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Impacts of E-micromobility on Istanbul

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DECLARATION OF AUTHORSHIP

I hereby affirm that I wrote the master thesis titled Impacts of E-micromobility on Istanbul on my own without any assistance of third persons and without other resources and sources as denoted in my work. I indicated all parts which I integrated by wording or by meaning. This work was not in part or in all issue of other examination procedures and was not submitted to other examination authorities.

Date Signature

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And this study was carried out with the support of the Turkish Republic.

Abstract

E-micromobilities have developed rapidly in cities around the world in recent years and have an important share in the modal split of urban transportation. Nevertheless, it is not known yet whether these emerging modes play a sustainable role in cities, whether they are used as supplementary or complementary modes of public transport, such as last and first-mile solutions, or whether they are used just for fun/recreational travel purposes. This study aims to answer the above-mentioned issues and to gain a broader knowledge of how e-micromobility affects people's mobility behaviors and urban transport systems whereas comparing Istanbul, and findings from the global mobility studies in terms of e-micromobility impacts on travel behaviors, energy consumption, and environmental impacts, and the related safety issues and regulations. Travel behaviors are structured as average traveled time and distance, travel purposes, and modal shift from different modes to e-micromobilities and this research contains a questionnaire conducted with 240 people based in Istanbul. According to findings, while the average traveled distance in Istanbul was 3.1, literature findings were mostly between 0.72 and 2.4 km and the average traveled duration in Istanbul was 11.8 minutes and global findings were between 8 and 12 minutes. However, most studies reported the average traveled distance by e-bike in the range of 3-4.5 km and traveled time in the range of 15 and 20 minutes. It was also seen that most of the participants, especially in Istanbul, tended to replace their walking habits with e-scooters by 60 percent, and 62 percent of the participants use the e-scooter for fun and recreational purposes as well.

And this research uses Student’s T-test to analyze and compare the relationship between gender and e-scooter usage parameters (e.g., frequency of usage, duration and distance of usage).

Consequently, this study provides the findings of relevant studies in different cities around the world and compared with the findings of the questionnaire conducted in Istanbul and synthesized them to give an insight into the role of e-micromobility in the present and the future of urban transportation.

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List of Abbreviations

The International Energy Agency (IEA)

Turkey Statistical Institute (TUIK)

Energy Market Regulatory Authority (EMRA)

Bus Rapid Transit (BRT)

Istanbul Metropolitan Municipality (IMM)

Turkish Statistical Institute (TUIK)

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1. Introduction

Transportation is one of the most dynamic elements of cities, substantially affecting the other components of cities, as well as citizens' lives. In this context, there is a significant association between urban transportation and the sustainability of the urban environment in terms of energy consumption and emissions. According to the International Energy Agency (IEA, 2020), the transportation sector produced 24 percent of total CO2 emissions in the world in 2019, and it consumed 28 percent of the total energy in the USA. Furthermore, in Europe the transport sector accounted for 25 percent of CO2 emissions in 2016 and approximately 94 percent of the energy demand which is provided by fossil energy. Therefore, it is necessary to develop more sustainable mobility systems, which is defined as a sector that uses efficiently energy resources and generates fewer emissions and pollution related to transport congestion [1–5].

Recently, newly emerging mobility services have been developed in cities around the world, which citizens have adopted remarkably quickly. One of these new mobility modes is e-micromobility, which has gained a considerable share in the distribution of urban modes of transport. For instance, in the USA, e-scooter and e-bike sharing led to around 45 million trips in 2018 [6]. In this paper, e-micromobility refers to e-bikes and e-scooters. Micromobility is defined as small and lightweight (less than 500 kg) modes of transport with speeds less than 25 km/h, most of which are used individually, such as the use of bicycles, and with standing position, such as the use of scooters. E-micromobility vehicles are different from micromobility vehicles due to their motorized powertrains, which are electric, as in e-bikes, e-scooters, and e-skateboards [7,8]. Regarding the rapid growth rate of e-micromobility in global metropolises, some studies indicate that car ownership and car dependency have declined among young generations compared to older generations, and shared services are largely accepted and popular among them [6]. Thus, it is already possible to see their impacts on citizens' mobility behaviors, city infrastructure, and the related energy consumption behaviors. Nevertheless, e-micromobility is a new mode of urban transportation, and it is not yet known whether these emerging modes play a sustainable role in cities, whether they are used as supplementary or complementary modes of public transport, for instance as last- and first-mile solutions, or whether they are used just for fun and recreational travel purposes.

And this study' aim that to review and compare former studies to gain broader knowledge how e-micromobility affects people's mobility behaviors and urban transport systems and presents Istanbul's perspectives on this issue and a source for forthcoming studies. However, it should be noted that since there is no local or private shared e-bike initiative regarding e-bikes in Istanbul for the time being, e-bikes will only be compared and examined between other cities and countries.

There are a few international literature reviews in this field examining previous studies in different urban forms and geographies to give an insight into the future role of these new mobility modes. For instance, a systematic review by Boglietti et al. (2021) analyzed the effects of e-power micro-personal mobility from two different perspectives, examining its impacts on transport and urban planning, and safety issues and the environment. The main point of divergence between the article by Boglietti et al. and this study is the analysis of travel behaviors, including travel purposes, and the frequency of use and the energy consumption of e-micromobilities is one of the main parts [9]. To understand the role of e-micromobility in the sustainability of transportation, it is necessary to consider four aspects together, which are travel behaviors, energy consumption, the urban environment, and the safety issues of e-micromobility as well as the required regulations, which this study presents and differs significantly from other studies [9,10].

In this study, e-micromobility data in terms of the four above-mentioned impacts from different cities by previous studies will be compared with Istanbul as a city of approximately 15.5 million people. Istanbul is a large market which e-scooters entered the urban transportation system in 2019 and it is a matter of concern how this will affect sustainable urban transportation of Istanbul.

Background of the Case Study

Istanbul is an ancient city that has hosted many civilizations throughout its 8,000-year history. On account of its location between Asia and Europe, it has become an economic and cultural epicenter. With its rapidly increasing population, Istanbul's current population is approximately 15 million 462 people [11], and so, Istanbul is the most populated city in Europe and one of the world's mega-cities. It is plausible that transportation system of Istanbul is just as critical and complex due to its population and strategic location.

When we have a glance at the transportation system of Istanbul, a private vehicle-dominated transportation system attracts the attention straightaway. According to data from the Turkey Statistical Institute, almost 20 percent of motor vehicles and 25 percent of private vehicles are registered in Istanbul [12,13]. And regarding the Energy Market Regulatory Authority (EMRA), Istanbul covers 18 percent of total oil consumption in Turkey [13]. Based on these data, the impacts of Istanbul on environmental pollution are revealed. According to Tomtom Traffic Index, the traffic congestion in Istanbul is 51 percent in 2020, presumably due to COVID-19, congestion rate is 7 percent less compared to 2019 [14]. This rate means that i.e., a 30-minute journey would take 51 percent of more time than it would take if there was no traffic [14]. Considering the urban congestion worldwide ranking, Istanbul was 9th in 2019 and 5th in 2020 [14]. This ranking already gives the idea of how transportation system of Istanbul is.

To examine the topic in detail, its massive surface area and unique topography bring along a wide variety of modes of transport such as sea transportation due to the presence of Bosporus the strait that divides the city into two parts. In addition to sea transportation, road transportation, and rail transportation are also relatively developed and widely used. Most of the modes of transportation are as follows; private vehicle, bus, metro, tram, funicular, bus rapid transit (BRT), ferry, minibus and dolmus (8-passenger minibuses). Considering the modal split, the rate of public transportation in the modal split is 28 percent, and the use of private vehicles is 20 percent. Among public transportation, metro usage is 9.8 percent and total rail transport usage is 17.2 percent, road transport has the highest rate by 81.2 percent, sea transport has the lowest rate by 1.7 percent [13,15]. Metro networks have increased gradually with the investments made in recent years, and metro as a mode of transportation has become an important part of daily travel for citizens of Istanbul. In 2019, the total number of passengers carried by Metro Istanbul was determined as 704,479,711. When the number of passengers carried in 2019 and 2018 were compared, it can be seen that the number of passengers carried by rail systems increased by 6.2% in 2019 [15].

Future strategies of Istanbul Metropolitan Municipality (IMM) and the government, to increase intermodal transportation and shared modes and reduce the use of private vehicles, all plans and investments are being made to implement these strategies [13]. However, these goals cannot be achieved unless shared modes of transport are integrated into daily travel behaviors of citizens such as car sharing, ride sharing, bike or e-scooter sharing. Even though, in Turkey 81 percent of the people prefer to use their own cars [16]. Nevertheless, there are many initiatives in this context with sharing electric vehicles as well. Also, there are some ridesharing companies in Istanbul who offer services for the intercity trips. In consideration of bike sharing, IMM run the conventional bike sharing system which is called ISBIKE in the city with the well-functioning renting options. However, due to the topographical conditions of Istanbul, the bike sharing system is mostly located in the coastal sides of Istanbul.

E-scooters entered the transportation system of Istanbul in 2019 with a company called "martı" and many other companies followed suit. With the increasing usage of e-scooters and the growth of the market, the companies have started a competition among themselves and have made various pricing policies. The importance of regulations has increased from the perspective of both investor and entrepreneur, as well as user and pedestrian safety. Some e-scooter companies operating in Istanbul can be listed as; Bin Bin, Gezici Electric Scooters, MOBI, Palm Tech, HOP! Scooters, DUCKT, Kumru Scooter, ETKU [17].

The research is structured with four key questions to analyze the impacts of e-micromobility, as follows:

- Q1: What are e-micromobility's impacts on current travel behaviors?
- Q2: What are e-micromobility's impacts on energy consumption?
- Q3: What are e-micromobility's impacts on the urban environment?
- Q4: What are the safety issues of e-micromobility and required regulations?

The questions are divided into subtopics as shown in Figure 1.

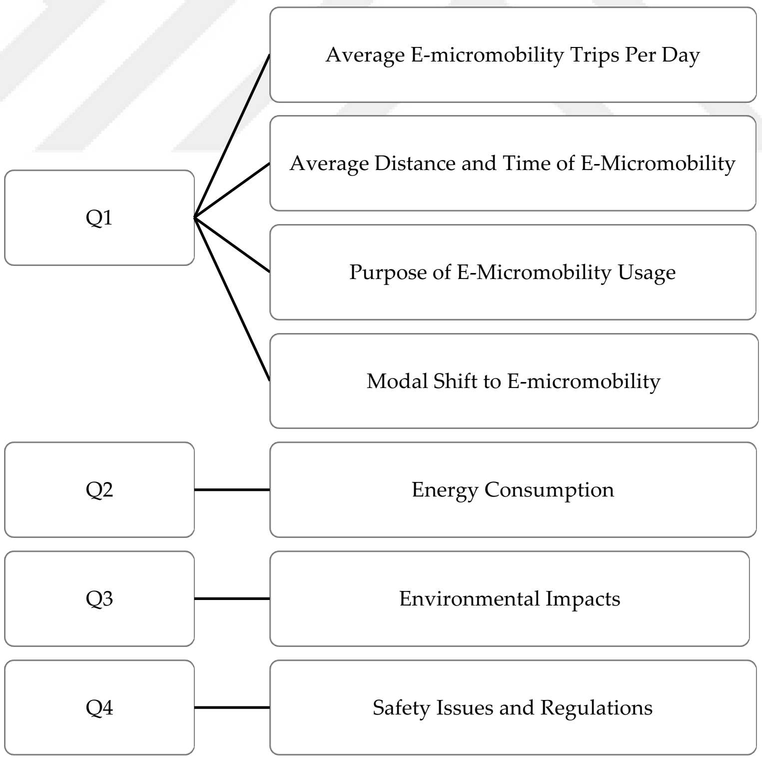

Figure 1. Organization of the Study

The framework of the study proceeds as follows. In Part 2, literature review clarifies how the literature was determined within the search method, the inclusion/exclusion criteria and the final selection, and analysis of selected studies to be used for comparing globally with the designated four key impacts of e-micromobilities. In Part 3, methodology of the study was explained thorough online questionnaire, which was conducted with 240 people based on Istanbul, and the method of this questionnaire and analysis method were explained. In Part 4, findings of online questionnaire were presented. Afterward, in Part 5 the discussion, the above-mentioned key questions were studied and compared the findings of Istanbul and the chosen literature to analyze e-micromobility impacts on travel behaviors, energy consumption, and the related safety issues and regulations. Impacts on travel behaviors were studied in four sub-topics, including average e-micromobility trips per day, the daily average traveled distance and time by e-micromobilities, purpose of travel, and modal shifts from different mobility modes to e-micromobilities. At the end, all these sub-topics will give us how people change their travel behaviors. And energy consumption was analyzed in the related studies to find impacts on energy consumption and environment, and the last topic of the discussion part focuses on the safety issues and regulations from the perspective of Istanbul and different cities around world. And in Part 6, analyses were made in SPSS to find the relation between the usage parameters of e-scooter and the gender. At the conclusion, summary of the study, and research limitations and suggestions for future studies were clarified.

2. Literature Review

It is an undeniable fact that e-micromobility has attracted the attention of researchers, urban planners, and policymakers. Since it is a new topic in mobility research, there is a limited number of studies in this field, and it is expected that the number of studies will increase considerably in the future. Therefore, related studies from around the world were reviewed and presented to gain a widespread understanding the e-micromobility phenomenon and its impacts.

Impacts of e-micromobilities on travel behaviors have been identified with certain parameters for example Bielinski and Wazna (2020) in terms of predicting user behaviors and characteristics of use such as trips per day and another example is Reck et al. (2020) studied shared micromobility usage and mode choice in Zurich, Switzerland using trips per day and average traveled distance and time parameters, likewise Feng et al. (2020), Mathew et al. (2019) and McKenzie (2019) to study shared dockless e-scooters/mobility services and analysis of their temporal usage patterns [18-22]. Li et al. (2020) compared the micromobility behavior before and during COVID-19 using data such as trips per day, average traveled distance and time, and travel purposes, likewise Hardt and Bogenberger (2019), they used same parameters to study usage of e-scooters in urban environments [23,24]. Other examples are as follows, Chang et al (2019) studied e-scooters using data such as trips per day, average traveled distance and time, and travel purposes, modal shift, likewise in the Pilot Evaluation from City of Chicago (2020) [6,25]. To study environmental impacts of shared e-scooters, modal shift data used by Hollingsworth et al. (2019) and in the study made by Agora Verkehrswende (2019) they compare three cities through using modal shift data and comparing energy consumption of the vehicles to find out how efficient e-micromobilities are [26,27].

In this regard, O'Hern and Estgfaeller (2020) studied articles which published between 1991 and 2020 about powered micromobility and made a systematic review by their data and topic, keywords, most cited authors, most cited articles, and their country. The objectives of O'Hern and Estgfaeller are evolution of mobility research in the field of micromobility in terms of time, region, and numbers of the citations however the indicators and measurement of four impact aspects were not compared and synthesized [10]. As a result, there is no study that uses all these parameters together and compares them globally. Therefore, the global-related studies were reviewed and presented to gain a wider understanding of the e-micromobility phenomenon and its impacts in terms of designated parameters.

In this study, online research conducted through search engines, like Google Scholar, Scopus, Web of Science and Research Gate. Figure 2 indicates the Prisma Flow Chart[1], which shows the whole process from the identification to inclusion and exclusion of the literature for a systematic review, including qualitative and quantitative synthesis. Literatures were gathered based on their titles and abstracts at the identification phase to gather all related studies.

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[1] Prisma is an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses.

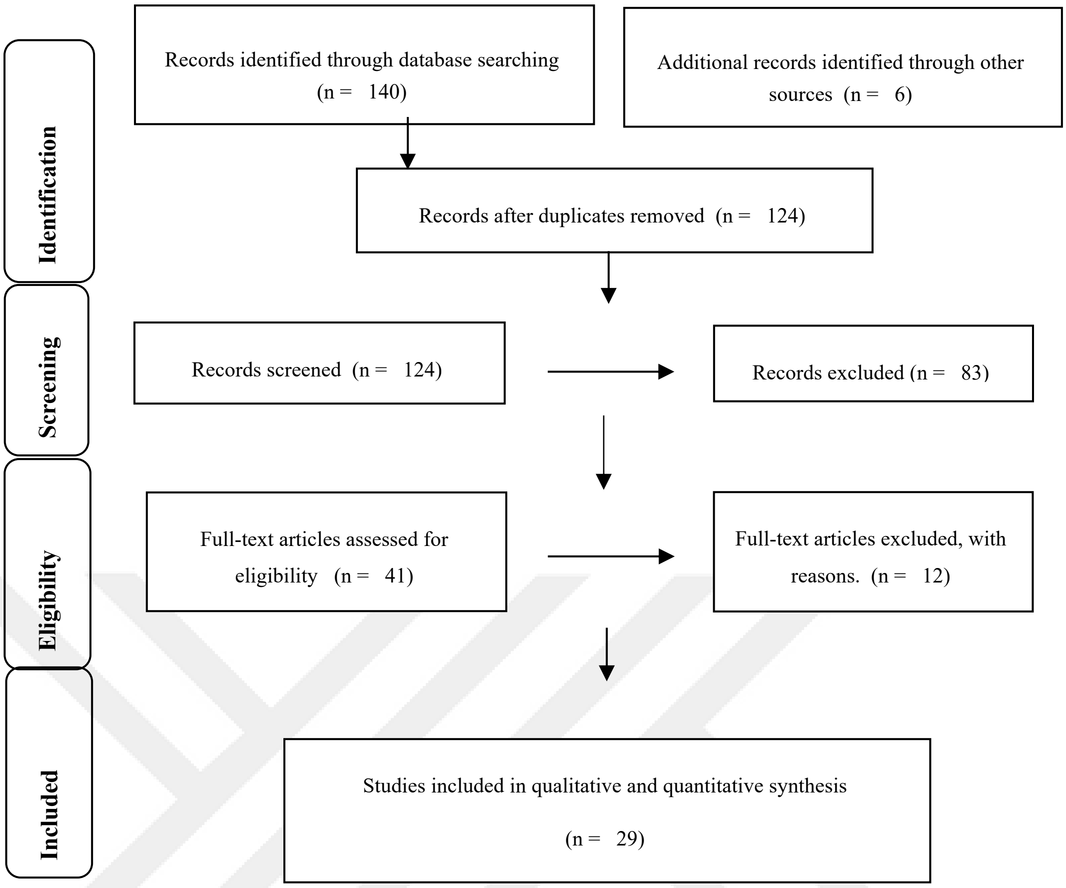

Figure 2. Systematic Review Scheme

146 literatures were compiled through searching the keywords "micromobility", "e-micromobility," in their titles and abstracts. At the identification stage duplicate studies were removed. Hence, 124 studies were screened and 83 of them were excluded regarding to their topic and contents. At the eligibility stage, full-text articles assessed for eligibility, and 29 studies were selected based on the relevance of their data to the main research purposes of this study.

At the included phase, 29 scientific articles, journal articles, conference proceedings, and reports were selected to be reviewed. Those studies are categorized into seven sub-topics depending on to find research questions' answers as declared before. Those categories will be explained in detail in the subsequent sections.

The 29 studies are reviewed in this study in different sections based on their findings and contexts. Table 1 shows the selected literature and its locations and its method. Studies before 2016 were not included in the literature review to examine up-to-date studies. While e-scooters and e-bikes have different years of entry into the market, e-scooter studies were conducted after 2018, and the studies after 2016 are mostly in the field of e-bikes. An additional consideration is the geographical allocation of the data. Studies are gathered mostly from the USA, Europe, Canada, UK, and New Zealand. Nine studies contained both e-scooters and e-bikes. On the other hand, five studies discussed only e-scooters, while four studies investigated dockless bikes and e-bike, along with docked bikes and e-bikes.

Table 1. Literature Review Sources

Source	**Country**	**Method / Data Type**
Agora Verkehrswende (2019)	France, Portland, San Francisco	Compiled Surveys
Bedmutha et al.	Pittsburg, USA	Collecting Data
Bielinski and Wazna (2020)	Tricity, Poland	Survey
Brdulak et al. (2020)	Poland	Simulation Model
Boglietti et al. (2021)	-	Systematic Review
Cairns et al. (2017)	Brighton, UK	Pilot Project / Survey
Campbell et al. (2016)	Beijing, China	Survey and Multinomial Logit
Campisi et al. (2020)	Palermo, Italy	Regression Model
Castro et al. (2019)	7 European cities	Online Survey (PASTA Project)
Chang et al. (2019)	Washington, USA	White Paper
Chery et al. (2016)	Kunming, China	Mixed Logit Model /Survey
City of Chicago, Pilot Evaluation (2020)	Chicago, USA	Online Survey
Feng et al. (2020)	-	Crowdsourcing Data Analytics and The Latent Dirichlet Allocation
Hardt and Bogenberger (2019)	Munich, Germany	Field Test / Usage Data Analysis
Hollingsworth et al. (2019)	Raleigh, USA	Life Cycle Assessment
Johnston et al. (2020)	Atlanta and Georgia, USA	Surveillance / Legal Epidemiology
Kim and Kim (2019)	New Zealand	Logistic Regression Model

Leger et al. (2018)	Ontario, Canada	White Paper
Li et al. (2020)	Zurich, Switzerland	Statistical Analysis
Martinez- Navarro et al. (2020)	Valencia, Spain	System Analysis
Mathew et al. (2019)	Indianapolis, USA	Collecting Data
McKenzie (2019)	Washington, USA	Temporal Spatial and Comparative Analyses
Moreau et al. (2020)	Brussels, Belgium	Life Cycle Assessment
Pimentel and Lowry (2020)	Washington, Oregon and Idaho, USA	Online Survey, Descriptive Statistics, Factor Analyses, Regression Analysis
Pimentel et al. (2020)	USA	Developed a Database to Facilitate the Collection, Storage and Analysis
Reck et al. (2020)	Zurich, Switzerland	Mode Choice Models
Severengiz et al.	Bochum, Germany	Global Warming Potential Assesment
Shaheen and Cohen (2019)	USA	Policy Toolkit
Tuncer and Brown (2020)	Paris, France	Ethnographic Video Study and Qualitative Methods

3. Methodology

The data collected throughout online questionnaire with 240 people, which was based on Istanbul, the largest Turkish city with the population of 15 million 462 people and has modal split of 28 percent public transportation, 20 percent private vehicles [11, 13]. And in the city several e-scooter providers operating since 2019.

The questionnaire was conducted through Google Forms and distributed through various social media platforms, groups/community, private sector, universities. Convenient sampling was used which is *"a type of non-probability sampling that involves the sample being drawn from that part of the population that is close to hand"* [28]. This method was used because it is easy to contact and reach people in this situation and 240 people participated questionnaire between 12 March and 23 May 2021. Regarding the literature review, e-scooter applications are web-based applications and e-scooter users make their bookings online, and these features of applications are the reason for choosing a web-based survey and the distribution of this survey via online channels. Because target users use online platforms.

The main purpose of the questionnaire was to identify travel behaviors and e-scooter usage characteristics of citizens. Questionnaire contains 26 questions, and it has three main sections which are (1) demographical and socioeconomic questions, (2) transportation related questions and (3) e-scooter related questions. And some questions have features to skip the particular questions based on participants' answers. Such as, some education related questions have features for non-students to skip the current education related questions and move on to the next section or if the person has never used e-scooter in their life, they can skip the questions about distance and duration of e-scooter usage.

According to the literature review, travel behaviors mostly associated with the socioeconomic parameters such as age, gender, income, ownership employment status, driving license [6,18]. Hence, questionnaire consists of some demographic and economic questions. Besides, economic questions such as monthly income and expenses were asked in the currency of Turkey and converted to the Euro regarding to exchange rate which designated by Central Bank of Turkey based on the month of April when the questionnaire was conducted [29]. Nevertheless, it should be mentioned that exchange rate is not stable the time being questionnaire conducted. Also, in order to make a logical comparison, average household income in Istanbul is € 410.325 and in the findings of questionnaire average income € 651.25 [30] (Figure 7). Therefore, in this sample, the average monthly income is higher than the average monthly income of Istanbul. When the average age of sample is examined, it is seen that the average age is concentrated in the ages of 25-30, and it can be said that the sample consists of a relatively young population (Figure 4).

In the transportation section of questionnaire, questions of daily travel behavior were asked such as their main mode of transportation going to or from work/school. The participants could select more than one option due to transportation patterns of Istanbul and it could be seen that participants' main mode of transportation is private car (Figure 9). Another important indicator of daily travel behavior is whether people's home or workplace/school are within a 10-minute walk distance in the metro/marmaray[2](train), 10-minute distance is defined as most walkable distance in terms of city planning. And the frequency of using public transportation also asked, selections as follows every day, at least 5 days a week, at least 2-3 days a week, once a week, a few times a month, and almost never. Then, COVID-19 related questions were asked, and comparative questions were asked about the frequency of public transportation use before and after COVID-19.

In the last section of findings, which is the main part of the questionnaire, e-scooter questions were asked to get the main idea of e-micromobility impacts on travel behaviors and started with the question of how often they use e-scooter (shared and private) and as mentioned before if the person selected 'never used in my life', the questionnaire takes the person to the question of the purposes of why they do not use e-scooter. Continuing with the questions about the usage of the e-scooter, it was asked to measure for how far and for how long the users use e-scooter and their purpose of using e-scooter was asked as well. Literature findings show that most of studies while studying e-micromobilities use same parameters such as, Reck et al. (2020) used trips per day and average traveled distance and time parameters to study shared micromobility usage and mode choice in Zurich, Switzerland, same as Li et al. (2020) compared the micromobility behavior before and during COVID-19 using data such as trips per day, average traveled distance and time, and travel purposes, likewise Hardt and Bogenberger (2019), they used same parameters to study usage of e-scooters in urban environments [19, 23, 24]. Likewise, Feng et al. (2020), Mathew et al. (2019) and McKenzie (2019) to study shared dockless e-scooters/mobility services and analysis of their temporal usage patterns [20, 21, 22]. Other examples are as follows, Chang et al (2019) studied e-scooters using data such as trips per day, average traveled distance and time, and travel purposes, modal shift, likewise in the Pilot Evaluation from City of Chicago (2020) [6, 25].

Concerning modal shift, two types of questions structured. The first question was direct question with the simple past which is "Before you began using e-scooters, which transportation mode did you use instead of it?" and the second question was indirect and counterfactual question which was relating to the case what has not happened, and the question was "For your last trip by e-scooters, what would you do if you cannot find available e-scooter?" and to answer this kind of question, participants need to think retrospectively and imagine a manipulated past. Both findings will be presented in Figure 21 and Figure 22.

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[2] Marmaray is a 76.6 km-long intercontinental commuter rail line in Istanbul, Turkey.

Besides, COVID-19 comparative questions were asked as well. Lastly, participants were asked about their perceptions on e-scooters.

Questionnaire does not consist of any e-bike related questions due to low frequency of usage of e-bikes and besides, there is no e-bike sharing system initiative neither private nor municipal yet in Istanbul. And, in the following section findings of questionnaire will be presented.

Lastly, to analyze the relationship between the usage parameters of the e-scooter and the gender, the Student's T-test was made on SPSS. Student's T-test is a statistical analysis method for independent groups, and it was used to test whether the means of two groups differ from each other. The data from the usage parameters used, such as the usage frequency of e-scooter and duration and distance of e-scooters, were coded on SPSS. Equality of variances was tested by Levene's test and regarding the independent samples test, groups were analyzed to whether the variances have a significant difference if the Sig. (2-tailed) value is less than 0.05, it means that group means are significantly different from each other, if the Sig. (2-tailed) value is higher than 0.05, there is no significant difference between the two variables.

4. Findings

In this section, the findings from the questionnaire conducted with 240 people about e-micromobility impacts on urban transportation of Istanbul will be examined under three parts, which are demographic-socioeconomic pattern of the participants, travel behaviors, and e-micromobility mode choices, respectively. Participants who have never used e-scooter are not included in the e-micromobility mode choices section.

4.1.Demographic and Socioeconomic Data

In order to examine the demographic and socio-economic patterns of the participants, the gender distribution of the participants was examined. In Figure 3, it is obvious that female participants were considerably higher than male participants by 6o percent and 40 percent. In addition, 66 percent of the male participants reported that they used e-scooters, while only 34 percent of female used e-scooters.

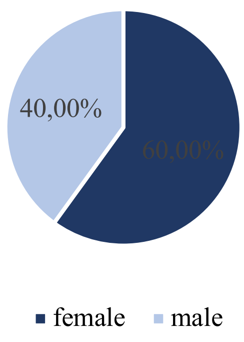


Figure 3. Gender Distribution of Participants

The mean age of sample was 27 and the age distribution of the participants as follows, 39 percent of them were between the ages of 25-30, 23 percent of them between the ages 20-25, 17 percent of them between the ages 15-20 and 9 percent of them between the ages 30-35 and 9 percent of them between the ages 35-40 (Figure 4). The oldest person using an e-scooter is 58.

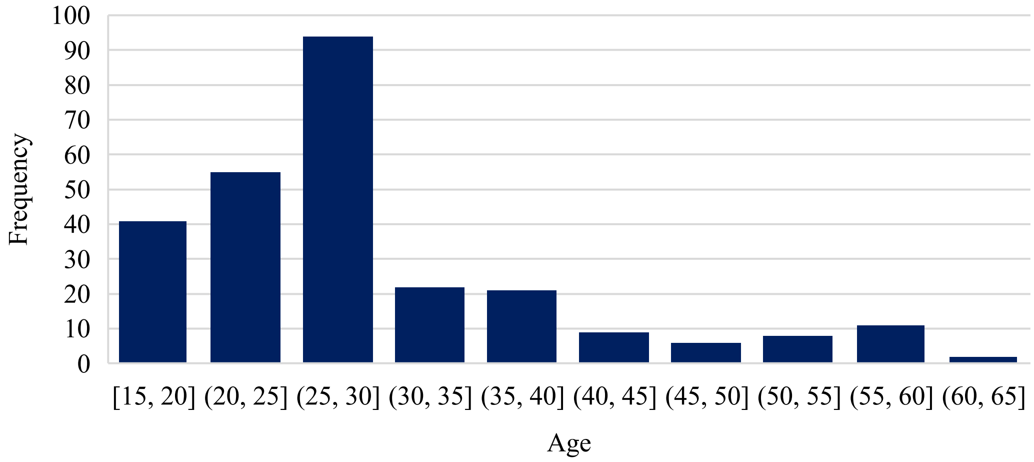


Figure 4. Age Distribution of the Participants

Figure 5 shows occupations of the participants and by 57 percent, most of the participants were employed full-time and followed by not currently employed (e.g., retired, student, looking for job) by 35.8 percent and this may be related with the participants age, since 40 percent of them were under the age of 25. And 3.3 percent of the participants were employed part-time and almost 4 percent of them were freelancer.

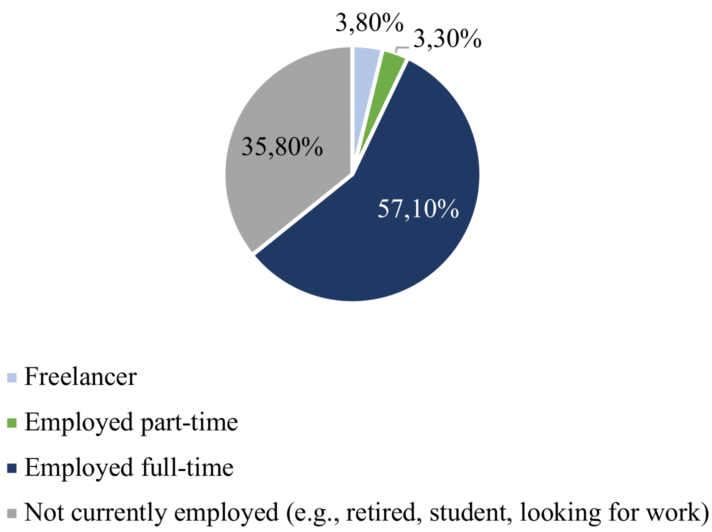


Figure 5. Occupation Data of Participants

And it is detected that among all participants, 37 percent were students. Furthermore, if we look at the educational background of the participants, 58 percent of them had a bachelor's degree, 22 percent of them have graduated from high school and 15 percent of them had a master's degree (Figure 6).

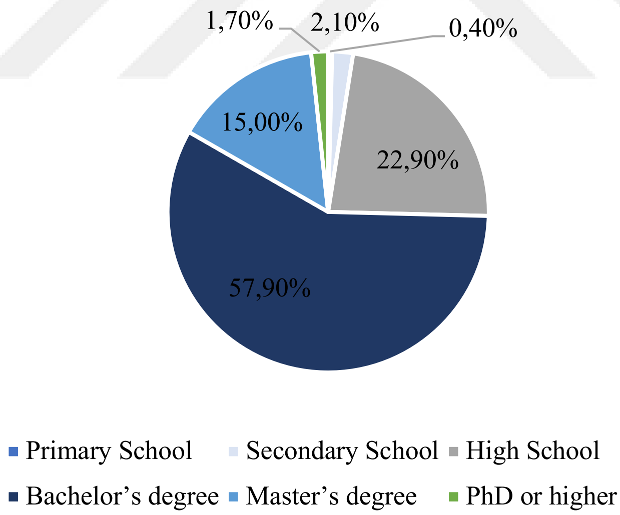


Figure 6. Educational Background of Participants

To investigate economic pattern of the sample, Figure 7 shows 25.8 percent of participants had a monthly income of between €500-800 and the second most common monthly income was under €150 by 23 percent, which may be related to age and employment status. 18 percent earn €300-500 monthly income, 10 percent earn €800-1,000, again 10 percent earn €150-300 and only 4 percent earn more than €1,500 per month.

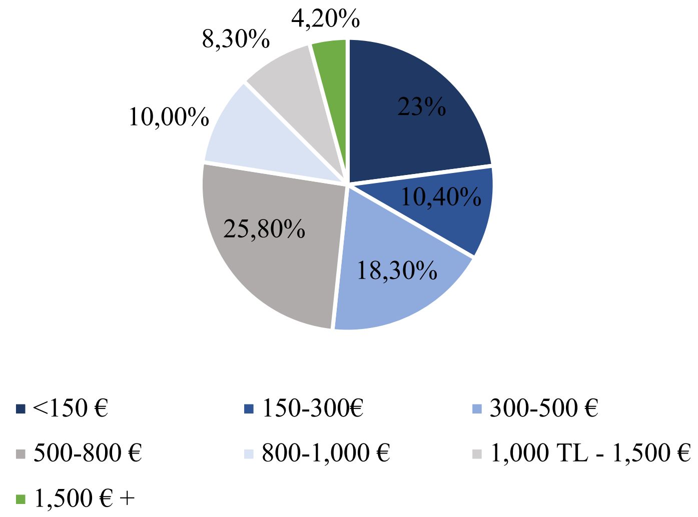


Figure 7. Monthly Income Data of Participants

In the questionnaire, monthly income and expenses were asked in the currency of Turkey and converted to the Euro regarding to exchange rate which designated by Central Bank of Turkey based on the month of April when the questionnaire was conducted [29]. Nevertheless, it should be mentioned that exchange rate is not stable the time being questionnaire conducted. According to Statistical Institution of Turkey, monthly average household income in Istanbul is €410.325 and the findings of questionnaire monthly average income was €651.25. So, it shows that sample group had higher income status compared to the statistics officially.

Additionally, participants' monthly expenses can be seen in Figure 8, the most common range was between €300-500 by 25 percent, second most common range is under 150 € by 25, followed by range of €500-800 by 18 percent and 15.8 percent; 150-300 €, 12.1 percent; 800-1,000 €, and only 2.1 percent of them declared as their expenses more than 1,500 €.

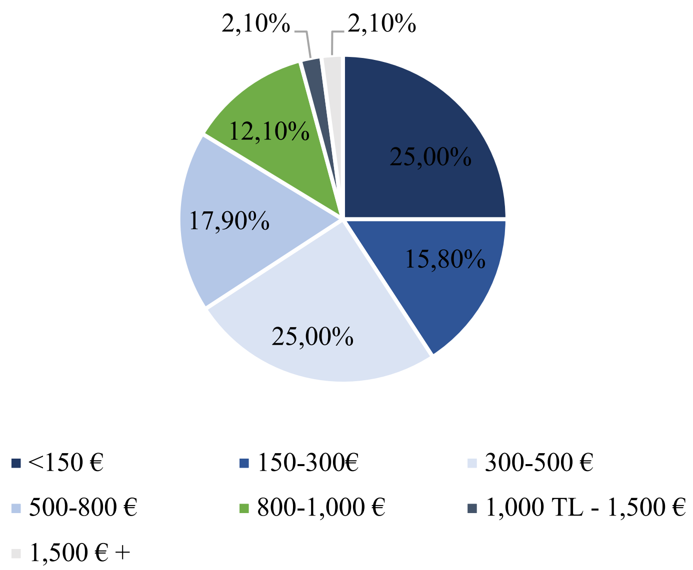


Figure 8. Monthly Expenses Data of Participants

4.2. Travel Behaviors

In order to examine the impacts of e-scooter on transportation behaviors, it is necessary to know the daily transportation behaviors of citizens. Thus, it will be possible to find out what this new mode of transportation has changed or affected by taking its place in urban transportation. For this reason, the daily travel behavior and public transportation behavior of the participants will be examined, in this section.

As shown in Figure 9, the participants were asked which main transportation modes they use to go to and from school/work and 35.4 percent of them stated that they use private car and bus was the second most common mode by 37 percent and followed by metro by 34.5 percent, almost 19 percent of the participants reported walking as a main mode, 15.8 percent; shuttle, 14 percent; Marmaray (train) and 5.8 percent of them reported e-scooter as a main mode of transportation to and from their school/workplace, but it should also be noted that participants were able to choose more than one mode.

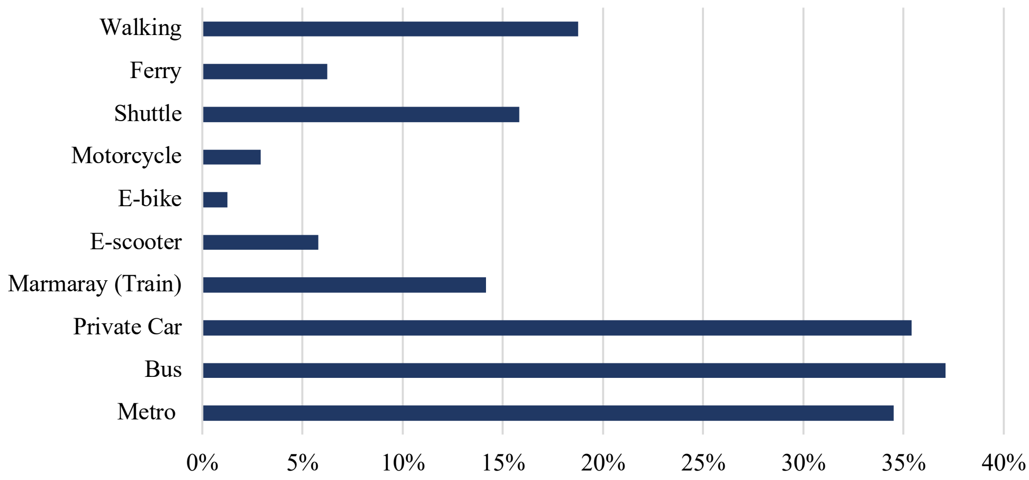


Figure 9. Main Modes of Transportation to and from School/Workplace

And another important thing to consider while examining travel behavior of citizen is how close citizen' homes or workplaces/schools are to major means of transport, such as to the metro. This situation plays an important role in determining people's daily transportation preferences. Nobody wants to walk a distance where the walking distance is more than 10 minutes in the morning or evening coming from their school or job, and their transportation preferences are shaped accordingly. As a result of the survey, it turns out that almost 63 percent of the participants' houses were in 10 minutes walking distance from the metro/marmaray station (Figure 10). In a city with a very greater surface area like Istanbul, this ratio seems fairly acceptable.

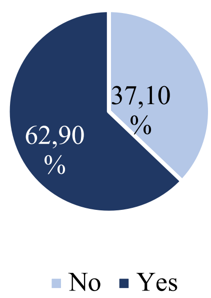


Figure 10. The Distribution of Participants' Houses within 10 minutes Walking Distance to the Metro

Also, as shown in Figure 11, 52 percent of the participants' works/school were within 10 minutes walking distance to metro/marmaray.

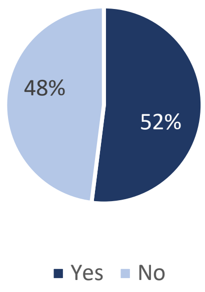


Figure 11. The Distribution of Participants' Works/Schools within 10 minutes Walking Distance to the Metro

Other essential indicator for examining travel behavior is the vehicles that people own. This indicator shows the transportation dynamics of a city to a large extent. In car-dense cities, car ownership is high the same as in bike-based cities bike ownership is high. Since Istanbul is a mostly car-based city, almost 70 percent of the participants own private cars, as can be seen in Figure 12 and this figure shows multiple ownership. 30 percent of them own bicycle, 7 percent own e-scooter, about six percent own motorcycle and about 3 percent own e-bike and almost 23 percent had none of them.

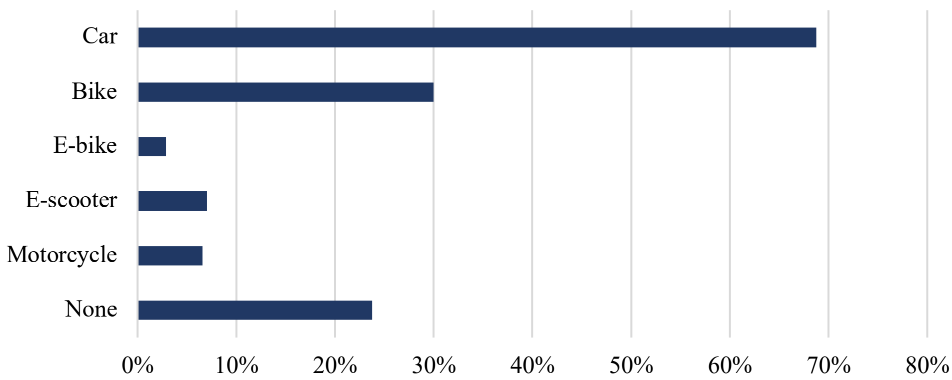


Figure 12. Ownership of Participants

About car ownership in detail, Figure 13 shows that more than half percent of the participants had a car in their household, 30 percent of them had no car in their household and 12.5 percent of them had 2 cars in their household. Also, almost 73 percent of the participants had driving license, 26 percent of them had no driving license, the difference between having driving license or not having is considerably high, it shows again that Istanbul is a car-oriented city.

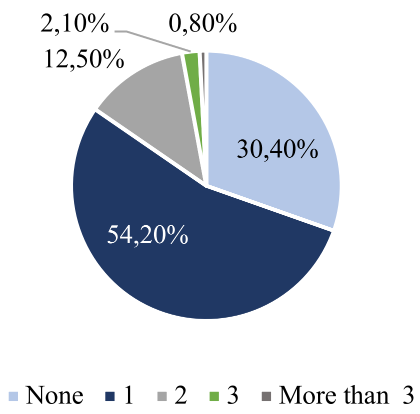


Figure 13. Car Ownership in the Household

And lastly, COVID-19 comparative public transport questions were asked to the participants. The first question is how often they used public transport before COVID-19. As indicated in Figure 14, 23.2 percent of the participants stated as every day, 20.3 percent of them 5 days in a week, 20 percent of them 2-3 days in a week, 8 percent of them once in a week, 13.3 percent a few times in a month and 14.8 percent said almost never used public transportation before COVID-19.

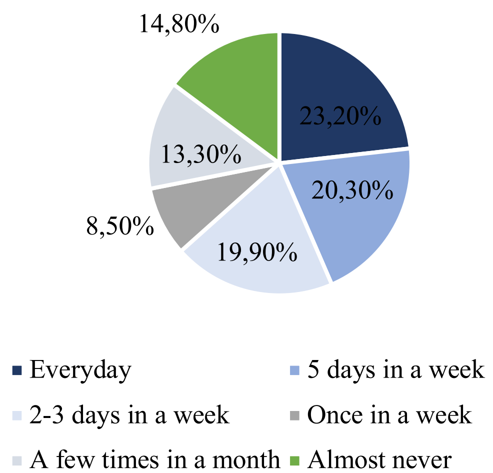


Figure 14. Public Transportation Frequency of Usage Before COVID-19

And during COVID-19, using public transportation everyday has decreased dramatically to 7.4 percent, and 52.8 percent of the participants stated they almost never use public transportation during this time and using 5 days in a week also decreased to 6.3 percent (Figure 15).

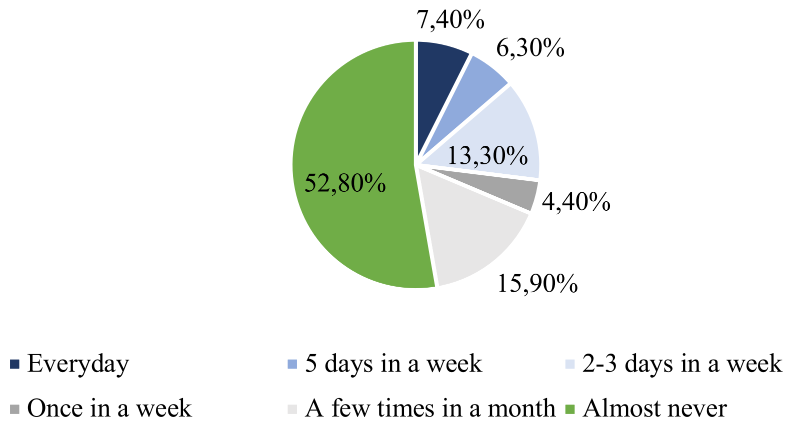


Figure 15. Public Transportation Frequency of Usage During COVID-19

4.3.E-micromobility Mode Choices

In this section, the data that gathered from e-scooter section from the questionnaire to expose e-micromobility impacts on travel behaviors with some certain questions such as how often people use e-scooter and for how long and how far they use, what their purposes are and finally, what they would use instead of it to have an idea of modal shift to e-scooter. The number of participants included in this section is 116 out of 240. People who have never used the e-scooter are not included in the e-scooter questions about travel behaviors.

4.3.1. Average E-micromobility Usage of Frequency

Although the exact number of daily trips cannot be known from the survey, it is possible to reach a general opinion about how often e-scooters have been using in Istanbul. As shown in Figure 16, 52 percent of the participants never used the e-scooter in their life, 26.3 percent of them use it a few times in a year, and 13 percent of the participants use it a few times in a month and 3.3 percent of them stated that they use it once in a week and 3 percent of them use 2-3 times in a week and people who use it every day by 2.9 percent.

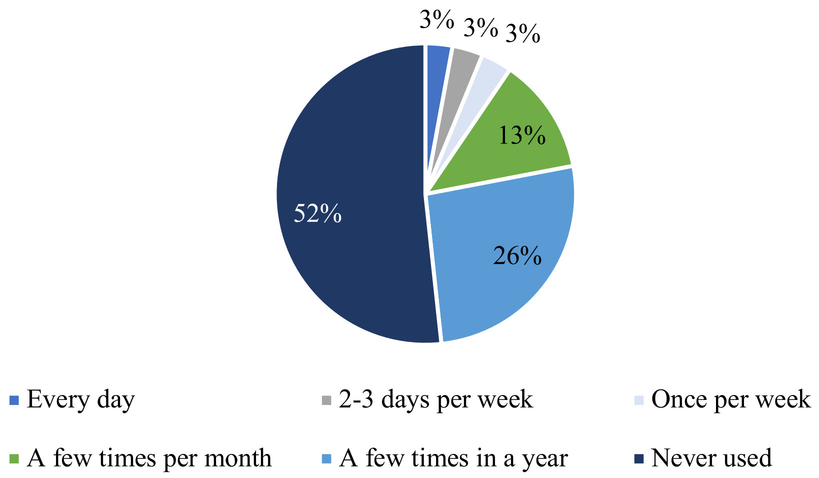


Figure 16. Usage Frequencies of E-scooter Based on Istanbul Survey

Considering the COVID-19, people were asked whether during COVID-19 the frequency of e-scooter usage changes compared to before COVID-19 (Figure 17). And according to the answers 18.3 percent of participants reported that their usage frequency has increased, 6.7 percent of them stated that their usage frequency has decreased and 75 percent of them stated that there is no change in frequency.

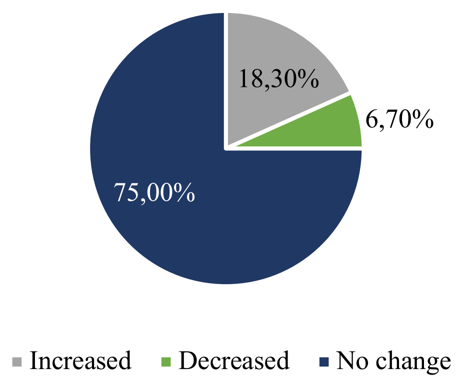


Figure 17. Corona Effects on Usage Frequency of E-scooter

4.3.2. Average Distance and Time of E-Micromobility

The highest distance range for using e-scooters was between 1-3 km by 36.2 percent and 25 percent of the participants use for less than 1 km, followed by 24 percent of the respondents stated that they use it between 3-5 km, 8.6 percent of them use for between 5-9 km and 6 percent of them use it distances for more than 9 km (Figure 18). And these percentages were based on those who have used e-scooters before which the exact number of these people was 117.

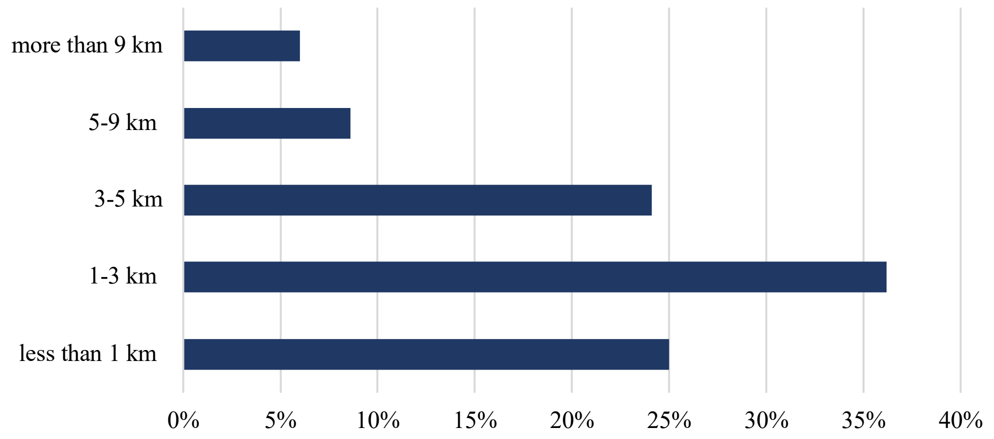


Figure 18. Trip Distance of E-scooters in Istanbul

Regarding the average trip duration of citizens of Istanbul, 25.9 percent of the participants reported that they use it for 10-15 minutes, followed by those who use 5-10 minutes by 23.3 percent and using less than 5 minutes by 19.8 percent. 12.1 percent of the users stated as their trip duration is between 20-30 minutes, 9.5 percent of users use e-scooters between 15-20 minutes, and 9.5 percent of the users use more than 30 minutes (Figure 19).

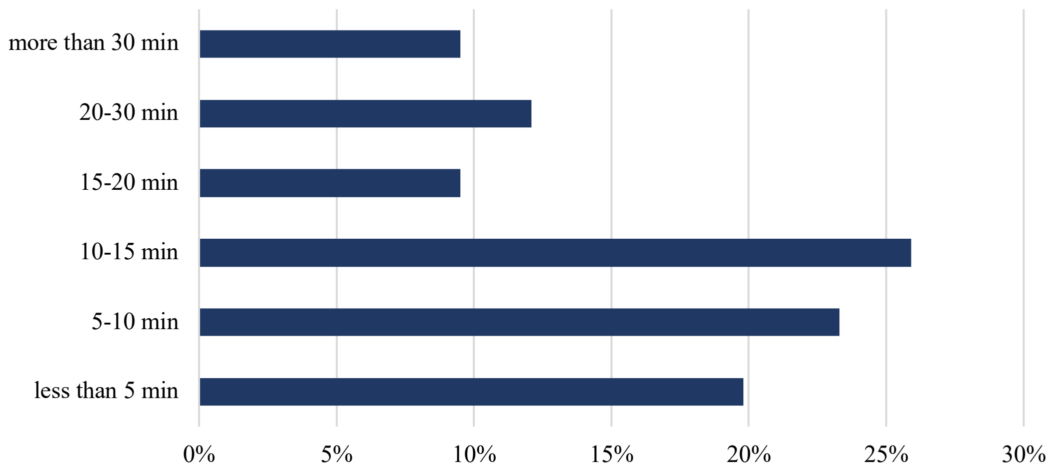


Figure 19. Trip Duration of E-scooters in Istanbul

4.3.3. Purpose of E-Micromobility Usage

Another indicator to examine e-scooter behaviors is usage of purposes. Figure 20 shows that 62 percent of the participants use e-scooters for fun and recreational reasons, 18 percent of them use e-scooter for shopping and running errands, 13.8 percent of them use for going to or from transportation and 6 percent of them use for commuting to school or work. Besides, it should be also noted that participants were allowed to choose only one option.

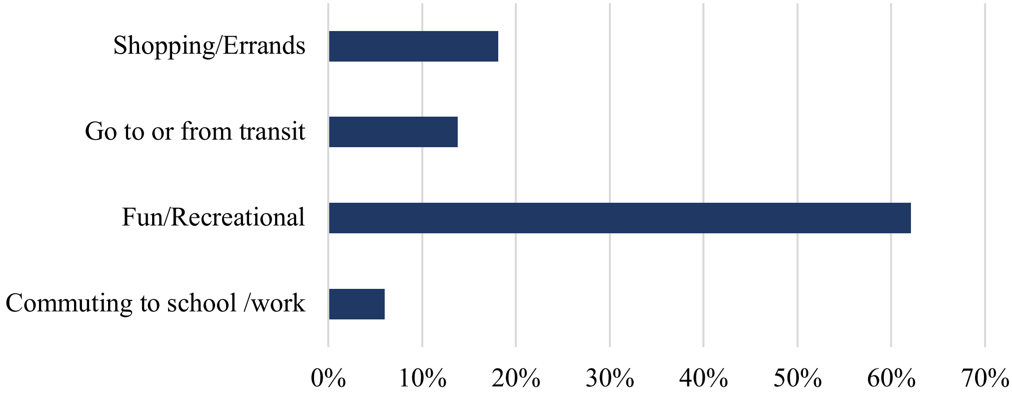


Figure 20. Usage Purpose of E-scooters in Istanbul

4.3.4. Modal Shift to E-micromobility

Concerning modal shift, two types of questions structured. The first question was direct question with the simple past which is "Before you began using e-scooters, which transportation mode did you use instead of it?". And the second question was indirect and counterfactual question which was relating to the case what has not happened, and the question was "For your last trip by e-scooters, what would you do if you cannot find available e-scooter?" and to answer such questions, participants need to think retrospectively and imagine a manipulated past. And findings indicate that most of the participants' walking habits tend to replace with e-scooters (Figure 21). They were allowed to choose only one option. And the findings show that replacing walking was the highest portion by 60.3 percent, followed by replacing private cars was the second highest by 13.6 percent and replacing public transportation by 10.3 percent, replacing taxi was by 8.6 percent, replacing biking by 4.3 percent and replacing minibuses by 2.6 percent.

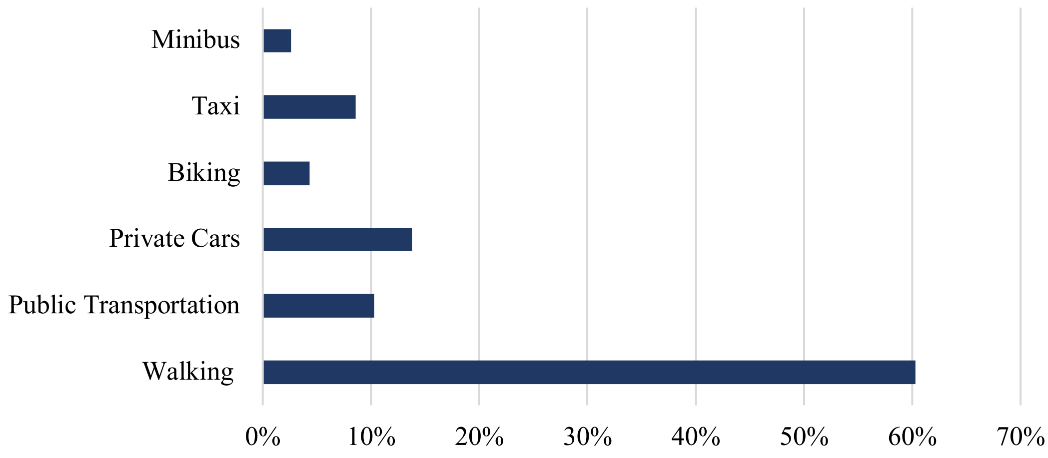


Figure 21. Modal Shift to E-scooter in Istanbul

Figure 22 shows the second question which was "For your last trip by e-scooters, what would you do if you cannot find available e-scooter?" and the results indicate that 64.7 percent of the participants reported they would have walked, 11.2 percent would have used private cars, 10.3 percent would have used taxi and 6 percent would have used public transportation and 5.2 percent would have used biking in their most recent trips if e-scooters were not available.

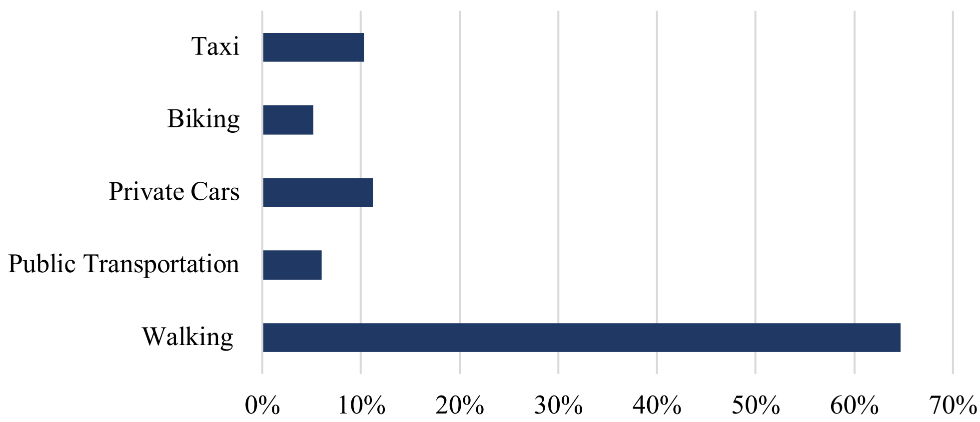


Figure 22. Modal Shift to E-scooter Regarding E-scooter Availability in Istanbul

And in the questionnaire, it has been asked to the participants about the reasons discourage them to use e-scooters, they were allowed to choose more than one reason. The reasons are presented in Figure 23.

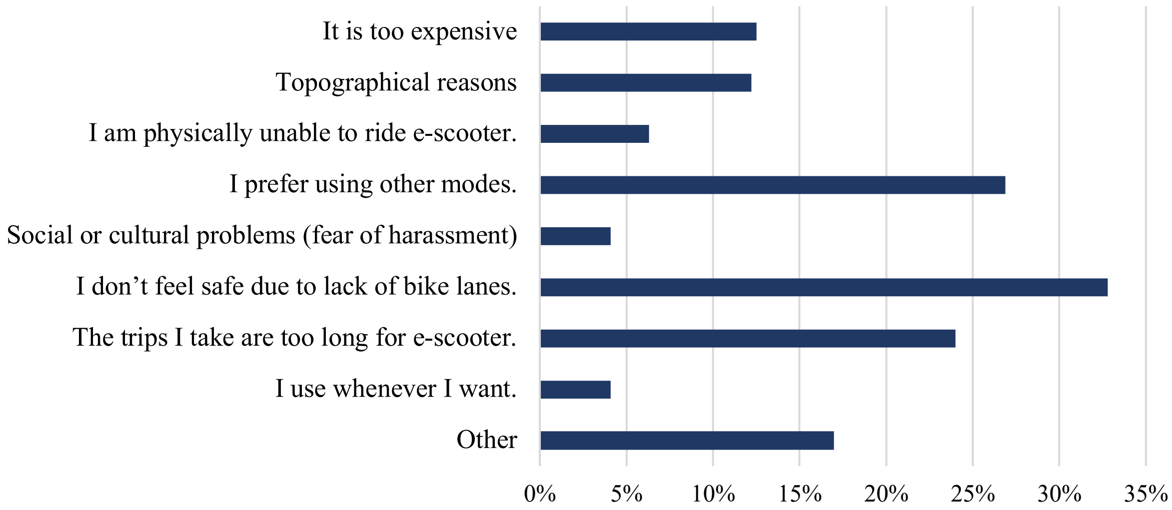


Figure 23. Reasons for not Using E-scooter

The main reasons that discourage participants were lack of bike lanes which considering that the bicycle paths in Istanbul are concentrated only on the coastline, it is a very reasonable reason for the city that has intense car traffic. The other common reasons followed as taking longer trips and preferring other modes.

5. Discussion

Micromobility has the capability to be used for all the trips with different travel purposes, which are less than 8 kilometers, which is 50 to 60 percent of total trips in China, the European Union, and the United States [31]. Therefore, it could be assumed that micromobility vehicles might substitute most of the car trips, which is known most of the car trips are made for less than 8 kilometers distance [32].

In this section, to gain broader knowledge about the impacts of e-micromobility on cities findings of the survey and previous studies from all over the world will be compared and presented in terms of defined four key questions in the beginning of this study which are;

- Q1: What are e-micromobility’s impacts on current travel behaviors?
- Q2: What are e-micromobility’s impacts on energy consumption?
- Q3: What are e-micromobility’s impacts on the urban environment?
- Q4: What are the safety issues of e-micromobility and required regulations?

5.1.Impacts on Travel Behaviors

To address the first research question, that is, determining “e-micromobility’s impacts on current travel behaviors”, in this paper we discuss the average trips per day, the average distance and time for the daily usage of e-micromobility vehicles, as well as modal shifts to e-micromobility from different modes of transport. These findings are essential in order to evaluate their impacts on the current travel behaviors of citizens and to predict forthcoming travel behaviors. First, the findings of average e-micromobility trips per day will be examined.

5.1.1. Average E-micromobility Trips Per Day

E-micromobility services offer unique pleasure to their users, such as riding in the open air, control of the vehicle, liberty, and flexibility during their travels [6]. Table 1 shows the findings from the selected literature in terms of how many trips were made per day. It is considerably challenging to reach any common result among the studies. For instance, in Chicago, with a population of 2,725,296, 105,479 e-scooter trips were made per day in 2019 [25]. Meanwhile, in Washington, with a population of around 5,322,000, 2821 e-scooter trips were made per day in 2019 [33]. In Zurich, with around 434,000 inhabitants (1.5 million in the metropolitan area), 1032 dockless e-scooter trips were made in 2020 [19].

In the case of Istanbul, the exact number of daily trips cannot be known at the moment, however it is possible to reach a general opinion from questionnaire about how often e-scooter users use e-scooter. 52 percent of the participants never used the e-scooter in their life, 26.3 percent of them use it a few times in a year, and 13 percent of the participants use it a few times in a month and 3.3 percent of them stated that they use it once in a week and 3 percent of them use 2-3 times in a week and people who use it every day by 2.9 percent.

Table 2. Literature Review About Average Trips Per Day

Source	Literature review about average trips per day[3]
Bielinski and Wazna (2020)	168,300 trips were made per day with an electric bike-sharing system of 4080 vehicles in Tricity, Poland.
Castro et al. (2019)	Conducted survey in seven European cities (PASTA project) with 204 people reported that the average number of trips per day with e-bikes was 0.8.
Chery et al. (2016)	The number of e-bike trips in 2008 was reported as 1.16, in 2011 it was reported as 1.05, and in 2012 it was reported as 1.03 per day in Kunming, China.

[3] The results are found by dividing the total amount of trips over the conducted research period.

City of Chicago, Pilot Evaluation (2020)	According to the information that e-scooter companies provided, an average of 6846 trips per day were made with e-scooters in Chicago, USA.
Feng et al. (2020)	It was reported that 105,479 e-scooter trips were made per day in the USA (according to The National Association of City Transportation Officials (NACTO)).
Fyhri and Fearnley (2015)	The study conducted with 66 participants in Norway reported 1.4 e-bike trips per day.
Hardt and Bogenberger (2019)	As a result of a pilot project with 6 vehicles and 38 participants in Munich, an average of 49 trips were made per day.
Li et al. (2020)	In Zurich, Switzerland, according to the provided data, 465 trips per day were made with docked e-bikes in a normal period, which covered 15 February to 14 March 2020. During COVID-19 (15 March to 14 April 2020), 299 trips per day were made. For dockless e-bikes, 241 trips per day were made in the normal period, and 102 trips per day during COVID-19. For dockless e-scooters, 60 trips per day were made in the normal period, and 50 trips per day during COVID-19 (for each of the three types of micromobility services, trip data were collected from three operators: Publibike, Bond, and Bird)
Mathew et al. (2019)	In Indianapolis, 4,830 e-scooters trips were made per day.
McKenzie (2019)	According to the collected data, Bird reported 170 trips per day, Lime reported 214 per day, Lyft reported 835 trips per day, Skip reported 1487 trips per day, reported has 115 trips per day, and Jump e-bikes reported 325 trips per day, which led to a total of 2821 e-scooter trips per day, in Washington, USA (the results were obtained by dividing the total amount of trips over the 4-month research period).
Reck et al. (2020)	The study based on the Zurich, Switzerland reported approximately 2,800 trips per day, 1181 docked e-bike trips, 419 docked bike trips, 244 dockless e-bike trips, 1,032 dockless e-scooter trips.

According to Hardt and Bogenberger (2019), 49 trips were made per day in their pilot project conducted in Munich, Germany, and this amount was considerably higher than those of the other studies, presumably due to the fact that this pilot project was conducted with a relatively small number of vehicles and participants [24]. Another survey in Munich in 2019 reported 5.5 trips per day using e-scooters [32]. Furthermore, according to a future model concerning 2030 made by McKinsey and Company (2019), there will be approximately 250 million shared-micromobility trips in Munich, which represents approximately 8 to 10 percent of all trips in Munich in that year, in which shared-micromobility trips made up less than 0.1

percent of all trips in 2019 [32]. According to the data collected by McKenzie (2019), Bird reported 170 trips per day, Lime reported 214 per day, Lyft reported 835 trips per day, Skip reported 1487 trips per day, Spin reported 115 trips per day, and Jump e-bikes reported 325 trips per day, which is in total 2821 e-scooter trips per day, in Washington, USA [22]. Furthermore, regarding e-bike trips, another study conducted with 66 participants in Norway reported 1.4 e-bike trips per day [34]. During COVID-19, 50 to 60 percent of the passenger-kilometers decreased, which also affected the use of micromobility, according to the survey they conducted in May 2020, including seven countries such as China, Germany, France, Japan, Italy, the US, and UK. They assume that after COVID-19 the use of micromobility may increase, suggesting that 9 percent of people tend to have private micromobility and 12 percent of them tend to use shared micromobility in the “next normal” era [35].

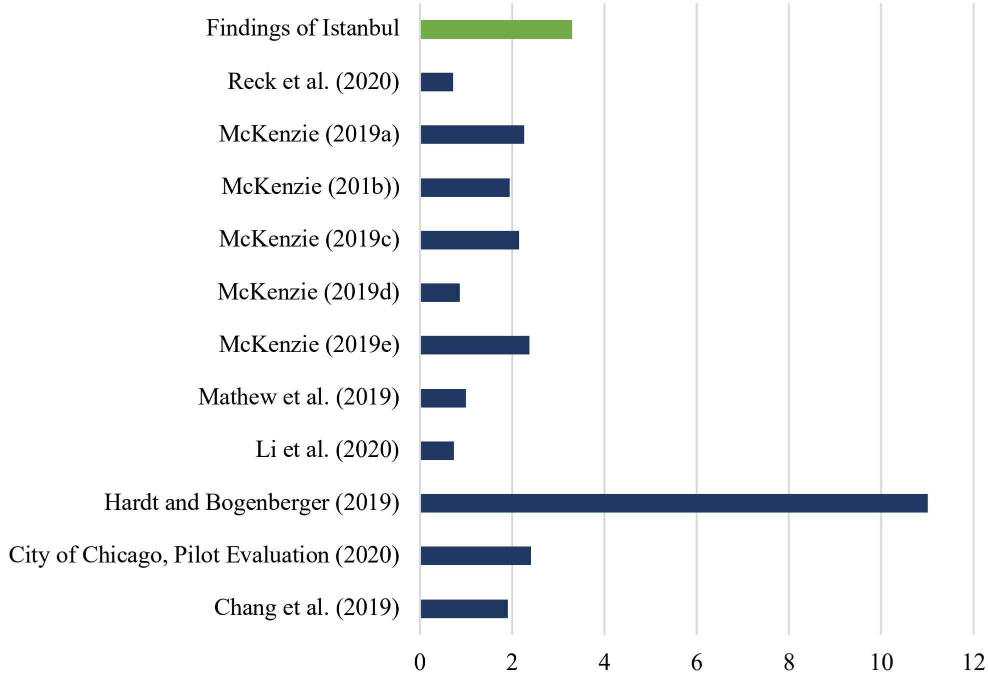
Regarding the survey of Istanbul, during COVID-19, 16.75 percent of participants reported that their usage frequency has increased, 5.9 percent of them stated that their usage frequency has decreased and 77.4 percent of them stated that there is no change in their frequency of using e-scooter.

Moreover, according to the 2019 Global ACES2 Consumer Survey, 70 percent of participants would consider buying their own micromobility vehicles for commuting to work or school, which will cause more micromobility trips per day [35].

5.1.2. Average Distance and Time of E-Micromobility

E-bikes and e-scooters have shown different average travel distances and times in cities. The findings of various studies indicate that the average distance traveled on e-scooters is shorter than that on e-bikes (Figure 24,25). The difference in the travel distance and time between e-bikes and e-scooters depends on several factors, such as the speed and electric power of the vehicles [36]. Moreover, people have reported that when they want to make longer recreational trips, they choose e-bikes instead of conventional bikes, which shows that e-bikes are mostly preferred for longer trips [37].

In the case of Istanbul, the highest range for the e-scooter was between 1-3 km by 36.2 percent and 25 percent of the participants use for less than 1 km, followed by 24 percent of the participants stated that they use it between 3-5 km, 8.6 percent of them use for between 5-9 km and 6 percent of them use it distances for more than 9 km. The average traveled distance for Istanbul was 3.1 km. Figure 24 illustrates the average distance traveled of e-scooters from different studies.



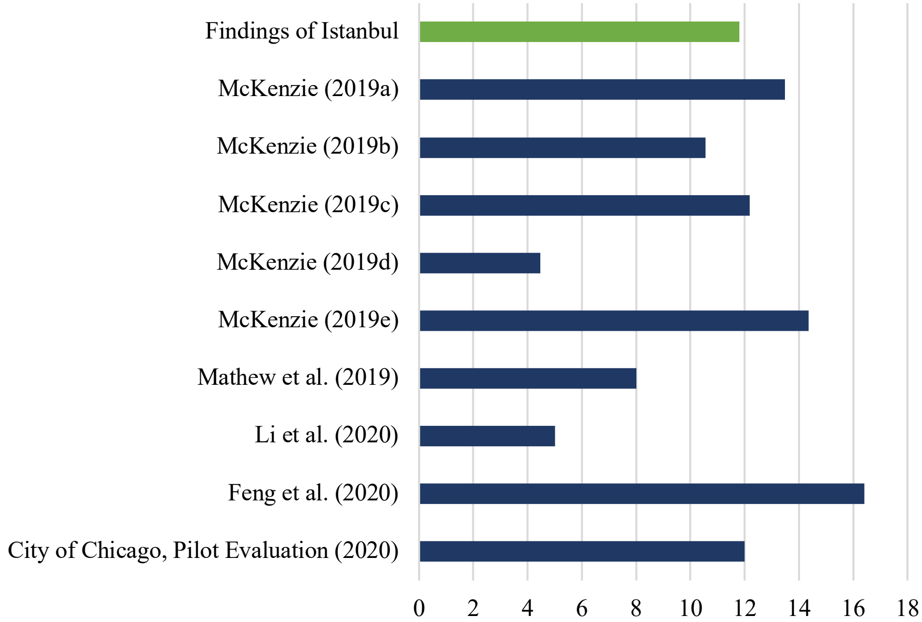
[a] Spin, [b] Skip, [c] Lyft, [d] Lime, [e] Bird

Figure 24. Average Distance of E-scooters (km)

Hardt and Bogenberger (2019) reported the longest average distance traveled by e-scooters that was 11 km, which was estimated within a study pilot including 38 participants in Munich (Germany) [24]. Presumably, due to doing a pilot project with few numbers of people and vehicles, the average distance was significantly high [24]. In contrast, e-scooters are known to be used for short trips, and according to Chang et al. (2019), 70 to 73 percent of trips are less than 1 mile (1.6 km) in Washington [6].

However, literature findings were mostly between 0.72 and 2.4 km for average e-scooter distance and Istanbul's average distance is slightly higher than overall findings. This may be associated with the considerably wide surface of Istanbul; distance would take longer going to or from one place to another.

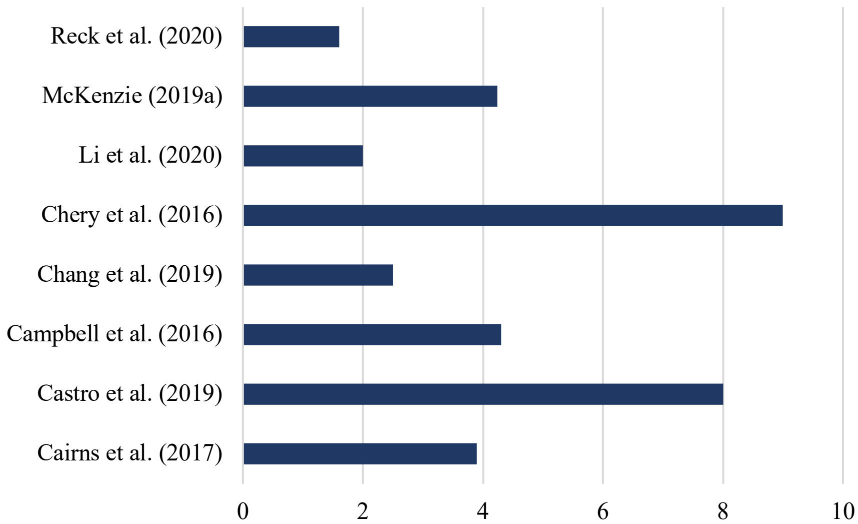
Regarding the traveled time of e-scooters, according to data from survey of Istanbul, 25.9 percent of the participants reported that they use e-scooters for 10-15 minutes, followed by those who use 5-10 minutes by 23.3 percent and people using less than 5 minutes by 19.8 percent. 12.1 percent of the users stated that their trip duration is between 20-30 minutes, 9.5 percent of users use e-scooters between 15-20 minutes, and 9.5 percent of the users use more than 30 minutes. The average duration of findings from Istanbul was 11.8 minutes. Figure 25 shows findings from other studies and average duration was between 8 and 12 minutes, so overall findings are mostly similar to each other.



[a] Spin, [b] Skip, [c] Lyft, [d] Lime, [e] Bird

Figure 25. Average Duration of Using E-scooters (minutes)

The data on the average daily distance traveled on e-bikes, collected from eight designated studies, are presented in Figure 26 and there is no data to be used in terms of e-bikes based on Istanbul yet.



[a] Jump

Figure 26. Average Distance of E-bikes (km)

To be more precise, in the case of Castro et al. (2019), the data were gathered from a survey of 10,000 people from seven cities in Europe, and it was stated that 365 people used e-bikes [37]. It is known that in these cities, bicycles are used as one of the major daily modes of transportation, and e-bikers used e-bike for almost half of the month. Furthermore, they stated that e-bikers' daily usage of bikes was significantly more than that of conventional bikers, and with 8 km and 32.2 min, the longest average time of use was reported by this study, among the studies (Figure 27) [37]. The longest average distance was 11.4 km, reported for Kunming, China, by Chery et al. (2016) [36]. Moreover, the shortest average distance for docked and dockless e-bikes was 1.6 km, which was declared for Zurich, Switzerland, by Reck et al. (2020) [19], and the shortest time was 15 minutes again for Zurich, Switzerland by Li et al. (2020) [23]. However, most studies reported average distances traveled by e-bike in the range of 3–4.5 km and travel times in the range of 15 and 20 min.

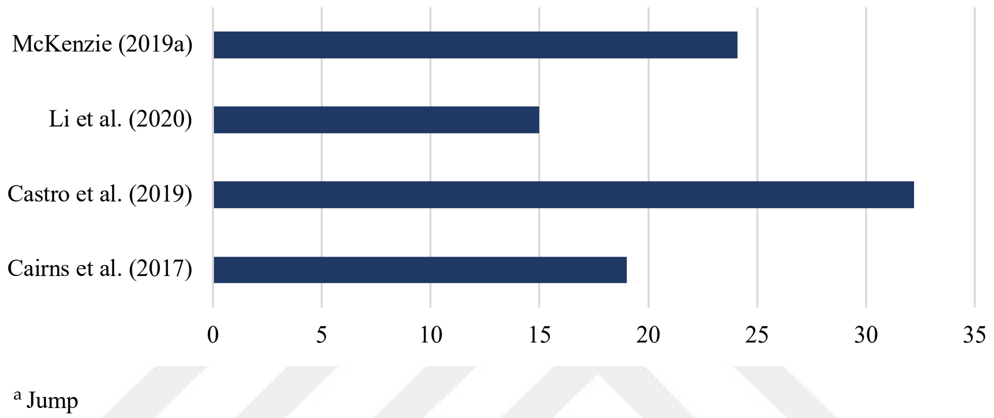
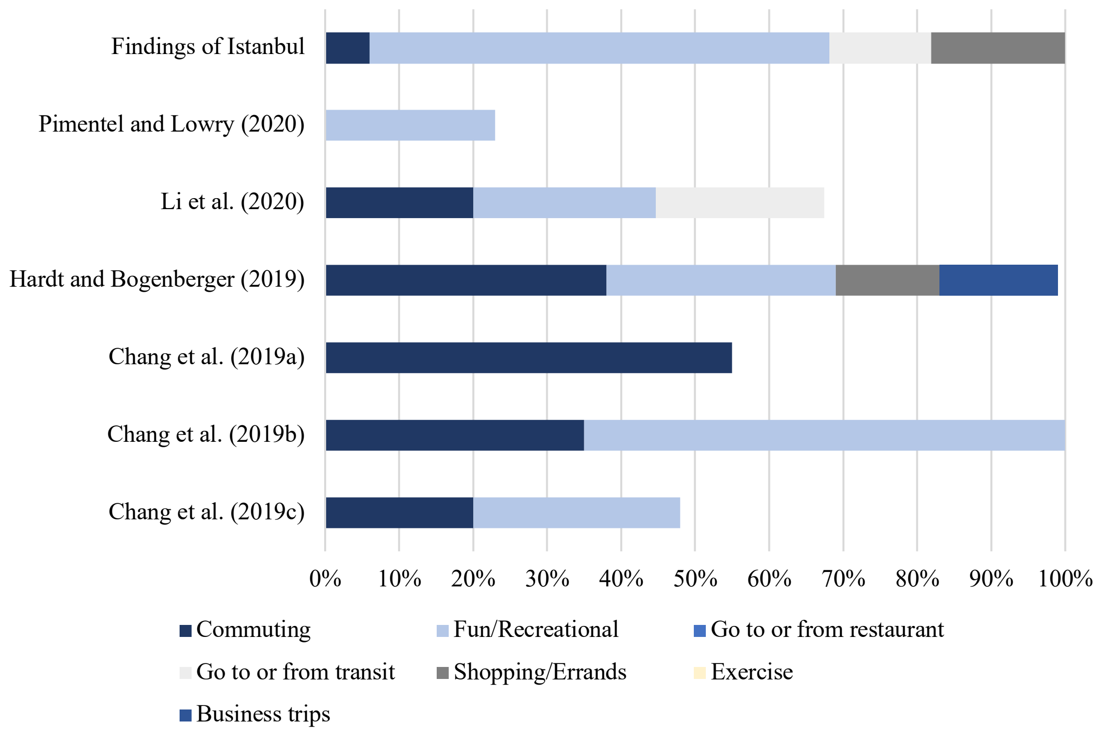


Figure 27. Average Duration of Using E-bikes (minutes)

The trip distance for dockless e-bikes and e-scooters has remained similar during COVID-19, whereas the trip distance for docked e-bikes has increased compared to the normal period in Zurich [23]. In contrast, the US micromobility companies have reported that e-scooter average trip distance increased by 26 percent during the COVID-19, e.g., in Detroit, trip distances have increased up to 60 percent [31,32]. Therefore, people tend to use e-scooters for a longer distance than before, instead of using public transportation during COVID-19.

5.1.3. Purpose of E-Micromobility Usage

As mentioned in the previous section, e-scooters are not preferred for long journeys, which causes that they are used for limited travel purposes. Regarding the case of Istanbul, the main purpose of usage was for fun and recreational reasons by 62 percent, shopping and running errands was 18 percent, for going to or from transportation was 13.8 percent and commuting to school or work was 6 percent. Figure 28 illustrates the usage purposes of e-scooter among the selected literature. In the USA, most e-scooters were used to commute to work and school, or fun/recreation, and proportions of these purposes were notably close to each other [6,25,38]. Percentages varied from city to city in the USA as well as in Europe. For instance, in Chicago, 50 percent of users stated that they had been using e-scooters for social/entertainment reasons [25]; however, in Austin, Portland, and San Francisco, the most specified purpose of usage was commuting to work or school [6].



[a] San Francisco, [b] Austin, [c] Portland

Figure 28. E-scooter Usage Purposes

In the study by Chang et al. (2019), in Portland, the most common e-scooter usage was recreational, reported by 28 percent of participants, and the second most common form of e-scooter usage was commuting to work and school, reported by 20 percent [6]. Moreover, in Austin, the most common purpose for dockless e-scooter and e-bike usage was commuting to work and school, reported by 35 percent of participants. In San Francisco, the most common e-scooter usage was commuting to work and school, at 55 percent [6]. In the study by Hardt and Bogenberger conducted in Munich (2019), the usage purposes for e-scooters were reported as 38 percent for commuting trips, 31 percent for leisure, 16 percent for business trips, 8 percent for shopping, and 6 percent for errands [24]. In the study by Li et al. (2020) from Zurich (Switzerland), 24.64 percent of e-scooter trips were for leisure purposes, 22.77 percent were for going home, and 20.06 percent were for going to work in the normal period (in the study, the normal period referred to before the COVID-19 pandemic) [23]. Furthermore, according to Pimentel and Lowry (2020), in Washington, Oregon and Idaho, USA, the most common purpose for e-scooter usage was recreation, at 23 percent [38].

Regarding the pilot evaluation made by the city of Chicago (2020), the travel purposes for e-scooter users consisted of 50 percent for social/entertainment, 42 percent for going to or from restaurants, 41 percent for fun/recreation, 30 percent for commuting, 34 percent for going to or from transit, 28 percent for shopping/errands, 10 percent for going to/from business appointment, 4 percent for going to or from school, and 2 percent for exercise [25]. Presumably, in the Chicago survey, participants were able to choose more than one option for their travel preferences. Therefore, the cumulative percentages are higher than one hundred, as is the case in the study by Leger et al. (2018) [25,33]. Regarding Leger et al. (2018), in Ontario (Canada), the usage purposes for e-scooters were reported as commuting (70 percent), recreation (more than 80 percent), errands (more than 50 percent) and first-/last-mile travel (about 40 percent) [33].

As indicated in Figure 8, in the study by Cairns et al. (2017) in Brighton, UK, the most common purpose of the use of e-bikes was commuting to work, followed by recreational usage, including daily activities, in second place [39]. Castro et al. (2019) reported that it can be presumed that e-bikes were used for longer recreational trips compared to conventional bikes [37].

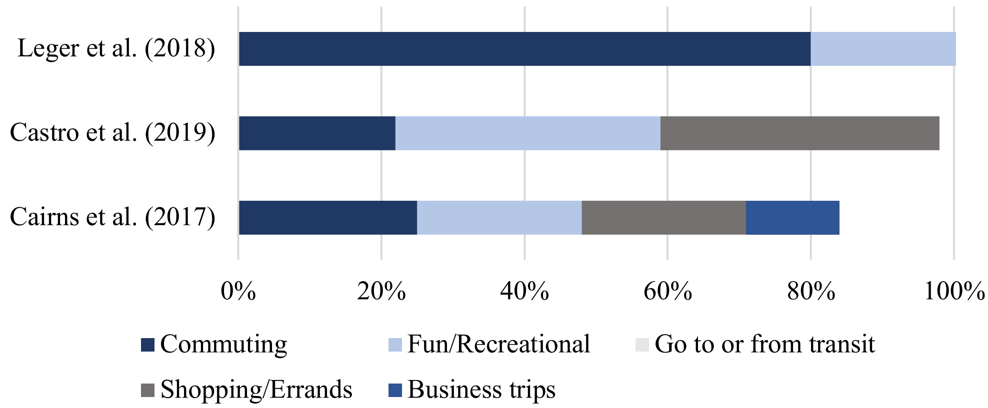


Figure 29. E-bike Usage Purposes

As mentioned earlier in relation to the purposes of using e-scooters, participants could choose more than one option for their travel preferences in the survey by Leger et al. (2018) [33]. Therefore, the cumulative percentages are higher than one hundred. In that study, the purposes for the usage of e-bikes were reported as commuting to work (more than 80 percent), recreational purposes (more than 90 percent), first-/last-mile travel (50 percent), and errands (more than 70 percent) in Ontario, Canada [33]. Li et al. (2020) reported that the most common purpose for the usage of docked bikes and e-bikes was commuting in Zurich, Switzerland [23]. In the COVID-19 period, the most common usage purpose was home activity, at 28.58 percent [23]. Pimentel and Lowry (2020) stated recreation purposes as the most common purpose for the usage of e-bikes, at 37.5 percent in Washington, Oregon, and Idaho, USA [38].

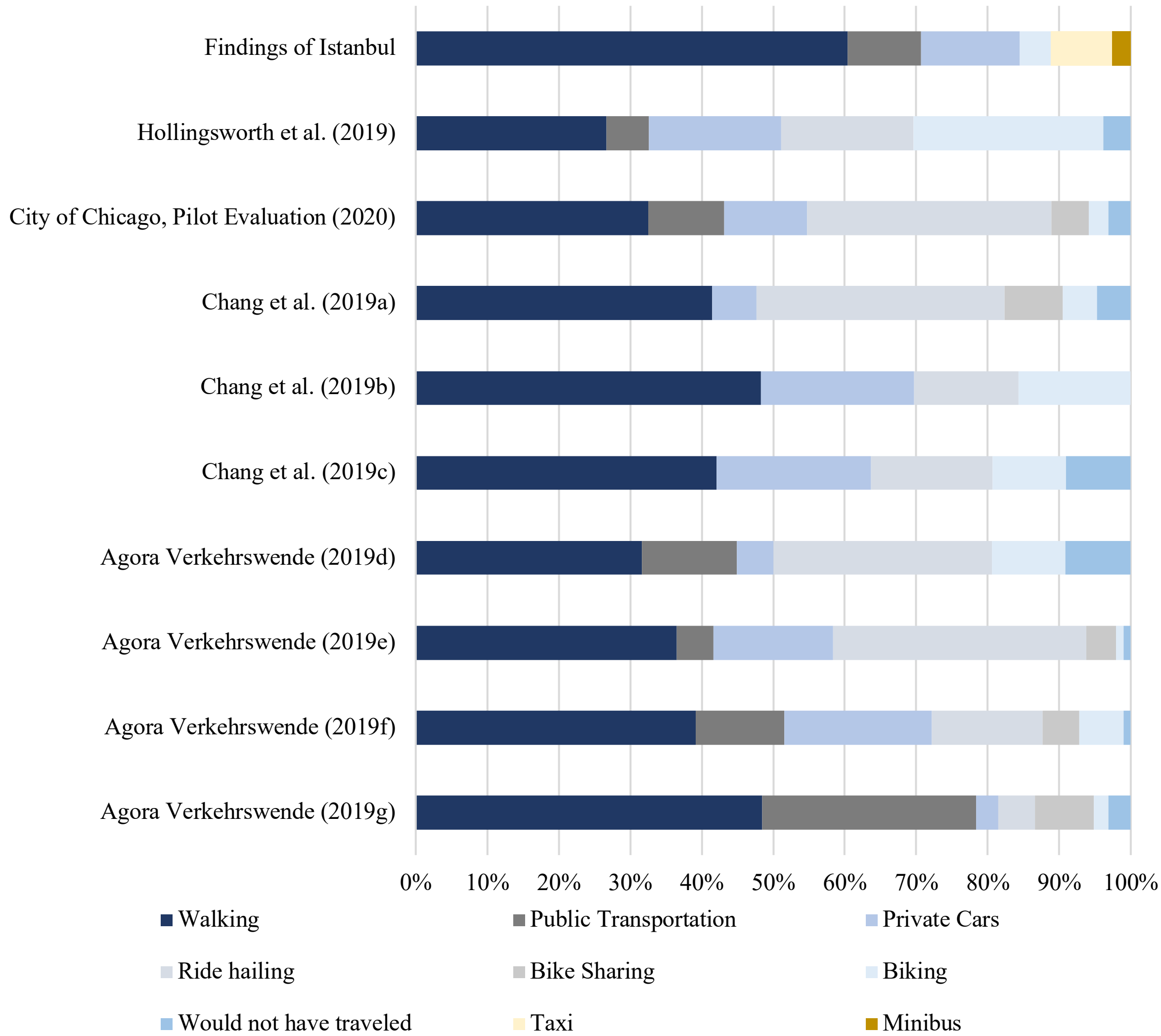
In the case of the purpose of the usage of e-bikes, most e-bikes are thus used for commuting. Admittedly, the purpose of recreation is also significantly common. Notably, in the study by Reck et al. (2020), they stated that docked modes were used mostly for commuting in Zurich, Switzerland [19]. Thus, we can presume that people's mode choices are more risk-free when traveling for certain reasons such as commuting [19].

5.1.4. Modal Shift to E-micromobility

Cities have been struggling with traffic congestion over the past several years. The modal shift from private cars to new mobility solutions such as ICT-based mobility modes and sharing modes in cities, particularly in central business districts (CBDs), will be a sustainable and effective way of improving urban transportation systems [40–43]. With the launch of e-micromobility in urban transportation, their use rises day by day. However, it has been stated that, based on the growth in the European and Asian scooter market since 2014, the modal shifts from walking and public transportation have been increasing oriented to this new mode of mobility [24]. It would be an advantage for urban sustainability if e-micromobility vehicles replace private cars and are used as last-mile or first-mile solutions as a complement to public transport.

As mentioned earlier, in the case of Istanbul, two types of questions structured to find the modal shift to e-scooter. It has been found out that most of the participants' walking habits tend to replace with e-scooters. Replacing walking was the highest rate by 60.3 percent, followed by replacing private cars was the second highest by 13.6 percent and replacing public transportation by 10.3 percent, replacing taxi was by 8.6 percent, replacing biking by 4.3 percent and replacing minibuses by 2.6 percent. Secondly, in their most recent trips if e-scooters were not available, 64.7 percent of the participants reported they would have walked, 11.2 percent would have used private cars, 10.3 percent would have used taxi and 6 percent would have used public transportation and 5.2 percent would have used biking. And again, walking is the most shifted mode of mobility.

Regarding three surveys by Agora Verkehrswende (2019), participants were asked that what they would have done in their most recent trips if e-scooters were not available and the answers are as follows, by 47 percent of French respondents would have walked, and 29 percent of them would have used public transportation instead of e-scooters, 20 percent of respondents in Portland would have used private cars, and 15 percent of them would have taken taxis, Uber or Lyft, if the e-scooters were not available and almost half of the tourists in Portland would have used cars and in San Francisco, one-third of participants would have used Uber, taxi or Lyft, if e-scooters were not available (Figure 30) [27].



[a] San Francisco, [b] Denver, [c] Portland, [d] San Francisco, [e] Portland (Visitors/Tourists), [f] Portland (Locals), [g] France

Figure 30. E-scooter Modal Shift

Chang et al. (2019) reported that 43 percent of the e-scooter users replaced walking and 14 percent of them replaced biking, 32 percent of them replaced ride sourcing and private vehicles in Denver [6]. In Portland, 37 percent of the participants reported that they would have walked, or 9 percent would have cycled in their most recent trips if e-scooters were not available [6]. According to a Lime survey in San Francisco, 61 percent of the participants reported they would have walked, 12 percent would have chosen station-based bike-sharing, and 7 percent would have chosen personal bike in their most recent trips if e-scooters were not available [6]. The survey of City of Chicago indicates that 31.8 percent of e-scooter users would have used ride-hailing, 30.2 percent would have walked, 10.8 percent would have driven, 9.9 percent would have used bus, 4.8 percent would have used bike-sharing, 4.2 percent would have used train, 2.9 percent would not have taken the trip, 2.6 percent would have cycled in their most recent trips if e-scooters were not available [25]. And regarding to Hollingsworth et al. (2019) in Raleigh, USA, end of the survey, it has been reported that 7 percent of users would not have taken the trip, otherwise, 49 percent would have biked or walked, 34 percent would have used a personal automobile or ride-share service, and 11 percent would have taken public bus in their most recent trips if e-scooters were not available [26]. It can be comprehended in Hollingsworth et al.'s (2019) study, nearly half of the respondents would have walked the distance they used for e-scooters in Raleigh, USA [26]. Therefore, it is assumed that they have been using the e-micromobility for the distance they could have walked, replacing walking is considerably high. In contrast, according to Cairns et al.'s (2017) pilot project in Brighton, known for extraordinary walking levels, using e-bikes during the project had reductions in car driving by 43 percent of the people [39]. According to Lime, 30 percent of users replaced car trips, while 27 percent used e-scooter as first-last mile solutions for their recent trip [44].

Notably, it was reported by Reck et al. (2020), that docked e-bikes were preferred for the commuting instead of using private cars in traffic in peak hours in Zurich, Switzerland [19]. Likewise, in the U.K and the Netherlands, e-bike users have replaced cars, as well as in Sacramento, California [33]. In contrast, in China e-bike users have replaced public transit [36]. And end of the Cairns et al. (2017)'s trial, it has been reported that 20 percent of car mileage is reduced and at least 70 percent of participants would like to have an e-bike in Brighton, UK [39]. They also found that most of the participants' walking habits tended to be replaced with cycling [39]. At the end of trial carried out by Castro et al. (2019), it was observed that among participants who replaced their mode of travel with e-bikes, 25 percent of participants used to travel by means of private motorized vehicles (car or motorbike), 23 percent of participants by means of non-electric bicycles, and 15 percent of participants by means of public transport, based on data from seven European cities [37]. In Antwerp, bicycle and private motorized vehicle users shifted to e-bikes; in contrast, public transport users shifted to e-bikes in Zurich [37]. According to the surveys conducted by Pimentel and Lowry

(2020) in Washington, Oregon, and Idaho, USA, it was found that 66 percent of the participants expected to use these modes of transport more often in the future [38].

Consequently, the modes of transport replaced by e-micromobility vehicles are different based on the country or even differ from city to city, e.g., in Denver 43 percent of e-scooter users replaced walking [6], yet in Raleigh 34 percent replaced personal automobile or ride-share services [26]. In cities with extreme urban density, people tended to replace public transportation with e-bikes [36]. In contrast, it was reported that e-bike users replaced more cars than other modes of transport in Sacramento, California [33].

Furthermore, millennials have a go-nowhere attitude and fewer traveling habits than back in the days. They do not tend to spend as much money on cars as previous generations did and for this reason, micromobility may be a more attractive form of transport for these people. It has been stated that car trips are the least joyful trips, and even this might cause a modal shift from the use of private cars [6]. According to Campisi et al. (2020), it has been declared that there is a correlation between car ownership (85.5 percent of participants) and the willingness to rent a micromobility vehicle [45]. Therefore, an increase in car ownership decreased the willingness to rent micromobility vehicles. Furthermore, it has been claimed that the likelihood of renting micromobility vehicles is higher among students compared to the working class [45].

5.2.Impacts on Energy Consumption

Two thirds of the world's population will live in cities by 2050, and inevitably, urban settlements will face several further problems [46]. Due to the fact that the world's resources are being depleted, cities are becoming less livable every day, e.g., global warming has reached a very serious level. To change this situation, it is reasonable to focus on cities, and the first place should be the transport sector, which is responsible for 24 percent of global CO_2 emissions, 29 percent of global energy demand, and 65 percent of the world's total oil consumption [47].

The development of e-micromobility might change overall energy consumption in the mobility sector. Bedmutha et al. (2020) indicated that if trips of 5–8 km that are currently made using conventional motorized vehicles were replaced with the use of e-micromobility vehicles, energy demand would drop by 50 percent in Pittsburg [48]. Since that study was based on Pittsburg, if we consider this in the wider context of the USA and China, which are the largest CO_2 producers in the world, e-micromobility could be a game-changer. In this section, the energy consumption of e-micromobility vehicles and their environmental impacts are reviewed.

The question of whether electric vehicles are energy efficient is still the subject of many studies, and there are many dependent variables in relation to this topic. Hence, it does not seem to be possible to reach a definitive conclusion for now. Nevertheless, in this section, the related studies are examined to gain a general estimation. Although there is not yet a very extensive body of literature on this subject, we have compiled and compared studies in terms of energy consumption per mile/km, as well as impacts on global warming in respect to environmental impacts, i.e., the amount of CO2 emitted per passenger-km will be compared among various modes of transport and studies.

As shown in Figure 31, Martínez-Navarro et al. (2020) estimated e-scooters' energy consumption to be 0.012 kWh/km, Brdulak et al. (2020) reported it to be 0.04 kWh/km, and Agora Verkehrswende (2019) reported it to be 0.01 kWh/km [27,47,49]. Plainly, the numbers by themselves do not mean anything; it is necessary to associate them with other comparable variables to reach a conclusion. Some comparative studies have indicated that electric scooters can travel 128 km with 1 kW/h of energy, whereas a gasoline-powered car can travel less than 1.6 km and a more energy efficient Tesla can travel 6.4 km with the same amount of energy [50]. Furthermore, approximately the same numbers are given in the study by Agora as follows—with the same amount of energy, an e-scooter can travel a 50-times greater distance than a conventional car [27]. Based on the Bird e-scooter, with 1 kW/h of energy, e-scooters can travel approximately 100 km, whereas an electric car can travel 6 km [27]. According to Brdulak et al. (2020), who made an assumption based on data from rental companies in Poland, an e-scooter can travel 100 km with 4 kWh energy [49]. According to Wired (2018), e-micromobility vehicles are 20 times more efficient than electric vehicles and 102 times more efficient than conventional fossil fuel vehicles; furthermore, e-scooters cover their cost in just 4 months and are seen as the most cost-effective vehicles for short distances compared to other transportation modes [44].

Hence, it shows that when e-scooters substitute either conventional cars or electric cars, it leads to a reduction in energy consumption for transportation. Meanwhile, studies have shown that the environmental impact of the amount of energy used while charging e-scooters has a considerably lower impact than their production phase and their collection each night for recharging [26].

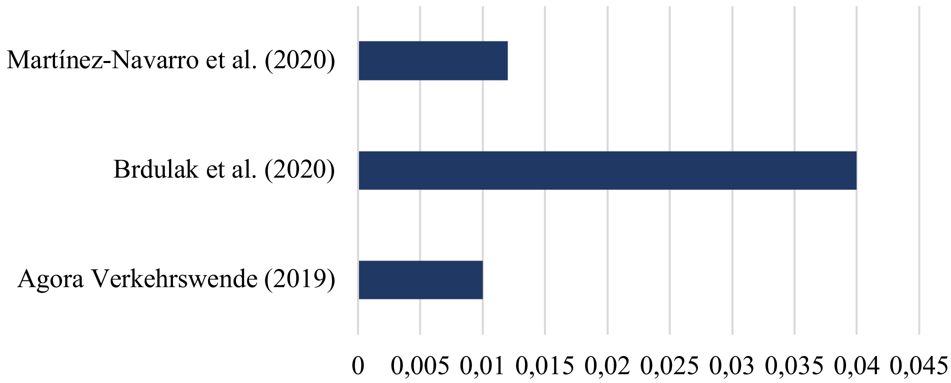


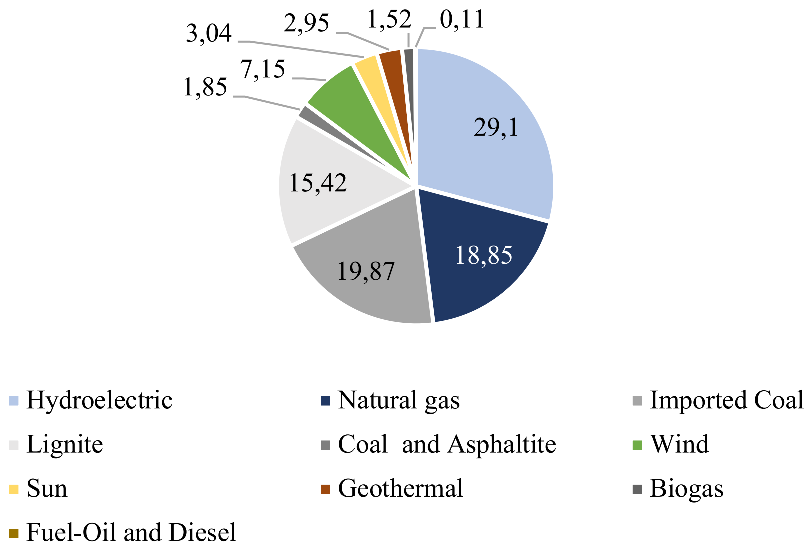
Figure 31. Energy Consumption of E-scooter (kWh/km)

A simulation of the demand for electricity in Poland from e-scooters was performed by Brdulak et al. (2020). At the time of their calculations, they made a four-year forecast, claiming that e-scooter ownership in 2023 would reach 30,000 vehicles, and they found that the daily energy consumption of an e-scooter was 1.12 kWh, and that 9.24 GWh was required by a city to power a private e-scooter fleet including 30,000 units for one year [49]. Moreover, to make a comparison, it has been stated that the energy demands of the Warsaw M1 and M2 Metro Lines annually totaled about 125 GWh in 2018, so the difference between two variables is considerably high [49]. In this case, the energy demand of private e-scooters would not be a major load for Polish cities if the ownership rate continues as expected [49]. Nevertheless, a transition to green energy solutions will be a necessary step to generate more electricity from renewable energy resources.

Modal shift from non-motorized modes which do not demand any energy to e-micromobility increases energy demands. If these energy demands continue to be supplied through electricity from fossil fuels, this will create a new burden on energy load, especially for countries that meet most of their energy demand through the use of fossil fuels.

The topographic profiles of cities should be considered in terms of the energy consumption of e-micromobility vehicles. The amount of energy used by e-micromobility vehicles is higher in hilly cities. Martinez-Navarro et al. (2020) estimated the maximum trip distance for e-scooters as 22.2 km with a fully charged battery [47]. However, the maximum travel distance depends on the battery capacity and life. Another factor to be considered is the different amounts of energy consumption between shared and private electric scooters and bikes [51]. To recharge shared micromobility vehicles, it is necessary to collect all the vehicles with combustion-engine cars/trucks, whereas for private scooters and bikes, there is no need for this surplus energy consumption [51]. However, if shared e-micromobility vehicles are used instead of unsustainable modes of transport such as private fossil fuel cars, then this disadvantage of surplus energy consumption can be ignored compared to the energy savings caused by the modal shift away from fossil fuel cars [51].

If we look at the Istanbul's energy situation through electricity generation, 78,822 GWh of electricity generated from Hydroelectric annually which was the highest rate of generation of electricity by 29.1 percent and followed by 60,394 GWh imported coal by 19 percent, and 57,288 GWh natural gas by 18.8 percent. Share of renewable energy generation in 2021 is 36 percent [52] (Figure 32).



Source: Turkish Electricity Transmission Corporation

Figure 32. Generation of Electricity in Turkey (2019)

If the popularity of e-scooters increases at this pace, it will be necessary to consider the extra demand for energy in a country with a renewable energy generation rate of 36 percent.

However, when the modal shift data was re-examined, it was seen that most of the participants, especially in Istanbul, tended to replace their walking habits with e-scooters with a rate of 60 percent, and the findings also show that 62 percent of the participants use e-scooters for fun and recreational purposes. In the light of these findings, it can be said that e-scooters are not very sustainable for urban transportation in the current situation, considering their purpose of use and the mode they replace. If the replaced mode would be more of private cars, this would be another case but in the current situation e-scooters cannot be sustainable unless the source of energy is used from renewable sources, since it is going to create an extra energy demand. Moreover, global findings show that the modal shift to e-micromobility depends on urban forms and travel culture. So, cities and people will show how this new mode integrates into urban transportation in the foreseeable future.

5.3.Environmental Impacts

Hollingsworth et al. (2019)' conducted a Monte Carlo analysis about e-scooter's CO2 life cycle and they estimated 125 g CO2-eq per passenger per km, which 50 percent of this amount comes from materials and manufacturing, 43 percent from the collection for overnight charging (Figure 33) [26].

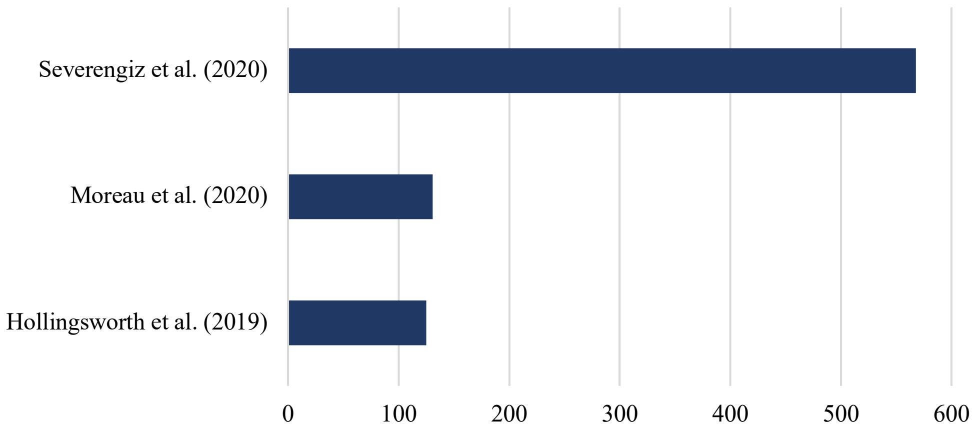


Figure 33. E-scooter's Environmental Impact (g CO2- eq/passenger-km)

Moreau et al. (2020) estimated the global warming potential (GWP) of the use of shared e-scooters and regarding that the GWP was 131 g CO_2-eq/passenger-km more than the users' replaced mode of transportation, which is 110 g of CO_2- eq/passenger-km [53]. On the other hand, it should not be ignored that all of these are related to the short lifetime of the vehicles, because this finding was based on the shared e-scooters, which have a shorter lifespan compared to private e-scooters, and private e-scooters' CO_2-eq/passenger-km is 67 g [53]. Thus, the difference in CO_2-eq/passenger-km between shared and private e-scooters is considerably high. There are dozens of pieces of misinformation about these vehicles' lifespans. The lifetime of e-scooters varies according to the quality of the product. There are even rumors that shared e-scooters last only 28 days [54]. Another opinion on this issue is that first generation shared e-scooters are not designed for renting in the United States and their lifespan has become very short due to irresponsible use by people, and today their average lifespan is reported to be 2 years [54]. In addition, there have been some improvements to the overnight charging collection process. Now, most e-scooter companies use swappable charging batteries and collect these batteries with the use of e-cargo bikes. This makes the whole process more energy efficient [26].

5.4. Safety Issues and Regulations

E-micromobility has shown a sharp growth rate in many cities. Therefore, it is essential to consider the infrastructure of the docked or dockless e-micromobility vehicles in the urban management of space, pavement and curb as well as identify the related safety issues, and potentials for accidents, and causalities. Then implementation of regulations will have a visible counterpart in city infrastructure. As explained in the previous chapter, e-micromobility trips had boosted more when the e-scooter entered the market in 2018. However, most users still do not know how to use them properly and even though their speeds around 25 km per hour, it poses a huge safety risk. If we look at the e-scooter accident numbers, the Austin Public Health Report (2019) indicated that 20 trips out of every 100,000 e-scooter trips resulted in injuries during their study time [6]. According to the other study by Trivedi et al. (2019), 249 e-scooter accidents were reported in Southern California between September 2017 to August 2018, and 80 percent of injuries are fell, 11 percent crash to an object, and 9 percent hit by moving vehicle [55]. The other study on injuries by Feng et al. (2020), collected tweets and images between 2018-2020 and reported 153 injuries, 22.88 percent of them are head-related, 27.45 percent of them are trunk and hands related, and 49.67 percent of them are legs and foot-related [20]. According to AASHTO 's guide, cycling or riding on sidewalks causes more accidents than when they ride on the road [6]. Because sidewalks are designed for pedestrians, that's why cyclists are not capable to ride on sidewalks properly, and e-scooter users had very low helmet use rates. Furthermore, when they investigated the injuries, they found that only less than 5 percent of users wore a helmet [6]. Additionally, the City of Chicago Pilot Evaluation Survey (2020) shows us 24 percent of the participants stated that they used the e-scooter on the pavement at least for a while, and 5 percent of them used it on the pavement at least half of the time [25]. Observations made as 10 percent of riders used the e-scooter on the sidewalk at the street with a bike lane, and 2.7 percent of riders wore a helmet [25]. Observations for parking show that 18.4 percent of e-scooters are incorrectly parked on the sidewalk, especially on cycle paths etc. This is another safety issue for pedestrians and people with disabilities [25].

Another case from Italy, reported by Campisi et al. (2020), due to comfort and safety reasons, men tend to use e-scooters more than women [45]. E-scooters have been used at approximately 17 km/h on shared sidewalks, which occurs danger for pedestrians [45].

Safety issues mostly come from the right of way confusion and inappropriate parking, these causes mostly accidents, and we can see low rate of wearing helmet, as well. Furthermore, Pimentel and Lowry (2020) stated that also misinformation causes safety problems. Users should be informed about the rules [38].

Glancing at e-scooter regulations, it is quite possible to encounter inconsistent policies across states, cities, and regions. One of the reasons for these policy inconsistencies is that e-scooters are a new and dissimilar mobility mode, though they have become one of the basic ones. These differences among regulations have surely been expected, since city administrators have tried to regulate e-scooters based on the user experience to date [56].

And in the case of Istanbul, very first e-scooter launched in Istanbul in 2019 with the company is called "martı" and after this, other companies quickly entered the market, as well. Following Istanbul, e-scooters, which aroused great interest, have been used in other big cities. With the increasing usage and the growth of the market, the companies started a competition among themselves and made various pricing policies. The importance of regulations has increased from the perspective of both investor and entrepreneur, as well as user and pedestrian safety. Some e-scooter companies in Istanbul can be listed as; Bin Bin, Gezici Electric Scooters, MOBI, Palm Tech, HOP! Scooters, DUCKT, Kumru Scooter, ETKU.

In order to organize the whole e-scooter business activities as required by the country's economy and to maintain order and safety, to protect environment by reducing the negative effects of transportation, to increase mobility and to use shared e-scooters instead of using private vehicles for short-distance trips, and determine rights, obligations and responsibilities of service providers and service beneficiaries and integration into the sustainable transportation system with other transportation modes. Hence, the Ministry of Infrastructure and Transportation started to prepare legislation on this issue in August 2019. And regulation of e-scooter is published on 14th April 2021. The basics of this legislation can be summed up in three areas: (i) safety measures, (ii) licensing, and (iii) usage planning. Rules are as follows; e-scooter is prohibited from riding on pavements and if there is a separate bike path or bike lane it is prohibited riding on the road and on highways, intercity highways with a maximum speed limit of 50 km/h as well. And it is forbidden that two e-scooters go side by side on the road and riding by hold onto another vehicle or hanging and riding by performing acrobatic movements, except for the shows performed with permission, riding with one hand, except when signaling for maneuver, parking in a way that violates public order, violates private property, and prevents safe and independent movements, vehicle, and pedestrian traffic of pedestrians, the disabled or people with reduced mobility. It is forbidden that while following, passing, maneuvering other vehicles behaviors that make the movement of road users difficult and dangerous, transportation of other people other than the driver, carriage of cargo and passengers other than personal belongings that can be carried on the back. E-scooter to be used; easily noticed by other vehicle drivers and pedestrians at night; It must be equipped with a headlight giving white light at the front and illuminating the front for at least 20 meters, a lamp giving a red light at the rear, a red reflector, and a bell, horn or similar sound device that can be heard from 30 meters away. And it is determined that the maximum speed limit for e-scooters as 25 km/h. In addition, it is foreseen those scooters will not be used on intercity roads and highways with a maximum speed limit of 50 km/h. Preventing the use of more than one person at the same time in terms of users; The subjects of encouraging the use of protective equipment such as helmets, knee pads, reflectors and jackets and introducing license requirements are regulated. Secondly, companies that will operate in the e-scooter industry will need to obtain a permit from the e-government. To launch the e-scooters to the market, some requirements as follows; a minimum of 500,000 Turkish Liras capital, at least two thousand e-scooters and must have a mobile application. Following, companies that will operate in the market must apply to the Transportation Coordination Center or Provincial Traffic Commission for e-scooters and obtain a usage permit. Finally, while addressing the usage planning to be integrated with public transportation vehicles in every city and providing support to users through call center and mobile applications, it is also brought to the agenda to promote companies using domestic products within the scope of encouraging the use of domestic software and hardware [57].

As shown in Table 3, studies including the regulations and restrictions of e-micromobility from other countries and cities are presented. First, we found that many studies have started to regulate these vehicles, primarily by restricting age and speed. Concerning regulations on the speed of these vehicles, the limit in Poland is 25 km/h [18]. The speed limit in Chicago is 15 mph, which is approximately 24 km/h, and in Oregon the limit is also 15 mph, except there is an inconsistency in Oregon, namely, that micromobility vehicles are also prohibited from traveling at a slower speed than the speed of traffic, i.e., traffic flows at 25 mph, so e-scooters should not travel more slowly than 25 miles per hour (approx. 40 km/h) [25,58]. In this case, how quickly should e-scooter users ride? Another significant regulation from the studies collected here—and perhaps the most agreed-upon one—is the prohibition of riding these vehicles on the pavement. Considering the pedestrians' rights of way and the higher risk of accidents on the pavement, this decision can be seen to be a highly appropriate decision.

Table 3. Literature Review About Regulations

Source	Literature review about regulations
Istanbul	E-scooter is prohibited from riding on pavements and if there is a separate bike path or bike lane it is prohibited riding on the road and it is determined that the maximum speed limit for e-scooters as 25 km/h.
Bielinski and Wazna (2020)	In Poland, the speed limit is designated as a maximum 25 km/h for shared e-scooters.
Campisi et al. (2020)	In Italy, the use of micromobility is limited and applying the license to rent vehicles, for certain age groups and for using at certain of the day and the places where you can use micromobility vehicles, and the speed of travel is regulated by rules.
City of Chicago, Pilot Evaluation (2020)	In Chicago, the travel speed of e-micromobility is limited to 15 mph (approx. 24 km/h), and their use on pavements is prohibited, they will be used on bicycle paths, but as an exception, children under 12 years of age can use on the pavement. The age restriction for shared electric scooters is designated as 18. Only 16-year-olds can ride with a guardian.
Feng et al. (2020)	Based on the ten cities in USA, users are required to wear protective gear such as a helmet when using e-scooters. Stickers or lights should be used to make a difference for night rides. Drivers should not use electronic devices while driving, nor should more than one person use a vehicle unless it is not specifically designed for more than one person. E-scooters can be used on bike paths or on the sidewalk with speeds of 15 mph (approx. 25 km/h) and cannot be parked in car parks or parked in a way that prevents pedestrians.
Leger et al. (2018)	In British Colombia age limit is 6+, max speed is 32km/h, in most regions no need for licenses or registration, but a helmet is required. In Alberta, the age limit is 12+, the helmet is required in most regions, in Manitoba and Quebec age limit is 14+.
Pimentel et al. (2020)	The study states that the main problem is inconsistencies in the law. For instance, in Oregon, e-scooters are

	prohibited used on the pavement, and the speed limit is 25 km per hour (approx. 15 mile/h), although by law, micromobility vehicles are also prohibited from traveling at a slower speed than the speed of traffic, i.e., if traffic flows at 25 mph, e -scooter should not travel slower than 40 km. In West Hollywood, California, e-bikes are prohibited from driving on the sidewalk. In King County, Washington, wearing a helmet is mandatory but not mandatory in other parts of the state. When an E-micromobility user changes the district, the age restriction application may change. Helmets are not compulsory when using e-bikes and e-scooters in more than 20 states, although 6 states have required helmets for e-bike users.

In Japan, e-scooters are prohibited to be used on the pavement and riders should have license plates [59]. In Dubai, the age limitation is 14, riders must wear a helmet and park at designated areas, and riders are prohibited from carrying objects or a second passenger [60].

Another implementation that differs among countries is the pricing policy. In this context, the EU exhibits the cheapest price, almost half of that of the US, and China applies a 20 percent higher price than the US price [21]. Pricing could seem like a company strategy. However, it is indirectly a city policy that affects people's travel behavior. Furthermore, regarding alternative payment options, Atlanta and Los Angeles require non-credit card payment options, and for non-smartphone users, it is mandatory to have alternative activation methods in Austin, Los Angeles, and Portland [61]. After rising numbers of e-scooters in the streets of Paris between 2018 and 2019, the city authorities restricted the shared e-scooter fleet in the city due the fact that too many companies were entering the market, with numerous vehicles without any regulation [62]. In Paris, the service providers are limited to just three companies, and a limit of 15,000 total vehicles, and this is also the case in San Francisco, Atlanta, and Washington DC. In addition, e-scooters are restricted to bike lanes, with designated parking spots [62,63]. Moreover, regarding the positive impacts of online navigation apps on the sustainable mobility behaviors of citizens through optimizing travel time and route planning [64], there is a potential to use these online platforms to inform citizens about the accessibility of shared e-scooters and their regulations and restrictions in different urban zones.

The other important thing to consider is e-scooter companies' disruptive distribution strategies, which affect the right of equal access to services and limits e-micromobility usage. Equal distribution of services is one of the basic principles that city administrators should consider [56]. For example, in the USA, in Portland, 15 percent of the e-scooter fleet must be available in East Portland, but in Charlotte, Austin, and Los Angeles, there is no such practice yet [61]. This practice is mostly made so that low-income regions can obtain equal access to the service. Incentives have been provided to some companies that implemented the principle of equal distribution in Los Angeles [61].

It is also crucial to consider that the popularity of e-micromobility has increased during the COVID-19 pandemic, and cities have embarked on quick implementations, with effects on the infrastructure of these cities. Some of these implementations are as follows—in Milan 35 km, in Paris 50 km, in Brussels 40 km, and in Seattle 30 km of car lanes have been converted to bicycle lanes [35]. According to McKinsey and Company (2019), the micromobility industry will be a USD 300 billion to USD 500 billion market by 2030 [31]. Still, the effects of the pandemic on the industry and the micromobility market cannot be known for certain. Hence, to examine this accelerating market and to prepare cities for its adoption, as well as to create more sustainable, equitable, and more livable cities, regulations will have to apply in this field.

6. Analysis

The Student's T-test is a statistical analysis method for independent groups, and it was used to test whether the means of two groups differ from each other [65]. Basic assumptions of the Student's T-tests are as follows;

1. The groups to be compared are independent of each other (e.g., men and women).

2. The measurements obtained from these groups must be measured at least at the equally spaced scale level.

3. The variables in each group must show a normal distribution.

The descriptive statistics tables below are given the groups' basic information such as how many people are in each group and the mean and standard deviation of each group (Table 4).

And one of the assumptions of the Student's t-test is that the variances in the two groups are similar. This assumption is tested by Levene’s test. The independent samples test table shows that the F value which is the test statistics of Levene’s test, and the Sig. value is used to test whether the variances are homogeneous and if the Sig. value is greater than 0.05 means that the variances are homogeneous. If the variances are homogeneous, the p-value in the first line is preferred which is the “equal variances not assumed” row for the t-test, and if not, the p-value, which is “equal variances not assumed” row, is preferred and it means that p-value of Levene’s test (Sig.) is less than 0.05, thus it is accepted that the variances of groups are significantly different from each other [66].

After testing equality of variances, if the Sig. (2-tailed) value is less than 0.05, it means that group means are significantly different from each other, if the Sig. (2-tailed) value is higher than 0.05, there is no significant difference between the two variables.

The data were coded to analyze the relationship between the usage parameters of e-scooter and gender. The first usage parameter of e-scooter is the usage frequency of e-scooter, and its data were coded as follows;

- Never used in my life = 0
- A few times in a year = 1
- A few times per month = 2
- Once per week = 3
- 2-3 days per week = 4
- Every day = 5

The second usage parameter of e-scooter is duration of e-scooter usage, and its data were coded as follows;

- Less than 5 minutes = 1
- 5-10 minutes = 2
- 10-15 minutes = 3
- 15-20 minutes = 4
- 20-30 minutes = 5
- More than 30 min = 6

The third usage parameter of e-scooter is distance of e-scooter usage, and its data were coded as follows;

- Less than 1 km = 1
- 1-3 km = 2
- 3-5 km = 3
- 5-9 = 4
- More than 9 km = 5

6.1.Frequency of E-scooter Usage and Gender Analysis

The relation between gender and frequency of e-scooter usage was analyzed by Student's T-test. As seen in Table 4 descriptive statistics, 144 females and 96 males were in the group. And mean of each group was 0.6 and 1.2.

Table 4. Descriptive Statistics Table of Frequency of E-scooter Usage

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
EscooterNum	Female	144	.6458	.89653	.07471
	Male	96	1.2604	1.55763	.15897

When we look at Levene's test Sig. value is 0.00, so $p < 0.05$ which means variances are not homogeneous. Thus, we should look at the "equal variances not assumed" row for the t-test. In the second row, Sig. (2-tailed) value is 0.01 which is below 0.05, so it can be said that the variances are not homogeneous, and females and males have a significant difference in terms of usage frequency of e-scooter.

Table 5. Student's T-test Analysis of Frequency of E-scooter Usage

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
EscooterNum	Equal variances assumed	31.177	.000	-3.872	238	.000	-.61458	.15874	-.92729	-.30187
	Equal variances not assumed			-3.499	137.152	.001	-.61458	.17565	-.96193	-.26724

Consequently, it is proven that females and males have different usage patterns in terms of the frequency of e-scooter usage. As can be seen from the mean of variables, the females' mean was 0.5. This can be interpreted that female frequency of usage is between "never used in my life" and "a few times in a year". And for males, the mean was 1.2 which is between "a few times in a year" and "a few times per month". This situation shows that the frequency of usage of e-scooter by females is less than males. Many reasons can lead to this situation, such as females not feeling secure or comfortable while driving e-scooter. And it should be noted that the most common reason that people not using e-scooter was the lack of bike lanes in Istanbul.

6.2.Duration of E-scooter Usage and Gender Analysis

The second Student's T-test compared the means of duration of e-scooter usage in gender base. As seen in Table 6 descriptive statistics are indicated as 63 females and 53 males were in the group. The total number of groups is different from the total number of people in the analysis of frequency of e-scooter usage (Table 4). The reason for this is that those who have never used e-scooters before were not included in the time and distance analysis. The mean time for each gender was 2.81 and 3.13.

Table 6. Descriptive Statistics Table of Duration of E-scooter Usage

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Time	Female	63	2.81	1.366	.172
	Male	53	3.13	1.744	.239

To check the equality of variances, looking at Levene's test and "Sig." < 0.05 which means variances are not equal. In this case, the "equal variances not assumed" so the bottom line is considered and the values in the top line would be ignored (Table 7). Accordingly, Sig. (2-tailed) value is 0.27 which is higher than 0.05, thus it can be said that the variances are homogeneous.

Table 7. Student's T-test Analysis of Duration of E-scooter Usage

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Time	Equal variances assumed	4.924	.028	-1.117	114	.266	-.323	.289	-.895	.250
	Equal variances not assumed			-1.094	97.723	.277	-.323	.295	-.908	.263

Hence, between females and males has no significant difference in terms of the time of e-scooter usage. If we look at the means of both groups, they used e-scooter mostly between 5-15 minutes.

6.3.Distance of E-scooter Usage and Gender Analysis

At the third analysis, the relation between gender and distance of e-scooter usage was analyzed by Student's T-test. As seen in Table 8 descriptive statistics are shown that 63 females and 53 males were in the group. And the mean of each group was 2.38 and 2.98.

Table 8. Descriptive Statistics of Distance of E-scooter Usage

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Distance	Female	63	2.3810	1.40768	.17735
	Male	53	2.9811	1.48700	.20426

If we look at Table 9, Levene's test' Sig. value is higher than 0.05, which means variances are homogeneous, and the "equal variances assumed" row has to be looked at. The first row indicates that the Sig. (2-tailed) value is 0.028 which is less than 0.05, thus it can be said that the variances are not homogeneous and there is a significant difference between female and male data about how far they use e-scooter.

Table 9. Student's T-test Analysis of Distance of E-scooter Usage

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Distance	Equal variances assumed	.013	.909	-2.229	114	.028	-.60018	.26922	-1.13350	-.06685
	Equal variances not assumed			-2.219	108.324	.029	-.60018	.27051	-1.13635	-.06401

It can be stated that female and male means are significantly different about how frequent and how far e-scooter using. The frequency of usage of e-scooter by females is less than males. Many reasons can lead to this situation, such as females not feeling secure or comfortable while driving e-scooter because of the lack of bike lanes in Istanbul. In terms of the duration of e-scooter usage, gender has no significant effect, but there is a significant difference in distance between the two genders. This difference can be assumed as males using e-scooter faster than females because of the absence of a significant difference between the means of the durations. The significant difference between the means of the distances might be explained by the speed of the e-scooters.

Conclusion

This study tried to shed light on the impacts of e-micromobility on the sustainability of urban transportation whereas comparing Istanbul, and findings from the global mobility studies. First, the survey was conducted with 240 people based in Istanbul, and the findings of this survey were presented. The study of e-micromobility impacts was categorized into 4 sub-topics in the terms of travel behaviors, energy consumption, environmental impacts, and related safety issues and regulations.

The impacts of e-micromobilities on travel behaviors have been identified with certain parameters such as average travel time and distance, travel purposes, and modal shift from different modes to e-micromobilities. And findings show that the average traveled distance for Istanbul was 3.1 km. However, literature findings were mostly between 0.72 and 2.4 km for average e-scooter distance and Istanbul's average distance is slightly higher than overall findings. This may be associated with the considerably wide surface area of Istanbul; distance would take longer going to or from one place to another. As well as the average duration from Istanbul was 11.8 minutes and global findings were between 8 and 12 minutes, so Istanbul's average traveled duration by e-scooter is close to the highest average duration of the overall findings and considering the average traveled distance that is very expected. However, most studies reported the average traveled distance by e-bike in the range of 3-4.5 km and traveled time in the range of 15 and 20 minutes. Therefore, e-micromobility has the capability to be used for all trips which are less than 8 kilometers, consisting of 50 to 60 percent of total trips in China, the European Union, and the United States [31]. So, these findings indicate a great potential for the modal shift to e-micromobilities. Plus, people tend to use e-scooters for a longer distance than before, instead of using public transportation during COVID-19 [31,32].

Though, according to the modal shift data, it has been found out that most of the participants' walking habits tend to replace with e-scooters, especially in Istanbul. The findings show that replacing walking was the highest portion by 60.3 percent in Istanbul and the global findings indicate that the modal shift to e-micromobility depends on the urban forms and the travel culture. For instance, the second most replaced mode was ride-hailing in the American cities, while in France it was public transportation [27]. When we look at the e-bike's modal shift, in countries with an extreme urban density such as China, people tended to replace public transportation with an e-bike, in contrast, it was reported that e-bike users replaced more cars than other modes in most of the US's cities [26,33,36]. Again, it can be said that replaced mode depends on the people's travel behaviors and city culture. Though in the current situation it has been shown that most people replaced walking which means a substantial increase in the energy demand through the modal shift from non-motorized modes to e-modes.

Another key finding from this research is the usage purpose of e-micromobilities. In Istanbul, 62 percent of the participants use e-scooters for fun and recreational reasons. In the USA, commuting to work/school and fun/recreation proportions were notably close to each other [6,25,38]. Precisely, in Chicago, 50 percent of users stated that they have been using e-scooters for social/entertainment reasons, however, in Austin, Portland, and San Francisco, the specified purpose of usage was mostly commuting to work or school [6,25]. In the case of e-bikes' purpose of usage, most of the e-bikes were using for commuting. Admittedly, the purpose of recreation was significantly much, as well.

Furthermore, the findings in the field of the energy consumption indicate that e-scooters could travel 128 km with 1 kW/h of energy, which a fossil fuel car can travel less than 1.6 km and the best-in-class e-cars can travel 6.4 km with the same amount of energy [50]. The e-micromobility development might change overall energy consumption in the mobility sector. The findings in Pittsburg indicated that the modal shift from the conventional motorized modes to e-micromobility for the trips in the range of 5-8 km would decrease the mobility energy demands by 50 percent [48]. In terms of the environmental impact of this mobility mode, e-scooter's CO_2 emission is approximately between 125-131 g per passenger per km, including 50 percent from manufacturing process and materials, 43 percent from the collection for overnight charging. Therefore, their lifespan has an important environmental impact, because of the considerable emission of their production process [26,54,55].

However, when the modal shift data was re-examined, it was seen that most of the participants, especially in Istanbul, tended to replace their walking habits with e-scooters with a rate of 60 percent, and the findings also show that 62 percent of the participants use e-scooters for fun and recreational purposes. In the light of these findings, it can be said that e-scooters are not very sustainable for urban transportation in the current situation, considering their purpose of use and the mode they replace It would be an advantage for urban sustainability if e-micromobility vehicles replace private cars and are used as last-mile or first-mile solutions as a complement to public transport but in the current situation, e-scooters cannot be sustainable unless the source of energy is used from renewable sources, since it is going to create an extra energy demand. If the popularity of e-scooters increases at this pace, it will be necessary to consider the extra demand for energy in a country with a renewable energy generation rate of 36 percent.

Regarding safety issues and regulations, the mentioned benchmarks in this study give city authorities and regional planners an insight into how the infrastructure of e-micromobility should be integrated into cities to assure the safety of the citizens.

Lastly, the Student's T-test revealed that the means of males and females have a significant difference in how often and how far e-scooter use was in Istanbul. As a result of the analysis, it has been proven that the frequency of use of e-scooters by females is less than males. Many reasons can lead to this situation, such as the fact that females do not feel safe and comfortable while using e-scooters due to the lack of bicycle paths in Istanbul. In addition, the result of the analysis shows that gender does not have a significant effect on the duration of e-scooter usage, but gender has a significant effect on the usage distances of e-scooter. It can be assumed that males use e-scooters faster than females since there is no significant difference between the means of duration but the distance.

Research Limitation and Recommendations for The Further Research

This study gives an idea about the impacts of e-micromobility on urban transport in terms of four aspects such as impacts on current travel behaviors, energy consumption, urban environment, safety issues, and required regulations. However, it is suggested to investigate surplus energy demand for future research, considering that the energy demand will increase due to the modal shift from non-motorized to e-micromobility. Another future research suggestion is to investigate the impacts of land use parameters and urban forms on citizens' propensity to use e-micromobility, as well as the impact of population density on mode choice.

Besides, the advanced survey is suggested for Istanbul to find the exact numbers of future energy demand, to investigate e-scooter impacts on land use and mode choice parameters.

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