Traffic & Transportation

Estimating Travel Demand with a Multimodal Transport Model Including e-Scooters in Iași, Romania

Ovidiu-Laurențiu HARPALETE

Original Scientific Paper
Submitted: 11 Jan. 2023
Accepted: 9 May 2023

ovidiu20022003@yahoo.com, Doctoral School of Transports, Politehnica University of Bucharest

Publisher:
Faculty of Transport and Traffic Sciences, University of Zagreb

ABSTRACT

Cities, even medium-sized and small ones, have become overwhelmed by traffic and congestion. Innovative solutions are required and recent studies have focused on sustainable approaches. This study aims to develop a multimodal transport model consisting of an urban public transportation (UPT) service combined with an e-scooter sharing service. The main purpose of the model is a comparison between two travel alternatives (car and UPT + e-scooter), calculating their associated levels of utility. The methodology is based on a multinomial logit model, implemented in Matlab software, using results from an online mobility survey (socio-economic characteristics of potential users of e-scooters). The additional aim is related to the assessment of the inhabitants' availability to shift from car to multimodal service or to simple e-scooter service. The developed micromodel was applied in Iași, a mid-sized city located in the northeast of Romania. Several price strategies were analysed in order to find their influence on users' mobility behaviour. It turned out that the price for the shared e-scooter is too high at this moment to be used for daily travel. Without a price decrease and public authorities' involvement in facilitating the multimodality, the e-scooter remains only an entertainment activity.

KEYWORDS

travel demand; e-scooter; multimodal transport; travel utility; transport policy.

1. INTRODUCTION

In 2015, the average car ownership rate in Europe was about 500 cars per 1000 inhabitants, higher by 21.5% compared to the 2000 level. According to literature, all kinds of modes of transport are available in large cities (bus, underground/metro, tram, trolleys), and the use of public transportation surpasses that of cars. This is not the case, though, for medium-sized cities, where conventional types of public transportation are not so varied. As a result, an urban area enters a vicious circle of urban decline, with the number of cars continuously increasing and generating even more congestion and pollution [1].

Citizens need to capitalise on technological progress for sustainable mobility, as it can reduce the disadvantages of existing modes of travel [2]. The electric car is a good start in reducing carbon emissions. However, since the majority of car flows (even electric ones) are single-occupancy or low-occupancy, the congestion problem is still persistent. Electricity consumption is increasing, and the only solution of renewing fleets with electric cars ends up not being sustainable enough. Recently, shared micromobility options have started to gain attention, including from researchers who are trying to solve congestion problems.

The main purpose of micromobility is to cover short distance trips, here included as the first/last mile problem. This problem concerns the access and egress stages, which, along with waiting and transfer times, are considered the weakest parts of a multimodal public transportation chain, while their contribution to total travel disutility is substantial [3]. Various studies state that people are willing to walk to a public transport station about 400 m, which argues the need for research and finding solutions to the first/last mile problem, so as to increase the use of public transportation [4]. Reck et al. [5] claim that the distance is even shorter, between 60 m and 200 m. The micromobility category can include any small and lightweight vehicle that does not reach speeds over 45 km/h, such as bicycles or scooters, electric or not, privately owned or not [6]. Shared vehicles belong to the Mobility-as-a-Service (MaaS) category. Despite potential benefits, MaaS is still generally untested and there is not enough evidence and conclusions about its impact [7].

The use of electric scooters (as a business – rental on demand) has led to diversified alternatives of urban mobility, disrupting the market previously dominated by bike sharing, by offering more flexibility. They are dockless and they can be ridden on sidewalks and streets, while shared bikes are limited to bike lanes [8]. Sanders et al. [9] found that the e-scooter is a convenient way of travel, especially in the heat, replacing walking and getting people to their destination 22% faster than the bicycle. However, this type of business has faced problems of reliability and conflict with third parties [10]. The introduction of e-scooters has resulted in a considerable public debate, because it has started to affect other users of public spaces, like pedestrians who do not feel safe anymore on the sidewalks as some e-scooter users drive irresponsibly. James et al. [11] showed that 16% of the observed e-scooters were not parked properly, while 6% of them were blocking pedestrian access. This has led to public complaints or even acts of vandalism. Mitra and Hess [12] confessed that at the moment of their study shared e-scooters were illegal in their study area, the city of Toronto and its surroundings. Although many people around the world have asked authorities to restrict or to ban these services, their efforts progressed in the opposite direction, with some countries, such as UK or Germany, legalising e-scooters [10]. If e-scooters and public transportation were to be integrated, as means of multimodal transport, the utility would grow exponentially [13]. The purpose is to increase the competitiveness of public transportation against the car, in terms of costs and travel time, but also to contribute to the limitation of congestion and pollution.

Multimodal travel, although on an upward trend, has been somehow neglected over time in travel demand research [4]. A multimodal journey involves changing the mode of transport at least once, considering a single journey from origin to destination (*Figure 1*). This should not be confused with related journeys, which are in fact different stages of a tour that involves several activities.

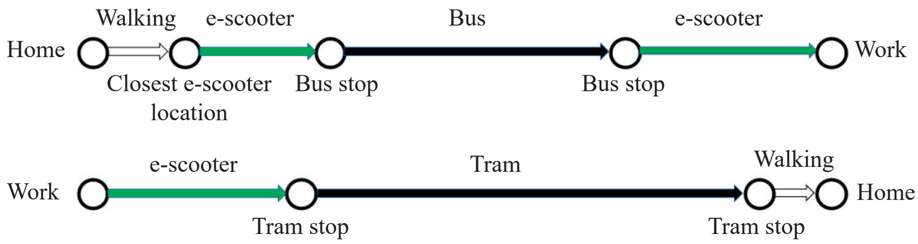

Figure 1 – Examples of multimodal transport involving the e-scooter

For the study scope, a multimodal travel model consists of a chain of services, with transfer in public transportation stations. According to the above definition, the chain of services contains the following components:

- access mode, in which an e-scooter is taken from home or near home to the nearest bus or tram stop;
- main mode, namely the longest part of the journey, represented by bus or tram, from the closest station to the passenger's home or to the closest station to his destination;
- egress mode, another e-scooter taken from the immediate vicinity of the public transport station at which it descended to its destination.

Kagerbauer et al. [14] showed that 22% of the trips were made by more than one travel mode, but also that walking and cycling are underrepresented in the modes' shares. Bakogiannis et al. [15] wrote about the cooperation between public transportation and shared bicycles in Athens, as a solution for residents of suburbs to be more motivated to use public modes more often, becoming less car-dependent. Hamadneh and Jaber [16] studied transport choice behaviour in Budapest, Hungary, using a decision-tree technique and discrete choice modelling. They revealed the importance of the variables used, notably the negative impact of travel time and travel cost on the travel mode, but they did not include the new transport modes, such as e-scooter or other ride-sharing services. Jie et al. [17] studied the current and potential impact of different forms of shared mobility, focusing on the shire of Wanneroo in Western Australia. The results showed that a high percentage of respondents used shared mobility options, but mostly for social activities and less for work-related activities. A significant percentage of respondents declared they would use shared mobility services in the future. Ma et al. [8] imagined a multimodal travel model, connecting metros with shared e-scooters. They compared the use of shared e-scooters against shared bikes and taxis for connecting trips to metro stations by extracting massive amounts of trip-related data through APIs and developing multinomial logistic regression models to see how the mode choices varied in different contexts. Their conclusion was that the preference of shared e-scooters varies depending on the land use and time period. Reck et al. [5] contributed by collecting a large dataset with matching GPS tracks, booking data and survey data for more than 500 travellers, and they estimated a first-choice model between eight transport modes, including e-scooters. The main findings were that trip distance, access distance and precipitation are fundamental for the mode choice, but also that shared e-scooters emit more CO_2 than the transport modes they substitute. Esztegar-Kiss et al. [18] conducted a stated preference survey to reveal users' utility for e-scooter usage in five big cities (Copenhagen, Munich, Barcelona, Tel Aviv, Stockholm) and applied 3 types of logit models (multinomial, mixed and nested) to extract the coefficients. The results showed different degrees of interest for the new personal mobility option. Shokouhyar et al. [19] explored the challenges and opportunities that the COVID-19 pandemic has brought to the sustainability of shared mobility. The study serves as a catalogue of gaps and necessities for new studies in this field. The research gaps include the calculation of separate utility functions for each travel mode, and not taking into account the utility of combined travel services, the limitation of the number of dependent variables, which may not be representative enough for the real level of utility. Also, more attention needs to be accorded to small and mid-sized cities, because all over the world they are much more numerous than the big ones, which already have good accessibility.

The contributions of this research gravitate around the interpretation of the behaviour of people of Iași when choosing a travel mode for the two main activities, work and leisure. The literature on this topic studies big cities with complex and dense urban transportation, while this article considers a mid-sized city in expansion with accessibility issues, where people living in the suburbs face problems of poor accessibility, while e-scooters are available in the city since a few months. An MNL model was applied for the two types of activities, using data from the dedicated online travel survey, posted on different Facebook groups, to assure participant randomness. Compared to most relevant studies on this topic, this research improves by integrating a unique utility function for the multimodal travel option of e-scooters and UPT, and considered as a direct competitor for car usage. Moreover, all the utility functions were built with the maximum number of dependent variables, to be able to cover as many influencing factors of utility as possible.

2. STUDY AREA AND DESCRIPTIVE STATISTICS

The city of Iași has seen a continuous growth of its population, almost doubling in the last 10 years. At the time of the 2011 census it had 290,422 inhabitants, whereas in 2019 it already reached 507,100 inhabitants [20], due to economic and financial opportunities, which determine the migration of Moldovan citizens, but also the migration of young people from neighbouring counties who come to study in Iași and settle there. The Iași metropolitan area is now the second largest in Romania, after Bucharest, the new city expanding in all directions (*Figure 2*) [20].

The most numerous age category is the one between 30–34 years old, with 43,253 inhabitants in 2021, followed by the one between 35-39 years old, with 30,374 inhabitants. Also, the younger age groups are more numerous than the older ones, which means that the population is predominantly young and growing. Moreover, Iași County is the least demographically aged, compared to other counties in northeastern Romania, with about 15% of the elderly population in the total population [21]. The fact that the population of Iași is young and growing makes it relevant from the point of view of the e-scooter potential use. The younger are more suitable to adopt this new travel mode, compared to the older populations, who are more sceptical. This was one of the reasons for which the city of Iași was selected for this study, as it is a good place to implement a multimodal transport model based on e-scooters.

The public transport network is a complex public or private system that must equally meet the mobility needs of the population of an urban system [22]. An unfortunate consequence of excessive urbanisation has proved to be the isolation of peripheral neighbourhoods, a problem not completely solved until today [23]. After 1990, the strong modernisation of the city centre continued, to the detriment of residential neighbourhoods, which remain weakly polarised in the public transport system, their only chance being private transport. Starting with 2017, the Public Transport Company Iași has operated 8 tram routes and 25 bus lines in the city [20]. The number of registered cars in circulation in Iași has also continuously increased, from almost 80,000 in 2007 to over 200,000 in 2020 [20]. Although the number of cars has increased from year to year, the length of public roads remained approximately the same, which means that the degree of congestion is also increasing. Transport is not considered an activity or purpose per se, so it is in a dynamic regime of adaptation

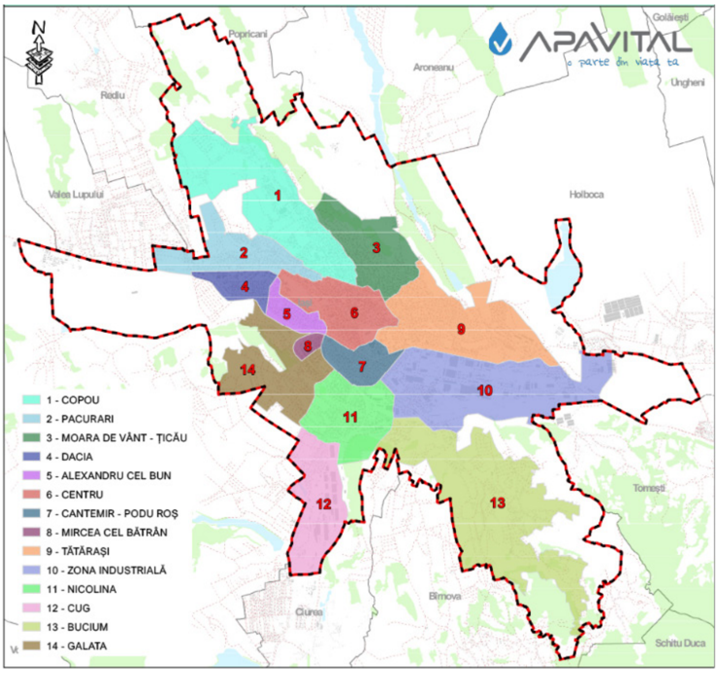

Figure 2 – The main neighbourhoods in Iași (source: https://www.apavital.ro/harta-municipiului-Iași)

to socio-economic functions [24], and with the hypertrophic extension of the city, it has become much more difficult for public transportation to serve all the suburbs [25].

Starting with 8 April 2022, e-scooters provided by Lime are available for rent in Iași city. In order to use this service, the user must download the mobile application "Lime" (*Figure 3*), where you can see the location of available e-scooters, thanks to GPS technology, choose the nearest e-scooter and unlock it with your phone, scanning a QR code from it. At the end of the trip, the e-scooter can be left anywhere, within the defined perimeter, requiring a photo with it in a suitable place to end the trip. The usage costs are about 0.136 EUR/minute, and the unlock costs 0.4 EUR.

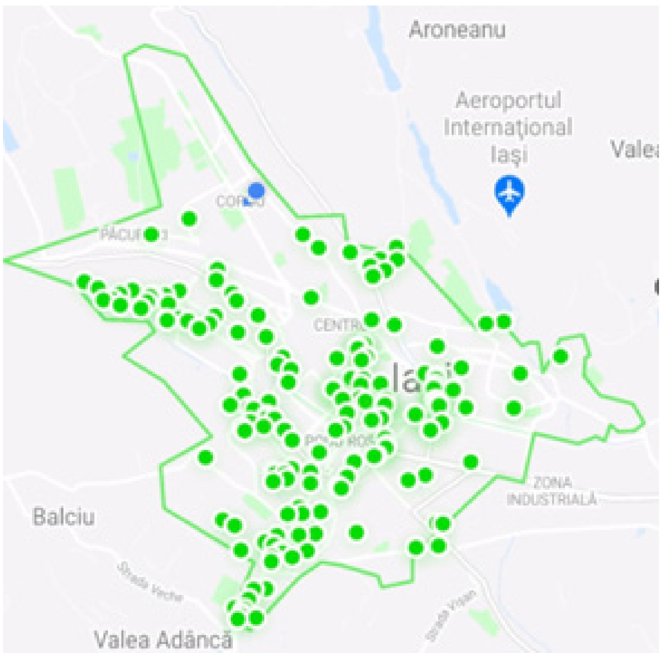

Figure 3 – Available scooters in Iași in Lime application

For Romania, the costs are not considered as being the most affordable for long distances, at this moment, considering that a 30-minute trip, for example, costs about 4.48 EUR, and one-hour ride is about 8.56 EUR.

3. METHODOLOGY

3.1 Travel survey for determining the declared travel preferences of the population of Iași

Surveys play a key role in assessing mobility, and the volume and quality of collected data are essential for correctly understanding travel behaviour, assessing generated and attracted flows by points of interest, but also identifying appropriate solutions to meet mobility needs. While many studies have focused on walking and cycling as access and egress options [4], as highlighted in the literature review, we will focus on e-scooters for the same purpose.

An online travel survey was developed, using the Google Forms application, containing 17 questions. It was posted on various Facebook groups of the city of Iași, and it obtained 492 answers, within 2 months (April–May 2022). This method of posting the survey on different social media groups on different topics and purposes assures the randomness and diverse range of individuals. The survey is aiming to extract the socio-demographic characteristics of the respondents (questions 1–3 about gender, age, income range), the mobility options availability (questions 4–6 about car, e-scooter, public transport pass possessions), the preference of travel mode for work and leisure (questions 7 and 8), distance to the closest bus or tram station (question 9), the fear of travelling by public transportation means, due to the COVID-19 pandemic, as the questionnaire was sent in 2022, when there was still a degree of reluctance in this regard (question 10) and the users' view towards e-scooters (questions 11–16). The questions had a single-choice format and had the role to find individuals' utility for different alternatives and populations' opinions about e-scooters. Compared to other similar studies, where surveys included more than a hundred questions (e.g. Reck et al. [5] – 171 questions), our survey was conceived with a minimum number of questions, to increase the participation chances. The more questions a survey has, the less likely it is to have patient and interested respondents.

3.2 Maximising travel utility

Although the e-scooter travel choice topic has gained in popularity, there is limited understanding of how people make mode choice decisions between e-scooters and competing alternatives, especially the car. Travel utility is a concept that measures the traveller's perceived value of using a travel mode, and his decision is influenced by factors such as cost, time, comfort, purpose etc. According to the traveller behaviour theory, one is going to choose the mode with the highest utility of all [26]. Mokhtarian et al. [27] showed that the socio-economic variables and indicators of distance, purpose and mode have a strong connection with the pleasantness and fatigue of travellers. Discrete choice modelling theory was applied to determine the travel utility for each travel mode. For analysing a discrete choice problem, there are three main setup steps:

a) *choice-set determination*: the following modes of transport were considered: walking, e-scooter, car and public transportation, the last one in combination with walking and with e-scooters.
b) *formulate a model of how the user chooses among the choice set*: most studies in the literature lack the scenarios based on the combined travel modes, but instead, the utilities of single modes are calculated and compared as alternatives, which is not actually the point of multimodal choice behaviour [26]. For this study, the following utility functions were built for the considered modes, in order to estimate the multinomial logit model (MNL):

Walking

$$U_{WA} = \beta_{WA} + \beta_{timeWA} \cdot time_{WA} + \beta_{comfortWA} \cdot comfort_{WA} \tag{1}$$

with

$$\beta_{WA} = \beta_{WA0} + \beta_{sexWA} \cdot sex + \beta_{ageWA} \cdot age + \beta_{carWA} \cdot hh_{car} + \beta_{ESWA} \cdot hh_{ES} + \beta_{incomeWA} \cdot income \tag{2}$$

e-Scooter

$$U_{ES} = \beta_{ES} + \beta_{timeES} \cdot time_{ES} + \beta_{costES} \cdot costs_{ES} + \beta_{comfortES} \cdot comfort_{ES} \tag{3}$$

with

$$\beta_{ES} = \beta_{ES0} + \beta_{sexES} \cdot sex + \beta_{ageES} \cdot age + \beta_{carES} \cdot hh_{car} + \beta_{incomeES} \cdot income \tag{4}$$

$$\beta_{cost} = - e^{\beta cost0 + \sigma cost \cdot \zeta 1} \tag{5}$$

Car

$$U_{PC} = \beta_{PC} + \beta_{timePC} \cdot time_{PC} + \beta_{costPC} \cdot cost_{PC} + \beta_{parkingPC} \cdot parking_{PC} + \beta_{comfortPC} \cdot comfort_{PC} \tag{6}$$

with

$$\beta_{PC} = \beta_{PC0} + \beta_{sexPC} \cdot sex + \beta_{agePC} \cdot age_{PC} + \beta_{incomePC} \cdot income + \beta_{PTpassPC} \cdot PTpass \quad (7)$$

$$\beta_{cost} = - e^{\beta cost0 + \sigma cost \cdot \zeta 1} \quad (8)$$

Walking + UPT

$$U_{WA+PT} = \beta_{WAPT} + \beta_{distancePT} \cdot distance_{PT} + \beta_{timeWA} \cdot time_{WA} + \beta_{comfortWA} \cdot comfort_{WA} + \beta_{waitPT} \cdot wait_{PT} + \beta_{timePT} \cdot time_{PT} + \beta_{costPT} \cdot cost_{PT} + \beta_{crowdingPT} \cdot crowding_{PT} + \beta_{comfortPT} \cdot comfort_{PT} \quad (9)$$

with

$$\beta_{WAPT} = \beta_{WAPT0} + \beta_{sexWAPT} \cdot sex + \beta_{ageWAPT} \cdot age + \beta_{carWAPT} \cdot hh_{car} + \beta_{WAPT} \cdot hh_{ES} + \beta_{incomeWAPT} \cdot income + \beta_{PTpassWAPT} \cdot PTpass \quad (10)$$

e-Scooter + UPT

$$U_{ES+PT} = \beta_{ESPT} + \beta_{distancePT} \cdot distance_{PT} + \beta_{timeES} \cdot time_{ES} + \beta_{costES} \cdot costs_{ES} + \beta_{comfortES} \cdot comfort_{ES} + \beta_{waitPT} \cdot wait_{PT} + \beta_{timePT} \cdot time_{PT} + \beta_{costPT} \cdot cost_{PT} + \beta_{crowdingPT} \cdot crowding_{PT} + \beta_{comfortPT} \cdot comfort_{PT} \quad (11)$$

with

$$\beta_{ESPT} = \beta_{ESPT0} + \beta_{sexESPT} \cdot sex + \beta_{ageESPT} \cdot age + \beta_{carESPT} \cdot hh_{car} + \beta_{incomeESPT} \cdot income + \beta_{PTpassESPT} \cdot PTpass \quad (12)$$

c) *estimating unknown structural parameters of the model (marginal utilities):* the utilities of using the following travel modes were calculated: walking, e-scooter, car, walking+UPT and e-scooter+UPT, using a multinomial logit model (MNL). The MNL model was chosen because the individual's utility is linearly dependent on the respondent's socio-demographics and the attributes of the different multimodal alternatives. It is one of the most popular models used in travel mode choice analysis, because it allows to easily add or remove choice alternatives and the estimation and interpretation are not very difficult [26]. Overall, the MNL model is a powerful tool for analysing and predicting outcomes in situations where there are multiple possible outcomes. Thus, the probability of mode *j* to be chosen is as follows:

$$P_j = \frac{\exp(\beta V_j)}{\sum_{i=1}^{J} \exp(\beta V_i)} = \frac{1}{1 + \sum_{i \neq j} \exp\left[\beta(V_i - V_j)\right]} \quad (13)$$

where β is the parameter, V_j is the utility of mode *j* (the observed part from the utility function), usually obtained by linear regression [28].

The variables involved in the model estimation are defined below (*Tables 1 and 2*). Their values are extracted from the survey answers and represent the factors that affect the choice of travel mode. To be able to estimate the model and the coefficients with the Matlab code, dummy variables are defined in *Tables 1 and 2*.

4. RESULTS

The most relevant results of the online survey can be found in the table below (*Table 3*). Also, results from the last Romanian census in 2022 were presented as a comparison, when they were found available. The most responsive two age groups were the ones between 18–30 and 30–40 (~35%), while the percentages of population of Iași in these categories are much smaller (~18–19%). Among the declared results, as transport modes used mostly for work trips, 43.7% answered they use public transportation, 40% use a car, and the rest use walking or other travel means. The use of cars has a big proportion; as a comparison, the same as Zurich had in 2000, while in 2015 it reached only 25% [5]. Also for comparison, Budapest has a modal share of 35% for the car [16]. For non-work trips, the results were a little different, 47.6% using a car and only 32.1% using the public transportation. The repartition by distance to the closest public transport stop is almost even in each category, from 0–200 m to more than 1000 m, similar to what Roșu [23] determined in his study. Regarding the questions about electrical scooters, we find that 43.3% of the population have seen e-scooters available in their home area, but small percentages of people would use one for different activities. Only 13.4% would ride an e-scooter from home to work, 22% would use an e-scooter as access to public transportation, respectively 12.4% for egress, and 32,9% would pay for an e-scooter for other activities, like to try it for fun. When asked why they would not use an e-scooter, 51.4% answered that the cost is too high, 14.4% said the e-scooters are

Table 1 – Socio-economic variable definition

Variable	Options	Unit	Denotation
Sex	Male	-	Male
	Female	-	Female
Age	18–30	Years	Age1
	30–40	Years	Age2
	40–50	Years	Age3
	50–60	Years	Age4
	>60	Years	Age5
Income	<200	EUR/month	Income1
	200–400	EUR/month	Income2
	400–600	EUR/month	Income3
	600–800	EUR/month	Income4
	800–1000	EUR/month	Income5
	>1000	EUR/month	Income6
	0: Owns no car	-	Nocar
	1: Owns one or more cars	-	Car
	0: Owns no private e-scooter	-	noES
	1: Owns private scooter	-	ES
	0: Possess no PT pass	-	noPTpass
	1: Possess a PT pass	-	PTpass
Distance to the closest public transport stop	0–200	m	Dist1
	200–400	m	Dist2
	400–600	m	Dist3
	600–800	m	Dist4
	800–1000	m	Dist5
	>1000	m	Dist6

Table 2 – Alternative modes variable definition

Variable	Options	Unit	Denotation
	Travel time	min	ttime
	Waiting time	min	wtime
	Parking search time	min	ptime
	Cost	EUR	cost
	Comfort	-	comfort
Fear of crowding	No fear of crowding	-	Fear0
	A little fear of crowding	-	Fear1
	Medium fear of crowding	-	Fear2
	Big fear of crowding	-	Fear3
	Very big fear of crowding	-	Fear4

Table 3 – Descriptive statistics of the online survey (sample size: 492, mean distance to work: 5.3 km)

Variable	Options	N	Sample (%)	City (%)
Sex	Male	263	53.5	47.3
	Female	229	46.5	52.7
Age	18–30	171	34.8	18.3
	30–40	174	35.4	19.1
	40–50	63	12.8	13.8
	50–60	53	10.7	15.4
	>60	31	6.3	12.1
Income	<200	29	5.9	11.5
	200–400	120	24.4	13.2
	400–600	184	37.4	18.2
	600–800	103	20.9	21
	800–1000	38	7.7	32.1
	>1000	18	3.7	4
Car ownership	Yes	283	57.5	64.9
	No	209	42.5	35.1
e-Scooter ownership	Yes	36	7.3	
	No	456	92.7	
PT pass	Yes	226	45.9	
	No	266	54.1	
Work travel mode	walking	52	10.6	
	UPT	215	43.7	
	car	197	40	
	others	28	5.7	
Leisure travel mode	walking	58	11.8	
	UPT	158	32.1	
	car	234	47.6	
	others	42	8.5	
Distance to UPT	0–200 m	47	9.6	
	200–400 m	81	16.5	
	400–600 m	115	23.4	
	600–800 m	142	28.9	
	800–1000 m	74	15	
	>1000 m	33	6.7	
e-Scooter in area	Yes	213	43.3	
	No	279	56.7	
e-Scooter -> work (potential use)	Yes	66	13.4	
	No	426	86.6	
e-Scooter+UPT -> work (potential use)	Yes	108	22	
	No	384	78	
e-scooter -> leisure (potential use)	Yes	162	32.9	
	No	330	67.1	
e-Scooter+UPT -> leisure (potential)	Yes	111	22.5	
	No	381	77.5	

not available in their area, 13% considered them dangerous, 6.9% declared they prefer walking, while 5.9% live too close to a UPT station to need it as an access/egress mode.

For the parameter's estimation, we run the Matlab code for the chosen MNL model and calculate the modes' utilities, direct and combined, in 2 cases: work trips (*Table 4*) and non-work trips (*Table 5*). In Matlab, the function for the MNL model is "[beta, dev, stats]=mnrfit (X, y);" and the function to predict the probabilities for each travel mode is "p=mnrval(beta, X);". As we are interested mostly in the use of the e-scooter, we used as criteria the answers from the survey regarding the presence of e-scooters in their area and their willing to use them, as a Mobility-as-a-Service benefit. The estimation results are the following:

Table 4 – Results of the multinomial logit model for work mode-choice

Variables	Walking		e-scooter		Car		Walking+UPT		e-scooter+UPT	
	Coeff	P	Coeff	P	Coeff	P	Coeff	P	Coeff	P
Male	ref		ref		ref		ref		ref	
Female	0.65	0.003	-0.1	0.011	1.1	0.002	1.4	0.002	-0.05	0.003
Age1: 18–30	ref		ref		ref		ref		ref	
Age2: 30–40	1.56	0.001	0.9	0.003	1.4	0.013	0.9	0.005	0.89	0.009
Age3: 40–50	0.6	0.030	0.05	0.002	1.23	0.002	0.09	0.005	0.15	0.008
Age4: 50–60	-0.2	0.010	-0.03	0.001	1.4	0.002	1	0.007	-0.002	0.002
Age5: >60	-0.01	0.008	-0.06	0.002	1.41	0.003	1.2	0.009	-0.004	0.003
Income1: <200	ref		ref		ref		ref		ref	
Income2: 200–400	1.2	0.001	-0.003	0.002	0.9	0.003	1.3	0.001	-0.001	0.002
Income3: 400–600	0.9	0.004	0.04	0.005	1.23	0.058	1.01	0.001	0.06	0.002
Income4: 600–800	0.6	0.001	0.4	0.005	1.38	0.003	0.91	0.002	0.48	0.005
Income5: 800–1000	0.4	0.001	0.9	0.003	1.4	0.001	0.63	0.013	1.03	0.021
Income6: >1000	0.3	0.006	1	0.001	1.43	0.016	0.45	0.014	1.09	0.020
Nocar	ref		ref		ref		ref		ref	
Car	-0.001	0.012	-0.01	0.014	-		-0.03	0.007	-0.02	0.003
noES	ref		ref		ref		ref		ref	
ES	-0.2	0.010	-		-		-0.2	0.001	-	
noPTpass	ref		ref		ref		ref		ref	
PTpass	-		-		-0.02	0.005	1.32	0.001	1.32	0.020
Dist1: 0–200	ref		ref		ref		ref		ref	
Dist2: 200–400	-		-		-		1.69	0.002	0.22	0.005
Dist3: 400–600	-		-		-		1.4	0.004	0.93	0.021
Dist4: 600–800	-		-		-		0.9	0.009	0.99	0.015
Dist5: 800–1000	-		-		-		0.2	0.012	1.05	0.009
Dist6: >1000	-		-		-		0.1	0.016	1.28	0.005
Travel time	-0.311	0.003	-0.201	0.003	-0.172	0.006	-0.085	0.001	-0.069	0.004
Waiting time	-		-		-		-0.012	0.005	-0.012	0.007
Parking search time	-		-		-0.08	0.001	-		-	
Cost	-		-2.23	0.001	-1.90	0.004	-1.76	0.005	-2.01	0.001
Comfort	-0.81	0.002	0.92	0.002	1.89	0.001	-0.02	0.007	0.01	0.002
Crowding: Fear0	ref		ref		ref		ref		ref	
Crowding: Fear1	-		-		-		-0.001	0.003	-0.001	0.005
Crowding: Fear2	-		-		-		-0.001	0.003	-0.001	0.006
Crowding: Fear3	-		-		-		-0.002	0.004	-0.002	0.008
Crowding: Fear4	-		-		-		-0.003	0.002	-0.003	0.004

Table 5 – Results of the multinomial logit model for leisure mode-choice

Variables	Walking		e-scooter		Car		Walking+UPT		e-Scooter+UPT	
	Coeff	P	Coeff	P	Coeff	P	Coeff	P	Coeff	P
Male	ref		ref		ref		ref		ref	
Female	0.68	0.001	-0.08	0.001	1.1	0.005	1.4	0.002	-0.15	0.001
Age1: 18–30	1.78	0.001	0.9	0.002	1.1	0.001	1.3	0.004	0.9	0.003
Age2: 30–40	1.6	0.002	0.8	0.002	1.5	0.001	0.7	0.002	0.69	0.002
Age3: 40–50	0.9	0.002	0.05	0.004	1.33	0.002	0.04	0.007	0.11	0.006
Age4: 50–60	0.2	0.009	-0.03	0.004	1.5	0.001	0.7	0.007	-0.05	0.005
Age5: >60	ref		ref		ref		ref		ref	
Income1: <200	ref		ref		ref		ref		ref	
Income2: 200–400	1.3	0.003	-0.002	0.003	0.9	0.005	1.2	0.001	-0.001	0.004
Income3: 400–600	1.2	0.005	0.06	0.006	1.34	0.010	0.97	0.001	0.01	0.002
Income4: 600–800	0.8	0.006	0.8	0.002	1.41	0.002	0.82	0.012	0.04	0.001
Income5: 800–1000	0.39	0.006	1.04	0.001	1.51	0.002	0.46	0.003	0.34	0.002
Income6: >1000	0.2	0.004	1.1	0.002	1.74	0.002	-0.01	0.003	0.03	0.004
Nocar	ref		ref		ref		ref		ref	
Car	-0.001	0.003	-0.01	0.002	-		-0.03	0.002	-0.02	0.003
noES	ref		ref		ref		ref		ref	
ES	-0.5	0.002	-		-		-0.5	0.002	-	
noPTpass	ref		ref		ref		ref		ref	
PTpass	-		-		-0.02	0.004	1.1	0.001	1.1	0.009
Dist1: 0–200	ref		ref		ref		ref		ref	
Dist2: 200–400	-		-		-		1.54	0.004	0.2	0.018
Dist3: 400–600	-		-		-		1.26	0.004	0.75	0.010
Dist4: 600–800	-		-		-		0.61	0.003	0.79	0.005
Dist5: 800–1000	-		-		-		0.24	0.009	0.89	0.005
Dist6: >1000	-		-		-		-0.02	0.021	0.92	0.003
Travel time	0.06	0.014	-0.174	0.007	-0.16	0.003	-0.025	0.003	-0.03	0.015
Waiting time	-		-		-		-0.005	0.003	-0.013	0.010
Parking search time	-		-		-0.03	0.003	-		-	
Cost	-		-1.05	0.001	-1.2	0.005	-0.09	0.030	-1.33	0.002
Comfort	-0.38	0.008	0.94	0.001	1.66	0.001	-0.01	0.004	0.005	0.003
Crowding: Fear0	ref		ref		ref		ref		ref	
Crowding: Fear1	-		-		-		-0.001	0.005	-0.001	0.005
Crowding: Fear2	-		-		-		-0.001	0.005	-0.001	0.005
Crowding: Fear3	-		-		-		-0.002	0.005	-0.002	0.004
Crowding: Fear4	-		-		-		-0.003	0.004	-0.003	0.006

5. DISCUSSION

Analysing the socio-economic variables, we noticed that for females we have negative e-scooter trip values, no matter if it is direct or combined, for work (-0.1; -0.05) or for leisure (-0.08; -0.15), which means that women are more reluctant to use this travel mode. This finding is actually in contradiction with what Jie et al. [17] presented in their research, saying that women use shared mobility more, based on their time saving needs due to having more childcare responsibilities. When looking over the age groups, we see that the utility decreased with the age increase, going even to negative for the categories over 50 years old. As expected, the values of the coefficients increase with the income, having negative values only for the category between 200–400 EUR (-0.003 for e-scooter only, -0.001 for e-scooter combined with public transportation to work). Similar to what Esztergar-Kiss et al. [18] determined for German people, respondents in Iași are willing to travel more by car if their income increases, but are also more open to try an e-scooter. Owning a car decreases the utilities of all other travel modes, similar to what Liu et al. [26] found, while owning an e-scooter negatively influences the walking mode. Having a public transport pass has a small negative impact on using the car (-0.02 for both work and leisure trips), but a big positive impact on using public transportation combined with walking or with an e-scooter. We also wanted to see if the distance from home to the closest bus or tram stop influences the utilities of walking and e-scooter as an access/egress purpose. We noticed that, in case of walking+UPT to work, the coefficients decreased from 1.69 for a distance to the closest UPT stop between 200–400 meters to 0.1 for a distance more than 1000 meters, while in case of e-scooter + UPT, the coefficient values increased from 0.22 to 1.28 in the same case, meaning that the higher the distance, the higher the probability of using an e-scooter as an access or egress mode. Similarly, Reck et al. [5] showed that trip distance substantially and significantly influences mode choice. We can observe that for leisure trips, the multimodal e-scooter+UPT has lower coefficient values than the ones for work, meaning that people would not prefer this combination to go shopping or to go to the park. Instead, the e-scooter alone has higher coefficient values for leisure trips, comparable to what Jie et al. [17] concluded for shared modes. Although some people are still wary of crowding in UPT due to the recent Covid-19 pandemic and the infection risk, our study revealed a very low negative value of the crowding coefficient (-0,003), which does not have a high significance for the utility, with the results being very similar with the ones of Krauss et al. [6]. The coefficients for car mode are all quite high for all kind of trips, which means that people in Iași prefer to use the car in any situation.

Time is one of the most important attributes in a transport mode, followed by the cost of travel [29]. This study reinforces the fact that cost and travel time are the most influencing and important attributes, having the biggest negative impact on a mode's utilities (coefficient -2.23 for the cost of the e-scooter to work). Of course, the car mode has the highest score when it comes to perceived comfort. Also, a contributing factor is long distance to public transport stops. Taking into consideration the considerable fuel price rises in Romania during the year 2022, using an e-scooter in combination with the UPT starts to be a good option for many.

The fundamental problem of UPT is to find technical and socio-economic solutions for long-term sustainability and profitability. Thus, transport analysis must take into account not only the demand and supply, but also transport policies [24]. People tend to think that transport problems can always be solved with infrastructure investments, but very rarely do they consider changing people's mobility patterns [25]. In the case of Iași, although integrating e-scooters in trips by UPT reduces the need of infrastructure extending to the peripheries, the considerable cost makes this alternative often unaffordable. For this reason, some price modification hypotheses were tested, to see how the probabilities of choosing each travel mode changes. In the utility functions of travel modes, the cost for a work day was calculated taking into account the price per unit of each travel mode and the means of each range category of distance between home and work, respectively of the distance between home and the closest UPT stop. For leisure trips, random distances were used. The considered prices for the travel modes were:

- Car: 10 litres / 100 km => 0.1 litres/km => 0.156 EUR/km
- PT pass: 16 EUR/month => 0.8 EUR/day
- e-scooter: 0.4 EUR/unlock · 2 + (0.136 EUR/min · x) · 2
- e-scooter+PT pass: 0.4 EUR/unlock · 2 + (0.136 EUR/min · y) · 2 + 0.8 EUR/day

where:

x – $(60 \cdot m)/25$ (considering the average speed of an e-scooter of 25 km/h)
m – the mean of the declared range of distance between home and work (0–1 km / 1–3 km / 3–5 km / 5–7 km

/ 7–9 km / >9 km)

y – (60·n)/25 (considering the average speed of an e-scooter of 25 km/h)

n – the mean of the declared range of distance between home and the closest UPT stop (0–200 m / 200–400 m / 400–600 m / 600–800 m / 800–1000 m / >1000 m).

The utility functions and the probabilities of choosing the travel modes were recalculated, considering the following price changes (*Table 6*):

- decrease/increase of the price for e-scooters by 10% (0.122/0.15 EUR/min);
- decrease/increase of the public transport pass price by 10% (14.4/17.6 EUR/month);
- decrease/increase of fuel price by 10% (0.14/0.176 EUR/km).

Table 6 – Cost policy modification analysis

Change of cost	Walking choice probability (%)	e-Scooter choice probability (%)	Car choice probability (%)	Walking+PT choice probability (%)	e-Scooter+PT choice probability (%)
Before change of cost	13.5	2.4	38.8	40.2	5.1
Cost of e-scooter +10%	14.7	1.1	39.1	41.5	3.6
Cost of e-scooter -10%	12.6	3.9	35.8	38.3	9.4
Cost of PT +10%	15.4	2.5	43	37.1	2
Cost of PT -10%	9.7	2.1	37.2	43.5	7.5
Cost of car fuel +10%	17.2	2.7	29.3	44.4	6.4
Cost of car fuel -10%	12.7	2.2	41.9	39	4.2

We notice that initially, before the price change simulation, the highest probability of travel mode choice was for walking+UPT with 40.2%, followed closely by car with 38.8%. The probability of choosing UPT in combination with e-scooters was quite low (5.1%), and even lower considering single e-scooter mode (2.4%). An e-scooter price decrease of 10% would increase its use probability, but not by more than a few percentage points (9.4 % in combination with UPT and 3.9% for single use). An increase in car fuel price of 10% would rather maximise the probability of choosing walking+UPT. The most important observation in the table is that the highest probability of using the combination e-scooter+UPT (9.4%) is in the case of e-scooter cost decrease. The probability of using an e-scooter in Iași city, at this moment, is quite low, because of the high cost and reluctance of the population of using one. Therefore, higher price modifications should be tested as well.

We would recommend public authorities to implement different solutions that will promote the general use of UPT in combination with the e-scooter: a public-private collaboration with e-scooter providers, offering an integrated pass, discounts and different benefits for this integrated multimodal mode, as well as facilitating parking spots for e-scooters near public transport stops, creating dedicated lanes for e-scooters and/or using existing bicycle lanes.

As recommendations for future research, we suggest studying the correlation between the level of education and the willingness to use an e-scooter, combined with UPT or not, because the willingness to help reduce pollution through reduced car usage also comes from good education. Moreover, a simulation of this research should be done with the Random Regret Minimisation (RRM) technique as well.

Traditional survey-based methods with questionnaires are often limited by sample sizes and subjective responses. For future studies, a GPS-based survey is recommended, as it can provide massive location-based data. For example, real-time locations for all parked e-scooters from the Lime vendor and their daily activities can be accessed through an API.

6. CONCLUSION

The study presented a methodology for determining the travel utility of different travel modes, applied to the city of Iași, with an accent on the combined services of UPT and shared e-scooters, as an alternative to cars.

The methodology was based on a stated preference survey and a multinomial logit model, implemented in the Matlab software to extract the variable coefficients and the probabilities of choosing a mode/service.

Analysing the resulting coefficients, we have drawn some important conclusions. We noticed that cost and travel time are the most influencing and important attributes. They have the biggest negative impact on a mode's utility. As expected, higher income increases the probability of choosing an e-scooter for travel, but for categories with lower income, cost has the most decisive impact. In fact, very few of the participants with low income would take an e-scooter instead of a car. Although other studies have revealed that users aged 40 to 50 are the ones prone to choose combined classic travel mode, our research, which included the e-scooter, indicates a much younger population for the same idea, the category between 20 and 30 years. If we evaluate the chances to replace the car with the combination e-scooter and UPT services, we can say that this is more achievable among young males with medium to high income, but in strong concurrence with the car. Also, the shared e-scooter is seen at this moment more like a fun activity than a daily travel mode. As the people of Iași consider that the e-scooter price is quite high at this moment, compared to their income, we were interested to see how the probabilities of choosing each mode/service change if the cost changes. The price policies considering modifications of +/- 10% of the prices did not give significant results, but only a change of few percentage points in the probabilities.

ACKNOWLEDGEMENT

This work has been funded by the European Social Fund from the Sectoral Operational Programme Human Capital 2014–2020, through the Financial Agreement with the title "Training of PhD students and postdoctoral researchers in order to acquire applied research skills - SMART", Contract no. 13530/16.06.2022 – SMIS code: 153734.

REFERENCES

[1] Polydoropoulou A, Pagoni I, Tsirimpa A, Tsouros I. Modelling travelers' behavior in the presence of reward schemes offered for green multimodal choices. *Data Analytics: Paving the Way to Sustainable Urban Mobility*. 2019; p. 353-361. DOI: 10.1007/978-3-030-02305-8_43.

[2] Raicu Ș, Costescu D. *Mobilitate. Infrastructuri de trafic* [*Mobility. Traffic infrastructures*]. Bucharest, Romania: AGIR Publishing; 2020.

[3] Krygsman S. *Activity and travel choice(s) in multimodal public transport systems*. Ph.D. thesis. Utrecht University, Faculty of Geographical Sciences; 2004.

[4] Clifton K, Muhs C. Capturing and representing multimodal trips in travel surveys. *Transportation Research Record: Journal of the Transportation Research Board*. 2012;2285(1):74-83. DOI: 10.3141/2285-09.

[5] Reck D, Martin H, Axhausen K. Mode choice, substitution patterns and environmental impacts of shared and personal micro-mobility. *Transportation Research Part D: Transport and Environment*. 2022;102. DOI: 10.1016/j.trd.2021.103134.

[6] Krauss K, Krail M, Axhausen K. What drives the utility of shared transport services for urban travellers? A stated preference survey in German cities. *Travel Behaviour and Society*. 2022;26:206-220. DOI: 10.1016/j.tbs.2021.09.010.

[7] Crist P. The innovative mobility landscape. The case of mobility as a service. *International Transport Forum*. 2021; p. 9, 62. https://www.itf-oecd.org/sites/default/files/docs/innovative-mobility-landscape-maas.pdf [Accessed 3rd Feb. 2023].

[8] Ma Q, et al. Connecting metros with shared electric scooters: Comparisons with shared bikes and taxis. *Transportation Research Part D: Transport and Environment*. 2022;109. DOI: 10.1016/j.trd.2022.103376.

[9] Sanders R, Branion-Calles M, Nelson T. To scoot or not to scoot: Findings from a recent survey about the benefits and barriers of using e-scooters for riders and non-riders. *Transportation Research Part A*. 2020;139:217-227. DOI: 10.1016/j.tra.2020.07.009.

[10] Tuncer S, Brown B. E-scooters on the ground: lessons for redesigning urban micro-mobility. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 2020; p. 1-3. DOI: 10.1145/3313831.3376499.

[11] James O, et al. Pedestrians and e-scooters: An initial look at e-scooter parking and perceptions by riders and non-riders. *Sustainability*. 2019;11(20):1-2. DOI: 10.3390/su11205591.

[12] Mitra R, Hess P. Who are the potential users of shared e-scooters? An examination of socio-demographic, attitudinal and environmental factors. *Travel Behaviour and Society*. 2021;23:100-107. DOI: 10.1016/j.tbs.2020.12.004.

[13] Fearnley N, Berge SH, Johnsson E. *Patterns of e-scooter use in combination with public transport*, *Transport Findings*. 2020; p. 1-3. DOI: 10.32866/001c.13707.

[14] Kagerbauer M, Hilgert T, Schroeder O, Vortisch P. Household travel survey of intermodal trips – Approach, challenges and comparison. *Transportation Research Procedia*. 2015;11:330-339. DOI: 10.1016/j.trpro.2015.12.028.

[15] Bakogiannis E, Vlastos T, Athanasopoulos K, Vassi A. Exploring motivators and deterrents of cycling tourism using qualitative social research methods and participative analytical hierarchy process (AHP). *Sustainability.* 2020;12(6). DOI: 10.3390/su12062418.

[16] Hamadneh J, Jaber A. Modeling of intra-city transport choice behaviour in Budapest, Hungary. *Journal of Urban Mobility*. 2023;3. DOI: 10.1016/j.urbmob.2023.100049.

[17] Jie F, et al. Factors affecting the adoption of shared mobility systems: Evidence from Australia. *Research in Transportation Business & Management.* 2021;41. DOI: 10.1016/j.rtbm.2021.100651.

[18] Esztergar-Kiss D, Tordai D, Lopez Lizarraga J. Assessment of travel behavior related to e-scooters using a stated preference experiment. *Transportation Research Part A: Policy and Practice.* 2022;166:389-405. DOI: 10.1016/j.tra.2022.11.010.

[19] Shokouhyar S, Shokoohyar S, Sobhani A, Gorizi AJ. Shared mobility in post-COVID era: New challenges and opportunities. *Sustainable Cities and Society.* 2021;67. DOI: 10.1016/j.scs.2021.102714.

[20] Wikipedia. *Iași*. https://ro.wikipedia.org/wiki/Ia%C8%99i [Accessed 25th Feb. 2023].

[21] Romanian National Institute of Statistics. http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table [Accessed 11th Oct. 2022].

[22] Dragu V, Roman EA. Accesibility of urban public transport network component of sustainable development. *Quality Research Center*. 2011. p. 109-117. https://msdjournal.org/wp-content/uploads/vol3issue1-21.pdf [Accessed 5th Mar. 2023].

[23] Roşu L. Metode de analiză a accesibilității populației la mijloacele de transport în comun. studiu de caz: Municipiul Iaşi [Methods of analyzing the population's accessibility to public transport. Case study: Iasi Municipality]. *Geographia Napocensis.* 2013;7:1-4.

[24] Ghionea F. *Transport urban. Fenomenul* [*Urban transport. The phenomenon*]. Bucharest, Romania: MATRIX ROM print; 2005.

[25] Poli C. *Mobility and environment. Humanists versus engineers in urban policy and professional education*. London, UK: Springer Dordrecht Heidelberg London; 2011.

[26] Liu Y, Chen J, Wu W, Ye J. Typical combined travel mode choice utility model. *Sustainability*. 2019;11(2). DOI: 10.3390/su11020549.

[27] Mokhtarian P, Papon F, Goulard M, Marco D. What makes travel pleasant and/or tiring? An investigation based on the French National Travel Survey. *Transportation*. 2014;42:1103-1128. DOI: 10.1007/s11116-014-9557-y.

[28] Wang Y, Zhu X, Li L, Wu B. Integrated multimodal metropolitan transportation model. *Procedia – Social and Behavioral Sciences.* 2013;96:2138-2146. DOI: 10.1016/j.sbspro.2013.08.241.

[29] Sharma B, Hickman M, Nassir N. Park-and-ride lot choice model using random utility maximization and random regret minimization. *Transportation*. 2017;46:217-232. DOI: 10.1007/s11116-017-9804-0.

Ovidiu-Laurențiu Harpalete

Estimarea cererii de deplasare cu un model de transport multimodal incluzând trotinete electrice în Iași, România

Abstract

Orașele, chiar și cele medii și mici, au devenit copleșite de trafic și de aglomerație. Sunt necesare soluții inovatoare, iar studiile recente s-au concentrat pe abordări sustenabile. Acest studiu își propune să dezvolte un model de transport multimodal alcătuit dintr-un serviciu de transport public urban (TPU) combinat cu un serviciu de sharing al trotinetelor electrice. Scopul principal al modelului este compararea între două alternative de deplasare (mașină și TPU + trotinetă electrică), calculând nivelurile de utilitate asociate acestora. Metodologia se bazează pe un model Logit Multinomial, implementat în software-ul Matlab, folosind rezultatele unei anchete de mobilitate online (caracteristicile socio-economice ale potențialilor utilizatori de trotinete electrice). Un scop adițional este legat de evaluarea disponibilității călătorilor de a trece de la autoturism la serviciul multimodal sau la serviciul simplu de închiriere trotinete electrice. Micromodelul dezvoltat este realizat într-un oraș mediu situat în Nord-Estul României, orașul Iași. Au fost analizate mai multe politici de preț pentru a găsi influența acestora asupra comportamentului de mobilitate al utilizatorilor. S-a dovedit că prețul pentru o trotinetă electrică închiriată este prea mare în acest moment pentru a fi folosit pentru călătoriile zilnice. Fără o scădere a prețurilor și implicarea autorităților publice în facilitarea multimodalității, trotineta electrică rămâne doar o activitate de divertisment.

Cuvinte cheie
cerere de deplasare; e-scooter; transport multimodal; utilitatea deplasării; politici de transport.