Braga show great potential to be carried out using sustainable modes of transport. Figure 47 shows the active mobility trip flow (aggregated in both directions) within the Municipality of Braga.

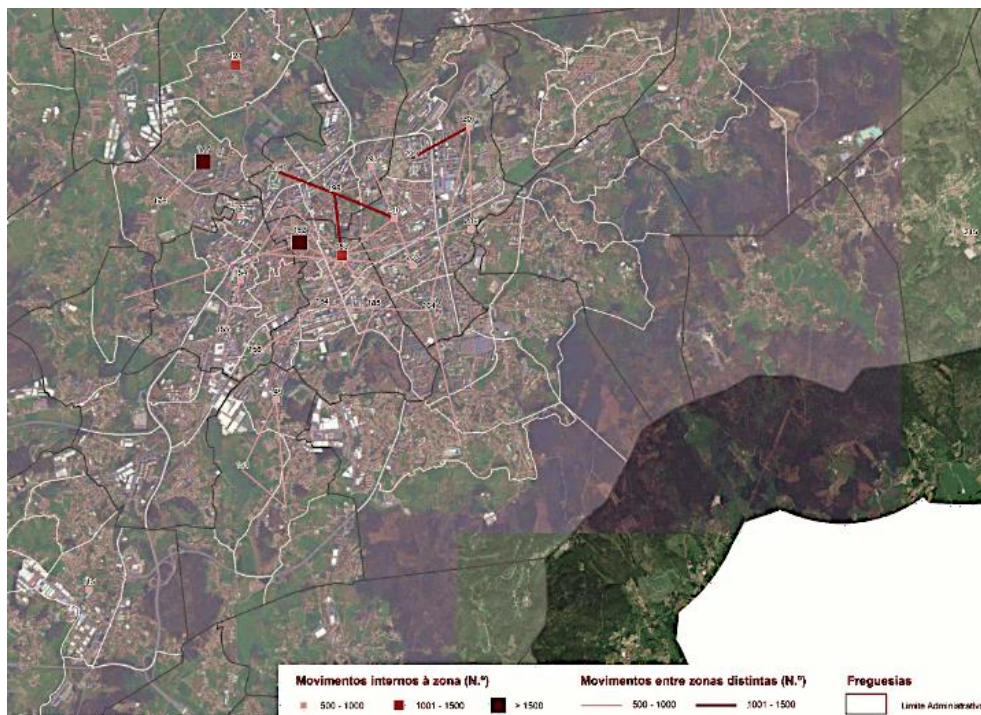


Figure 47: Active mobility trip flow within the city boundaries (MPT, 2018b)

Results from the account of trips made by shared e-scooters and shared e-bikes in Braga (from September 2022 until June 2023) show that most trips made in shared active modes occur within the parishes of

São Victor, São Vicente, and São José de São Lázaro e São João do Souto, with particular attention to the trips made in the green route next to Ave River. Figure 48 shows the heat map obtained from the project “Bicification” in Braga, which shows the same trip patterns for regular bicycle users.



IV.4.4.1. The context for the stated choice experiment for leisure trips

This second stated choice experiment assesses the willingness to shift from private cars to sustainable modes of transportation, namely shared e-scooters, shared e-bikes, and walking, in short-distance leisure trips. The previous stated choice experiment used a well-known route in Braga to assess residents' willingness to shift from private vehicles to sustainable modes of transportation for commuting. The second stated choice experiment follows the perspective of identifying the attributes with a higher potential impact on the sustainability and decarbonization of the transportation system for leisure activities or shopping. Therefore, it is essential to measure how different types of trips can contribute to the goal of sustainable mobility and the use of sustainable and shared modes.

For this, respondents need to select whether they would or wouldn't choose a sustainable mode of transportation for their leisure/shopping trips according to different attributes that improve displacements by foot, shared e-scooter, and shared e-bike.

IV.4.4.2. Alternatives, attributes, and attribute levels

For this stated choice experiment, respondents were asked to choose between two different alternatives: using a private car for their leisure-shopping short-distance trip or a sustainable mode of transportation that can be walking, shared e-scooter, or shared e-bike.

The attributes for the trip are:

- Travel time: for this attribute, each alternative has one level that characterizes the difference in travel time from the trip made by car. Thus, the same journey takes 10 more minutes on an e-bike and an e-scooter, and 20 extra minutes is made by foot;
- Voucher (monetary): this attribute takes into consideration two projects launched by the City of Braga, which are the "Bicification" (Município de Braga, 2022b) and the "Reactivity" (Município de Braga, 2023). These two projects allow citizens to earn monetary vouchers to be spent in local shops if they take sustainable modes of transport, such as walking, micromobility, and bus. This attribute in the experiment is intended to measure how gamification projects can affect people's willingness to shift from cars to alternative modes with monetary incentives. Respondents face three attribute levels for vouchers: they can either earn nothing (non-existence of gamification projects), earn EUR 2.5 per month (the average value of the voucher for people

that walk for 20 km per month on leisure trips), or EUR 5 per month (the average value of the voucher for people that walk for 35 km per month in leisure trips);

- **Greenery:** this attribute comprises the presence of trees along the route. The literature review shows that the presence of trees is essential to make walking more pleasant in urban environments, which can also affect the usage of micromobility. This attribute comprises three levels: the inexistence of trees along the route, 50% of the route covered with trees, and the entire (100%) route covered with trees;
- **Infrastructure:** another significant aspect that enables walking and micromobility usage is the provision of safe infrastructure. This attribute intends to measure to what extent respondents are willing to walk or use shared micromobility if they have to share the space (although it is not referred to in the Portuguese Road Code, sharing space between walking and micromobility is the reality in many cities, including Braga) if they can make their journey in a dedicated infrastructure (i.e., sidewalk for pedestrians and cycle lane for micromobility), and if they can have dedicated infrastructure for the journey as well as the provision of dedicated parking (only for micromobility). The need for dedicated parking was found to be one of the top three measures needed in Braga to allow more shared e-scooter usage in the RP survey.

1. Summary of alternatives, attributes, and attribute levels

Table 33 summarizes the attributes and attribute levels for the three alternatives to cars in leisure trips: walking shared e-bike and shared e-scooter. Level 1 in attributes “Voucher”, “Greenery”, and “Infrastructure” represents the base level for the attributes, while levels 2 and 3 were created for the experiment. It is essential to mention that the “Travel Time” attribute refers to only one mode of transportation since they will be presented separately for the respondents, meaning that each respondent would have to choose between continue using the car for leisure trips or shifting to the designated mode given in the scenario.

Table 33: Attributes and levels of attributes for the stated choice experiment for leisure trips

Attribute	Level	Alternative to car
Travel time	1	+ 10 min (shared e-bike)
	2	+ 10 min (shared e-scooter)
	3	+ 20 min (walking)
Voucher (monetary)	1	0
	2	EUR 2.5 per month EUR
	3	EUR 5.0 per month

Attribute	Level	Alternative to car
Greenery	1	No
	2	50% of the route
	3	100% of the route
Infrastructure	1*	No dedicated infrastructure
	2*	100% dedicated infrastructure
	3**	100% dedicated infrastructure for micromobility modes + parking

*Only for walking

**For micromobility

The levels of attributes consider that improvements are made in the transportation system to boost sustainable modes of transportation for short-distance leisure trips (i.e., non-commuting purposes). The provision of a monetary reward (i.e., voucher) is related to testing how gamification programs can affect sustainable modes of transportation usage in Braga, while the presence of trees tests how respondents weigh the built environment characteristics to improve their sustainable mobility options. In addition, the scenarios use the expected increase in travel time due to the usage of active modes and micromobility, as well as the infrastructure needed for a safe trip.

IV.4.4.3. Experimental design

The software Ngene (ChoiceMetrics, 2021a) was used to create the experimental design of the SC experiment for leisure trips in Braga. The software's interaction with the attributes and attribute levels resulted in 9 scenarios to assure orthogonality. This number of generated scenarios complies with the good standard for SC experiments; therefore, they were all selected to be presented to all respondents, meaning that every respondent had to face the nine generated scenarios.

IV.4.4.4. Pilot survey

The pilot survey for this SC experiment followed the methodology proposed by Bateman et al. (2002) to test the survey and identify any problems related to the proper understanding of the situations proposed. The pilot survey was conducted on November 21st with a sample of 30 respondents (Bateman et al., 2002) between 18 and 60 years old, and 37% of the respondents were male.

In the pilot survey, it was possible to confirm that respondents understood all the questions presented and all that was required to choose the most suitable scenario for them in each situation.

Moreover, to increase the quality of the data collected, the face-to-face data collection of interviews was selected since it allows higher response rates and greater sample control.

IV.4.4.5. Structure of the SC survey for leisure trips

The SC survey (Appendix C) is used to identify the possible modal shift from cars to sustainable modes of transportation in leisure trips in Braga. It starts with the introduction of the research objectives and asks respondents to consent to answer the following questions (Figure 49).



Início

Estudo de Preferências de Mobilidade em Braga (viagens para lazer/compras)

O presente estudo é desenvolvido no âmbito da investigação de doutoramento em Engenharia Civil entre a Universidade do Minho e o LNEC, e o seu principal objetivo é identificar os principais fatores que podem **influenciar alterações nos padrões de mobilidade para modos mais sustentáveis em viagens de curta distância para atividades de lazer ou compras em Braga.**

As opções de mobilidade sustentável consideradas para este estudo são: trotinete elétrica partilhada, bicicleta elétrica partilhada e caminhada.



Para mais informações sobre a mobilidade em Braga, clique [aqui](#).

O estudo é de responsabilidade de Gabriel Dias (id8651@alunos.uminho.pt), que pode ser contactado para esclarecer qualquer dúvida ou partilhar algum comentário.

Todas as informações coletadas pela sua participação voluntária serão tratadas de forma anónima e serão utilizadas exclusivamente para fins científicos.

Declaro ter compreendido os objetivos do estudo e aceito preencher o questionário de forma anónima, pelo que:

☐

 Sim, aceito participar do estudo

☐

 Não, não aceito participar do estudo

Figure 49: SC survey for leisure trips (first page)

The following part of this SC survey collected RP information regarding the number of cars in the respondent's household, if they have already used shared e-scooters and e-bikes in Braga, and how likely they were to use shared micromobility and walking to promote sustainable modes of transportation.

Then, the context for the SC experiment was explained to respondents, and the attributes and respective attribute levels were presented so they could choose the most suitable option for their needs. Unlike the SC experiment for commute trips, this experiment presented only one alternative trip in opposition to the usual car trip made by the respondents. Therefore, they had to choose between making the trip by car or shifting to the presented trips with their attributes (Figure 50).

Nestas condições, consideraria substituir o automóvel por um modo de transporte sustentável nas viagens de curta distância para lazer/compras?



Figure 50: Example of a card presented to respondents in the SC experiment for leisure trips

After the respondents faced the nine SC scenarios, they were presented with a sociodemographic questionnaire to state their gender, age, professional situation, education status, monthly household income, and the number of people in the household. The survey developed on Qualtrics was disseminated

from 12 December 2023 to 11 April 2024 in downtown Braga, near the University of Minho campus, in shopping malls, and city parks.

IV.4.5. Results from the SC experiment for leisure trips

A binary logit model was specified to estimate the discrete choice model for leisure trips in Braga. This model was selected because, in this SC experiment, respondents were faced with only two alternatives per scenario: continue using the car for their leisure trip or switch to the sustainable mode of transportation presented.

The Biogeme software package (Bierlaire, 2023) was used to estimate the models. The collected data was divided into three different binary logit models: i) considering the choice of the car or walking, ii) considering the choice of the car or a shared e-bike, and iii) considering the choice of the car or a shared e-scooter. All tables with results from the model present the maximum likelihood estimation for the model ($\mathcal{L}$), as well as the rho-square results for the model (ρ^{-2}).

For the base models of each binary choice, two alternative-specific constants were used to assess the differences in preference for the two modes of transport. However, when testing the socio-demographic characteristics of each model, only the alternative-specific constant for the car (ASC_CAR) was used since it allowed to understand the differences in the choice of the alternative mode of transport.

The sample of 397 answers (3573 observations) represents the population of Braga, considering a 95% confidence level and 5% margin of error. Respondents were required to be 18 years old and older and use the car as the primary mode of transportation for leisure trips. Table 34 describes the sample.

Table 34: Sample description of the SC experiment for leisure trips

Category	Subcategory	N Sample	% Sample	% Braga*
Gender	Female	206	51.9%	52.4%
	Male	188	47.4%	47.6%
	Other	1	0.2%	-
	Prefer not to say	2	0.5%	-
Age	Up to 24 years old	71	17.9%	11.4%
	25-39 years old	161	40.6%	19.2%
	40-54 years old	137	34.5%	23.6%
	55-64 years old	25	6.3%	13.9%

Category	Subcategory	N Sample	% Sample	% Braga*
Age	Above 65 years old	3	0.8%	18.2%
Education	Up to secondary education	113	28.5%	63.7%
	Technical course	28	7.1%	0.2%
	Bachelor's or equivalent	165	41.6%	39.9%
	Master's degree	82	20.7%	5.6%
Education	Doctoral degree	8	2.0%	1.0%
Occupation	Students	72	18.1%	9.4%
	Employee	288	72.5%	56.8%
	Employer	19	4.8%	5.8%
	Unemployed	14	3.5%	4.7%
Family size	1 person	54	13.6%	19.5%
	2 persons	102	25.7%	30.5%
	3 persons	116	29.2%	24.5%
	4 persons	97	24.4%	19.1%
	More than 4 persons	28	7.1%	6.4%
Household monthly income	Up to EUR 760	14	3.5%	-
	EUR 761 – EUR 1000	50	12.6%	-
	EUR 1001 – EUR 1500	100	25.2%	-
	EUR 1501 – EUR 2000	64	16.1%	-
	EUR 2001 – EUR 2500	51	12.8%	-
	Above EUR 2501	66	16.6%	-

*Population of Braga considering the minimum age of 18 years old (minimum age to have a driver's license and to rent an e-scooter or e-bike)

Moreover, 42.6% of respondents stated that their households have one car and that 92.2% have a driver's license. Also, 77.8% never used shared e-scooters in Braga, and 96% never rode a shared e-bike in the city.

Respondents preferred walking and e-bikes over cars for short-distance leisure trips in Braga. However, the preference for shared e-scooters and cars was almost equal since e-scooters were selected in 51.3% of the cases. Figure 51 shows the preferences for leisure trips in Braga when comparing the car with a sustainable mode of transport.

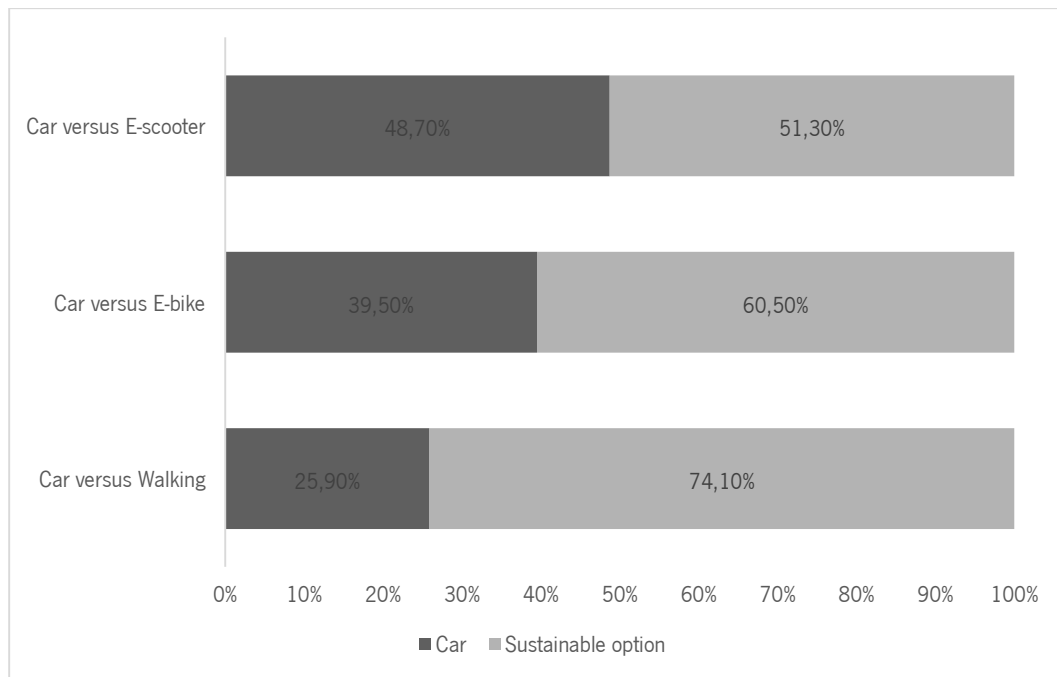


Figure 51: Choice of sustainable modes of transportation over cars for leisure trips

Walking is the preferred mode of transportation to shift from cars for leisure trips in Braga, which is consistent with what is expected since walking is a vital part of the transportation systems and is more appropriate for short-distance trips. Shared micromobility, however, is still not the dominant option over cars, but in the case of leisure trips, these modes of transportation may support a modal shift from cars.

The following subsections present the results from the binary logit models comparing the choice of a car or a sustainable mode of transportation (i.e., walking, shared e-bike, and shared e-scooter) for leisure trips in Braga. Also, the gender, age, and income of the respondents are tested to identify how these sociodemographic characteristics influence the choice of a mode of transportation for leisure trips.

For these binary logit models, travel time, infrastructure, the offer of a monetary reward for utilizing a sustainable mode of transportation (e.g., voucher), and the presence of trees on the route are considered to influence mode choice.

IV.4.5.1. Walking

Table 35 shows the model estimation results for the binary choice of a car or walking for a leisure trip in Braga. All estimated coefficients are statistically significantly different from zero. The alternative specific

constant for the car is negative, which indicates that, in a configuration where the variables in the model are equal for the two modes presented, a car is less preferred than walking.

The positive coefficient for travel time (ASC_TIME) indicates that the increase in travel time for choosing to walk on a leisure trip also increases the perceived utility for decision-makers, meaning that an increase in the time spent traveling by foot would not decrease the choice to make the trip walking.

Infrastructure (ASC_INFRA) and the presence of trees (ASC_TREES) also have a positive coefficient in the model, as expected. This indicates that the utility perceived by the respondents for any of the two alternatives increases with an increase in the dedicated infrastructure offered and the presence of trees on the route. Meaning that the increased presence of trees and infrastructure would increase the choice to make the trip walking.

On the other hand, the negative coefficient for the provision of a voucher (ASC_VOUCHER) indicated that the respondent's perceived utility decreases with the increase in the monetary value of the voucher offered to make leisure trips by foot in Braga. This means that the choice for walking do not increase when the value of the voucher increases.

Table 35: Base binary logit model for the leisure SC experiment considering the car and walking

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_CAR	-0.808	0.066	-12.083	0.0
ASC_WALK	0.808	0.066	12.083	0.0
B_INFRA	0.494	0.138	3.570	0.0
B_TIME	0.161	0.013	12.083	0.0
B_TREE	0.031	0.006	4.720	0.0
B_VOUCHER	-0.158	0.033	-4.720	0.0
<i>Summary statistics</i>				
Number of observations = 1191				
$\mathcal{L}(\mathbf{0}) = -825.5383$				
$\mathcal{L}(\hat{\beta}) = -669.0296$				
$\rho^{-2} = 0.19$				

The next step is to introduce sociodemographic variables in the model to assess how different attributes influence the perceived utility of the available modes of transport.

Gender is now introduced, which indicates the respondent's gender. The variable is categorical and equals one if the gender is male and zero if female. Contrarily to attributes of alternatives, sociodemographic characteristics such as gender do not vary across other options. Therefore, their role in the model is to capture taste heterogeneity.

The results presented in Table 36 show that for both genders studied (male and female), the sign for all coefficients are the same, meaning that the perceived utility of variables for males and females are the same when comparing cars and walking for leisure trips in Braga.

The negative coefficient for the infrastructure (B_INFRA_CAR), travel time (B_TIME_CAR), and voucher (B_VOUCHER_WALK) show that the utility perceived by men and women decreases with the increase in infrastructure, travel time, and voucher. The positive sign infrastructure (B_INFRA_WALK), travel time (B_TIME_WALK), and presence of trees (B_TREE_WALK) show that for both genders an increase in the travel time for walking, the infrastructure for walking, and the presence of trees in a walkway would increase their choice for this mode of transportation.

Table 36: Binary logit model (car vs walking) with the sociodemographic characteristic gender

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_CAR_FEMALE	-0.284	0.047	-6.01	1.83e-09
ASC_CAR_MALE	-0.274	0.047	-5.75	8.81e-09
B_INFRA_CAR_FEMALE	-0.284	0.047	-6.01	1.83e-09
B_INFRA_CAR_MALE	-0.271	0.047	-5.75	8.81e-09
B_INFRA_WALK_FEMALE	0.421	0.196	2.15	0.031
B_INFRA_WALK_MALE	0.555	0.196	2.8	0.005
B_TIME_CAR_FEMALE	-0.014	0.002	-6.01	1.83e-09
B_TIME_CAR_MALE	-0.013	0.002	-5.75	8.81e-09
B_TIME_WALK_FEMALE	0.071	0.011	6.01	1.83e-09
B_TIME_WALK_MALE	0.068	0.011	5.75	8.81e-09
B_TREE_WALK_FEMALE	0.294	0.051	5.71	1.12e-08
B_TREE_WALK_MALE	0.306	0.052	5.86	4.77e-09
B_VOUCHER_WALK_FEMALE	-0.051	0.042	-1.22	0.223
B_VOUCHER_WALK_MALE	-0.161	0.043	-3.68	0.0
<i>Summary statistics</i>				
Number of observations = 1182				
$\mathcal{L}(\mathbf{0}) = -819.3$				
$\mathcal{L}(\hat{\boldsymbol{\beta}}) = -662.3994$				
$\rho^{-2} = 0.192$				

Then, the age of respondents was also tested to determine its interaction with the model. This sociodemographic characteristic was separated into two groups: young (i.e., between 18 and 39 years old) and old (i.e., people who are 40 years old and older).

The results presented in Table 37 show a positive sign for the attributes infrastructure (B_INFRA_WALK), travel time (B_TIME_WALK), and presence of trees (B_TREES_WALK), indicating that the utility perceived by all ages of respondents increases with an increase in the walkway infrastructure, the travel time for leisure trips by foot, and the increase in the presence of trees in the walking route. The negative sign for the variable voucher (B_VOUCHER_WALK) indicated that the perceived utility for the two groups (young and old) decreased when the value of the voucher increased for walking leisure trips in Braga. This means that for all group ages, the increase in the voucher value does not increase the choice for walking.

Table 37: Binary logit model (car vs walking) with the sociodemographic characteristic age

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_CAR_OLD	-0.377	0.056	-6.7	2.05e-11
ASC_CAR_YOUNG	-0.219	0.041	-5.23	1.72e-07
B_INFRA_CAR_OLD	-0.377	0.056	-6.7	2.05e-11
B_INFRA_CAR_YOUNG	-0.219	0.041	-5.23	1.72e-07
B_INFRA_WALK_OLD	0.482	0.234	2.06	0.039
B_INFRA_WALK_YOUNG	0.513	0.174	2.96	0.003
B_TIME_CAR_OLD	-0.018	0.002	-6.7	2.05e-11
B_TIME_CAR_YOUNG	-0.010	0.002	-5.23	1.72e-07
B_TIME_WALK_OLD	0.094	0.014	6.7	2.05e-11
B_TIME_WALK_YOUNG	0.054	0.010	5.23	1.72e-07
B_TREE_WALK_OLD	0.4	0.062	6.45	1.09e-10
B_TREE_WALK_YOUNG	0.24	0.045	5.25	1.52e-07
B_VOUCHER_WALK_OLD	-0.113	0.052	-2.16	0.030
B_VOUCHER_WALK_YOUNG	-0.105	0.037	-2.8	0.005
<i>Summary statistics</i>				
Number of observations = 1191				
$\mathcal{L}(\mathbf{0}) = -825.5383$				
$\mathcal{L}(\hat{\beta}) = -662.0188$				
$\rho^{-2} = 0.198$				

The model also tested the respondents' income to identify its synergy with the data collected. Table 38 shows the results considering two categories for the income variable: low (i.e., family monthly income lower than EUR 1250) and high (i.e., family monthly income higher than EUR 1251).

The positive signs for variables infrastructure (B_INFRA_WALK), travel time (B_TIME_WALK), and presence of trees (B_TREE_WALK) reveal that the perceived utility for both groups increases as the infrastructure for walking, the travel time for a leisure trip by foot and the presence of trees increase in the walkway, which means that the increase in these attributes make the choice for walking increase as well.

Differently, the two groups present distinct signs for the voucher variable (B_VOUCHER_WALK). This indicated that for high-income people, the perceived utility decreases when the voucher value increases, and for low-income people, the perceived utility increases when the voucher value increases.

Table 38: Binary logit model (car vs walking) with the sociodemographic characteristic income

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_CAR_INCOMEHIGH	-0.258	0.048	-5.33	9.79e-08
ASC_CAR_INCOMELOW	-0.239	0.086	-2.76	0.005
B_INFRA_CAR_INCOMEHIGH	-0.258	0.048	-5.33	9.79e-08
B_INFRA_CAR_INCOMELOW	-0.239	0.086	-2.76	0.005
B_INFRA_WALK_INCOMEHIGH	0.468	0.201	2.33	0.019
B_INFRA_WALK_INCOMELOW	0.714	0.361	1.98	0.047
B_TIME_CAR_INCOMEHIGH	-0.012	0.002	-5.33	9.79e-08
B_TIME_CAR_INCOMELOW	-0.012	0.004	-2.76	0.005
B_TIME_WALK_INCOMEHIGH	0.064	0.012	5.33	9.79e-08
B_TIME_WALK_INCOMELOW	0.059	0.021	2.76	0.005
B_TREE_WALK_INCOMEHIGH	0.28	0.052	5.3	1.14e-07
B_TREE_WALK_INCOMELOW	0.239	0.095	2.49	0.012
B_VOUCHER_WALK_INCOMEHIGH	-0.111	0.043	-2.57	0.010
B_VOUCHER_WALK_INCOMELOW	0.003	0.081	0.046	0.963
<i>Summary statistics</i>				
Number of observations = 1035				
$\mathcal{L}(\mathbf{0}) = -717.4073$				
$\mathcal{L}(\hat{\beta}) = -621.234$				
$\rho^{-2} = 0.134$				

IV.4.5.2. Shared e-bike

The choice between a car and a shared e-bike was also modeled to assess the respondents' preferences according to the attributes presented. As of the previous binary model, only travel time, infrastructure, presence of trees and a voucher were considered as affecting the choice.

The estimation results are shown in Table 39. All the estimated coefficients are statistically significantly different from zero. The alternative specific constant for the car is negative, which indicates that in a configuration where the variables in the model are equal for the two modes, the car is less preferred than shared e-bikes. The positive signs for the utilities of infrastructure, travel time, presence of trees, and provision of a voucher indicate that the utility perceived by the respondents increases with the increase in the infrastructure provided, the travel time, the provision of trees, and vouchers.

Table 39: Base binary logit for the leisure SC experiment considering the car and e-bike

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_BIKE	0.314	0.093	3.357	7.853e-04
ASC_CAR	-0.314	0.093	-3.357	7.853e-04
B_INFRA	0.436	0.064	6.786	1.146e-11
B_TIME	0.031	0.009	3.357	7.853e-04
B_TREE	0.781	0.141	5.536	3.089e-08
B_VOUCHER	0.151	0.040	3.721	1.978e-04
<i>Summary statistics</i>				
Number of observations = 1191				
$\mathcal{L}(\mathbf{0}) = -825.5383$				
$\mathcal{L}(\hat{\beta}) = -720.5987$				
$\rho^{-2} = 0.127$				

The respondents' gender was also included in the model to capture the preference heterogeneity. The characteristic gender interacted with all parameters of the model. Table 40 shows the alternative specific constants being positive. This indicated that males and females prefer cars to shared e-bikes. The positive signs for attributes infrastructure (B_INFRA_BIKE), presence of trees (B_TREE_BIKE), and voucher (B_VOUCHER_BIKE) indicate that the utility perceived by the decision maker in both genders increases when the dedicated infrastructure for bikes increases, as well as the presence of trees, increase, and the value of the voucher increases as well.

However, the negative sign for the attribute travel time (B_TIME_BIKE) indicates that the utility perceived by the respondents in both genders decreases when the travel time for a leisure trip by shared e-bike increases. This means that men and women negatively see the increase in travel time for e-bikes for a leisure trip.

Table 40: Binary logit model (car vs e-bike) with the sociodemographic characteristic gender

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_CAR_FEMALE	0.191	0.048	3.99	6.73e-05
ASC_CAR_MALE	0.195	0.050	3.88	0.0
B_INFRA_BIKE_FEMALE	0.463	0.11	4.2	2.7e-05
B_INFRA_BIKE_MALE	0.57	0.123	4.63	3.61e-06
B_INFRA_CAR_FEMALE	0.191	0.048	3.99	6.73e-05
B_INFRA_CAR_MALE	0.195	0.050	3.88	0.0
B_TIME_BIKE_FEMALE	-0.028	0.007	-3.99	6.73e-05
B_TIME_BIKE_MALE	-0.029	0.007	-3.88	0.0
B_TIME_CAR_FEMALE	0.009	0.002	3.99	6.73e-05
B_TIME_CAR_MALE	0.009	0.002	3.88	0.0
B_TREE_BIKE_FEMALE	0.67	0.174	3.86	0.0
B_TREE_BIKE_MALE	0.824	0.194	4.25	2.11e-05
B_VOUCHER_BIKE_FEMALE	0.125	0.058	2.15	0.031
B_VOUCHER_BIKE_MALE	0.153	0.065	2.35	0.018
<i>Summary statistics</i>				
Number of observations = 1182				
$\mathcal{L}(\mathbf{O}) = -819.3$				
$\mathcal{L}(\hat{\beta}) = -713.8758$				
$\rho^{-2} = 0.129$				

Next, the age of the respondents was also included in the model to assess its effect on their choices. Table 41 shows that the positive sign for attributes infrastructure (B_INFRA_BIKE), presence of trees (B_TREE_BIKE), and voucher (B_VOUCHER_BIKE) represents that the utility perceived by the respondents in all age groups increases when dedicated infrastructure, the presence of trees and voucher increase for both groups (e.g., young and older adults). Travel time presents a negative sign, which means that the utility perceived by respondents decreases when travel time for e-bike leisure trips increases for both groups, which means that an increase in travel time decreases the choice of e-bikes for these groups.

Table 41: Binary logit model (car vs e-bike) with the sociodemographic characteristic age

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_CAR_OLD	0.211	0.054	3.9	9.47e-05
ASC_CAR_YOUNG	0.181	0.045	4.02	5.82e-05
B_INFRA_BIKE_OLD	0.418	0.119	3.51	0.0
B_INFRA_BIKE_YOUNG	0.583	0.115	5.06	4.29e-07
B_INFRA_CAR_OLD	0.211	0.054	3.9	9.47e-05
B_INFRA_CAR_YOUNG	0.181	0.045	4.02	5.82e-05
B_TIME_BIKE_OLD	-0.031	0.008	-3.9	9.47e-05

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
B_TIME_BIKE_YOUNG	-0.027	0.006	-4.02	5.82e-05
B_TIME_CAR_OLD	0.010	0.002	3.9	9.47e-05
B_TIME_CAR_YOUNG	0.009	0.002	4.02	5.82e-05
B_TREE_BIKE_OLD	0.608	0.187	3.26	0.001
B_TREE_BIKE_YOUNG	0.837	0.182	4.6	4.29e-06
B_VOUCHER_BIKE_OLD	0.090	0.061	1.46	0.145
B_VOUCHER_BIKE_YOUNG	0.189	0.062	3.04	0.002
<i>Summary statistics</i>				
Number of observations = 1191				
$\mathcal{L}(\mathbf{O}) = -825.5383$				
$\mathcal{L}(\hat{\beta}) = -708.2786$				
$\rho^{-2} = 0.142$				

Income was also tested for young and older adults regarding choosing between a car and a shared e-bike for leisure trips in Braga. Table 42 shows the results for the model with the interaction of this sociodemographic characteristic. The positive signs for the infrastructure (B_INFRA_BIKE), presence of trees (B_TREE_BIKE), and voucher (B_VOUCHER_BIKE) indicate that the utility perceived by respondents in both income groups increases with the increase of the dedicated infrastructure for e-bikes, the increment of trees in the route, and the increment in the value of the voucher to use shared e-bikes for both low and high-income people. However, the negative sign for travel time (B_TIME_BIKE) demonstrates that the perceived utility for this attribute decreases when travel time for e-bikes increases.

Table 42: Binary logit model (car vs e-bike) with the sociodemographic characteristic income

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_CAR_INCOMEHIGH	0.191	0.051	3.74	0.0
ASC_CAR_INCOMELOW	0.147	0.084	1.74	0.082
B_INFRA_BIKE_INCOMEHIGH	0.534	0.124	4.29	1.75e-05
B_INFRA_BIKE_INCOMELOW	0.364	0.191	1.91	0.056
B_INFRA_CAR_INCOMEHIGH	0.191	0.051	3.74	0.0
B_INFRA_CAR_INCOMELOW	0.147	0.087	1.74	0.082
B_TIME_BIKE_INCOMEHIGH	-0.028	0.007	-3.74	0.0
B_TIME_BIKE_INCOMELOW	-0.022	0.012	-1.74	0.082
B_TIME_CAR_INCOMEHIGH	0.009	0.002	3.74	0.0
B_TIME_CAR_INCOMELOW	0.007	0.004	1.74	0.082
B_TREE_BIKE_INCOMEHIGH	0.767	0.196	3.92	8.89e-05
B_TREE_BIKE_INCOMELOW	0.53	0.3	1.77	0.077
B_VOUCHER_BIKE_INCOMEHIGH	0.166	0.066	2.5	0.012
B_VOUCHER_BIKE_INCOMELOW	0.0787	0.099	0.789	0.43

Summary statistics

Number of observations = 1035

$\mathcal{L}(\mathbf{O}) = -717.4073$

$\mathcal{L}(\hat{\beta}) = -651.5389$

$\rho^{-2} = 0.0918$

IV.4.5.3. Shared e-scooter

Besides modeling the binary logit models for cars versus walking and shared e-bikes, the choice of shared e-scooters in leisure trips was also tested. The estimation results are presented in Table 43. All estimated coefficients are statistically significantly different from zero.

The alternative specific constant for the car is negative. This indicates that, in a configuration where the variables in the model are equal for the two modes, the car is less preferred than shared e-scooters for leisure trips. The negative signs for the generic coefficients for trees and vouchers indicate that the utility perceived by the respondents decreases with the increase in the presence of trees in the route and with the rise in the value of the voucher. Nonetheless, the positive signs for the generic coefficients of infrastructure and time indicate that the utility perceived by respondents increases with the increased dedicated infrastructure and travel time, which suggests that, for leisure trips, an increase in travel time by shared e-scooters does not influence negatively the choice for this mode of transportation.

Table 43: base binary logit for the leisure SC experiment considering the car and e-scooter

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_CAR	-0.052	0.065	-0.806	0.420
ASC_SCOOTER	0.052	0.065	0.806	0.420
B_INFRA	0.192	0.085	2.261	0.023
B_TIME	0.005	0.006	0.806	0.420
B_TREE	-0.305	0.109	-2.794	0.005
B_VOUCHER	-0.052	0.040	-1.305	0.191

Summary statistics

Number of observations = 1191

$\mathcal{L}(\mathbf{O}) = -825.5383$

$\mathcal{L}(\hat{\beta}) = -812.4045$

$\rho^{-2} = 0.0159$

Sociodemographic characteristics were also tested to assess the heterogeneity in taste when choosing between cars and shared e-scooters. Table 44 presents the results, considering the respondents' gender

in the binary logit model. The positive signs for the coefficients for infrastructure (B_INFRA_SCOOTER) and travel time (B_TIME_SCOOTER) indicate that the utility perceived by the respondents in both groups increases with an increase in the dedicated infrastructure for shared e-scooters, as well as travel time for leisure trips in shared e-scooters for both genders. This indicates that an increase in the provided infrastructure and travel time increases the choice of this mode of transportation.

The negative signs for coefficients tree (B_TREE_SCOOTER) and voucher (B_VOUCHER_SCOOTER) indicate that the utility decreases with an increase in the presence of trees in the route, as well as the value of the voucher for both genders.

Table 44: Binary logit model (car vs e-scooter) with the sociodemographic characteristic gender

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_CAR_FEMALE	-0.016	0.034	-0.488	0.626
ASC_CAR_MALE	-0.085	0.036	-2.32	0.020
B_INFRA_CAR_FEMALE	-0.016	0.034	-0.488	0.626
B_INFRA_CAR_MALE	-0.085	0.036	-2.32	0.020
B_INFRA_SCOOTER_FEMALE	0.26	0.090	2.87	0.004
B_INFRA_SCOOTER_MALE	0.236	0.095	2.48	0.013
B_TIME_CAR_FEMALE	-0.0008	0.001	-0.488	0.626
B_TIME_CAR_MALE	-0.004	0.001	-2.32	0.020
B_TIME_SCOOTER_FEMALE	0.002	0.005	0.488	0.626
B_TIME_SCOOTER_MALE	0.012	0.005	2.32	0.020
B_TREE_SCOOTER_FEMALE	-0.351	0.174	-2.02	0.043
B_TREE_SCOOTER_MALE	-0.17	0.183	-0.931	0.352
B_VOUCHER_SCOOTER_FEMALE	-0.030	0.050	-0.618	0.537
B_VOUCHER_SCOOTER_MALE	-0.060	0.053	-1.14	0.254
<i>Summary statistics</i>				
Number of observations = 1182				
$\mathcal{L}(\mathbf{0}) = -819.3$				
$\mathcal{L}(\hat{\beta}) = -804.5736$				
$\rho^{-2} = 0.018$				

Table 45 shows that older people prefer cars to shared e-scooters when testing the perceived difference in different age groups. The negative signs for coefficients tree (B_TREE_SCOOTER) and voucher (B_VOUCHER_SCOOTER) for both age groups show that the utility perceived decreases when the presence of trees in the route increases, as does the value of the voucher. The positive sign for the infrastructure coefficient shows that the utility perceived by respondents increases when the dedicated

infrastructure for shared e-scooters increases. Thus, people in both group ages are more likely to choose shared e-scooters if more infrastructure is offered.

However, the signs for the coefficient time (B_TIME_SCOOTER) differ between the two groups. The negative sign for older respondents represents a decrease in utility when the travel time of e-scooters increases. For younger respondents, the positive sign indicates an increase in travel time does not affect negatively the choice for a shared e-scooter for a leisure trip in Braga.

Table 45: Binary logit model (car vs e-scooter) with the sociodemographic characteristic age

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_CAR_OLD	0.019	0.038	0.491	0.623
ASC_CAR_YOUNG	-0.095	0.033	-2.86	0.004
B_INFRA_CAR_OLD	0.019	0.038	0.491	0.623
B_INFRA_CAR_YOUNG	-0.095	0.033	-2.86	0.004
B_INFRA_SCOOTER_OLD	0.121	0.102	1.18	0.237
B_INFRA_SCOOTER_YOUNG	0.353	0.087	4.02	5.8e-05
B_TIME_CAR_OLD	0.0009	0.001	0.491	0.623
B_TIME_CAR_YOUNG	-0.004	0.001	-2.86	0.004
B_TIME_SCOOTER_OLD	-0.002	0.005	-0.491	0.623
B_TIME_SCOOTER_YOUNG	0.014	0.005	2.86	0.004
B_TREE_SCOOTER_OLD	-0.199	0.195	-1.02	0.306
B_TREE_SCOOTER_YOUNG	-0.336	0.168	-2.0	0.045
B_VOUCHER_SCOOTER_OLD	-0.098	0.056	-1.76	0.079
B_VOUCHER_SCOOTER_YOUNG	-0.007	0.048	-0.162	0.871
<i>Summary statistics</i>				
Number of observations = 1191				
$\mathcal{L}(\mathbf{0}) = -825.5383$				
$\mathcal{L}(\hat{\beta}) = -796.7578$				
$\rho^{-2} = 0.0349$				

Next, the model tested the difference in income to assess its effects on the choice of a mode of transportation for leisure trips. Table 46 shows the results of the model's interaction. The positive coefficient for the car (ASC_CAR_INCOMELOW) indicated a preference for the vehicle by people with lower incomes.

The positive sign for the coefficient for infrastructure (B_INFRA_SCOOTER) indicated that respondents' perceived utility increases when dedicated infrastructure for e-scooters is added to the routes. The negative sign for the presence of trees (B_TREE_SCOOTER) demonstrates that the perceived utility of

trees for both groups decreases when the number of trees is increased in the route, indicating that an increase in the number of trees along the route does not affect increase the choice of a shared e-scooter.

The signs for travel time (B_TIME_SCOOTER) differ between lower—and higher-income people. The positive sign indicates that the utility of travel time increases for high-income people. In contrast, the negative sign indicates that the utility decreases for low-income people.

The same happens for the voucher offered (B_VOUCHER_SCOOTER). The coefficient's negative sign indicates that the utility decreases when the voucher's value increases for high-income people. On the other hand, the positive sign suggests that the utility increases when the voucher's value increases for low-income people.

Table 46: Binary logit model (car vs e-scooter) with the sociodemographic characteristic income

Parameter	Parameter estimate	Rob. std err	Rob. t-test	Rob. p-value
ASC_CAR_INCOMEHIGH	-0.118	0.038	-3.09	0.002
ASC_CAR_INCOMELOW	0.093	0.062	1.48	0.138
B_INFRA_CAR_INCOMEHIGH	-0.118	0.038	-3.09	0.002
B_INFRA_CAR_INCOMELOW	0.093	0.062	1.48	0.138
B_INFRA_SCOOTER_INCOMEHIGH	0.275	0.097	2.83	0.004
B_INFRA_SCOOTER_INCOMELOW	0.261	0.163	1.6	0.109
B_TIME_CAR_INCOMEHIGH	-0.005	0.001	-3.09	0.002
B_TIME_CAR_INCOMELOW	0.004	0.003	1.48	0.138
B_TIME_SCOOTER_INCOMEHIGH	0.017	0.005	3.09	0.002
B_TIME_SCOOTER_INCOMELOW	-0.014	0.009	-1.48	0.138
B_TREE_SCOOTER_INCOMEHIGH	-0.154	0.188	-0.819	0.413
B_TREE_SCOOTER_INCOMELOW	-0.589	0.312	-1.89	0.059
B_VOUCHER_SCOOTER_INCOMEHIGH	-0.114	0.054	-2.09	0.036
B_VOUCHER_SCOOTER_INCOMELOW	0.058	0.090	0.647	0.518
<i>Summary statistics</i>				
Number of observations = 1035				
$\mathcal{L}(\mathbf{O}) = -717.4073$				
$\mathcal{L}(\hat{\beta}) = -701.523$				
$\rho^{-2} = 0.0221$				

Once the sociodemographic characteristics were tested in the model to better understand how they affect the preference for sustainable modes of transportation for leisure trips in Braga, the incremental effects of the models were compiled in Table 47.

Table 47: Incremental effects for the choice of sustainable modes of transportation in the leisure SC experiment

	Variable/Description of the interaction effect		Model represents a statistical improvement
Walking	Age	Age of the respondent (senior)	Yes
	Gender	Gender of respondent (female)	Yes
	Income	Above 1251 EUR	Yes
E-bike	Age	Age of the respondent (senior)	Yes
	Gender	Gender of respondent (female)	Yes
	Income	Above 1251 EUR	Yes
E-scooter	Age	Age of the respondent (senior)	Yes
	Gender	Gender of respondent (female)	Yes
	Income	Above 1251 EUR	Yes

The results for the stated choice experiment for leisure trips in Braga show a statistical improvement in all models with sociodemographic characteristics. It is still important to mention that, for this type of trip, sustainable modes of transportation could be preferred over cars with specific planning conditions are offered to residents, such as the increase in infrastructure for micromobility. Therefore, promoting the necessary means to increase sustainable modes of transportation is vital to increase their share in urban displacements.

IV.5. Synthesis of main findings

The case study starts by choosing Braga as the study location. The city was selected because it has had a consolidated shared e-scooter service since 2019. Trip data was obtained from the Municipality, and there was a shared e-bike service in the city for a short period. This characteristic was also an opportunity to assess how cities endured shared e-bikes after they were consolidated as a mode of transport.

Shared e-scooters experienced a rise in usage during the first years of availability after the COVID-19 pandemic. And since 2023, along with the decrease in vehicle availability, the number of trips has also dropped. Shared e-bikes, on the other hand, experienced a lower number of trips in Braga compared to the trips made by shared e-scooters. However, it was noticed that shared e-bikes would be used for longer

journeys and that the area of usage was similar for e-bikes and e-scooters. Unfortunately, after a short period, the shared e-bike service was shut down, not allowing Braga's dwellers to get used to the service. The comparison of trip data from both shared e-micromobility can help answering RQ 5 in what concerns the competitiveness between the services. It has been seen that they could work jointly to provide residents with different modes of transportation that could fill their needs depending on the type of journey.

The results from the RP survey regarding shared e-scooter usage and not usage in Braga show that this mode of transportation is used because the trips are pleasant, it provides a quick displacement to the destinations, and it offers less physical effort in the trips that last between five to nine minutes. Since people use e-scooters to reach destinations quicker with less physical effort, the primary mode of transportation replaced is walking, followed by private cars and the bus.

For non-users of the service, the lack of road safety, dedicated parking, and zoning are crucial to stop them from sharing e-scooters. It is seen by users and non-users that the best interventions to allow increased shared e-scooter ridership would be implementing more dedicated infrastructure (i.e., cycle lanes), zoning, and dedicated parking spots.

In Braga, it has been seen that gender, the parish of origin of trips, and the current mode of transportation influence the usage of e-scooters. Women are underrepresented among users, which can be due to the feeling of unsafety, and people who live or start their journeys in parishes where shared e-scooters are not available tend not to be familiarized with the service, therefore not using it. Differently, people who achieved higher educational levels are overrepresented among users and students.

Considering university students' perspective on shared e-scooters, this mode of transportation is still regarded as pleasant to ride, and the quick displacements are reasons to use the service. However, the students who do not use shared e-scooters do so because they prefer to use public transportation or the car or they do not know how to use an e-scooter. Women in this group of respondents state that they do not use e-scooters because they feel unsafe.

The younger population (student sample) also sees e-scooters as a sustainable mode of transportation regarding environmental issues. However, they do not think shared e-scooters could promote gender equity or equity among different sociodemographic groups.

The regulation of shared e-scooters that could contribute to increasing their usage is related to the provision of areas where micromobility has priority over cars, the implementation of traffic calming zones and restriction of car speed limits, as well as the restriction of cellphone usage by e-scooter riders, and the requirement to have only one person in each e-scooter.

The stated choice experiment for commute trips considers the main factors for shared e-scooter usage and not usage, as well as the interventions needed to boost the service, such as providing more dedicated infrastructure and increasing safety by implementing sensors. The results show that the increase in dedicated infrastructure and sensing in micro vehicles positively affects the choice of sustainable modes of transportation, including shared e-scooters and shared e-bikes. On the other hand, the increase in travel time and cost negatively affects the selection of these modes of transportation. These results corroborate the data collected in the RP survey.

When respondents faced different modes of transportation to replace the car, the bus was the most chosen replacement, followed by shared e-bikes and shared e-scooters. However, as choices are affected by respondents' sociodemographic characteristics and background, the choice information was modeled with these characteristics.

For commute trips, people over 40 years old tend not to choose shared micromobility. This choice is also negatively affected if the person identifies as a female and has a monthly bus pass. If the person already has the pass to take the bus, the choice to replace the car with public transportation is higher. Unlike the RP survey, the choice for shared micromobility is negatively affected if the person is a student. The discrepancy in the results can be because when the SC experiment was deployed, students were provided with free monthly bus passes, which increased their willingness to take the bus instead of other modes of transportation. In addition, for commuting, people with higher educational levels tend not to choose shared micromobility, as well as people in more numerous families and with a higher monthly income.

When the trip is for leisure, people are more enthusiastic about shifting to shared micromobility as a sustainable transportation mode, even though walking was the preferred mode to replace the car. When the binary choice between walking and the car was presented to respondents, the provision of dedicated infrastructure was seen to positively affect the choice for an alternative mode of transportation, as well as the provision of trees in the walkway and the increase in travel time, which shows that a longer walking journey is not a drawback to choose this mode for a leisure trip. In addition, the gender and age range of the respondent do not affect the perception of different attributes in order to choose walking. Differently, the increase in the value of the voucher offered for walking affects positively the choice of this mode of transportation by people from low-income families.

When comparing cars and shared e-bikes for leisure trips, the e-bike is preferred. The increase in dedicated infrastructure provision, the increased presence of trees along the way, and the value of the voucher positively affect the choice for this mode of transportation. The increase in travel time by shared e-bike also positively affects the choice of this mode of transportation for leisure trips. Also, the difference in gender, age range, and income level does not affect the perception of different attributes of this mode of transportation.

Confirming what was expected, shared e-scooters were positively perceived for leisure trips compared to cars. The increase in dedicated infrastructure provision and the increase in travel time affects positively the choice of this mode of transport, meaning that people do not consider a longer journey by shared e-scooter to be a drawback. However, the provision of vouchers and the increased presence of trees along the way do not increase the willingness to choose shared e-scooters. Men and women perceive different attributes for shared e-scooter usage the same way. However, increased travel time negatively influences older people's choice of shared e-scooters. The family monthly income also influences the choice since the increased voucher value positively affects the choice of shared e-scooters by lower-income people, and the increased travel time negatively affects the choice by the same group.

Chapter V. Conclusion, Policy Recommendations, and Future Work

This section presents the main contribution generated from this research that adds to the state of the art of the shared micromobility and shared e-scooter subject. Firstly, the research contributions are presented as the responses to the research questions proposed. Then, the policy and planning recommendations are delineated. Finally, the limitations of the work, as well as future work proposals, are presented.

V.1. Contributions of the research

The research's main contributions were to assess if shared e-scooters could be considered a driver for sustainable mobility for short-distance trips if proper planning and infrastructure are offered. Also, the results from the research allowed the acknowledgment of the main drivers/determinants of shared e-scooter usage, the planning strategies that can influence their usage, the impacts they can have on cities' sustainability, how they interact with shared e-bikes, and their contribution to urban mobility during the COVID-19 pandemic.

The research considers the recent implementation of shared e-scooter services in cities worldwide and the need to unravel their potential to promote a modal shift from cars, improved city environmental conditions, and a mode of transportation that a diverse group can use. Five research questions are proposed, and the answers are compiled in this section.

Firstly, the literature review and the data recording from Braga during the pandemic corroborated the answer to **RQ1 – How did the COVID-19 pandemic influence the usage of shared e-scooters?** Using shared

e-scooters was undoubtedly positive in disruptive events such as the COVID-19 pandemic. This mode of transportation provided safe displacements for first respondents and essential workers in many cities worldwide. The partnership between municipalities and companies allowed an alternative to crowded public transportation that did not use private cars to flood streets with polluting vehicles. The usage of micromobility during this period reinforced the experience of users who perceived the need to implement more dedicated infrastructure, which was translated into pop-up cycle lanes that became permanent once the mobility restrictions were lifted.

Some successful cases, such as Rotterdam, Milan, Rome, and some cities in the U.S.A., show the importance of joined forces between public and private sectors (i.e., shared e-scooter and e-bike providers) to accomplish comprehensive and sound planning in order to provide transportation solutions that can be competitive to cars during disruptive events. The offering of new and renewed public spaces for adults and children so they can choose different modes of transportation depending on their travel needs, as well as the implementation of specific charging schemes for first respondents and essential workers, also helped shared micromobility to be a success when public transportation was avoided and shifting to cars was not a valuable option.

Besides, the investment in shared micromobility and shared e-scooter usage in these cities during the COVID-19 pandemic relied on the implementation of pop-up cycle lanes that, in most cases, became permanent infrastructure to support sustainable transportation. The provision of dedicated infrastructure has been proven to influence the adoption of micromobility to avoid car usage positively.

Braga opted to shut down the service entirely in the opposite direction of the cities mentioned above that supported shared micromobility during the COVID-19 pandemic. For not supporting sustainable modes of transportation and diverse options for people who did not want to use public transportation during the pandemic, the last census shows an increase in car usage in the city, which reached the peak of representing 70% of the trips made, the highest number in the last twenty years.

Taking into consideration the case study in the city of Braga and the usage of shared e-scooters after the COVID-19 pandemic, this research investigates what would make people start using shared e-scooters more often and consequently avoid car usage. The thesis methodology envisioned three types of surveys (i.e., RP survey model, SC – commute trips survey model, SC – leisure trips survey model) that would be

able to detect users' and non-users perceptions of this mode of transport and how choice is affected by different sociodemographic characteristics and backgrounds.

The answers from the RP and SC surveys were used to assess the main drivers/determinants of shared e-scooter usage, which answers **RQ2 – What are the main drivers/determinants of shared e-scooter usage for commute and leisure trips?** This research question is divided into two components: commute and leisure trips. The results from the RP survey showed that providing specific conditions that improve rider safety is the primary determinant of shared e-scooter usage in Braga, and this can be interpreted as the implementation of dedicated infrastructure (i.e., cycle lanes), dedicated parking, and zoning. With the current efforts to provide shared e-scooters in Braga, this mode of transportation replaces mostly walking, which does not contribute to the modal shift from cars and, consequently, to the decarbonization of the urban environment.

Moreover, the service does not reach all sociodemographic groups the same way. Women are underrepresented as shared e-scooter users due to the feeling of unsafety. However, this group states that if the lack of safety is solved by providing safe infrastructure, they would be willing to use this mode of transportation. Also, the shared e-scooter service in Braga does not reach the population that lives far from downtown Braga, who are left behind with no access to this mode of transportation to start their daily journeys. The geofencing of the service, allowing the start and end of trips to be restricted to the central area of the city, increases the lack of equity among people from different parts of the town, limiting access to shared e-scooters only to people who live in eight designated parishes that are located near the city center.

Considering the answers from the university students of Braga, a representative group of shared e-scooter users worldwide and in the case study area, the pleasant and fun aspects of the trips are the main drivers for using the service. In addition, considering shared e-scooters as a sustainable mode of transportation also drives this group to choose this mode for their daily trips.

The results from the SC experiment for commute trips showed that shared e-scooters would perform poorly to replace car trips in trips with this purpose. The increase in the cost of shared e-scooter trips, mainly when the trip can be more expensive than a bus ride, negatively influences the usage of e-scooters. The provision of dedicated infrastructure where people can ride safely could motivate the usage of shared

e-scooters and e-bikes in Braga. Also, implementing sensors to announce possible street dangers can induce a higher choice for the micromobility option.

Also, the results of the SC experiment for commute trips corroborate to the results from the RP survey in what concerns some sociodemographic determinants of shared e-scooter and e-bike usage in Braga. The choice of shared e-scooters for commute trips is not positively affected by people above 40 years old, compared to people from 18 to 39 years old. Also, people who identify themselves as women do not tend to choose these modes of transportation. Furthermore, people who own a bus monthly pass would not prefer to take these modes of transportation but would use the bus, which is another sustainable mode of transportation.

One of the main drivers for shared e-scooter usage retrieved from the RP survey was the fun and pleasant aspect of trips. Therefore, the SC experiment for leisure trips was deployed in Braga to assess the differences in willingness to use this mode of transportation to destinations other than work sites and schools. It was found that shared e-scooters and e-bikes could perform exceptionally well in replacing car trips if these types of displacements occur.

According to the results from the SC experiment for leisure trips, it is possible to infer that an increased travel time due to replacing the car with an e-scooter, e-bike, or even walking would be fine in choosing a sustainable mode of transportation. The presence of greenery on the route would not increase the willingness to use e-scooters, and the possibility of monetary compensation (i.e., vouchers) would not increase the likelihood of choosing shared e-scooters for leisure trips. Even with the increase in travel time compared to cars, people would be willing to take this mode of transportation. However, the higher age range of the respondents, gender, family size, and income also influence this choice.

The data retrieved from the surveys (i.e., RP, SC – commute trips, SC – leisure trips) also contributes to answers **RQ3 – How do transportation planning and traffic management influence the safe usage of shared e-scooters?** Which comprises the influence of planning on shared e-scooter usage. For this, it has been seen that a critical part of shared e-scooter and generally shared micromobility planning is providing safety for the riders. Planning for shared e-scooters comprises the implementation of dedicated cycle lanes, parking, city area zoning, and 30km/h zones. The decrease in car speed also contributes to the feeling of safety when riding an e-scooter in Braga.

The results from the SC experiments for commute and leisure trips corroborate the fact that the planning of the transportation systems to incorporate shared e-scooters as a potential mode of transportation comprises the reduction in travel time by this mode of transportation, which can be achieved by the availability of dedicated lanes where these vehicles can reach a higher speed and have more direct routes. The planning for the cost of the trip also influences how people are willing to replace cars for shared e-scooters. If the trip by e-scooter becomes more expensive than the car, or when people do not have a direct route to their destination, and therefore, have to make a longer journey, which makes the trip more expensive since it is charged by the minute traveled, shared e-scooters become highly unattractive in commute trips.

These measures need to be considered, as well as the implementation of policies and planning strategies that allow the population to use shared e-scooters indistinctly. It is still a problem that women do not feel safe and welcome to ride shared e-scooters. The survey results have shown that proper transportation planning and traffic management to decrease car speeds could allow more women and older people to use them. The strategy and planning of the transportation system needs to consider shared e-scooters as a part of the mobility options to take cars from streets mainly for leisure.

Proper planning and implementing structural changes in the urban fabric can boost shared e-scooter usage and achieve possible sustainability impacts. For commute trips, shared e-scooters have shown that the potential environmental positive outcomes would be minimal since people are willing to shift from cars to shared e-scooters less than they would for buses or even shared e-bikes.

To answer **RQ4 – What are the impacts of shared e-scooter usage on the sustainability of the transportation system?** The three pillars of sustainability must be considered (i.e., environmental, social, and economic). The perspective of achieving environmental benefits from shared e-scooters would come from leisure trips. The modal shift from cars in commute trips has been seen to be minimal compared to other modes, such as the bus. On the other hand, if shared e-scooters are used to replace cars on leisure trips, the environmental outcomes could be representative. Most people are willing to leave their cars at home to ride an e-scooter if it is not to commute, which could reduce GHG emissions and improve air quality. Also, the reduced number of cars on the streets could cause a noise reduction.

The positive social impacts of e-scooters are still not prominent. This mode of transportation needs more equity in its provision since it does not reach women in the same proportion as men and people who live far from where shared e-scooters are deployed. Also, lower-income people are left out of the availability of the service provided by shared e-scooter companies.

Leaving lower-income people behind by the fact that specific economic inclusion programs are not made to increase their ridership also affects the economic sustainability of shared e-scooters. Other factors for economic sustainability were not studied in this research, but providing and allowing an efficient, economic standard that enable lower-income people to use the service would be critical. One example could be the provision of fare reductions and vouchers to incentivize lower-income people to ride more.

Lastly, the research results also allow for comparing the competitiveness of shared e-scooters and e-bikes, which answers **RQ5 – Are e-scooters more competitive than shared e-bikes for short and medium-distance trips?** Trip data from Braga shows that e-scooters and e-bikes are not competitors but can be complementary in urban mobility. They are expected to be used in the same city area (where they are deployed and where dedicated infrastructure is more prominent). Still, they can have different characteristics of trips since e-bikes are expected to be used in longer journeys. Also, shared e-bikes can be an asset for commute trips because they are chosen more frequently than e-scooters. However, proper infrastructure and safety tools (i.e., sensing) need to be provided for riders.

Besides, shared e-bikes have shown to be a more equitable mode of transportation in the city; even for leisure trips, the positive and negative perceptions of attributes are comparable for different genders, age groups, and family income ranges. Thus, it is essential to point out that if both shared micromobility modes cannot be offered simultaneously, priority should be given to shared bicycle and e-bike services since they cover commuters and leisure trips and provide a sustainable and more equitable way of displacement.

In short, the research also considered the population's preferences, characteristics, and choices in acknowledging the perspectives of shared e-scooters in cities to check the research hypothesis. Therefore, the results from the case study in Braga show that shared e-scooters can be considered a driver of sustainable mobility for short-distance trips in towns, mainly for leisure trips. The positive sustainability outcomes from implementing shared e-scooter services can only be achieved if proper planning is

considered and shared e-scooters are considered part of the transport system so they can act as a valuable option for the entire community.

V.2. Policy and planning recommendations

The policy recommendations for shared e-scooter usage can be divided into two sectors related to the infrastructure needed for usage and ensuring positive sustainability outcomes from its usage.

According to the research results, dedicated infrastructure was found to be a primary determinant for the surveyed population in the city of Braga. Therefore, cities must comply with this perceived need to boost shared e-scooter usage. However, it is essential to mention that the dedicated infrastructure is not only related to the provision of cycle lanes, which is the most appreciated infrastructure feature by users and potential users. The goal is to create a network where people can make their daily trips safely using shared micromobility. This includes the provision of dedicated parking spots in high-demand traffic generators. Where cycle lanes are impossible to implement, traffic calming measures can be applied, and the zoning of areas to prioritize e-scooters and micromobility in general. These measures need to focus on the main routes used by shared e-scooters and the main origins and destinations of trips.

Even though trees did not positively affect the usage of shared e-scooters, walking and shared e-bikes benefit from this urban feature. Therefore, if a city wants to create a network for sustainable modes of transport, it is essential to plan the built environment with greenery to accommodate more bicycle riders and walkers.

In addition to the city infrastructure needed to improve shared e-scooter usage, implementing sensors in these vehicles can benefit their usage. The planning and policies for this matter must involve the provider companies and the municipality. Before the implementation of the service, some minimum standards for the vehicles must be complied with since they need to be equipped with safety sensors to signal to riders when there is imminent danger on the road, such as nearby vehicles coming from behind, the possibility of skidding, tandem riding, and aggressive swerving.

Positive sustainability impacts can be achieved using shared e-scooters in cities if some critical aspects of policies and planning are conducted. According to the results from the SC experiment for leisure trips, shared e-scooters could impact the modal shift from cars to more sustainable modes of transportation.

Therefore, to increase the positive environmental impacts, shared e-scooter trips need to be encouraged through the availability of the service near recreational areas and leisure places (i.e., parks and tourist places), as shared e-scooters would perform exceptionally to replace cars in these kinds of trips and, therefore, contribute to the decrease in air pollutants and GHG emissions to the atmosphere.

Moreover, to bridge the gender gap in shared e-scooter usage, a critical improvement in the safety of this mode of transportation needs to be done, and it goes in the same direction as the infrastructural needs for planning better environments for shared e-scooters and boosting their usage. With dedicated infrastructure and safety sensors in the vehicle, women would feel keener to use shared e-scooters for leisure and commute trips. The advancements in safety would also be responsible for attracting older people to use shared e-scooters. However, depending on the region's cultural aspects, including Portugal and Braga, older people tend to stick to the feeling of insecurity over two-wheeled modes of transportation. Also, the area of the service's catchment needs to be expanded to other regions than downtown and the university campuses to give more access to the shared e-scooter service to people from all backgrounds who live far from the city's central region. With these policies and planning measures, shared e-scooters can increase their catchment area and user background profile, becoming a mode of transportation for all.

Transportation planning governance models and policymaking to boost shared e-scooters can be based on providing monetary rewards (i.e., vouchers and fare discounts) for disadvantaged people who use the service for commuting and leisure trips. In Braga, the offering of vouchers to boost bicycle usage was shown to be effective for this mode of transportation, and the results of the research indicated that this could positively affect shared e-scooter usage as well since the increase in the voucher value positively affects the usage by lower-income people.

In short, the study results have shown that shared e-scooters can be considered in cities as a sustainable mobility option that could act as a driver for modal shift from cars in leisure and recreational trips. Therefore, safety issues need to be addressed, such as the implementation of proper infrastructure and technological enhancements to alert riders of possible road danger, which has been pointed by this research as a way to increase people's willingness to choose micromobility for their daily travels. Moreover, the provision of tools and infrastructure to boost micromobility safety has a positive impact on decreasing the equity problems found mainly in shared e-scooter usage. Creating a reasonable

environment where more women and elderly people feel safer and welcome to shift from cars to this mode of transportation can lead to an increase in the general population's participation in micromobility usage. In addition, the provision of monetary benefits for low-income residents and the increase in the catchment area of the dockless shared micromobility modes needs to be enlarged so more people from all backgrounds are exposed to them. With a sound planning and policymaking strategy that is enabled by research, some key aspects, such as dedicated infrastructure, danger signaling technology in vehicles, offering of vouchers for low-income people, increase in the geofence area of availability of shared micromobility services, as well as the development of an attractive urban environment (e.g., inclusion of greenery) can make shared micromobility a safe transportation option for a diverse population.

V.3. Limitations of the work

While all research questions proposed could be answered through the literature review and the pilot study conducted in Braga, some further outcomes could have been further explored to enhance the policy and planning proposes, such as the degree of available infrastructure or the specific value of vouchers that better increase shared e-scooter usage. For example, different infrastructure availability was proposed in the stated choice experiments (e.g., 0%, 50%, 100% of the route covered in dedicated infrastructure), so the knowledge of the specific availability of infrastructure that increases usage of shared micromobility could be used to delineate future planning and policy recommendations better.

More specific data on shared e-scooter and e-bike usage could not be used to stipulate the most used routes in Braga due to a lack of geospatial information and the unavailability of GIS data to perform geospatial studies. If geospatial data were available, better planning of the location of dedicated parking spots and dedicated infrastructure could be known to improve the planning for a network of micromobility in the city.

Also, data on accidents and road accidents involving micromobility modes in Braga were unavailable. This information could have been used to propose better and safer routes for shared micromobility riders. Also, the accident data could have been used to acknowledge areas where the implementation of dedicated infrastructure and traffic calming have priority in Braga.

The RP survey implemented in Braga suffered from an excessive number of answers from students. Even if this group is usually among the primary users of shared e-scooters, the sample could have been more

aligned with Braga's population. The difficulty of collecting data from a more diverse group of people is directly connected to the restrictions from the pandemic since this survey was implemented right after the contact restrictions were lifted, and people could go freely to the streets in Portugal.

Even if it was considered an addition to the research's scope, the COVID-19 pandemic also played an important role in its implementation's limitations. The timeline for the tasks proposed had to be realigned after the mobility restrictions that removed shared e-scooters from the streets of Braga were lifted. Also, as e-scooters were not used during the pandemic, trip data could only be available later that year, which postponed its evaluation.

Also, the lack of recognition of shared e-scooters as a mode of transportation and their non-inclusion in the census data increase the lack of prior information that can be obtained from their usage. The only data available is from the companies that provide the service.

V.4. Future works

For future works, implementing geospatial and land use data could lead to more effective interventions in cities' built environment. The interaction between the current data presented in this research and geospatial data would increase the outcomes of the proper planning process of shared e-cooters, even for the last mile, and their connection with public transportation in Braga.

Besides, using mixed logit models could allow a better understanding of all sociodemographic groups when choosing sustainable modes of transportation for commute trips since it allows a modeling process that refines the answers obtained. Also, since the bus was the most preferred mode of transportation to replace cars in commute trips, a deeper understanding of the needs of potential users could be addressed since respondents reported having issues with bus availability and timetable to commute while answering the survey. Therefore, other attributes and attribute levels could be used to a new SC experiment focusing on bus usage.

In addition, random parameters logit model specification could be used in future research incorporating the data collected through the SC commute and SC leisure experiments. The "observed heterogeneity" can be allowed to vary randomly over each individual/respondent (teste variation). In the models presented in this research, the "observed heterogeneity" was treated as fixed for each group of

respondents (with the same observed characteristics such as age, gender, etc.).

The advancements in the structural parts of shared e-scooters could be also studied in the future, both for the life cycle analysis of the service, as well as to understand and test how could shared e-scooters function as a way to help clean the air of cities through implemented tools on the vehicle that allow particulate filtering.

Also, the introduction of machine learning and AI could be studied to analyze how shared e-scooters could increment mobility in smart cities and how real-time urban mobility monitoring could interfere shared e-scooter usage connected with different modes of transportation. This could be linked to the connection to public transportation and the provision of park-and-ride stations where shared e-scooters could be available on request for drivers to use it complementary to their cars.

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Appendixes

Inquérito relativo à utilização atual e futura de trotinetes partilhadas no município de Braga

O presente questionário é apresentado no âmbito da investigação de doutoramento em Engenharia Civil entre a Universidade do Minho e o LNEC.

O seu principal objetivo é identificar as características das viagens realizadas por trotinetes partilhadas no município de Braga através da perspetiva dos utilizadores, assim como as motivações para utilização, e as principais barreiras encontradas pelos não utilizadores do sistema de trotinetes partilhadas de Braga. Esta investigação é financiada pela Fundação para a Ciência e a Tecnologia - FCT.

Eu e meus orientadores agradecemos que preencha o questionário a partir da sua experiência com o serviço de trotinetes partilhadas de Braga.

Todas as informações coletadas pela sua participação voluntária serão tratadas de forma anónima e serão usadas exclusivamente para fins científicos.

Desde já, muito obrigado pela participação.

Quaisquer dúvidas podem ser direcionadas para o e-mail: id8651@alunos.uminho.pt

** Indica uma pergunta obrigatória*

1. 1. Utiliza o serviço de trotinetes partilhadas em Braga? *

Marcar apenas uma oval.

☐ Sim *Avançar para a pergunta 5*

☐ Não *Avançar para a pergunta 2*

Uma vez que não utiliza as trotinetes partilhadas

2. 2. Quais os principais fatores para a NÃO utilização das trotinetes partilhadas? *

Marcar tudo o que for aplicável.

- ☐ Desconfortável
- ☐ Elevada velocidade de tráfego nas vias
- ☐ Exposição às intempéries (ex.: chuva)
- ☐ Má condição do pavimento (ex.: estado de conservação, descontinuidade, etc.)
- ☐ Não há locais para estacionamento de trotinetes junto aos locais onde frequento
- ☐ Não sei como utilizar a trotinete
- ☐ Perímetro de utilização limitado (existência de áreas onde a utilização é proibida)
- ☐ Preço elevado
- ☐ Sensação de insegurança viária
- ☐ Prefiro utilizar o automóvel
- ☐ Prefiro utilizar o transporte público
- ☐ Prefiro me deslocar a pé
- ☐ Outra: _____

3. 3. Selecione as TRÊS principais prioridades de intervenção para que venha a utilizar as trotinetes partilhadas

Marcar tudo o que for aplicável.

- ☐ Aulas de condução de trotinetes gratuitas
- ☐ Criação de zonas de 30 km/h (velocidade máxima de 30 km/h para o tráfego automóvel)
- ☐ Criação de zonas de 20 km/h (velocidade máxima de 20 km/h para o tráfego automóvel)
- ☐ Criação de zonas dedicadas à utilização das trotinetes (ex.: zoneamento)
- ☐ Implementação de mais locais de estacionamento exclusivos para trotinetes
- ☐ Implementação de trotinetes partilhadas em locais com menor disponibilidade de linhas de autocarro
- ☐ Implementação de vias dedicadas à circulação das trotinetes (ex.: ciclovias)
- ☐ Inclusão de outras formas de pagamento mais simples (ex.: cartões pré-pagos)
- ☐ Integração de bilhética entre trotinetes partilhadas e autocarros
- ☐ Maior regulação e fiscalização na utilização das trotinetes partilhadas
- ☐ Outra: _____

4. 4. Se os fatores acima forem solucionados/implementados, gostaria de utilizar as trotinete partilhadas?

Marcar apenas uma oval.

☐ Sim

☐ Não

Avançar para a pergunta 27

Uma vez que utiliza as trotinetes partilhadas

5. 2. Quais as principais motivações para a utilização das trotinetes partilhadas? *

Marcar tudo o que for aplicável.

- ☐ Conforto
- ☐ Descontos e promoções oferecidos pelas empresas de aluguer de trotinetes
- ☐ Esforço físico reduzido nas viagens
- ☐ Modo agradável/divertido de se locomover
- ☐ Possibilidade de deslocação porta-à-porta
- ☐ Preço
- ☐ Rapidez na deslocação
- ☐ Serviço disponível quando o horário dos autocarros é reduzido (ex.: à noite ou fins de semana)
- ☐ Meio de transporte não poluente
- ☐ Outra: _____

6. 3. Quando não usa a trotinete partilhada na viagem, que outro modo utiliza nas suas deslocações?

Marcar apenas uma oval.

- ☐ A pé
- ☐ Automóvel (como condutor)
- ☐ Automóvel (como passageiro)
- ☐ Bicicleta
- ☐ Motociclo
- ☐ Serviço de táxi ou similares (ex.: Uber, Bolt)
- ☐ Transporte público
- ☐ Trotinete pessoal
- ☐ Outra: _____

7. 4. Quanto tempo em média anda até encontrar uma trotinete disponível? *

Marcar apenas uma oval.

- ☐ De 1 a 4 minutos
- ☐ De 5 a 9 minutos
- ☐ Mais de 9 minutos

8. 5. Em que período do dia utiliza mais a trotinete partilhada durante a semana? *

Marcar apenas uma oval.

- ☐ Manhã
- ☐ Hora do almoço
- ☐ Tarde
- ☐ Noite
- ☐ Não utilizo durante a semana

9. 6. Em que período do dia utiliza mais a trotinete partilhada durante o fim de semana? *

Marcar apenas uma oval.

- ☐ Manhã
☐ Tarde
☐ Hora do almoço
☐ Noite
☐ Não utilizo durante o fim de semana

10. 7. Qual é geralmente o seu ponto de partida da primeira viagem de trotinete do dia? *

Marcar apenas uma oval.

- ☐ Espaço de serviço público (ex.: Loja do Cidadão, Loja das Finanças)
☐ Loja ou centro comercial
☐ O meu local de trabalho/estudo
☐ O meu local de residência
☐ Uma paragem de autocarro
☐ Outra: _____

11. 8. Qual é geralmente o seu ponto de partida para a última viagem de trotinete do dia? *

Marcar apenas uma oval.

- ☐ Bar/Restaurante
☐ Ginásio
☐ Meu local de trabalho/estudo
☐ Meu local de residência
☐ Outra: _____

12. 9. Com que frequência utiliza as trotinetes por semana? *

Marcar apenas uma oval.

- ☐ Todos os dias da semana
☐ 5 vezes por semana
☐ 3 vezes por semana
☐ 1 vez por semana
☐ Ocasionalmente

13. 10. Quantas vezes por dia utiliza as trotinetes? *

Marcar apenas uma oval.

- ☐ Mais de 3 vezes por dia
☐ 3 vezes por dia
☐ 2 vezes por dia
☐ 1 vez por dia

14. SE RESPONDEU 3 VEZES POR DIA OU MAIS DE 3 VEZES

11. Qual é o destino mais frequente das suas viagens de trotinete partilhada?

Marcar tudo o que for aplicável.

- ☐ Bar/restaurante
☐ Casa de amigos/familiares
☐ Centro histórico da cidade
☐ Espaço de serviço público (ex.: Loja do Cidadão, Loja das Finanças)
☐ Ginásio
☐ Loja, supermercado ou centro comercial
☐ O meu local de trabalho/estudo
☐ O meu local de residência
☐ Parques da cidade (ex.: Parque da Rodovia, Parque da Ponte)
☐ Uma paragem de autocarro
☐ Outra: _____

15. 12. Pretende continuar a utilizar as trotinetes partilhadas para se deslocar? *

Marcar apenas uma oval.

- ☐ Sim
☐ Não

16. 12.1. Se respondeu SIM à questão 12. Quais os motivos para continuar? Se "outra opção" escreva qual.

Marcar tudo o que for aplicável.

- ☐ Maior flexibilidade
☐ Mais barato
☐ Mais confortável
☐ Mais rápido
☐ Mais seguro
☐ Menor emissão de gases poluentes durante as deslocações
☐ Outra: _____

17. 12.2. Se respondeu NÃO à questão 12. Quais os motivos para não continuar?

Marcar tudo o que for aplicável.

- ☐ Risco de acidente (acho perigoso circular de trotinete)
☐ Disponibilidade insuficiente de trotinetes
☐ Pretendo comprar minha própria trotinete
☐ Preço elevado para utilização
☐ Trotinetes estão mal conservadas
☐ Outra: _____

18. 13. Selecione as TRÊS principais prioridades de intervenção para utilizar de forma regular as trotinetes partilhadas

Marcar tudo o que for aplicável.

- ☐ Aulas de condução de trotinetes gratuitas
- ☐ Criação de zonas de 30 km/h (velocidade máxima de 30 km/h para tráfego automóvel)
- ☐ Criação de zonas de 20 km/h (velocidade máxima de 20 km/h para o tráfego automóvel)
- ☐ Criação de zonas dedicadas à utilização das trotinetes (ex.: zoneamento)
- ☐ Implementação de mais locais de estacionamento exclusivos para trotinetes
- ☐ Implementação de trotinetes partilhadas em locais com menor disponibilidade de linhas de autocarro
- ☐ Implementação de vias dedicadas à circulação das trotinetes (ex.: ciclovias)
- ☐ Inclusão de outras formas de pagamento mais simples (ex.: cartões pré-pagos)
- ☐ Integração de bilhética entre trotinetes partilhadas e autocarros
- ☐ Maior regulação e fiscalização na utilização das trotinetes partilhadas
- ☐ Outra: _____

19. 14. Quando utiliza as trotinetes partilhadas, em que tipos de infraestrutura se desloca? *

Marcar apenas uma oval.

- ☐ Berma
- ☐ Faixas cicláveis/ciclovias
- ☐ Passeios
- ☐ Vias de tráfego rodoviário

20. 15. Como geralmente utiliza a trotinete? *

Marcar apenas uma oval.

- ☐ Sozinho na trotinete
- ☐ Com várias pessoas, estando cada uma em uma trotinete
- ☐ Com mais de uma pessoa na mesma trotinete

21. 15.1. Se respondeu que realiza viagens com mais de uma pessoa na mesma trotinete. Qu o motivo para viajar desta maneira?

Marcar apenas uma oval.

- ☐ É divertido/agradável
- ☐ É mais prático
- ☐ O preço da viagem pode ser dividido entre as pessoas
- ☐ Não havia outra trotinete disponível
- ☐ Outra: _____

22. 16. Conhece a legislação que regula o uso das trotinetes em vias públicas? *

Marcar apenas uma oval.

- ☐ Sim
- ☐ Não

23. 17. Avalie de que forma as seguintes regras podem melhorar a utilização das trotinetes. *

Marcar apenas uma oval por linha.

	Muito	Neutro	Pouco	Pararia de utilizar
Apenas circular em ciclovias	☐	☐	☐	☐
Apenas circular em vias de tráfego	☐	☐	☐	☐
Circulação em áreas onde há prioridade aos peões e bicicletas (zonas coexistência)	☐	☐	☐	☐
Circulação em áreas de velocidade controlada (ex.: zonas 30 km/h)	☐	☐	☐	☐
Não utilizar telemóvel ou auriculares durante a condução	☐	☐	☐	☐
Transporte de apenas uma pessoa na trotinete	☐	☐	☐	☐
Utilização de capacete (recomendado e não obrigatório)	☐	☐	☐	☐
Velocidade máxima de 25 km/h para todos os veículos	☐	☐	☐	☐

24. 18. Utilizaria as trotinetes partilhadas combinadas com os autocarros se... *

Marcar tudo o que for aplicável.

- ☐ a qualidade do serviço do transporte público fosse melhorada
- ☐ houvesse sempre disponibilidade de trotinetes nas paragens de autocarro
- ☐ o preço do bilhete de autocarro integrasse a utilização da trotinete
- ☐ Não utilizaria estes dois modos conectados

25. 19. Considera as trotinetes partilhadas um modo de transporte sustentável? *

Marcar apenas uma oval.

- ☐ Sim
- ☐ Não

26. 20. Para cada afirmação abaixo sobre trotinetes partilhadas, escolha uma opção entre "discordo totalmente" e "concordo totalmente"

Marcar apenas uma oval por linha.

	Discordo totalmente	Discordo	Neutro	Concordo	Concordo totalment
Ajudam à redução de emissão de gases poluentes	☐	☐	☐	☐	☐
Ajudam a promover a resiliência (p.ex. diversidade de opções flexíveis de mobilidade urbana)	☐	☐	☐	☐	☐
Ajudam a promover a equidade de género	☐	☐	☐	☐	☐
Ajudam a promover um estilo de consumo sustentável (economia de partilha)	☐	☐	☐	☐	☐
Melhoram a equidade entre diferentes grupos sociais	☐	☐	☐	☐	☐
Permitem a conexão com o transporte público para percorrer a parte final da deslocação até ao destino	☐	☐	☐	☐	☐
Permitem uma utilização mais sustentável do espaço público	☐	☐	☐	☐	☐
Promovem um estilo de vida saudável	☐	☐	☐	☐	☐

Questionário socio económico

27. 1. Género *

Marcar apenas uma oval.

- ☐ Masculino
- ☐ Feminino
- ☐ Outro
- ☐ Prefiro não responder

28. 2. Idade *

Marcar apenas uma oval.

- ☐ Menos de 9 anos
- ☐ Entre 10 e 14 anos
- ☐ Entre 15 e 19 anos
- ☐ Entre 20 e 24 anos
- ☐ Entre 25 e 29 anos
- ☐ Entre 30 e 34 anos
- ☐ Entre 35 e 39 anos
- ☐ Entre 40 e 44 anos
- ☐ Entre 45 e 49 anos
- ☐ Entre 50 e 54 anos
- ☐ Entre 55 e 59 anos
- ☐ Entre 60 e 64 anos
- ☐ 65 ou mais anos

29. 3. Nível de escolaridade mais alto que completou *

Marcar apenas uma oval.

- ☐ Sem nível de escolaridade
- ☐ Ensino básico (1º ciclo)
- ☐ Ensino básico (2º ciclo)
- ☐ Ensino básico (3º ciclo)
- ☐ Ensino Secundário
- ☐ Curso técnico superior profissional
- ☐ Licenciatura
- ☐ Mestrado
- ☐ Doutoramento

30. 4. Situação profissional *

Marcar apenas uma oval.

- ☐ Estudante
- ☐ Empregador/patrão
- ☐ Trabalhador por conta própria ou isolado
- ☐ Trabalhador por conta de outrem (empresa municipal, universidade, escolas e outras entidades da administração pública)
- ☐ Trabalhador por conta de outrem (empresa privada)
- ☐ Desempregado

31. 5. Número de elementos do agregado familiar *

Marcar apenas uma oval.

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ +4

32. 6. Rendimento mensal líquido do seu agregado familiar *

Marcar apenas uma oval.

- ☐ Até €665
- ☐ Entre €666 e €1000
- ☐ Entre €1001 e €1500
- ☐ Entre €1501 e €2000
- ☐ Entre €2001 e €2500
- ☐ Entre €2501 e €3000
- ☐ Entre €3001 e €3500
- ☐ Entre €3501 e €4000
- ☐ Acima de €4001
- ☐ Não sei
- ☐ Prefiro não responder

33. 7. Freguesia de origem da maioria das suas deslocações *

Marcar apenas uma oval.

- ☐ Adaúfe
- ☐ Espinho
- ☐ Esporões
- ☐ Figueiredo
- ☐ Gualtar
- ☐ Lamas
- ☐ Mire de Tibães
- ☐ Padim da Graça
- ☐ Palmeira
- ☐ Pedralva
- ☐ Priscos
- ☐ Ruílhe
- ☐ São Vicente
- ☐ São Victor
- ☐ Sequeira

- ☐ Sobreposta
- ☐ Tadam
- ☐ Tebosa
- ☐ U.F. de Arentim e Cunha
- ☐ U.F. de Cabreiros e Passos São Julião
- ☐ U.F. de Celeirós, Aveleda e Vimieiro
- ☐ U.F. de Crespos e Pousada
- ☐ U.F. de Escudeiros, Penso Santo Estevão e Penso São Vicente
- ☐ U.F. de Este São Pedro e Este São Mamede
- ☐ U.F. de Ferreiros e Gondizalves
- ☐ U.F. de Guisande e Oliveira São Pedro
- ☐ U.F. de Lomar e Arcos
- ☐ U.F. de Maximinos, Sé e Cividade
- ☐ U.F. de Merelim São Paio, Panóias e Parada de Tibães
- ☐ U.F. de Merelim São Pedro e Frossos
- ☐ U.F. de Morreira e Trandeiras
- ☐ U.F. de Nogueira, Fraião e Lamações
- ☐ U.F. Nogueiró e Tenões
- ☐ U.F. de Real, Dume e Semelhe
- ☐ U.F. de Santa Lucrécia de Algeriz e Navarra
- ☐ U.F. de São José de São Lázaro e São João do Souto
- ☐ U.F. de Vilaça e Fradelos
- ☐ Outro

34. 8. Freguesia de destino da maioria das suas deslocações *

Marcar apenas uma oval.

- ☐ Adaúfe
- ☐ Espinho
- ☐ Esporões
- ☐ Figueiredo
- ☐ Gualtar
- ☐ Lamas

- ☐ Mire de Tibães
- ☐ Padim da Graça
- ☐ Palmeira
- ☐ Pedralva
- ☐ Priscos
- ☐ Ruílhe
- ☐ São Vicente
- ☐ São Victor
- ☐ Sequeira
- ☐ Sobreposta
- ☐ Tadim
- ☐ Tebosa
- ☐ U.F. de Arentim e Cunha
- ☐ U.F. de Cabreiros e Passos São Julião
- ☐ U.F. de Celeirós, Aveleda e Vimieiro
- ☐ U.F. de Crespos e Pousada
- ☐ U.F. de Escudeiros, Penso Santo Estevão e Penso São Vicente
- ☐ U.F. de Este São Pedro e Este São Mamede
- ☐ U.F. de Ferreiros e Gondizalves
- ☐ U.F. de Guisande e Oliveira São Pedro
- ☐ U.F. de Lomar e Arcos
- ☐ U.F. de Maximinos, Sé e Cividade
- ☐ U.F. de Merelim São Paio, Panóias e Parada de Tibães
- ☐ U.F. de Merelim São Pedro e Frossos
- ☐ U.F. de Morreira e Trandeiras
- ☐ U.F. de Nogueira, Fraião e Lamações
- ☐ U.F. Nogueiró e Tenões
- ☐ U.F. de Real, Dume e Semelhe
- ☐ U.F. de Santa Lucrécia de Algeriz e Navarra
- ☐ U.F. de São José de São Lázaro e São João do Souto
- ☐ U.F. de Vilaça e Fradelos
- ☐ Outro

35. 9. Modo de transporte principal que utiliza nas deslocações casa-escola/trabalho *

Marcar apenas uma oval.

- ☐ A pé
- ☐ Bicicleta
- ☐ Motociclo
- ☐ Automóvel (como condutor)
- ☐ Automóvel (como passageiro)
- ☐ Serviço de taxi e similares (ex.: Uber, Bolt)
- ☐ Transporte público
- ☐ Trotinete
- ☐ Outra: _____

Este conteúdo não foi criado nem aprovado pela Google.

Google Formulários

Appendix B. Stated Choice survey for commute trips



Início

Estudo de Preferências de Mobilidade em Braga (viagens casa-trabalho/escola)

O presente estudo é desenvolvido no âmbito da investigação de doutoramento em Engenharia Civil entre a Universidade do Minho e o LNEC, e o seu principal objetivo é identificar os principais fatores que podem influenciar **alterações nos padrões de mobilidade para modos mais sustentáveis em viagens pendulares de curta distância em Braga.**

As opções de mobilidade sustentável consideradas para este estudo são: trotinete elétrica partilhada, bicicleta elétrica partilhada e autocarro elétrico.



Para mais informações sobre a mobilidade em Braga, clique [aqui](#).

O estudo é de responsabilidade de Gabriel Dias (id8651@alunos.uminho.pt), que pode ser contactado para esclarecer qualquer dúvida ou partilhar algum comentário.

Todas as informações coletadas pela sua participação voluntária serão tratadas de forma anónima e serão utilizadas exclusivamente para fins científicos.

Declaro ter compreendido os objetivos do estudo e aceito preencher o questionário de forma anónima, pelo que:

- ☐ Sim, aceito participar do estudo
- ☐ Não, não aceito participar do estudo

Padrões de Mobilidade Pessoal

Questões sobre mobilidade pessoal

Principal modo de transporte que utiliza nas deslocações diárias entre casa-trabalho/escola

- ☐ A pé
- ☐ Automóvel (como condutor)
- ☐ Automóvel (como passageiro)
- ☐ Bicicleta
- ☐ Motociclo
- ☐ Serviço de taxi ou similares (ex.: Uber, Bolt)
- ☐ Transporte público
- ☐ Trotinete

Número de carros no agregado familiar

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3+

Possui carta de condução?

- ☐ Sim
- ☐ Não

Utiliza o serviço de autocarros em Braga regularmente?

- ☐ Praticamente todos os dias
- ☐ Pelo menos uma vez por semana
- ☐ Pelo menos uma vez por mês
- ☐ Pelo menos uma vez por ano
- ☐ Nunca

Tem passe de transportes públicos (passe TUB)?

- ☐ Sim
☐ Não

Já utilizou o serviço de trotinetes partilhadas em Braga?

- ☐ Sim
☐ Não

Já utilizou o serviço de bicicletas partilhadas em Braga?

- ☐ Sim
☐ Não

Utilizaria os meios de transporte abaixo associados ao autocarro como medida para combater as alterações climáticas?

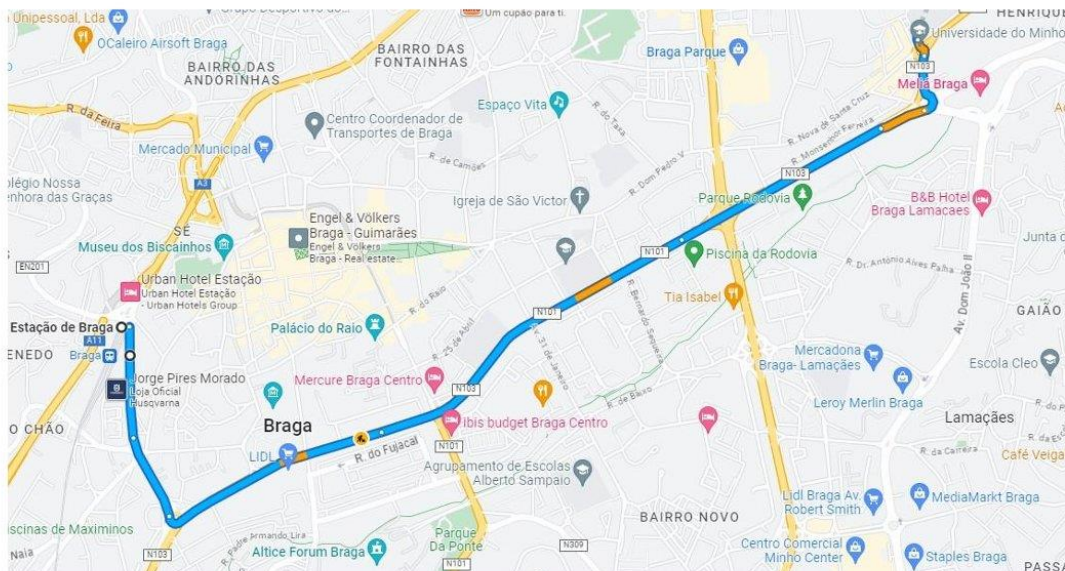
	Muito pouco provável	Pouco provável	Neutro	Provável	Muito provável
Trotinete elétrica partilhadas	☐	☐	☐	☐	☐
Bicicleta elétrica partilhada	☐	☐	☐	☐	☐

Questões para escolha

Contexto para Avaliação de Preferências - escolha do modo de transporte (próxima página)

Nesta secção pretende-se avaliar cenários alternativos que possibilitem a utilização de modos sustentáveis em viagens de curta distância entre a área central da cidade (Estação de Caminhos de Ferro) e a freguesia de Gualtar, onde fica localizado o campus da Universidade do Minho.

Para efeitos de construção dos cenários, um corredor muito conhecido em Braga foi selecionado. Este compreende uma distância de 4,5 km e inclui a passagem pelas seguintes vias: Rua de Caires, Avenida Conde Dom Henrique, Avenida da Imaculada Conceição, Avenida João XXI e Avenida João Paulo II, conforme imagem abaixo.



O tempo gasto para percorrer este trajeto em um automóvel é de **8 minutos**, e o custo da viagem é de **3,5 euros** (o custo da viagem considera gastos com combustível, estacionamento, manutenção, seguro, depreciação do veículo).

Para cada uma das 12 situações alternativas seguintes, indique se está disposto a substituir a sua deslocação no veículo automóvel por uma deslocação em trotinete elétrica partilhada, bicicleta elétrica partilhada ou autocarro. **Por favor, considere que todos os atributos que não estão referidos (exemplo: disponibilidade imediata do meio de transporte para início da viagem, disponibilidade de estacionamento para trotinetes e bicicletas) são comuns a todos os cenários.**

Atributos para os meios de transporte nas situações alternativas:

- **Tempo de viagem (minutos):** tempo gasto no meio de transporte em relação ao tempo gasto por um automóvel para percorrer o mesmo trajeto.
- **Custo da viagem (EUR):** preço estimado para a viagem em relação ao custo para percorrer o mesmo trajeto em um automóvel. Para bicicletas ainda é possível ganhar um vale de desconto para utilizar no comércio do centro de Braga.
- **Presença de infraestrutura dedicada:** existência de faixa BUS (via preferencial para deslocação mais rápida do autocarro) ou não, e existência de local apropriado e seguro para que bicicletas e trotinetes possam se deslocar neste percurso (ex.: ciclovias).

- **Presença de tecnologia para melhoria da viagem:**

- **Autocarro:** presença ou não de Wi-Fi (serviço de internet) nos autocarros.
- **Trotinetes e bicicletas elétricas partilhadas:** existência ou não de tecnologia sonora em trotinetes e bicicletas para alertar os utilizadores em caso de haver peões próximos, de haver mais de uma pessoa no veículo, realização de manobras perigosas ou da viagem ser realizada no passeio.

Cenários Bloco 1

Cenário 1.1

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 - 1,5 € - 1,5 € do custo da deslocação atual	 0% 0% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 Igual ao custo da deslocação atual + vale de desconto	 0% 0% da deslocação em ciclovias	 Existência de detetores de obstáculos
Autocarro		 + 4 min + 4 minutos ao tempo da deslocação atual	 Grátis Deslocação gratuita	 Inexistência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 2.1

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		+ 2 min  + 2 minutos ao tempo da deslocação atual	+ 1,5 €  + 1,5 € do custo da deslocação atual	100%  100% da deslocação em ciclovia	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		+ 17 min  + 17 minutos ao tempo da deslocação atual	 Igual ao custo da deslocação atual + vale de desconto	0%  0% da deslocação em ciclovia	 Inexistência de detetores de obstáculos
Autocarro		+ 1 min  + 1 minutos ao tempo da deslocação atual	- 3,0 €  - 3,0 € do custo da deslocação atual	 Existência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 3.1

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € do custo da deslocação atual	 0% 0% da deslocação em ciclovias	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € ao custo da deslocação atual	 100% 100% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Autocarro		 + 1 min + 1 minutos ao tempo da deslocação atual	 - 3,0 € - 3,0 € do custo da deslocação atual	 Inexistência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuaria a utilizar o automóvel

Cenário 4.1

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 = Custo da deslocação igual ao atual	 50% 50% da deslocação em ciclovias	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € ao custo da deslocação atual	 100% 100% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Autocarro		 + 4 min + 4 minutos ao tempo da deslocação atual	 Grátis Deslocação gratuita	 Inexistência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada

- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 5.1

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 - 1,5 € - 1,5 € do custo da deslocação atual	 0% 0% da deslocação em ciclovia	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 - 1,5 € +  - 1,5 € ao custo da deslocação atual + vale de desconto	 100% 100% da deslocação em ciclovia	 Inexistência de detetores de obstáculos
Autocarro		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 2,75 € - 2,75 € do custo da deslocação atual	 Inexistência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 6.1

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € do custo da deslocação atual	 100% 100% da deslocação em ciclovia	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 - 1,5 € +  - 1,5 € ao custo da deslocação atual + vale de desconto	 100% 100% da deslocação em ciclovia	 Inexistência de detetores de obstáculos
Autocarro		 + 1 min + 1 minutos ao tempo da deslocação atual	 Grátis Deslocação gratuita	 Existência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuaria a utilizar o automóvel

Cenário 7.1

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 1,5 € - 1,5 € do custo da deslocação atual	 100% 100% da deslocação em ciclovia	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € ao custo da deslocação atual	 50% 50% da deslocação em ciclovia	 Existência de detetores de obstáculos
Autocarro		 + 7 min + 7 minutos ao tempo da deslocação atual	 Grátis Deslocação gratuita	 Inexistência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada

- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 8.1

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 = Custo da deslocação igual ao atual	 50% 50% da deslocação em ciclovia	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € ao custo da deslocação atual	 50% 50% da deslocação em ciclovia	 Inexistência de detetores de obstáculos
Autocarro		 + 1 min + 1 minutos ao tempo da deslocação atual	 - 2,75 € - 2,75 € do custo da deslocação atual	 Existência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 9.1

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 = Custo da deslocação igual ao atual	 0% 0% da deslocação em ciclovias	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 + + Igual ao custo da deslocação atual + vale de desconto	 50% 50% da deslocação em ciclovias	 Existência de detetores de obstáculos
Autocarro		 + 4 min + 4 minutos ao tempo da deslocação atual	 - 3,0 € - 3,0 € do custo da deslocação atual	 Existência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 10.1

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € do custo da deslocação atual	 50% 50% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 + + Igual ao custo da deslocação atual + vale de desconto	 50% 50% da deslocação em ciclovias	 Existência de detetores de obstáculos
Autocarro		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 2,75 € - 2,75 € do custo da deslocação atual	 Existência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada

- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 11.1

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 1,5 € - 1,5 € do custo da deslocação atual	 50% 50% da deslocação em ciclovia	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 - 1,5 € +  - 1,5 € ao custo da deslocação atual + vale de desconto	 0% 0% da deslocação em ciclovia	 Existência de detetores de obstáculos
Autocarro		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 3,0 € - 3,0 € do custo da deslocação atual	 Existência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 12.1

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 = Custo da deslocação igual ao atual	 100% 100% da deslocação em ciclovia	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 1,5 € +  - 1,5 € ao custo da deslocação atual + vale de desconto	 0% 0% da deslocação em ciclovia	 Existência de detetores de obstáculos
Autocarro		 + 4 min + 4 minutos ao tempo da deslocação atual	 - 2,75 € - 2,75 € do custo da deslocação atual	 Inexistência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuaria a utilizar o automóvel

Cenários Bloco 2

Cenário 1.2

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 - 1,5 € - 1,5 € do custo da deslocação atual	 50% 50% da deslocação em ciclovias	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 1,5 € +  - 1,5 € ao custo da deslocação atual + vale de desconto	 100% 100% da deslocação em ciclovias	 Existência de detetores de obstáculos
Autocarro		 + 1 min + 1 minutos ao tempo da deslocação atual	 Grátis Deslocação gratuita	 Existência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 2.2

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 = Custo da deslocação igual ao atual	 100% 100% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 - 1,5 € +  - 1,5 € ao custo da deslocação atual + vale de desconto	 100% 100% da deslocação em ciclovias	 Existência de detetores de obstáculos
Autocarro		 + 4 min + 4 minutos ao tempo da deslocação atual	 - 3,0 € - 3,0 € do custo da deslocação atual	 Existência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada

- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 3.2

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € do custo da deslocação atual	 100% 100% da deslocação em ciclovia	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € ao custo da deslocação atual	 50% 50% da deslocação em ciclovia	 Existência de detetores de obstáculos
Autocarro		 + 4 min + 4 minutos ao tempo da deslocação atual	 Grátis Deslocação gratuita	 Existência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 4.2

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		+ 17 min + 17 minutos ao tempo da deslocação atual	- 1,5 € - 1,5 € do custo da deslocação atual	0% 0% da deslocação em ciclovia	Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		+ 2 min + 2 minutos ao tempo da deslocação atual	+ 1,5 € + 1,5 € ao custo da deslocação atual	50% 50% da deslocação em ciclovia	Existência de detetores de obstáculos
Autocarro		+ 1 min + 1 minutos ao tempo da deslocação atual	- 3,0 € - 3,0 € do custo da deslocação atual	Inexistência de faixa BUS	Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 5.2

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		+ 7 min + 7 minutos ao tempo da deslocação atual	+ 1,5 € + 1,5 € do custo da deslocação atual	50% 50% da deslocação em ciclovia	Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		+ 17 min + 17 minutos ao tempo da deslocação atual	- 1,5 € ao custo da deslocação atual + vale de desconto	50% 50% da deslocação em ciclovia	Existência de detetores de obstáculos
Autocarro		+ 1 min + 1 minutos ao tempo da deslocação atual	- 2,75 € - 2,75 € do custo da deslocação atual	Inexistência de faixa BUS	Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada

- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 6.2

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 igual ao atual Custo da deslocação igual ao atual	 0% 0% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 1,5 € ao custo da deslocação atual + vale de desconto	 50% 50% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Autocarro		 + 7 min + 7 minutos ao tempo da deslocação atual	 Grátis Deslocação gratuita	 Existência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 7.2

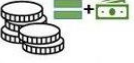
Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 Igual ao custo da deslocação atual	 50% da deslocação em ciclovias	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 Igual ao custo da deslocação atual + vale de desconto	 0% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Autocarro		 + 7 min + 7 minutos ao tempo da deslocação atual	 Grátis Deslocação gratuita	 Inexistência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 8.2

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 1,5 € - 1,5 € do custo da deslocação atual	 100% da deslocação em ciclovias	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 Igual ao custo da deslocação atual + vale de desconto	 0% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Autocarro		 + 1 min + 1 minutos ao tempo da deslocação atual	 - 2,75 € - 2,75 € do custo da deslocação atual	 Inexistência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada

- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 9.2

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € do custo da deslocação atual	 50% 50% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € ao custo da deslocação atual	 0% 0% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Autocarro		 + 4 min + 4 minutos ao tempo da deslocação atual	 - 3,0 € - 3,0 € do custo da deslocação atual	 Inexistência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 10.2

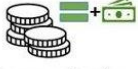
Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 = Custo da deslocação igual ao atual	 0% 0% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € ao custo da deslocação atual	 0% 0% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Autocarro		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 2,75 € - 2,75 € do custo da deslocação atual	 Existência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 11.2

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € do custo da deslocação atual	 0% 0% da deslocação em ciclovias	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 = +  Igual ao custo da deslocação atual + vale de desconto	 100% 100% da deslocação em ciclovias	 Existência de detetores de obstáculos
Autocarro		 + 4 min + 4 minutos ao tempo da deslocação atual	 - 2,75 € - 2,75 € do custo da deslocação atual	 Inexistência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada

- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 12.2

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 - 1,5 € - 1,5 € do custo da deslocação atual	 100% 100% da deslocação em ciclovia	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 Igual ao custo da deslocação atual + vale de desconto	 100% 100% da deslocação em ciclovia	 Inexistência de detetores de obstáculos
Autocarro		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 3,0 € - 3,0 € do custo da deslocação atual	 Existência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenários Bloco 3

Cenário 1.3

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 Igual ao custo da deslocação atual	 100% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 Igual ao custo da deslocação atual + vale de desconto	 50% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Autocarro		 + 1 min + 1 minutos ao tempo da deslocação atual	 Grátis Deslocação gratuita	 Inexistência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 2.3

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 - 1,5 € - 1,5 € do custo da deslocação atual	 50% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 Igual ao custo da deslocação atual + vale de desconto	 50% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Autocarro		 + 4 min + 4 minutos ao tempo da deslocação atual	 - 3,0 € - 3,0 € do custo da deslocação atual	 Existência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada

- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 3.3

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 igual ao atual Custo da deslocação igual ao atual	 50% 50% da deslocação em ciclovias	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 - 1,5 € ao custo da deslocação atual + vale de desconto	 0% 0% da deslocação em ciclovias	 Existência de detetores de obstáculos
Autocarro		 + 1 min + 1 minutos ao tempo da deslocação atual	 - 3,0 € do custo da deslocação atual	 Inexistência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 4.3

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € do custo da deslocação atual	 0% 0% da deslocação em ciclovias	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 1,5 € +  - 1,5 € ao custo da deslocação atual + vale de desconto	 0% 0% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Autocarro		 + 4 min + 4 minutos ao tempo da deslocação atual	 Grátis Deslocação gratuita	 Existência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 5.3

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € do custo da deslocação atual	 100% 100% da deslocação em ciclovias	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € ao custo da deslocação atual	 0% 0% da deslocação em ciclovias	 Existência de detetores de obstáculos
Autocarro		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 2,75 € - 2,75 € do custo da deslocação atual	 Existência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada

- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 6.3

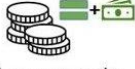
Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 - 1,5 € - 1,5 € do custo da deslocação atual	 0% 0% da deslocação em ciclovia	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € ao custo da deslocação atual	 0% 0% da deslocação em ciclovia	 Existência de detetores de obstáculos
Autocarro		 + 1 min + 1 minutos ao tempo da deslocação atual	 Grátis Deslocação gratuita	 Existência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 7.3

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 Igual ao custo da deslocação atual	 0% da deslocação em ciclovias	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 Igual ao custo da deslocação atual + vale de desconto	 100% da deslocação em ciclovias	 Existência de detetores de obstáculos
Autocarro		 + 1 min + 1 minutos ao tempo da deslocação atual	 - 2,75 € do custo da deslocação atual	 Existência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 8.3

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 + 1,5 € do custo da deslocação atual	 50% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 Igual ao custo da deslocação atual + vale de desconto	 100% da deslocação em ciclovias	 Existência de detetores de obstáculos
Autocarro		 + 7 min + 7 minutos ao tempo da deslocação atual	 Grátis Deslocação gratuita	 Inexistência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada

- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 9.3

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 = Custo da deslocação igual ao atual	 100% 100% da deslocação em ciclovia	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € ao custo da deslocação atual	 100% 100% da deslocação em ciclovia	 Existência de detetores de obstáculos
Autocarro		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 3,0 € - 3,0 € do custo da deslocação atual	 Inexistência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 10.3

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 1,5 € - 1,5 € do custo da deslocação atual	 50% 50% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € ao custo da deslocação atual	 100% 100% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Autocarro		 + 4 min + 4 minutos ao tempo da deslocação atual	 - 2,75 € - 2,75 € do custo da deslocação atual	 Existência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 11.3

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 - 1,5 € - 1,5 € do custo da deslocação atual	 100% 100% da deslocação em ciclovias	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 17 min + 17 minutos ao tempo da deslocação atual	 - 1,5 € + - 1,5 € ao custo da deslocação atual + vale de desconto	 50% 50% da deslocação em ciclovias	 Inexistência de detetores de obstáculos
Autocarro		 + 4 min + 4 minutos ao tempo da deslocação atual	 - 2,75 € - 2,75 € do custo da deslocação atual	 Inexistência de faixa BUS	 Inexistência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada

- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Cenário 12.3

Nas condições apresentadas abaixo, substitui a viagem em automóvel por qual meio de transporte alternativo para percorrer o trajeto entre a estação CP e o campus de Gualtar da Universidade do Minho?

Trotinete elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 + 1,5 € + 1,5 € do custo da deslocação atual	 0% 0% da deslocação em ciclovia	 Existência de detetores de obstáculos
Bicicleta elétrica partilhada		 + 2 min + 2 minutos ao tempo da deslocação atual	 - 1,5 € +  - 1,5 € ao custo da deslocação atual + vale de desconto	 50% 50% da deslocação em ciclovia	 Inexistência de detetores de obstáculos
Autocarro		 + 7 min + 7 minutos ao tempo da deslocação atual	 - 3,0 € - 3,0 € do custo da deslocação atual	 Inexistência de faixa BUS	 Existência de Wi-Fi (serviço de internet)

- ☐ Trotinete elétrica partilhada
- ☐ Bicicleta elétrica partilhada
- ☐ Autocarro
- ☐ Continuar a utilizar o automóvel

Questionário sócio económico

Questionário sócio económico

Género

- ☐ Masculino
- ☐ Feminino
- ☐ Não binário / terceiro género
- ☐ Prefere não dizer

Idade

- ☐ Entre 18 e 19 anos
- ☐ Entre 20 e 24 anos
- ☐ Entre 25 e 29 anos
- ☐ Entre 30 e 34 anos
- ☐ Entre 35 e 39 anos
- ☐ Entre 40 e 44 anos
- ☐ Entre 45 e 49 anos
- ☐ Entre 50 e 54 anos
- ☐ Entre 55 e 59 anos
- ☐ Entre 60 e 64 anos
- ☐ 65 ou mais anos

Situação profissional

- ☐ Estudante
- ☐ Empregador/patrão
- ☐ Trabalhador por conta própria ou isolado
- ☐ Trabalhador por conta de outrem (empresa municipal, universidade, escolas e outras entidades da administração pública)
- ☐ Trabalhador por conta de outrem (empresa privada)
- ☐ Reformado
- ☐ Desempregado

Faz parte da comunidade da Universidade do Minho (aluno ou funcionário)?

- ☐ Sim
- ☐ Não

Nível de instrução máximo obtido

- ☐ Sem escolaridade
- ☐ Ensino básico
- ☐ Ensino secundário
- ☐ Curso técnico superior profissional
- ☐ Licenciatura

- ☐ Mestrado
- ☐ Doutoramento

Rendimento mensal líquido do agregado familiar

- ☐ Até 760€
- ☐ Entre 761€ e 1000€
- ☐ Entre 1001€ e 1500€
- ☐ Entre 1501€ e 2000€
- ☐ Entre 2001€ e 2500€
- ☐ Acima de 2501€
- ☐ Prefiro não responder

Número de elementos do agregado familiar

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ Mais de 4

Desenvolvido pela Qualtrics

Appendix C. Stated Choice survey for leisure trips



Início

Estudo de Preferências de Mobilidade em Braga (viagens para lazer/compras)

O presente estudo é desenvolvido no âmbito da investigação de doutoramento em Engenharia Civil entre a Universidade do Minho e o LNEC, e o seu principal objetivo é identificar os principais fatores que podem **influenciar alterações nos padrões de mobilidade para modos mais sustentáveis em viagens de curta distância para atividades de lazer ou compras em Braga.**

As opções de mobilidade sustentável consideradas para este estudo são: trotinete elétrica partilhada, bicicleta elétrica partilhada e caminhada.



Para mais informações sobre a mobilidade em Braga, clique [aqui](#).

O estudo é de responsabilidade de Gabriel Dias (id8651@alunos.uminho.pt), que pode ser contactado para esclarecer qualquer dúvida ou partilhar algum comentário.

Todas as informações coletadas pela sua participação voluntária serão tratadas de forma anónima e serão utilizadas exclusivamente para fins científicos.

Declaro ter compreendido os objetivos do estudo e aceito preencher o questionário de forma anónima, pelo que:

- ☐ Sim, aceito participar do estudo
- ☐ Não, não aceito participar do estudo

Padrões de Mobilidade Pessoal

Questões sobre mobilidade pessoal

Número de carros no agregado familiar

- ☐ 1
- ☐ 2
- ☐ 3+

Possui carta de condução?

- ☐ Sim
- ☐ Não

Já utilizou o serviço de trotinetes partilhadas em Braga?

- ☐ Sim
- ☐ Não

Já utilizou o serviço de bicicletas partilhadas em Braga?

- ☐ Sim
- ☐ Não

Utilizaria os meios de transporte abaixo como medida para combater as alterações climáticas?

	Muito pouco provável	Pouco provável	Neutro	Provável	Muito provável
Trotinete elétrica partilhadas	☐	☐	☐	☐	☐

Bicicleta elétrica
partilhada

☐☐☐☐☐

Deslocações a pé

☐☐☐☐☐

Questões para escolha

Contexto para Avaliação de Preferências - escolha do modo de transporte (próxima página)

Nesta secção pretende-se que escolha, em cada situação apresentada, qual o modo de transporte que iria preferir para a sua **viagem de curta distância para atividades de lazer e compras em Braga**, e assim substituir futuramente o automóvel neste tipo de deslocação.

Para cada uma das 9 situações alternativas seguintes, indique se está disposto a substituir a sua deslocação no veículo automóvel por um modo de transporte sustentável (Sim ou Não). **Por favor, considere que todos os atributos que não estão referidos (exemplo: disponibilidade imediata do meio de transporte para início da viagem, condições ambientais favoráveis) são comuns a todos os cenários.**

Atributos para os meios de transporte nas situações alternativas:

- **Tempo de viagem (minutos):** tempo gasto no meio de transporte em relação ao tempo gasto por um automóvel para realizar a deslocação.
- **Voucher (EUR):** possibilidade de ganhar apoio monetário em forma de vales para serem utilizados no comércio local.
- **Arborização:** presença de árvores no percurso.
- **Infraestrutura:** a viagem pode ser realizada sem infraestrutura dedicada (partilhada com outros meios de transporte) ou a viagem pode ser realizada em infraestrutura inteiramente dedicada para peões ou para micromobilidade (ciclovias), e ainda haver infraestrutura dedicada + lugares de estacionamento disponíveis próximos ao destino da viagem em trotinetes e bicicletas elétricas partilhadas

Cenários

Nestas condições, consideraria substituir o automóvel por um modo de transporte

sustentável nas viagens de curta distância para lazer/compras?

Trajeto em **bicicleta elétrica partilhada**



- ☐ Sim
- ☐ Não

Nestas condições, consideraria substituir o automóvel por um modo de transporte sustentável nas viagens de curta distância para lazer/compras?

Trajeto a pé



- ☐ Sim
- ☐ Não

Nestas condições, consideraria substituir o automóvel por um modo de transporte sustentável nas viagens de curta distância para lazer/compras?

Trajeto em **trotinete elétrica partilhada**

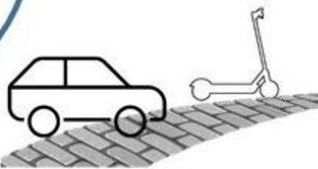
 **+ 10 min**

+ 10 minutos ao tempo da deslocação atual

 **€ 5,0** de voucher por mês



 **100%** do trajeto arborizado

 **Não existe** via dedicada para a deslocação

- ☐ Sim
- ☐ Não

Nestas condições, consideraria substituir o automóvel por um modo de transporte sustentável nas viagens de curta distância para lazer/compras?

Trajetos em **trotinete elétrica partilhada**



- ☐ Sim
- ☐ Não

Nestas condições, consideraria substituir o automóvel por um modo de transporte sustentável nas viagens de curta distância para lazer/compras?

Trajeto em **bicicleta elétrica partilhada**



- ☐ Sim
- ☐ Não

Nestas condições, consideraria substituir o automóvel por um modo de transporte sustentável nas viagens de curta distância para lazer/compras?

Trajeto a pé



- ☐ Sim
- ☐ Não

Nestas condições, consideraria substituir o automóvel por um modo de transporte sustentável nas viagens de curta distância para lazer/compras?

Trajeto a pé



- ☐ Sim
- ☐ Não

Nestas condições, consideraria substituir o automóvel por um modo de transporte sustentável nas viagens de curta distância para lazer/compras?

Trajeto em **trotinete elétrica partilhada**



- ☐ Sim
- ☐ Não

Nestas condições, consideraria substituir o automóvel por um modo de transporte sustentável nas viagens de curta distância para lazer/compras?

Trajetos em **bicicleta elétrica partilhada**



- ☐ Sim
- ☐ Não

Motivos para NÃO

Indique as principais razões para ter respondido "Não" nos cenários assinalados:

- ☐ Prefiro o conforto do automóvel
- ☐ Não sei como utilizar uma trotinete
- ☐ Não sei andar de bicicleta
- ☐ Sinto-me inseguro(a) devido ao elevado tráfego motorizado
- ☐ Sinto-me inseguro(a) devido à elevada velocidade de tráfego motorizado
- ☐ Sinto-me inseguro devido à insuficiente iluminação pública
- ☐ Os percursos pedonais não são atrativos (ausência de montras e esplanadas)
- ☐ Más condições do pavimento para utilização de bicicleta e trotinete (estado de conservação)

- ☐ Más condições dos passeios (estado de conservação, descontinuidades)
- ☐ Passeios estreitos
- ☐ Exposição à poluição e ruído
- ☐ Outra razão (por favor indique qual):

Questionário sócio económico

Questionário sócio económico

Género

- ☐ Masculino
- ☐ Feminino
- ☐ Não binário / terceiro género
- ☐ Prefere não dizer

Idade

- ☐ Entre 18 e 19 anos
- ☐ Entre 20 e 24 anos
- ☐ Entre 25 e 29 anos
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- ☐ Entre 35 e 39 anos
- ☐ Entre 40 e 44 anos
- ☐ Entre 45 e 49 anos
- ☐ Entre 50 e 54 anos
- ☐ Entre 55 e 59 anos
- ☐ Entre 60 e 64 anos
- ☐ 65 ou mais anos

Situação profissional

- ☐ Estudante
- ☐ Empregador/patrão

- ☐ Trabalhador por conta própria ou isolado
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- ☐ Trabalhador por conta de outrem (empresa privada)
- ☐ Reformado
- ☐ Desempregado

Faz parte da comunidade da Universidade do Minho (aluno ou funcionário)?

- ☐ Sim
- ☐ Não

Nível de instrução máximo obtido

- ☐ Sem escolaridade
- ☐ Ensino básico
- ☐ Ensino secundário
- ☐ Curso técnico superior profissional
- ☐ Licenciatura
- ☐ Mestrado
- ☐ Doutoramento

Rendimento mensal líquido do agregado familiar

- ☐ Até 760€
- ☐ Entre 761€ e 1000€
- ☐ Entre 1001€ e 1500€
- ☐ Entre 1501€ e 2000€
- ☐ Entre 2001€ e 2500€
- ☐ Acima de 2501€
- ☐ Prefiro não responder

Número de elementos do agregado familiar

- ☐ 1
- ☐ 2

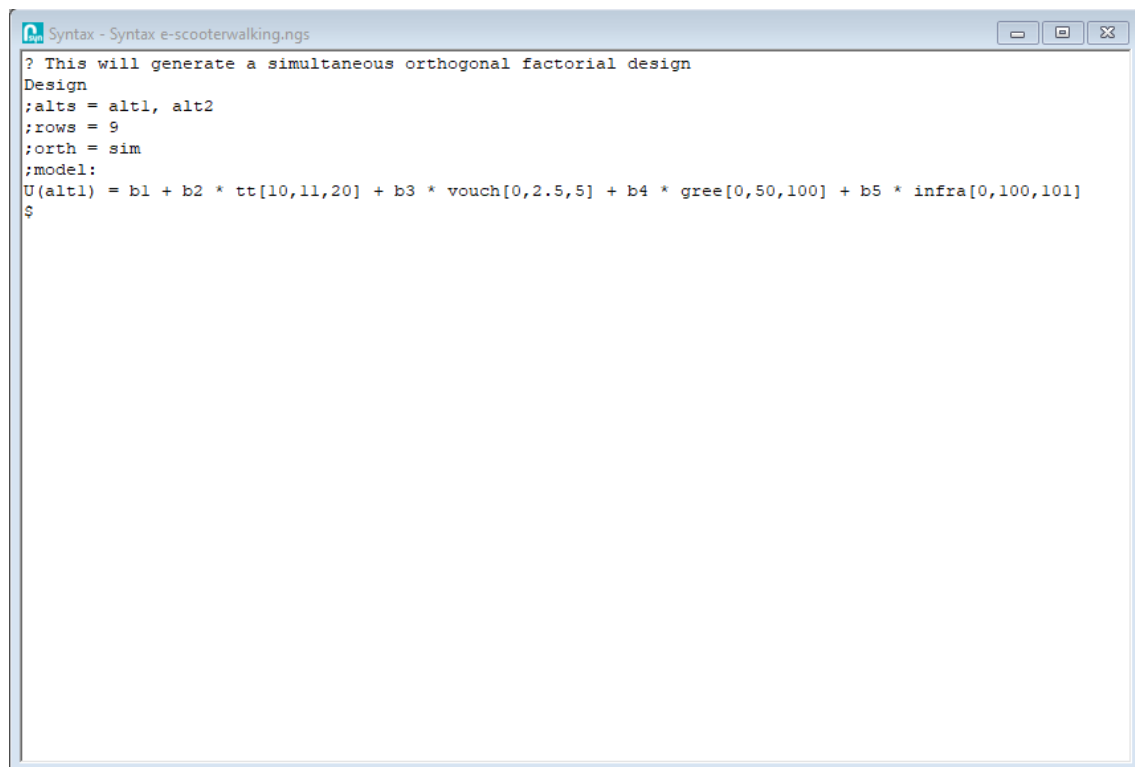
- ☐ 3
- ☐ 4
- ☐ Mais de 4

Desenvolvido pela Qualtrics

Appendix C. Ngene syntax of the stated choice survey for commute trips

```
Syntax - Untitled Syntax 2.ngs
? This will generate a simultaneous orthogonal factorial design with three blocks
Design
;alts = bus, escooter, bike
;rows = 36
;orth = sim
;block = 3
;model:
U(bus) = b1 + b2 * traveltime[7,4,1] + b3 * cost[2.75,3,0] + b4 * infra[0,1] + b5 * tech[0,1] /
U(escooter) = b2 * traveltime1[17,7,2] + b3 * cost1[1.5,1,1.51] + b4 * infra1[0,50,100] + b5 * tech1[0,1] /
U(bike) = b2 * traveltime2[17,7,2] + b3 * cost2[1.5,1,1.51] + b4 * infra2[0,50,100] + b5 * tech2[0,1]
$
```

Appendix D. Ngene syntax of the stated choice survey for leisure trips



```
Syntax - Syntax e-scooterwalking.ngs
? This will generate a simultaneous orthogonal factorial design
Design
;alts = alt1, alt2
;rows = 9
;orth = sim
;model:
U(alt1) = b1 + b2 * tt[10,11,20] + b3 * vouch[0,2.5,5] + b4 * gree[0,50,100] + b5 * infra[0,100,101]
$
```