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Influence of Dockless Shared E-Scooters on Urban Mobility: WTP and Modal Shift

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Abstract: Land use largely depends on the traffic policy of a city. The appearance of e-scooters can greatly affect the visual distribution of transportation, and thus the occupation of land, primarily in the central areas of cities. E-scooters as a shared micro-mobility service have become widespread worldwide since 2017. The advent of e-scooters has made changes in travel habits, especially in the central parts of big cities. However, many issues are focused on e-scooter shared mobility management policies. One of the important issues is the price of renting an e-scooter, on which the percentage of users who use e-scooters largely depend. In order to determine willingness to pay for e-scooter dockless shared mobility, a survey was conducted in the city of Belgrade (Serbia, Europe) on the willingness of participants to use this mode of transport for commuting and other travel purposes depending on the price of renting an e-scooter. The results showed that price plays an important role in the willingness of participants to use an e-scooter. The paper presents mathematical models, which include the cost of renting an e-scooter and the percentage of participants who would accept this type of transport. These mathematical models can help a decision maker to determine the pricing policy in order to maximize the profit from renting an e-scooter, as well as to influence modal shift in order to reduce car-dependent trips.

Keywords: e-scooter sharing; micro-mobility; willingness to use; mathematical model; rental price

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1. Introduction

E-scooters are most often used for shorter trips in central city areas [1,2]. Unlike passenger cars, where large amounts of capital investment are needed, rental prices are high, payment is required for parking, etc., shared e-scooters can cost as little as 2 £/2 € for a trip of a few kilometers. Dockless ride sharing allows the scooters to be left at a final destination of the user, ultimately to be retrieved by the next user or picked up for charging. Dockless shared e-scooters are touted as a solution to the last-mile problem, a means to reduce traffic congestion, and an environmentally preferable mode of transportation [3,4]. Compared to other vehicles, e-scooters require very little space for storage and parking, which allows them to function as an efficient public right-of-way transportation service. Similar to other micro-mobility services, riding a scooter increases users' physical activities and brings health benefits [5]. The way in which they are used, as well as the strategies and policies of cities for promoting e-scooters, differ between countries, and even between cities. Personal and rented e-scooters are most often used. The COVID-19 pandemic has led to an increase in the use of e-scooters [6–8]. On the other hand, in many studies, the safety of e-scooters, infrastructures, as well as the cost (of renting) are the three most common reasons for not using this type of transportation [2]. A number of countries, such as Germany, France, Singapore, New Zealand, Australia, and California, have fully regulated the use of e-scooters, while most countries are in the transition phase (such as the United Kingdom) or are still without any measures being taken [9]. Just as the law differs, so do the price and policy of renting an e-scooter from country to country.

Belgrade, the capital of Serbia (Europe), faces daily traffic jams due to the increased degree of motorization. One of the possible solutions for reducing traffic congestion is the use of micro-mobile vehicles. The advent of e-scooters has caught many European legislators off guard, with no regulations regarding use, driving, speed, or necessary measures related to the safety of both e-scooter users and other road users. This is also the case in Serbia, which has not regulated the e-scooter legal status yet [10]. As the use of these vehicles is becoming more common, future changes to the law that would regulate this category of vehicles are planned. The main goal of this paper is to determine, with the application of mathematical models, the willingness of users to pay for a shared mobility dockless e-scooter. The secondary goal is to determine influencing factors on the willingness to pay.

1.1. What Impact do E-Scooters Have and on Who?

E-scooter sharing services (Figure 1) were first introduced in Santa Monica, California in September 2017 [11], and since then the e-scooter sharing service has become a competitor to the use of e-bike sharing services. With this in mind, some studies have looked at the comparative analysis of the common usage patterns of e-bikes and e-scooters. For example, the results of a study conducted in the city of Austin, Texas showed that the average travel speed for e-bikes is higher than that for e-scooters and that users tend to ride e-bikes and e-scooters at a slower average speed for recreational purposes compared to commuting [12]. In addition, Bieliński & Ważna [13] conducted research regarding the characteristics and behavior of electric scooter and bike sharing users in northern Poland and came to the conclusion that e-bikes are mainly used as first and last kilometer transportation and for direct travel to various interesting places, while e-scooters are more often used for free rides. However, with the development of the dockless shared e-scooter service, there is an increasing amount of literature that investigates the impact of using a shared dockless e-scooter on various factors such as travel behavior [14–16], environment impact [3,17], and safety impact [18–20].

Figure 1. Electric scooter sharing (source: https://la.curbed.com/2018/6/7/17438168/ (accessed on 22 April 2023).

Travel behavioral studies show that shared e-scooters can meet the needs of short trips to a central city (for example, Louisville, Kentucky) [21] and short errands in places such as Indianapolis, Indiana [22]. On the other hand, although the use of a system of shared e-scooters can represent an adequate solution to reduce the movement of passenger cars, it does not necessarily represent an environmentally friendly solution. Namely, Hollingsworth et al. [3], based on the conducted research, came to the conclusion that the use of shared e-scooter systems has a negative impact on the environment. The reason for that is materials, manufacturing, and automotive use for e-scooter collection for charging. Severengiz et al. [23] conducted a life cycle assessment study using Berlin as an example for shared e-scooters. They concluded how product lifetimes, replaceable batteries, alternative collection logistics, and charging concepts affect the greenhouse balance compared to alternative means of transport.

In addition to the above, there are more and more studies dealing with the influence of certain factors on the use of shared dockless e-scooters. Younes et al. [24] and Mehzabin Tuli et al. [25] concluded that warmer temperatures and better visibility were associated with higher instances of travel per hour. Likewise, the effect of time of day is only positive on the use of shared dockless e-scooters from 12:00 to 3:00, but it has a negative effect in other time periods. The research results also show that user activity is highest on Saturdays compared to other days of the week; as well, holidays and local festivals have a positive effect on the use of e-scooters [24]. Mitra & Hess [26] investigated the socio-demographic, attitudinal, and built environment characteristics of potential users of shared e-scooters in Toronto and selected neighborhoods in Canada. The results showed that 21% of respondents were willing to consider e-scooters for some of their current trips, and the majority would replace their existing walking (60%) and transit (55%) trips with shared e-scooters. Moreover, there was no difference in e-scooter preferences between urban and suburban areas. In the research conducted by Mehzabin Tuli et al. [25], results indicate that densely populated areas with higher median income, mixed land use, more parks and open spaces, public bike sharing stations, higher parking rates, and lower crime rates generate more e-scooter trips. On the other hand, the results of the model estimation suggest that the purpose of travel, the type of travel and the time of travel influence the intention to use the shared dockless e-scooters service and that their effects vary depending on socio-demographic characteristics (e.g., years of ad revenue) and satisfaction with the existing mode of public transport [27].

Taking into account different sociodemographic characteristics, many studies have dealt with the influence of gender and age of respondents on the acceptability of e-scooter use. In their research, data from Denver and Portland indicate approximate gender splits of 70/30 and 64/34, respectively, between males and females [28,29]. Similarly to that, in Vienna, 75% of shared e-scooter users are men and only 25% are women [30], while in the city of Tricity in northern Poland, about 62% of e-scooter riders are men and 37% are women [31]. What may be the reason for the lower use of e-scooters by women is the difficulty of carrying shopping bags, as well as the feeling of safety [32].

Bearing in mind that the use of shared dockless e-scooters requires a certain fee, the question arises, what is the impact of an individual's income on the use of e-scooters? Some authors, using a simple statistical analysis or survey, have come to different conclusions about the relationship between income and e-scooter use. Namely, Mckenzie [33], in his research, came to the conclusion that in Washington, in areas where users have the lowest incomes, the least number of trips are made by e-scooter. Similarly, the authors of [34] found in their research that in addition to low income being one of the causes of the difference in e-scooter use, where low-income residents are associated with fewer e-scooter trips, it can also affect trip duration. In LA and New York, low income was identified as one cause of shorter e-scooter trip duration, while for DC and Chicago, low income was causally associated with longer trip duration. However, some research shows that e-scooter mobility can be a preferred mode of transportation for low-income individuals, such as in Austin, Texas ([14,35]).

In addition to the above, it is important to point out how the use of shared vehicles in general can affect overall utility mobility from an economic perspective. Although most of the previous works are based on the national or regional urban context, it is necessary to look at the same at the international level. Namely, Giglio et al. (2021) [36] examined in their work whether the characteristics of European cycles of logistics projects and corresponding accompanying policies affect their profit and profitability from the aspect of cycling. The results indicated that profit and profitability can vary significantly depending on the main type of bicycle used in European projects. In particular, profit is strongly positively affected by the adoption of cargo bikes or tricycles taken separately, and even more so by their combined use. On the other hand, profitability is most affected by the combination of cargo bikes and tricycles and traditional bikes. Low costs and short delivery times for such bike models are cited as the reason for this. This indicates the importance of using a certain type of vehicle, which can, in various combinations with other types, contribute to advantages during movement, as well as social and economic ones.

In order to achieve both social and economic profit, it is necessary to properly create a service functioning system, i.e., vehicle sharing. In this sense, Giglio & Palmieri (2016) [37] created a new platform architecture for vehicle pooling in southern Italy. It consisted of a Logistics Optimization (LOE) module integrated with a Social Networking (SE) module. The emphasis was on the greatest possible user satisfaction, so the subsystem of social networks suggests the most adequate companions in the passenger car depending on the user's preferences stored in the platform's database. On the other hand, the logistics optimization module is in charge of improving the user experience thanks to algorithmic procedures aimed at reducing the total travel time and/or costs. This would significantly affect the achievement of social innovations and favorable movement characteristics. The aforementioned studies would greatly contribute to the very concept of creating a transport policy for dockless shared e-scooters.

1.2. How Does the E-Scooter Influence the Change in the Modal Shift?

The impacts of shared e-scooters on modal shifts have received increased attention in recent years. The empirical data reveal that people use shared e-scooters in place of cars at substantial rates, which suggests that in many locations, shared e-scooters may be a good strategy for reducing car dependence [38]. Existing studies dealing with the impact of e-scooters on modal shift are mostly based on survey research.

For example, in Paris (France), the results obtained from two surveys indicate that for their last trip riding a shared e-scooter, for most users who would have walked or used public transportation, e-scooters had not been an option: 44.4% for walking and 31.4% for public transportation in the first survey and 37.2% for walking and 35.9% for public transportation in the second survey [39]. In another study, also conducted in Paris, Christoforou et al. found that 72% of users' movements by walking and public transport were replaced by a shared e-scooter, then 16% of those who used a motorized mode (private car, taxi, motorcycle) replaced the e-scooter, while very few would increase their mobility with new trips (6%) [40]. In addition, James et al. [41] conducted a survey where it was found that e-scooter trips in Rosslyn replaced trips by Uber, Lyft, or taxi (39%), walking (33%), cycling (12%), bus (7%), or car (7%). Fearnley et al. conducted a study in Oslo, finding that shared e-scooters mainly replaced walking (60%), public transport (23%), and motorized modes (taxi, private car) (8%) [42]. Results of the study conducted by Reck et al. indicate that, per kilometer, users in Zurich would replace public transport (38%), walking (25%), then passenger car (15%), and cycling (13%) for a shared e-scooter [43]. That e-scooters influenced changes in the way of movement is also indicated by the results of the study conducted by Fitt & Curl [44], where 58% of respondents replaced trips that would otherwise have been on foot, by bicycle, or by skateboard, while 11% would not have traveled at all. Similarly, Weschke et al. [45] found that in Germany, walking and public transport trips are replaced by e-scooters in more than 60% of trips, while private bicycles and private cars were replaced in about 11.5% of trips each.

Based on the presented studies' results, it can be concluded that moving by shared e-scooter most often replaces walking and public transport. The replacement of travel by passenger car ranges from 7% to 15% depending on the research region. From these results, it can be concluded that the use of shared e-scooters can significantly influence the promotion of sustainable forms of movement, as well as the reduction of motorized ones.

1.3. How Does an E-Scooter Influence Land Use?

Better street connectivity and more compact land use are associated with greater e-scooter use, confirmed by research by Jiao and Bai in Austin, Texas and by Sorkou et al. in Athens, Greece [14,46]. The increasing popularity and use of shared dockless e-scooters can have numerous effects on society and the environment, both positive (e.g., reduced motorized travel) and negative (e.g., speeding on pavements, inadequate parking, etc.). Having that in mind, one of the main motives for using shared e-scooters by car users is to avoid crowds and the need to search for parking, while public transport users especially appreciate better cleanliness and greater accessibility.

Weschke et al. [45] discovered in their research that the most important reason for users to take an e-scooter instead of a car is to avoid searching for parking (42%), followed by entertainment (37%), and shorter travel time (30%). Bearing in mind the above, it can be concluded that the increasing transition of users from motorized modes of movement to shared dockless e-scooters would affect the reduction of traffic jams and at the same time relieve traffic infrastructure. In addition, the need to park passenger cars would be reduced, and the use of sustainable and more environmentally friendly modes of transportation would be increased.

On the other hand, unprepared urban infrastructure, combined with unsafe operational policies and poor enforcement of regulations, has resulted in e-scooter riders using public pedestrian spaces for both movement and parking [47]. James et al. [41] analyzed land occupation resulting from illegal parking of shared e-scooters. They found that illegal parking includes obstructing access to street furniture (11%), obstructing access to a bus stop (3%), blocking amenities for vehicles (1%), blocking access to bike sharing stations (1%), and blocking pedestrian crossings (6%). Moreover, they believe that for land use, e-scooters were most often illegally parked near offices (25%) because they were parked on private property. Having that in mind, one of the possible consequences of the occupation of land by shared e-scooters, which is intended for other users, is reduced safety for both. Namely, in the event that a bicycle lane is not present, scooter drivers may feel forced to use the sidewalks intended for pedestrians. On the other hand, if a parked e-scooter blocks the sidewalk, pedestrians may be forced to walk on the main road, which reduces their safety and increases the risk of contact with a car [47]. From the above, it can be concluded that policy makers should take care of planning adequate infrastructure and legislation for movement and parking so that shared dockless e-scooter users do not come into conflict with other road users.

1.4. How E-Scooter Rental Works?

The functioning of e-scooter rental is similar among providers almost everywhere in the world. The key differences are in the technical and operational characteristics of the e-scooter (dimension, power, battery capacity, etc.). When a new provider appears on the ground, it starts by deploying its fleet at some strategic location in the street and releases a mobile phone app that the users must download. Then, the map in the app shows all nearby e-scooters, as well as data related to the battery charge of each e-scooter. Users can then add their payment information on the app and unlock the e-scooter with the help of a QR code. Users can drive the e-scooter within a perimeter defined by the provider and finally park the e-scooter wherever it is authorized [4]. After finishing the ride, the user has to open the app again and tap the button to lock the scooter. After that, the app shows the cost of driving time. However, once the battery is low or when maintenance is needed, an independent worker, a charging supplier, or one of the provider's employees will collect the e-scooter and either bring it to a charging place or to the provider's warehouse. Once the battery is fully charged, the e-scooter is then redeployed to strategic locations and users can use it again [4]. The most important thing for a certain provider is earnings. On the other hand, for (potential) users of rented e-scooters, the most important item is the rental price. This paper will try to provide answers for the management of the price of renting an e-scooter based on empirical data collected by the survey.

1.5. How Much Does it Cost to Rent an E-Scooter?

E-scooter rental prices vary depending on the operator, part of the city, country, season, etc. There are also different ways to pay for e-scooter rental, such as payment via mobile application, card, cash, etc. On the other hand, the e-scooter rental policy is implemented per minute or for a longer period of time (day, week, month, etc.). For example, one of the companies renting e-scooters in Rome (Italy) offers users a weekly ticket to unlock a scooter in the amount of 2.99 €. In the same city, there is also a rental of scooters on a monthly basis, with a limit of 30 min per day, at prices of 19.99 €—8 times a month, 44.99 €—25 times a month, 79.99 €—50 times a month, and a 3-month pass for 100 rides (149.99 €) [48].

When it comes to the price per minute of renting an e-scooter, in Italy and Spain, the price ranges from 0.15 to 0.25 €/min (with an unlocking price of 1), in Estonia, the price is about 0.5 €/min (with an unlocking price of 1), in Australia, around 0.30 €/min (with an unlocking price of 1), while in America, the stated price ranges between 0.15 and even up to 1 €/min [48]. Only the above examples of different prices show the complexity of this problem, which can have a great impact on the development of tourism, the functioning of traffic load in central urban areas, as well as on the distribution of traffic by type.

Many studies deal with current issues related to e-scooters in the form of e-scooter management policy [2,49–55], technical and operational characteristics [56,57], as well as willingness to use this type of transport [40,58–60]. However, although most of these studies analyze the costs of e-scooter exploitation [61], there is a scarce number of studies that have explicitly devoted themselves to examining the willingness of users to pay for e-scooter rental. For these reasons, the paper presents mathematical models, based on empirical data, which would help define the pricing policy of e-scooter rental.

The paper consists of five chapters. The introduction chapter presents the idea and goal of this paper. The methodology chapter describes the used method of analysis. The review of the analyzed results, a discussion of the obtained results, and the conclusion are the last three chapters. Figure 2 shows the paper structure.

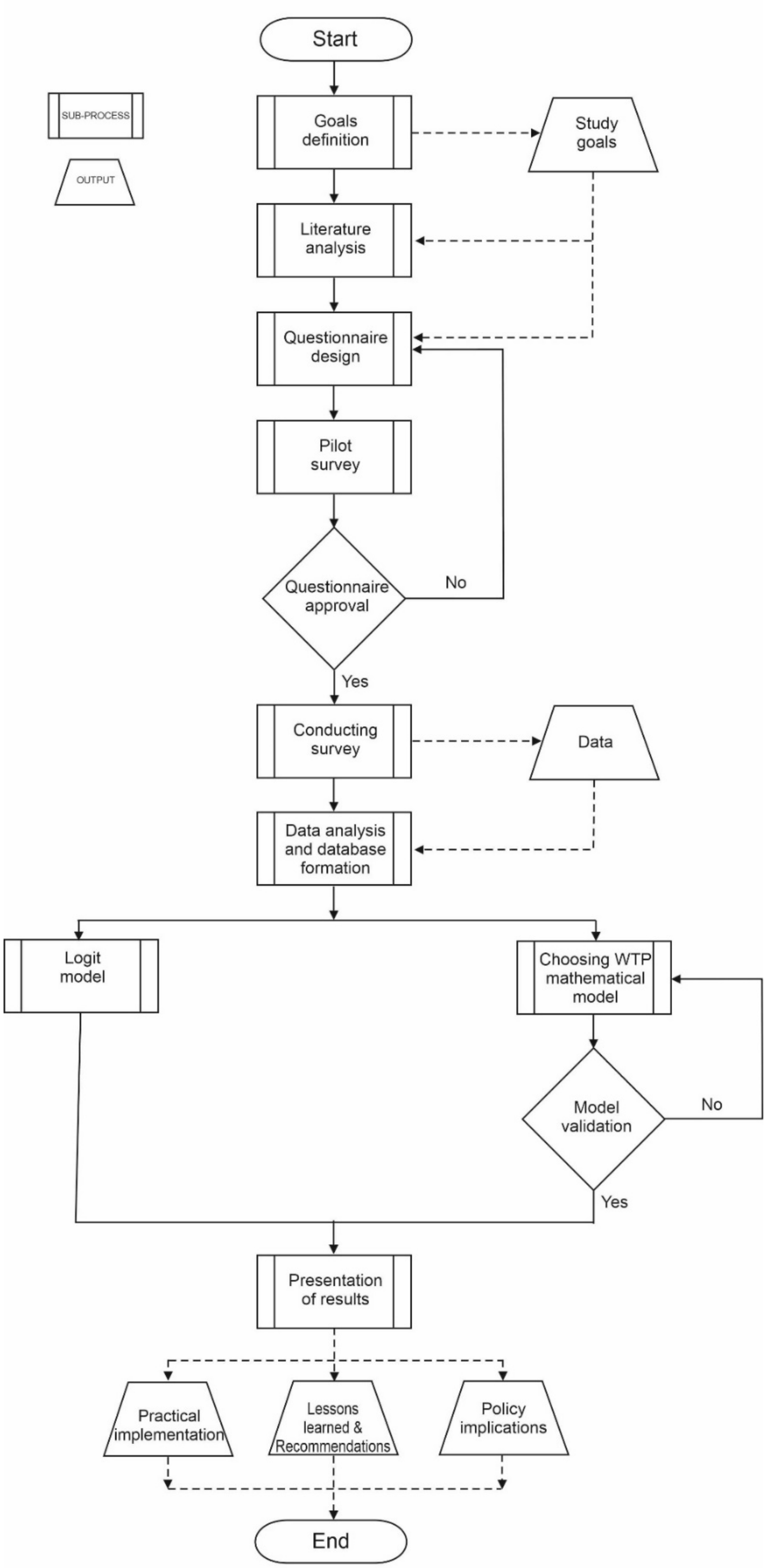

Figure 2. Flowchart research method diagram.

2. Methods

Research of users' attitudes about the use of e-scooters in current conditions was conducted online. The Internet survey was distributed as a link via email in the territory of the city of Belgrade. After incomplete questionnaires with inconsistent answers were removed from the sample, the valid sample used in further analysis consisted of 508 respondents. Respondents were not compensated for participating in the experiment, and the data were anonymous and used exclusively for the purpose of scientific research. During the survey, all ethical norms were respected.

The first part of the questionnaire contained general questions about the demographic and socio-economic characteristics of the respondents. The second part covered the attitudes and behavior patterns of the users, examined through the average distance traveled and the frequency of using a certain mode of transport and the combination of movement by e-scooters and public transport for certain travel purposes. In this work, the purposes chosen were going to work/school, as well as visiting, shopping, and recreation and leisure, while the chosen modes of transport were private vehicle, motorcycle/moped, public transport, walking, bicycle, e-bike, e-scooter, and others. The second part of the survey had the following questions to cover the most common purposes of travel, as well as the most common modes of transportation. The third part of the questionnaire consisted of four questions, in which the goal was to determine at what price the respondents would switch to using e-scooters. First of all, respondents were asked to answer the question whether they would use an e-scooter (personal or shared) for different travel purposes (commuting and other purposes) if they had a suitable cycling infrastructure and the option to use a dockless shared e-scooter at different charges. After that, respondents were asked to answer the maximum price they would pay to rent an e-scooter and at what price they would switch to using an e-scooter (four prices were offered: €0.05/min, €0.1/min, 0.2 €/min, and 0.3 €/min). All four price scenarios include a fee of €1 for unlocking the scooter. Price limits are taken over by companies that rent e-scooters in Belgrade. The stated prices are defined according to the tariff of the price of the public transport ticket (0.7 euros/90 min—within 90 min, the vehicle can be changed—tram, trolleybus, bus).

The defined scenarios, with different prices, represent hypothetical cases aimed at determining the attitudes and preferences of users on the acceptance of e-scooters. All four scenarios include the creation of a bicycle infrastructure, as well as the availability of a dockless shared e-scooter service at different charges. For this reason, the authors believe that the answers to these questionnaires can provide useful knowledge and lay the foundation for the formation of an adequate dockless shared e-scooter system in the territory of Belgrade.

All questions in the survey were closed-ended, while the third part used an open-ended question related to defining the maximum price that respondents would pay for the use of e-scooters. In order to obtain the best possible results, the respondents were offered through closed questions to choose, based on the offered answers, patterns of behavior during movement as well as hypothetical scenarios.

In this work, two approaches are combined, the method of revealed preference and the method of stated preference. The revealed preference method was used to analyze the respondents' existing habits regarding the use of a certain mode of transportation for different purposes, while the expressed preference method was used to analyze user preferences regarding the use of e-scooters at different prices (scenarios mentioned in the paper).

Collecting and Processing Data

Statistical analysis was carried out in the statistical software package IBM SPSS Statistics v. 28. Normality of distribution was tested by inspection of histograms and the Kolmogorov–Smirnov test. Since the data for all measured variables distribution were normally distributed, we used parametric methods. To assess the significance of differences, the Independent-Samples T-Test, and one one-way ANOVA were used. The null hypothesis (H_0) was that there is no statistically significant difference between variables, with the alternative hypothesis (H_a) being that there is a significant statistical difference between variables. The threshold for statistical significance (a) was set to 5%. Consequently, if probability (p) is smaller or equal to 0.05, H_0 is rejected and H_a is accepted. On the contrary, if $p > 0.05$, H_0 is not rejected. In addition, regression analysis was used to describe the impact of the level of respondents' incomes on the acceptable price of renting an e-scooter. Finally, logistic regression was used for predicting examinations of changes in the type of transport for the purpose of commuter and for other purposes of travel.

3. Results

The following chapter presents demographic data on respondents and the behavior of respondents who already use an e-scooter. Meanwhile, the second part of the chapter presents the results on the willingness of respondents to pay a certain price for renting an e-scooter for different travel purposes.

3.1. Descriptive Statistics

Out of the total number of the participants, 51.4% were female, while 48.6% were male. According to the respondents' age, 9.8% of the participants were under 18, 45.9% were between 19 and 25, 20.1% were between 26 and 35, 13.2% were between 36 and 45, while 11.1% of the respondents belonged to the age group between 46 and 55 (Table 1).

Table 1. Descriptive statistics of respondents.

	Gender		Age				
	Male	*Female*	*<18*	*19–25*	*26–35*	*36–45*	*46–55*
n	247	261	50	233	102	67	56
%	48.6%	51.4%	9.8%	45.9%	20.1%	13.2%	11%

Out of the total number of the respondents, 3.4% have a personal e-scooter. For commuter trips (work/school, etc.), 1.2% of the respondents use an e-scooter most frequently, while 0.3% of the respondents use an e-scooter and public transport most frequently. For trips with other purposes, 2.4% of the respondents use an e-scooter most frequently, while 0.4% of the respondents combine an e-scooter and public transport most frequently. The average distance covered by e-scooter is 2.4 km for commuter trips and 3.5 km for trips with other purposes.

3.2. Statistical Analysis of Demographic Data and E-Scooter Rental Prices

Respondents would set aside an average of 0.29 €/min for the commuter trip for renting a e-scooter, while for other purposes they would set aside an average of 0.38 €/min. Users who would pay more for e-scooters when traveling for other purposes are users who would not use them daily, on the contrary, very rarely. In this sense, they are less price sensitive than those who would use an e-scooter for daily commuting.

Male respondents are willing to spend more on renting scooters for commuter trips (male 0.41 €/min, female 0.3 €/min), which is confirmed by the results of the Independent-Samples T-Test ($t = 3.627$, $p < 0.001$). The results are similar for other travel purposes, and male respondents would also spend more money on renting an e-scooter (male 0.66 €/min, female 0.51 €/min) ($t = 6.416$, $p < 0.001$) (Table 2).

The results of the one-way analysis of variance (ANOVA) show that there are no statistically significant differences in the price that respondents would pay for renting an e-scooter according to the age of the respondents, neither for commuter trip ($F = 1.583$, $p = 0.209$), nor for other purposes ($F = 1.238$, $p = 0.167$).

Table 2. Gender differences—the Independent-Samples T-Test.

	Commuter Trip		Other Travel Purposes	
	Male	*Female*	*Male*	*Female*
mean	0.41	0.3	0.66	0.51
t	3.627		6.416	
p	<0.001		<0.001	

3.3. Factors Influencing the Use of E-Scooters

Table 3 below shows odds ratios from the logistic regression for switching to the use of e-scooters, for the purpose of "commuter trips" and "other purposes", with confidence intervals of 98%. Gender, age, areas, purpose of travel, distance, and price are predicting variables.

Table 3. Logistic regression odds ratios for commuter and other purposes.

	Commuter Trips	Other Purposes
Gender	1.498 (1.245–1.751)	1.485 (1.147–1.824)
Age	1.053 (0.992–1.114)	1.150 (1.024–1.277)
Areas	1.032 (1.023–1.041)	/
Distance	/	1.114 (1.084–1.145)
Price	1.832 (1.687–1.976)	1.867 (1.745–1.989)

The final model for "commuter trips" has the following parameters: χ^2 = 1023.24, df = 4, $p < 0.001$, pseudo RN^2 = 0.114, and correct classification in 79.6% of cases. To predict the willingness of respondents to use the e-scooter for communal travel purposes, the following variables are highlighted (Table 3):

- age: younger respondents would prefer to use an e-scooter;
- gender: male respondents are more likely to use an e-scooter than female respondents;
- areas: urban respondents are more willing to use the e-scooter than rural respondents;
- price: if the price of renting an e-scooter is lower, the respondents are more likely to use this type of transport.

The final model for "other purposes" has the following parameters: χ^2 = 864.47, df = 4, $p < 0.001$, pseudo RN^2 = 0.196, and correct classification in 74.7% of cases. The prediction of the respondents' willingness to use e-scooters, for other travel purposes, is influenced by the following variables (Table 3):

- age: younger respondents are more likely to switch to e-scooter use;
- gender: male respondents are more likely to use an e-scooter;
- distance: for longer trips (up to 4 km), respondents are more likely to use an e-scooter;
- price: if the price of renting an e-scooter is lower, the respondents are more likely to use this type of transportation for travel.

In both models, the least important factors are age, areas, and distance. On the other hand, the factors with the highest predictor values are price and gender for both models.

3.4. Mathematic Modeling of Willingness to Pay for the Use of E-Scooters

In order to determine at what maximum price the respondents would switch to the use of public e-scooters, the question was asked, "at what maximum price per minute would you agree to use an e-scooter (commuter trips and other purposes trips)?". The results of this question were crossed with the data on the monthly income of the respondents.

Figure 3 shows the relationship between monthly income and willingness to pay for the use of e-scooters for other travel purposes. It can be concluded that with the increase of the monthly income of the respondents, the price that the respondent is willing to pay for renting an e-scooter for other travel purposes also increases. In order for these results to be practical, a variable was created, which uses the respondent's monthly income as an independent variable "x" [€], while the dependent variable is the price that the respondent would accept to pay for renting an e-scooter "y" [€/min]. This variable is typically specified in a form as follows:

$$y^{-1} = a + b\ln x/x^2 \quad (1)$$

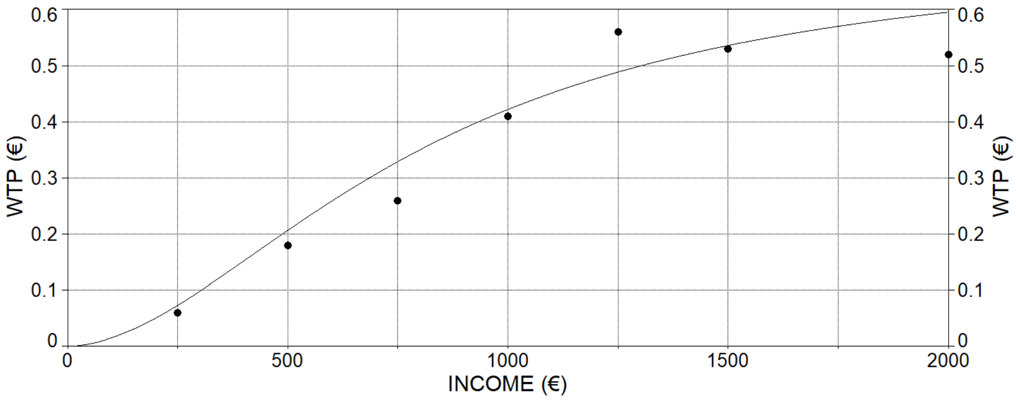

Figure 3. Relationship between the level of monthly income of respondents and the willingness to pay for the use of e-scooters—other travel purposes.

Based on the empirical results collected in this research, the final equation was obtained, based on which the willingness of users to pay the fee for renting an e-scooter [€/min], for other travel purposes, can be estimated depending on the monthly income:

$$y^{-1} = 1.41 + 137946,16\ln x/x^2 \quad (2)$$

For this model, the coefficient of determination is $R^2 = 0.9089$.

Figure 4 shows the relationship between the level of monthly income of respondents and the willingness to pay for the use of e-scooters for commuter trips. When it comes to commuter trips, the willingness to pay of respondents for renting an e-scooter increases to an income of 1250 euros/month, after which the price that respondents are willing to pay for renting an e-scooter stagnates (or even slightly decreases). In order to mathematically describe the relationship between the respondents' monthly incomes and their willingness to pay for e-scooter rental for commuter trips, a logarithmic function was used, the general form of which is shown in the following equation:

$$y^{-1} = a + b\ln x/x^2 \quad (3)$$

As in the previous equation, the independent variable "x" represents the monthly income of the respondents [€], while the dependent variable "y" is the willingness of the respondents to pay for renting an e-scooter [€/min]. The final form of the equation is shown as follows:

$$y = 1.82 + 228671.05\ln x/x^2 \quad (4)$$

The coefficient of determination for the presented model looks as follows:

$$R^2 = 0.9181.$$

3.5. Willingness of Respondents to Use an E-Scooter Depending on the Price

Although the use of e-scooters is becoming more and more popular in the world, the percentage of use depends on many factors, such as weather conditions, terrain topography, legal framework, infrastructure, scooter availability, e-scooter rental company policy, etc. In addition to the above factors, perhaps the most important factor is the rental price and the purpose of the trip. Figure 5 shows the percentage of e-scooter use depending on the rental price [€/min]. Respondents are more willing to set aside more money to rent an e-scooter for other purposes, as opposed to a commuter trip. What both types of travel have in common is that with the reduction of the price of renting an e-scooter, the percentage of using the e-scooter would increase, up to a level of 0.1 [€/min]. With a further decrease of price, the percentage of users of the e-scooter would remain the same. This is due to the fact that e-scooters have a maximum of up to 6% share in modal split in Serbian conditions.

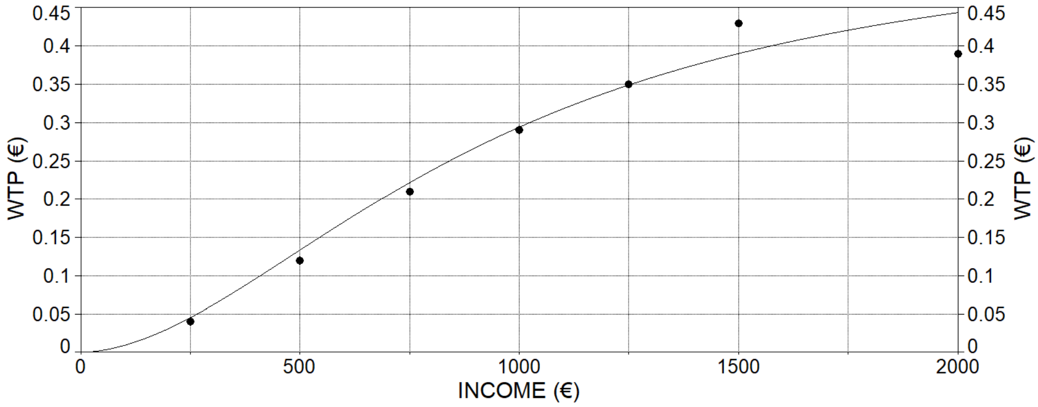

Figure 4. Relationship between the level of monthly income of respondents and the willingness to pay for the use of e-scooters—commuter trips.

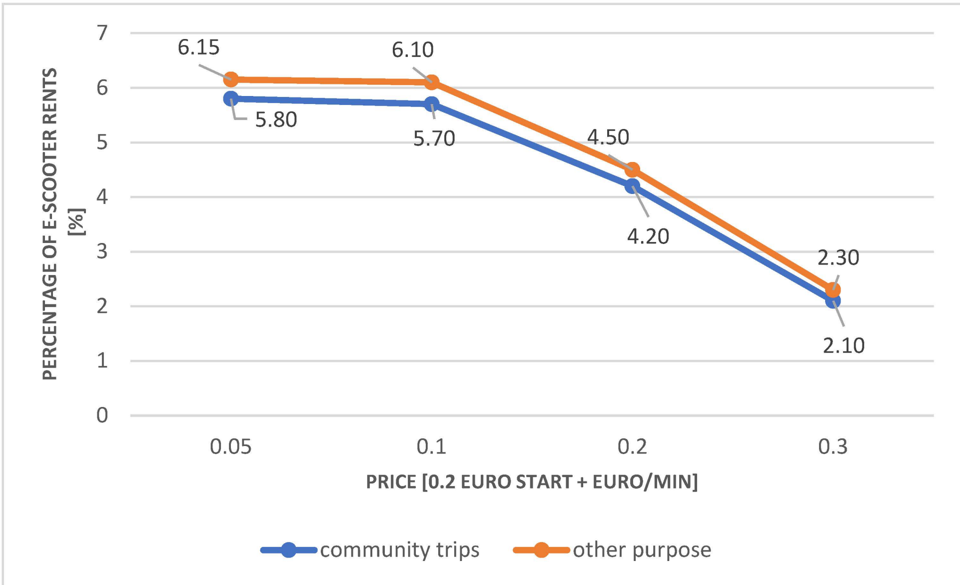

Figure 5. Willingness of respondents to use an e-scooter depending on the price for commuter and other purpose trips.

3.6. Modal Shift Scenarios

The presence of shared e-scooters affects the distribution of transport. If some users of passenger vehicles switch to using e-scooters, the benefits for the city can be multiple. E-scooters reduce the need for clearing land for parking lots. For every 1 vehicle parking space, 10–20 e-scooters can fit easily. The removal of trees and complementary vegetation for parking spaces eliminates vital air cleaners that help reduce the quantity of carbon dioxide in the air. Paved surfaces increase the “heat island effect”—meaning built areas are several degrees hotter than surrounding rural areas, which translates to increased energy demand (especially in warm months) and greater energy-related greenhouse gas emissions. Because e-scooter parking requires little space, e-scooters help minimize the heat island effect and also preserve habitats. However, another aspect of the e-scooter’s energy efficiency is reflected in its use and idle state. Namely, if there is a low rate of use of the e-scooter, it can significantly affect the battery consumption in the idle state. Having that in mind, e-scooters become an inefficient way of moving from an energy point of view, which is their disadvantage. In this sense, it is often proposed to combine modes of transportation, such as e-scooters and electric buses, as a possible solution for reducing energy consumption [62]. On the other hand, a thinner asphalt layer is used for the construction of e-scooter lanes, while they also occupy smaller areas of land.

For the above reason, the modal shift is important, that is, what percentage of users of other categories of vehicles (primarily passenger vehicles) would switch to using a shared e-scooter. From Table 4, it can be concluded that depending on the scenario, the percentage of users of different modes of transportation would change. If the sharing of e-scooters was to be introduced (with appropriate tariff policy, infrastructure, and legal framework), a certain percentage of users of passenger vehicles and public transport would switch to using, above all, shared e-scooters, but also (e-)bikes. On the other hand, some pedestrians would switch to using e-scooters and (e-)bicycles. In addition, due to their small dimensions and weight, e-scooters are very suitable for multimodal movements. For this reason, respondents often decide to combine an e-scooter with another mode of transportation, in this case, public transport. However, in order for this way of movement to be as widely accepted as possible, the quality of the public transport service, the destination, and the time are of great importance [63]. In Belgrade, the services of the public transport system are not yet sufficiently developed, in terms of frequency, comfort and timetable, which leads to low acceptability.

Table 4. The percentages of users' different modes of transportation depending on the type of scenario and purpose of travel.

	Starting Scenario		**Shared E-Scooters Scenario**	
	Commuter Trips	**Other Purpose**	**Commuter Trips**	**Other Purpose**
By foot	15.90%	18.50%	14.90%	17.50%
Passenger vehicles	43.20%	36.10%	37.50%	31.20%
Electric bicycle	1.10%	0.70%	1.70%	1.40%
Bike	4.60%	6.00%	7.40%	8.10%
Public transport	33.80%	37.30%	31.40%	34.85%
Rented electric scooter and public transport	0.60%	0.80%	5.80%	6.15%
Your (personal) electric scooter	0.80%	0.60%	1.30%	0.80%

4. Discussion and Conclusions

The use of e-scooters in the city of Belgrade is very low. Only 1.4% of respondents use an e-scooter for commuter trips, while 2.8% of respondents use an e-scooter for other travel purposes. The current percentage of e-scooter use in Belgrade is significantly below the limit of other countries, where e-scooters are used much more often [40,50–52,60]. Some studies conducted in the United States show that almost 30% of respondents use an e-scooter a couple of times a week [28,64,65]. Some authors justify the high percentage of e-scooter use by the fact that a large percentage of tourists use e-scooters [40]. One of the reasons for this low use of e-scooters (in Belgrade, the city in which the research was conducted) is the tariff policy of the city and companies that rent e-scooters. If the price of renting an e-scooter was reduced, from the current about 0.30 €/min to 0.10 €/min, about 6.15% of respondents would use e-scooters for other travel purposes, while about 5.80% of respondents would use e-scooters for commuter trips.

The results of the presented study confirm the fact that pricing policies are not managed on the territory of the city of Belgrade, while the distribution of traffic by types of transport is neglected. According to the results of the presented study, the young population is interested in transportation by e-scooter. The average trip by e-scooter is about 3 km. In order for the change in tariff policy to contribute to a percentage increase in e-scooter use, it is necessary to act permanently. Some studies state that revenues will multiply by 2024 [50,66,67], confirming the need to change the tariff policy for the use of e-scooters, both in Belgrade and in other cities across Europe.

For commuter trips, as for all other trips, male respondents are more willing to spend more money on e-scooter rental according to the results shown in the paper. The results of a study conducted in Puerto Rico show that men are more willing to use an e-scooter [2], while some studies show the results that female respondents emphasize traffic safety more as a reason for not using e-scooters [40,52–54].

In many cities around the world, e-scooters have emerged as a new sustainable mode of transport. In addition to owning their personal scooter, users in many cities can rent an e-scooter within the shared e-scooter system. The shared use of e-scooters, as an innovative transportation strategy, mainly includes the possibility to pick up and return an e-scooter at any location within a certain zone. In order to use this mode of transport, users have to pay a certain charge, which usually includes a fixed part for unlocking the scooter and a part that depends on ride duration.

The aim of this paper is to determine, with the application of mathematical models, the willingness of users to pay for a shared mobility dockless e-scooter depending on the price. Therefore, this research includes empirical data on the behavior of respondents, as well as user preferences regarding the use of transportation modes in hypothetical situations that include appropriate bicycle infrastructure, defined legislation, and the possibility of using a shared dockless e-scooter at different fees (€0.05/min, €0.1/min, 0.2 €/min, and 0.3 €/min).

Based on the data analyzed, the conclusions of this research are as follows:

- for commuter trips, 1.4% of the respondents use an e-scooter (scooter only or combination with public transport), while for trips with other purposes, 2.8% of the respondents use an e-scooter;
- male respondents are willing to set aside more money to rent an e-scooter than female respondents for commuter trips and other purposes;
- there are no significant statistical differences for the willingness of respondents to pay for renting an e-scooter according to age for commuter trips and other purposes;
- with the increase in the monthly income of the respondents, the acceptable price they would pay for renting an e-scooter (for commuter trips and other travel purposes) also increases up to a level of 0.43 €/min (commuter trips) and about 0.56 €/min (other travel purposes);
- for the prediction of willingness to switch to the use of e-scooters (both purposes of travel), the factors of gender and price have the greatest influence.

On the public policy side, it was clear that the authorities were finding it difficult to develop regulatory structures even before COVID-19 intervened. However, it is necessary to develop a policy in large cities aimed at using alternative and environmentally sustainable modes of transport. The results of this study can greatly help the authorities to manage the mobility of cities with the help of mathematical models for determining the price of renting an e-scooter. On the other hand, the results of this work can help companies that rent e-scooters to maximize their profits by managing the price of renting e-scooters.

4.1. Limitations

One of the main limitations of the paper is the data collection method, which could not fully ensure the accuracy and honesty of the respondents. Moreover, the results of this research may not be valid for other states and cities, but they represent fundamental research for comparison with future research.

4.2. Further Directions of Research

Further directions of the research should be focused on having a larger number of respondents, cities, and countries to participate in the research. It is also necessary to collect more data on respondents (e.g., work status, level of education, etc.), as well as to examine a wider range of price ranges, primarily due to the economic and energy crisis in Europe since 2022. In addition, future research directions should include a comparison of results with other modes of transportation, such as public transit, walking, and cycling. This would give a more comprehensive understanding of the potential impact of e-scooters on urban mobility and land use.

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