Mobility patterns of the shared e-scooter usage

Mariana da Penha Coutinho Cagica Pinto
Instituto Superior Técnico, Universidade de Lisboa
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Abstract

Shared e-scooters appeared in Lisbon at the end of 2018 with the aim of improving micro-mobility within the city and promoting shared mobility in the population. These new transportation modes are used for short distances as the "first and last mile" and may serve as a quick access to other modes of transport. To our knowledge, there are still few studies on what its impacts are in cities. Therefore, this study focuses on understanding the role of scooters in Lisbon and whether they are used as programmed and according to regulations.

A survey was therefore carried out targeting only users of shared e-scooters, which questioned participants about their regular mobility patterns; the usage of the shared e-scooter; preferences and opinions regarding e-scooter systems; and socio-demographic and housing characteristics.

Three analyses were developed from this survey. The first concerns the identification of types of users, through cluster analysis using the SPSS, which resulted in two groups: unimodal and multimodal. The second analysis was based on the origins and destinations of e-scooter trips and, using the QGIS, territorial and user usage patterns were determined. In the final analysis, two discrete choice models were developed which seek to explain users' choices regarding the reasons for travelling with the shared e-scooter and the modes that have been replaced by it.

Keywords: Micro-mobility; Shared mobility; Shared e-scooter; Discrete Choice Models; Lisbon

1. Introduction

Lisbon is a city that receives daily hundreds of people who arrive to study, work or visit, and the existing modes of transport help the population to move around to reach their destinations. Shared e-scooters are an example of such existing modes in the city. This new mode arrived in the city of Lisbon at the end of 2018 with between 200 and 400 e-scooters (Tomé, 2018) and, to date, there are about 4000 shared e-scooters circulating in Lisbon (Nunes, 2019). Shared e-scooters have emerged as an attractive and effective response to short distance travel, and are used for a variety of reasons, including utility and leisure. They are a fast, versatile, easy-to-use and distance-based cost mode of transportation. They are easily accessed through an app that is installed on current phones, and do not need a dock-station for parking, like some types of shared bikes. The maximum speed imposed by the Portuguese Highway Code is 25km/h (Lei nº 72/2013 - Diário da República nº 169/2013, Série I de 2013-09- 03, Artigo 112º).

In general, shared e-scooters are a good way of transportation that can help the population to meet their needs. However, public opinion is not very favorable when it comes to this issue. One of the biggest problems existing today is parking, and many of the e-scooters are left on the sidewalk, especially in areas of greater circulation and greater access to public transportation, making it difficult for pedestrians to walk. Another problematic aspect is the space of circulation of e-scooters. These should only circulate on bike paths and, when there is no bike paths, they should share the road carriage with reminding vehicles. However, users show a greater preference for the use of the sidewalk, due to the feeling of insecurity and accident risk when sharing the road network. The objective of this study is to analyze and characterize the patterns of use of shared electric scooters in Lisbon, as well as to identify the user profiles of this mode, in order to know their habits with respect to e-scooters usage. Such profiling would provide possible bases for the definition of public policies, namely for regulation and planning of public space, having as fundamental concern the safety of users and the comfort of other users of the public space. It also intends to inquire about their proposals for change in this emerging mode, so that they are considered when improving urban accessibility in Lisbon.

On this basis, a survey of users of shared e-scooters was carried out, for the purpose of obtaining answers regarding their modal options, the way of using the scooters, as well as a socio-demographic characterization of the respondent.

2. Methodology

2.1 Survey description

The survey of users of shared e-scooters focused particularly on users in Lisbon. Lisbon was chosen as the case study because it is one of the Portuguese cities with the most traffic, and it was the first to have shared e-scooters circulating, in Portugal. Consequently, there is a greater amount of data regarding the use of scooters. Since this survey was distributed through the existing communication channels between some operators of e-scooter systems in the city of Lisbon and their users, the people this survey targeted are only those who use the sharing systems or have an app from any operator installed on their smartphone. Thus, individuals who have not installed the app of any of the operators participating in the study are not part of the sample frame, including those who use their own e-scooters. Therefore, it was not possible to profile these types of users. Based on the answers given by the sample, five groups of respondents emerged (according to our classification criteria):

- Users: when the respondent answers that he uses the e-scooter frequently ("daily" or "a few times a week") and chooses "scooter" or "shared e-scooter" as a regular mode of transport;
- Potential user: when the respondent answers that he uses the shared e-scooter "less than 4 times a month" or chooses "scooter" or "shared e-scooter" as a regular mode of transport;
- Occasional: when the respondent answers that he has only used the system once or that he uses the e-scooter "less than 10 times in the last year", or that he does not choose "shared e-scooter" as a mode of transportation;
- Quitter: when respondent answered that he was using the shared e-scooter, but gave up using it, not temporarily;
- Non-User: when the respondent answers negatively to the question "Have you ever used any shared e-scooter system?"

2.2 Analysis methods

From the survey, it is possible to obtain a great diversity of information about the users of shared e-scooters. This includes not only information about the characteristics of individuals, but also about their daily choices regarding their way of transportation within the city. To understand the patterns of activities carried out by the population of Lisbon, the aim is to analyze this data in three different ways, for the purpose of obtaining results regarding the objectives outlined.

In order to define types of e-scooter users, a cluster analysis was performed using SPSS from IBM, which included variables extracted from the survey questionnaire. The analysis method performed is called "Two-Step Cluster" because the sample has a large dimension and consists of categorical and continuous variables.

To understand the patterns of e-scooters' users, we used QGIS. This analysis was mainly based on the points of departure (origins) and destinations given by the respondents, in order to find out the most common points of origin and destination, corresponding routes, the possibility of using the e-scooter as an intermodal mode and their parking patterns.

The final analysis models users' behavior and two discrete choice models were built, one concerning the reasons what was the trip motivation for using shared e-scooters, and the other concerning the modes replaced by shared e-scooters. The models allowed for the identification of the factors influencing both choices, i.e., trip motives and mode substitution. The way these factors influence the user's choice translates into the utility of that choice. After determining the utility of each choice, the probability of each respondent choosing each alternative was calculated. Finally, to validate the models, a prediction test was done from a portion of the sample that was not included in the model calibration.

3. Results and Analysis of the data

3.1 Descriptive Statistics

The survey to users of shared e-scooters was disseminated on 6 March 2020 by one of the shared e-scooter operators, and disseminated on 9 March by another operator, with responses being collected on 14 March 2020. The survey remained open until 29 April 2020, for future analysis, where 1724 replies were gathered.

Up to the day of collection, 1643 responses were gathered from users using the e-scooters of the operators who participated in the dissemination. The sample consists of 1016 valid answers (62%), such that the validation criteria imply coherent answers lasting more than one minute, in which the respondent answered all (or almost all) of the questions. Within valid answers, 2% of the respondents did not accept to participate in the survey, with a final sample for analysis of 995 answers. From this sample, 919 affirmative answers to the question "Have you ever used any shared electrical scooter system?" were collected.

The descriptive statistics of the socio-economic characteristics of respondents are:

- 80% of respondents are male;
- 77% of respondents are between 18 and 45 years of age, the average being 35.7 years;
- 32% of respondents have up to 12th grade (inclusive), 36% have a bachelor's degree (or similar), and the remaining 32% have a higher level of education;
- More than 50% of the respondents live in the municipality of Lisbon, while about 40% live in the Lisbon metropolitan area.

As for shared e-scooter usage, from the 919 responses collected, we conclude that:

- The main reasons for users' travels were "Strolling" (32%) and "Errands" (31%);
- 38% use the e-scooter less than once a month and the majority travel during the afternoon (32%);
- The majority of users (48%) claim to have parked the e-scooter in a bicycle/scooter parking lot, while 27% of them respond to having parked the vehicle against a building;
- A vast majority of users does not use the helmet, and the bike path is their preferred circulation carriageway.

Regarding the mobility patterns of respondents, it should be noted that:

- 111 of the 995 respondents walk regularly (11%);
- Of the remaining 884 respondents, 46% say they use only one mode of transport in their regular trips, i.e., private car;
- Of the 54% of respondents who carry out a combination of modes of transport, 124 declared that part of the journey includes walking (more than 10 minutes);
- The public transports modes that are more often combined are subway, bus/tram, car and train;
- 91% of the respondents' state that the e-scooter trip has replaced walking (32%) and subway (15%) trips.

As far as the above-mentioned respondent groups are concerned, the sample can be divided into 5 groups wherein 62 respondents are classified as users, 173 are classified as potential users, 417 are classified as occasional, 76 are classified as non-users and 267 are classified as quitters. With this classification, it can be observed that most of the respondents (42%) are classified as occasional users, and it can be assumed that the e-scooters are currently mostly

used on a casual basis, rather than as a daily or regular mode of transport.
The following pyramid illustrates the five groups presented above.

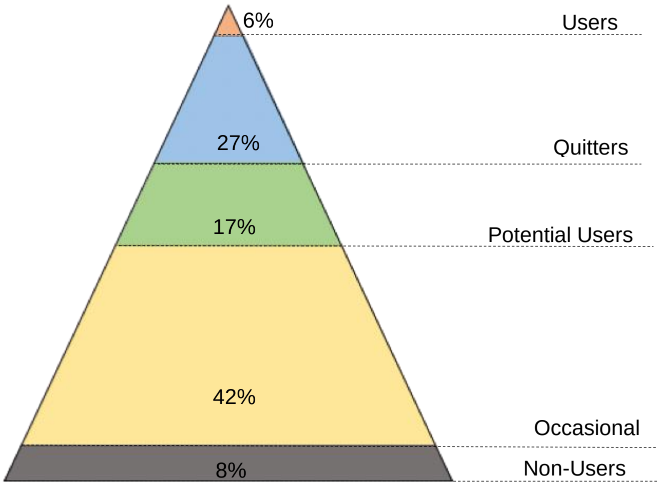

Figure 3.1 – Schematic pyramid of the groups of respondents

A general characterization of some socio-economic and mobility aspects of the different groups is presented in the table in Annex I. It should be noted that regular journeys included unimodal and multimodal trips (combination of modes in a single trip). The modes included were: soft and active modes include journeys with bicycles and scooters (electric or not) and walking trips; car trips (private or as a passenger); public transport, whether using a combination of car and public transport and other modes. The "other" group consists of motorcycle journeys, shared motorcycle, taxis, carsharing, and combinations of modes that are not shown in the table (e.g. shared motorcycle and walking).

3.2 Clusters Analysis

To define the user types of shared e-scooters of Lisbon, a clusters analysis was performed. As it is a relatively large sample (995 responses), integrating several types of categories, the "Two-Step Cluster" method was used to estimate the existing groups in the sample.
Taking into account that this analysis aims to determine the types of users, the first step was to exclude all Non-Users from the sample (respondents who answered "no" to the question "Have you ever tried any system of shared e-scooters?"). As a result, a sample of 919 answers remained.
As for the variables under study, it was assumed that they are the questions asked in the survey, totaling 63 variables (excluding the first and last questions). In order to minimize the number of variables to test in the cluster's analysis, we calculated the corresponding correlation matrix, where we could observe the higher correlations between variables and candidates for clustering. Given the categories of the variables, the categorical variables were transformed into binary variables, and some reclassified (due to the extensive number of responses - case of the modes of transport used) and the ordinal variables were reorganized.
In this way, a matrix of correlations with 52 variables was built. The correlation coefficient chosen for this matrix was the Spearman coefficient, because most of the variables are ordinal, except for the variable "Age" and the e-scooter classification variables, which are continuous. The correlations between variables whose level of significance (*p-value*) was greater than or equal to 0.1, were considered significant.
Therefore, the correlation matrix contains 564 pairs of significant correlations between variables. From this set, the pairs of variables that presented a correlation higher than 0.3 or lower than -0.3 were subject to a greater attention (refer to the table in Annex II).
Hence, the variables tested in the cluster analysis were some socio-economic variables, both related to daily travel, and to the e-scooter's usage.
We could cluster successfully two types of e-scooter users, incorporating 10 variables, of which three are related to daily mobility habits, three are related to the use of the e-scooter and the remaining four are socio-economic.
In this sense, the following figure illustrates the distribution of clusters by variables. The markers are arranged according to the category mode of each variable, and the size of the markers represents the importance it has in the formation of the cluster.

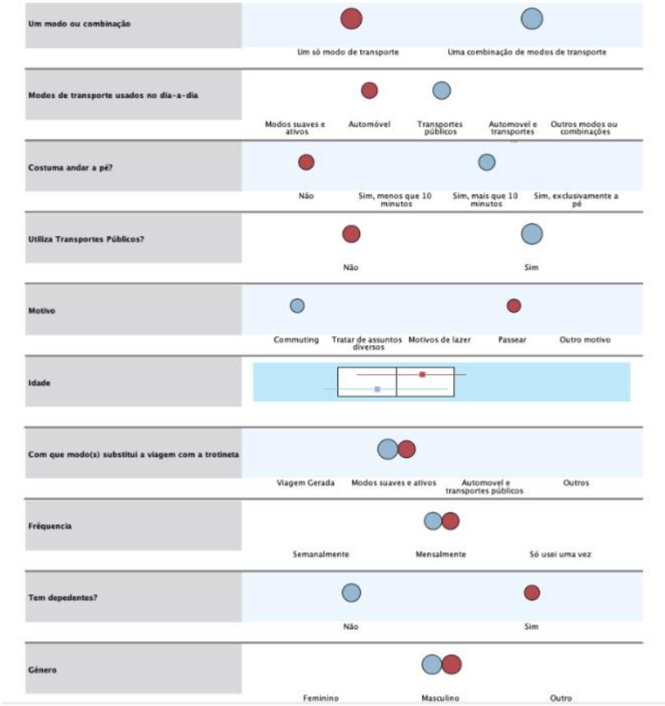

Figure 3.2 - Distribution of clusters by variables

It is then possible to distinguish two types of users: multimodal (cluster 1, represented in blue) and unimodal (cluster 2, represented in red). The multimodal are distinguished by the daily use of a combination of transport modes. The main mode are public transportation, while including also walking and e-scooters for commuting trips (i.e., home - work; home - school/university). They are younger users (average age 34 years), and without any children or other dependents. On the other hand, unimodal users resort to their private car, on a regular basis, while the reason for using the e-scooter is to wander around (i.e., for leisure). They are older (average age 38 years) and have children. Both types of respondents generally use the e-scooter monthly, they are men and e-scooters replace soft and active modes (mostly, walking).

3.3 Preliminary analysis of the patterns of use of e-scooters

In order to understand the movement patterns of users, in the case of the circulation space, multimodal use and parking place, the QGIS program was used to obtain a spatial and visual representation of these movements.
In the case of study, it was from the origins and destinations that the possible routes taken by the e-scooter were defined. Using the Open Route Service plugin of the QGIS program, the best routes were determined, taking into account several characteristics of the road network and mode of transport. In

the case of soft and active modes, the existence of a bike path and the slopes of the streets are important factors in choosing the best route. In the absence of the electric scooter option, the routes were determined based on the regular bike options.

Based on users' responses, we collected, 911 origins, of which 850 were valid, and 910 destinations, of which 830 were valid. Additionally, the program does not allow for a definition of routes when the origins and destinations coincide, and when the origin has no corresponding destination or vice versa. Therefore, we ended with 638 origin-destination (OD) pairs. As for the routes, although they should also be 638, the QGIS could not determine routes for 5 OD pairs due, because they were identified by a 4-digits postal code, which prevent QGIS to determine the most probable routes to link OD pairs.

The figures below show the origin (figure 3.3) and destination (figure 3.4) locations. It is possible to observe that in both origins and destinations there are 3 axes/zones where a greater number of pickups or drop outs of e-scooters can be distinguished: Parque das Nações, axis next to the Tagus River (Brasília Avenue) and a central axis (from Campo Grande to Marquês de Pombal).

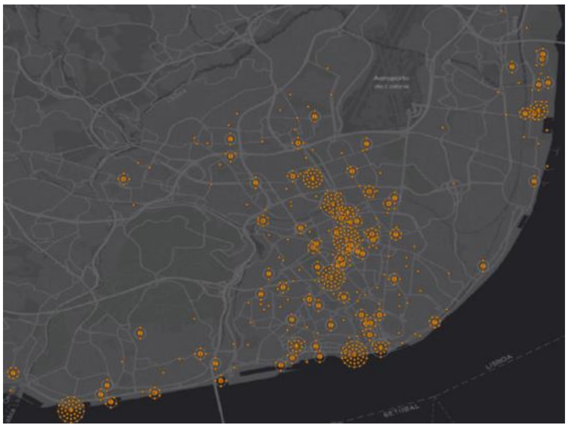

Figure 3.3 - Location of the origins of the routes using the shared e-scooter

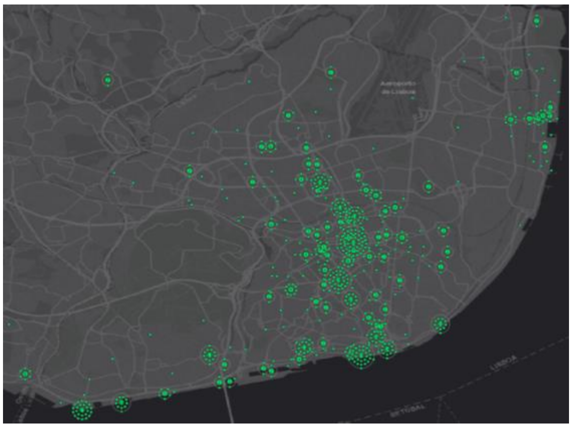

Figure 3.1 - Location of route destinations using the shared e-scooter

Territorial patterns of use

The purpose of this first phase was to understand the territorial patterns of use of the e-scooter by the two types of users: multimodal and unimodal. A separation was then made according to the type of user, where we multimodal trips are more frequent (59%) than unimodal (41%). When comparing the most common origins in both clusters, it is clear that in the area of Parque das Nações, unimodal trips have a greater number of origins concentrated in the leisure area, that is, next to Vasco da Gama Shopping Center and Altice Arena. In the axis next to the river, the unimodal trips have more origins than multimodal, with a stronger emphasis on the touristical POIs, such as Padrão dos Descobrimentos and Belém Tower, where there is also a greater concentration of origins of unimodal trips. On the contrary, in the area of Cais do Sodré and Terreiro do Paço, there is a greater concentration of multimodal trip origins. On the Central axis, there are more multimodal trip origins. It should be noted that in areas with public transportation (PT) interfaces there is a greater concentration of origins, both unimodal and multimodal. In this case, multimodal show higher numbers, suggesting that e-scooters might serve as *first-and-last miles* enablers.

Most common destinations, in the Parque das Nações area, multimodal trips have higher concentration areas in the Gare do Oriente, Vasco da Gama Shopping Centre and Altice Arena areas, while unimodal trips have more destinations only in the leisure areas. Close to the river, both types of users have a similar number of destinations and close to PT interface - Cais do Sodré and Terreiro do Paço - there is, once again, a greater number of multimodal destinations. As for the central axis, there are more multimodal destinations, again close to PT interface. It should be noted that in the case of destinations, unimodal users have a more dispersed behavior, ODs are more spread throughout the city than origins that are more concentrated on the zones/axes of most common origins and destinations.

Based on the analyses of the e-scooter users' OD pairs, we determined the corresponding routes. Figure 3.5 shows the possible paths that respondents would use for their e-scooter. Here it is possible to observe that the most used routes (the most loaded color) are in the area of Parque das Nações, on the axis next to the river and on the central axis of Lisbon, since most of the origins and destinations were located in these areas. Additionally, bicycle paths are available at these areas and, therefore, there is a greater affluence of trips in these axes.

Figure 3.5 - Routes that users could have taken with the e-scooter

Then, we estimated the distance and travel time of each OD pair, according to the route determined by QGIS (as we didn't have access to detailed trip data). Taking into account that the reference mode selected in QGIS was a regular bicycle, and knowing that it assumes an average speed of 16Km/h, the relation of the trip duration obtained by the QGIS was made for a duration where the maximum allowed speed is 25km/h. The histograms below present the distributions of distance and travel time of each trip, by type of user. In total, there are 633 trips, where 372 are multimodal, and the reminder, unimodal.

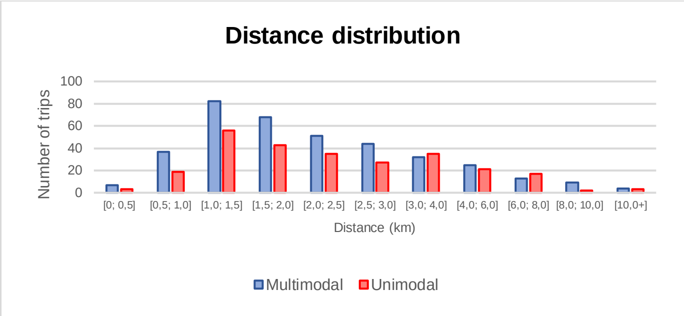

Figure 3.6 - Categorical distribution of distances, by type of user

From the analysis of the histogram above, in both types of users, the largest number of trips made covers between 1.0 and 1.5 km. It can also be seen that the distribution of the two clusters is quite similar, where the average distance of multimodal trips is 2.5km and of unimodal trips is 2.7km, except in the 3km and the 4km categories where there is an increase in the number of trips in the unimodal compared to the previous category. As such, multimodal travelers make shorter distance trips, more than 50% of their trips are shorter than 2km and 78% of their trips are shorter than 3km. As for unimodal trips, 46% are lower than 2km and 70% are shorter than 3km. On the other hand, 28 unimodal trips are longer than 5km, which corresponds to 11% of the trips, and 33 multimodal trips are longer than 5km, which corresponds to 9% of the trips.

As far as travel times are concerned, it is visible in figure 3.7 that the longest travel takes between 2 and 4 minutes, for both unimodal and multimodal users. Thus, the average travel time of the multimodal is 6.05 minutes and of the unimodal 6.46 minutes. In this histogram, it is also noticeable that the distributions of both clusters are identical. Also, 54% of multimodal trips last less than 5 minutes and 81% last less than 8 minutes. As for unimodal users, 51% of the trips last less than 5 minutes and 77% last more than 8 minutes. It should also be noted that 12% of the multimodal travels last more than 10 minutes, and 15% of the unimodal travels last more than 10 minutes.

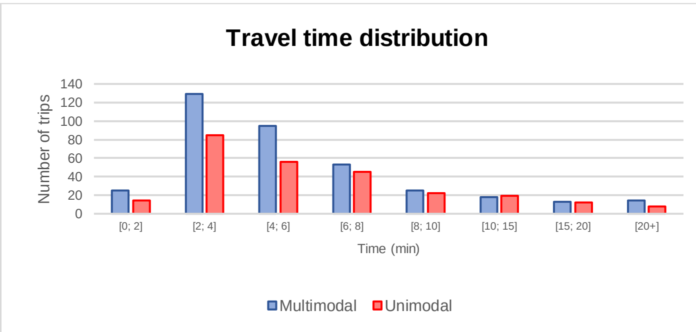

Figure 3.7 - Categorical distribution of travel times, by type of user

Multi-modal usage patterns (combination with other modes)

The second analysis aims to study multimodal patterns, that is, the possibility of respondents using the e-scooter as a combined mode with other modes of transport. Since these are combinations of transport modes, this analysis was based on respondents who belong to the multimodal cluster. In our analysis, we considered metro, ferry, buses and trains interfaces and terminals.

As referred previously, many multimodal trips' origins and destinations are concentrated close to PT interfaces. The figures below demonstrate the points of origin and destinations, respectively, of the users that are located near PT interfaces. Out of 377 origins and destinations, 201 origins and 185 destinations are located near interfaces. In these figures, the various stations are located as follows: bus terminals are represented by the dots in white; ferry terminals are represented by the dots in blue; subway stations are presented in green; and train stations are represented by the dots in red.

Figure 3.9 – Origins of multimodal close to interfaces with other modes

Figure 3.10 - Destinations of multimode close to interfaces with other modes

The distribution of both the origins and the destinations close to the stations is concentrated on the central axis of the city, such as Avenida da Liberdade, Avenida Fontes Pereira de Melo and Avenida da República, focusing particularly on Saldanha and Marquês de Pombal. On this axis, the main PT mode is the subway. Also relevant, ODs concentrated along the circular railway line of Lisbon, when it crosses the Avenida da República (of the central axis of Lisbon), particularly Roma-Areeiro, Entrecampos and Sete Rios stations (complementary to the metro stations). On the axis by the river, the Cais do Sodré station is the focus, a point that comprises 3 stations of collective transportation modes. It is also relevant to identify the Santos train station, the ferry terminal of Terreiro do Paço and the Algés road terminal. In the Parque das Nações area, the only existing point is the Gare do Oriente, which interfaces between the subway, the train station and the Oriente bus terminal.

E-Scooter parking patterns in Lisbon

The last analysis is related to their parking inside the city. Thus, this analysis focuses on the study of the answers given by users in the survey regarding how and/or the location of the e-scooter parking, and the visualization of the locations of the route destinations and the locations of the e-scooter hotspots, defined by the Lisbon City Council (Câmara Municipal de Lisboa, 2020).

With respect to the typology of the hotspots, they differ in terms of parking space. The following figures show the 3 types of hotspots in Lisbon, and their location: on the road, represented in green, on the sidewalk, represented in blue, and in a parking place, represented in brown. In these same figures are also shown the destinations that are located close to each type of hotspot. In these figures, it is visible how the hotspot types are distributed in the city. There are 221 hotspots in Lisbon, of which more than half (121) are in parking spaces. On the sidewalk, there are 87 hotspots, which are more spread throughout the rest of the city. On the track, it is possible to park the scooter in only 13 locations.

Figure 3.11 – Location of the hotspots on the road and destinations close to them

Figure 3.12 – Location of the hotspots in a parking place and destinations close to them

Figure 3.13 - Location of the hotspots on the sidewalk and destinations close to them

Comparing these locations with the answers given in the user survey, almost 50% of the respondents said they had left the scooter in a parking space, while in 638 valid destinations only 101 users could have parked the scooter in a parking space. As far as parking the e-scooter is concerned, it should be taken into account that the respondents may have given socially-desirable answers, which weakens the relevance of these answers.

4. Modelling the use of shared e-scooters

As already mentioned, shared e-scooters have been recently introduced in Lisbon and, as such, the habits of users of this mode are still unknown. To understand some of these users' behavior, we developed 2 models with the BIOGEME software (Bierlaire, 2019) : the first one refers to what was the trip motivation of e-scooters' users; and the second model refers to which modes were replaced by shared e-scooters. In the first model, the choice set consists of 3 possible alternatives: commuting (home - work and school/university - home), errands (where the answer of "recreation" was added) and strolling. The answers regarding "other" purposes were excluded from the model. In the second model, there are 4 alternatives to choose from: walking, soft modes (shared or own bicycle and own scooter), car and/or public transport and others (cab or motorcycle).

4.1 Results of the calibrated models

In the first model, 3 utility functions were studied, each one referring to 3 different travel reasons. The utility function V1, refers to "Commuting", V2 refers to "Leisure" and V3 to "Strolling". For this analysis, any other reasons were excluded, and a sample of 841 responses was obtained.

$$V1 = 2{,}66 + 0{,}949Week + 1{,}13RushH - 0{,}666ModeComb - 0666Auto + 0{,}477LiveLx \quad (4.1)$$

$$V2 = 0{,}608 * Adult + 0{,}439Bach\_Master + 0{,}207Income + 2{,}42Subs \quad (4.2)$$

$$V3 = 1{,}69 + 1{,}73Month + 2{,}47Once + 0{,}557Sidewalk + 0{,}53Female - 0{,}477LiveLx \quad (4.3)$$

The initial multinomial model had a lower pseudo-ρ^2 of 0.197. As such, we tested a "Nested Logit Model" (NL), where we fixed the 1st nest (commuting trips) and released nest 2 (leisure+strolling). We obtained a very significant pseudo-ρ^2 of 0.697, tripling its robustness.

Comparing both models, the p-values of variables' coefficients are low, although the p-values of the nested model are lower than the multinomial logit model, with most of them a significance level higher than 99%. Nevertheless, a likelihood ratio test was performed, such that the restricted model was the MNL model, where the "N_Stroll" equals 0, and the non-restricted model is the NL model where the "N_Stroll" is different from 0. In the end, we confirmed that the non-restricted model was preferable, ensuring that the nested model was the best final model.

Therefore, the utility functions of the model regarding the trip motivations of e-scooters are the following:

$$V1 = 0{,}61 * (3{,}52 + 1{,}51\text{Week} + 1{,}49\text{Rush}H - 0{,}924ModeComb - 1{,}05Auto + 0{,}504\text{Live}Lx) \quad (4.4)$$

$$V2 = 0{,}61 * (0{,}702Adult + 0{,}574\text{Bach\_}Master + 0{,}276\text{Income} + 3{,}21Subs) \quad (4.5)$$

$$V3 = 3{,}24 + 1{,}52Month + 2{,}29\text{Onde} + 0{,}527Sidewalk + 0{,}578Female - 0{,}504\text{Live}Lx \quad (4.6)$$

After defining these functions, the utility of each motive for each individual was calculated and, subsequently, the probability of each individual choosing against the set of options was calculated. Then, the average of all probabilities was calculated and the probability of choosing each motive before the sample under study was obtained. In order to validate the developed model, it was then decided to perform a prediction test. As there was a total sample of 882 responses, in which 841 were used to determine the choice probabilities, 41 responses were used as a validation sample for this model. The following table describes the probabilities of choice given by the model (Pin) and the percentage of actual choices made by users (Ein).

Table 4.1 - Probabilities of choice given in the first model and percentages of actual choices

Reasons (n=841)	P_{in}	E_{in}
Commuting	30,2%	34,1%
Leisure	34,4%	31,7%
Strolling	35,4%	34,1%

The second model deals with the modes that have been replaced by shared e-scooters, where 4 alternatives were included: V1 for "walking"; V2 for soft modes; V3 for car (private or as a passenger); V4 for any PT, taxi or motorcycle, owned or shared.

In the process of determining the utility functions, variables' β-coefficients were tested for attributes such as travel time and distance: $\beta_{distance}$ and β_{time}. Taking into account that these two attributes are not only attributes associated to the decision maker, but also attributes that vary according to the alternative, the likelihood ratio test was performed on both, in order to understand the value of time and distance that each decision maker gave to each alternative. Annex III presents the β-coefficients and the corresponding p-values.

In the restricted model, these β have a negligible weight in utilities, although the p-value of β_{Time} is less than 0.1. This model has a pseudo-ρ^2 equal to 0.42.

As for the non-restricted model, the p-value of the β's associated with the walking mode is highlighted, which is approximately 1, which means that these attributes do not bring any importance to the utility of the walking mode. This result is quite interesting, as it suggests that the travel distance or time have no influence on the decision to switch a walking trip to an e-scooter. This model has a log-likelihood of -698.4132 and a pseudo-ρ^2 equal to 0.422, slightly higher than the pseudo-ρ^2 of the restricted model. In these two models the likelihood ratio test was applied, and it was concluded that the restricted model is preferable.

Since in the restricted model the $\beta_{Distance}$ had a p-value higher than 0.1, a model was made such that this β was equal to 0. Keeping all the variables of the restricted model presented above and excluding the attribute "distance" from all the utilities, the utility functions of each mode are as follows, including the respective values of β. In this model, all of them have p-values lower than 0.1.

$$V1 = 3{,}71 + 0{,}465\mathrm{WalkMoreTen} + 0{,}341\mathrm{WanderAround} + 0{,}371\mathrm{Young} - 0{,}0109\,Time\_Walk \quad (5.16)$$

$$V2 = 2{,}29 + 0{,}907\,SoftM - 0{,}0109 Time\_Soft \quad (5.17)$$

$$V3 = 1{,}01 + 0{,}64 Auto + 1{,}01 PT + 0{,}915\,Auto\_PT - 0{,}0109 Time\_Auto \quad (5.18)$$

$$V4 = 1{,}45 Other + 0{,}448 Income \quad (5.19)$$

Once the final utility functions have been determined, the utility of each transport mode was calculated for each user and then the probability of each user choosing each mode of transport. Finally, the averages of these probabilities were calculated.

Finally, to validate this model, a forecast test was performed. The total sample consists of 870 responses, where 829 responses were used to define the model and calculate the probabilities of choice. From the total, 41 responses were left which were used as a validation sample for this model. Thus, in table 4.2 are the probabilities of choice given by the model (Pin) and the percentage of actual choices made by users (Ein).

Table 4.2 - Probabilities of choice given in the second model and percentages of actual choices

Replaced modes (n=829)	P_{in}	E_{in}
Walking	71,9%	73,2%
Soft Modes	10,1%	7,3%
Car and public transport	14,5%	14,6%
Other	3,5%	4,9%

5. Discussion, conclusions and Further Developments

The present study allowed for conclusions to be drawn regarding three main points:

- Types of shared e-scooter users;
- Patterns of use of this mode;
- Behavior of users of shared e-scooters, regarding different factors.

First, a clusters analysis was performed to define the types of users. In short, two types of users were determined, "unimodal" and "multimodal", since the main variable in this analysis refers to the use of a single mode or a combination of modes of transport. From the analysis performed results that what distinguishes users is their daily mobility patters, as suggested the uni- or multi-modality they stated, and not the typology of their trip with the e-scooter, as expected. In this cluster analysis, we observe that the main variables related to the use of the e-scooter (frequency of use, motive) are much less important in defining the types of users, which leads to the hypothesis of the e-scooter being a complementary mode (perhaps a first-and-last mile enabler), and the decision to use the e-scooter is not planned, but rather occasional.

Compared to the most chosen options when asked "why did you decide to use the e-scooter?", the most common answers were focused on the speed of the e-scooter, because walking would take longer, the user liked to ride the e-scooter and the user wanted to try the system. In this sense, we believe that it is possible to argue that, to some extent, the majority of e-scooter users are not regular but rather occasional.

The second analysis was based on a visual and spatial interpretation of the origins and destinations given by survey respondents. Here it can be observed that there are three main areas/axles where the e-scooter is picked up and dropped off, which are the area of Parque das Nações, the axis next to the Tagus River, and a central axis, located on the avenues between Marquês de Pombal and Campo Grande. In both types of users defined, these zones/axes are the main origins and destinations, although there is some difference between the number of origins and destinations in the Parque das Nações zone and the axis next to the river, more dedicated to leisure, and in the central axis, i.e., Lisbon's CBD. As for trip characteristics, most trips are shorter than 2km long and last less than 5min, i.e. e-scooters are used for short distances, confirming their role in micromobility.

In this second study the possibility of these trips with the e-scooters being made as "first and last mile" of the trip was also analyzed. This means using them in combination with other modes. As it was possible to observe, many of the origins and destinations of the central axis mainly coincided with PT interfaces, specially metro stations.

The last point dealt with e-scooters' parking, a conflict generator between users and pedestrians. In this matter the crossing between the destinations and the location of the hotspots of the e-scooters was performed. As it was possible to observe, there is a great agglomeration of hotspots near the central axis, while in the rest of the city they are quite scarce. More than half of the survey respondents claimed to have left the e-scooter in an appropriate parking place, which means more than 300 users. Unfortunately, it is not possible to be certain that this is what really happens, and the possibility of this being the result of an intention of giving a socially correct answer should not be excluded, especially when we see a considerable number of e-scooters on the sidewalks.

In the third analysis, the study focused not only on the user behavior through several attributes but also on how these attributes influence the choice of respondents in two situations. The first situation, which corresponds to the first model studied, concerns the motive for the trip with the e-scooter. As a result, it is possible to conclude that "strolling" is currently the main trip motive for choosing e-scooters. The corresponding utility is than other motives (commuting or leisure). Taking into account that the purpose of the e-scooters coming to Lisbon is to use them for utilitarian motives and not for leisure, this model proves that what is happening today is quite different. This conclusion is consistent with the "commuting" motive being the one that presents the least probability of choice among the three alternatives, as described.

The second model studied the modes that were replaced by the e-scooter. The result obtained by the utility functions is that the "walking" mode is much more likely to be replaced than any other mode. It is recalled that one of the most chosen reasons for respondents to use the e-scooter was "because walking would take longer", further emphasizing the probability of this being the chosen mode. Once again, we stress that the goal of introducing shared e-scooters in Lisbon was to replace other modes, among several reasons to decrease pollution in the city. Bearing in mind that walking is the most ecological mode because it does not produce any kind of contamination, its replacement by the e-scooter actually introduces an increase of pollution in the ecosystem. Such increase does not result from the CO2 emissions, but from the materials that compose the e-scooter (such as batteries), which are more polluting than "walking".

In this sense, this third study complemented the results previously obtained, which affirm that shared e-scooters are not fulfilling their purpose in the city. The use of motorized modes is not being reduced using the e-scooter and the e-scooter is generating more trips and, consequently, more traffic (in terms of bicycle paths and sidewalk occupation) in the city. Walking trips are the ones being replaced by e-scooters, generating more consumption of battery components, plastics and steel to construct the e-scooters, while reducing an active life of the Lisbon population, and thus contributing to lower healthy lifestyles. It was also concluded that it is necessary to change the way the e-scooter is seen by the population, i.e., leisure and not utilitarian, and that this requires the introduction of incentives or changes in management of this mode.

At the same time, it takes into account the times in which we live today. The existence of a worldwide pandemic and the care to be taken are different from when this study started. With the limitations on public transportation, and the fear generated in the population, the use of transportation modes will change. The car will be the preferred mode of use, generating more traffic within the city, and the use of public transportation will decrease. In this sense, it is possible to increase the use of soft and active modes, such as bicycles and e-scooters. According to Lelièvre (2020), in France, sales of e-scooters increased by 105% in 2019 and therefore, although it is not the increase in the use of shared e-scooters, it is an increase in micromobility modes, which can improve traffic within the city, and encourage the population to use "greener" modes of transportation.

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Annex I

	Users n=62		Potential Users n=173		Occasional n=417		Non-Users n=76		Quitters n=267	
	n	%	n	%	n	%	n	%	n	%
Age										
Average	33		35		37		38		35	
Gender										
Female	5	8%	31	18%	93	22%	17	23%	47	18%
Male	56	92%	142	82%	322	78%	58	77%	219	82%
Education										
Until end of high school	19	31%	52	31%	140	34%	27	36%	82	31%
Bachelor	24	39%	60	34%	156	38%	29	38%	87	33%
Level higher than bachelor	19	31%	61	35%	120	29%	20	26%	95	36%
Own transport modes										
Scooter	10	16%	14	8%	33	8%	6	8%	31	12%
Automobile	46	74%	138	80%	350	85%	53	72%	207	79%
Area of residence										
Municipality of Lisbon	36	58%	94	54%	182	44%	32	42%	152	57%
Metropolitan Area	19	31%	58	34%	161	39%	29	38%	73	27%
Composition of regular trips										
One mode of transportation	4	6%	81	47%	270	65%	45	59%	124	46%
A combination of transport modes	58	94%	91	53%	147	35%	31	41%	143	54%
Transport modes on regular trips										
Soft and active modes	8	13%	29	17%	67	16%	22	29%	55	21%
Main Mode: Automobile	9	15%	64	37%	175	42%	22	29%	65	24%
Main Mode: Public Transportation	25	40%	52	30%	112	27%	18	24%	96	36%
Combination of public transport + car	1	2%	15	9%	32	8%	8	11%	24	9%
Others	19	31%	13	8%	31	7%	6	8%	27	10%

Annex II

Variable i	Variable j	Correlation	Variable i	Variable j	Correlation
Do you use the e-scooter during rush hours?	Do you use the e-scooter at other times?	**-0,982**	Do you use soft or active modes **(walk)**?	Have you replaced it with a car or public transportation?	**-0,659**
Do you circulate on the Road?	Do you circulate on the Bicycle Path?	**-0,632**	Do you use Public Transportation?	Do you use a car?	**-0,581**
Do you circulate on the Sidewalk?	Do you circulate on the Bicycle Path?	**-0,513**	Do you use public transportation on a daily basis?	Do you use a car?	**-0,492**
Wander around	Errands	**-0,468**	Do you usually walk?	Do you use a car?	**-0,446**
Commuting	Wander around	**-0,427**	Did you park against a building?	Did you park in a scooter parking lot?	**-0,425**
Commuting	Errands	**-0,419**	Do you use a car?	A mode or combination**?**	**-0,379**
Do you use public transportation on a daily basis?	Do you have a car that you can use?	**-0,354**	Do you use a car?	Do you use soft or active modes (walk)?	**-0,318**
Do you use soft or active modes (walk)?	Do you use public transportation on a daily basis?	**-0,309**	Do you have a car that you can use?	Do you use Public Transportation?	**-0,308**
Have you replaced it with walking or soft mode?	Do you replace it with motorcycles or cabs?	**-0,307**	Do you use soft or active modes (walk)?	A mode or combination**?**	**-0,306**
Do you have a car that you can use?	Do you use a car?	**0,314**	Age	Qual a sua situação laboral?	**0,315**
Do you use Public Transportation?	Do you usually walk?	**0,318**	Frequency	Wander around	**0,323**
A mode or combination?	Do you usually walk?	**0,326**	Age	Income	**0,328**
Classify the system globally	Classify the power	**0,337**	Age	Education	**0,356**

Do you combine car + public transportation in everyday life?	A mode or combination?	**0,36**	Education	Income	**0,361**
Classify the power	Classify the comfort	**0,37**	Age	Do you have dependents?	**0,373**
Do you circulate on the Sidewalk?	Frequency	**0,398**	A mode or combination=	Do you use Public Transportation?	**0,419**
Frequency	When was the last time you used it?	**0,422**	When was the last time you used it?	Have you quit using the e-scooter?	**0,438**
Classify the system globally	Classify the cost of use	**0,44**	A mode or combination?	Do you use public transportation on a daily basis?	**0,449**
Do you use soft or active modes (walk)?	Do you usually walk?	**0,452**	How many people live in your place of residence?	Do you have dependents?	**0,481**
Classify the system globally	Classify the maneuverability	**0,509**	Do you use Public Transportation?	Do you use public transportation on a daily basis?	**0,526**
Classify the safety	Classify the maneuverability	**0,542**	If no e-scooter was available, what would you do?	Have you replaced it with walking or soft mode?	**0,55**
Classify the speed	Classify the power	**0,585**	Classify the safety	Classify the system globally	**0,585**
Classify the system globally	Classify the comfort	**0,599**	Classify the maneuverability	Classify the comfort	**0,603**
Classify the safety	Classify the comfort	**0,618**			

Annex III

Name	Restricted model		Unrestricted model	
	Value	**p-value**	**Value**	**p-value**
$\beta_{Distance}$	0,0505	0,468	-	-
$\beta_{Distance\_Walk}$	-	-	-0,611	0,992
$\beta_{Distance\_Auto}$	-	-	0,197	0,142
$\beta_{DIstance\_Soft}$	-	-	0,159	0,678
β_{Time}	-0,0121	0,00389	-	-
β_{Time_AWalk}	-	-	0,0452	0,993
β_{Time_Auto}	-	-	-0,0737	0,273
β_{Time_Soft}	-	-	-0,054	0,593