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Analysis of traveler's behavior using electric scooters based on surveys.

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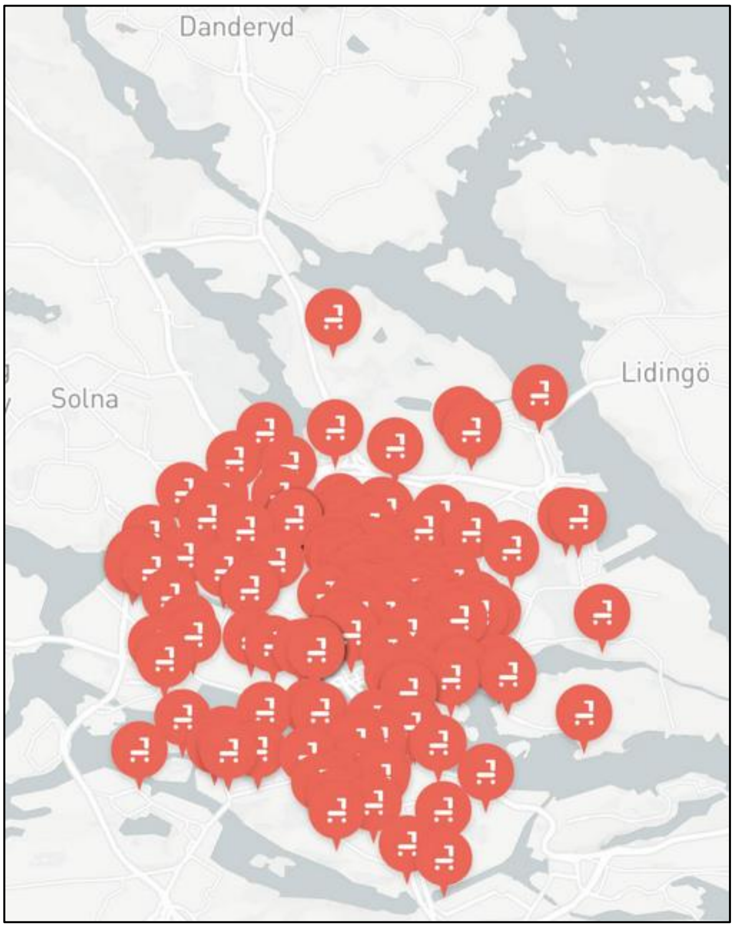
Analyses of travelers' behaviors using E-scooters based on surveys validated by historical data.



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Summary

In this study, travel behavior for the users of E-scooter is analyzed based on survey questions. The main purpose of the study is to understand the nature of E-scooters users and their preferences as well as analyzing their trip parameters. The survey was designed to cover most of the behavioral influential factors. To represent the motives and barriers towards E-scooter adoption in greater Stockholm. it was sectioned into demographic data, general travel preferences, E-scooter choice preferences, last trip parameters and general discussion questions.
Findings of this study suggested that E-scooters are mainly used by residents aged between 18-24. In Stockholm, public transportation facilities are very accessible and affordable than other private transportation modes. Travel time and travel cost were highly evaluated by the users and were considered as deciding criteria prior to making any trip in Stockholm. Findings suggested that trips made by E-scooters are mainly for fun and leisure rather than commuting and services. However, regarding normal trips, it was found that walking replaced the use of E-scooters more often. Historical data was used to validate and support the survey findings. Survey questions did not consider questions regarding impacts of COVID-19 on travel behaviours as well as the changes in travel patterns. Furthermore, the absence of highlights on research areas such as safety which covers the adoption of risky behaviours (i.e., driving on sidewalks, driving opposing traffic flow) and helmet use. The tool was used for research purposes was 'Questionpro'.

Sammanfattning

I denna studie analyseras resebeteendet för användarna av E-scooter baserat på enkätfrågor. Huvudsyftet med studien är att förstå E-scooters användares natur och deras preferenser samt att analysera deras tripparametrar. Undersökningen var utformad för att täcka de flesta av de beteendemässiga inflytelserika faktorerna. Att representera motiv och barriärer mot e-scooter-adoption i större Stockholm. den delades in i demografisk data, allmänna resepreferenser, val av E-scooter-val, parametrar för sista resan och allmänna diskussionsfrågor. Resultaten av denna studie föreslog att E-skotrar huvudsakligen används av invånare i åldrarna 18-24. I Stockholm är anläggningar för kollektivtrafik mycket tillgängliga och prisvärda än andra privata transportsätt. Restid och resekostnader utvärderades mycket av användarna och ansågs vara avgörande kriterier innan de gjorde en resa i Stockholm. Resultaten föreslog att resor med e-skotrar främst är för skoj och fritid snarare än pendling och tjänster. När det gäller normala resor fann man dock att promenader ersatte användningen av E-skotrar oftare. Historiska data användes för att validera och stödja undersökningsresultaten.

Keywords

Micro mobility, E-scooters, Travel Behavior, Analysis of travel behavior, Travel parameters, Transport policy.

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NOMENCLATURE

Abbreviations

MOD	Mobility on demand
MaaS	Mobility as a service
SL	Stockholms lokaltrafik (The public transportation authority of Stockholm)
GHG	Greenhouse gas
ID	Identity
GPS	Global positioning system
QR	quick response
SEK	Swedish crowns
URL	Uniform resource location
CSV	Comma separated values.

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1. INTRODUCTION

1.1. Theoretical background

1.1.1. Mobility Theory

Technological advancements are now taking new shifts in all fields including environmental and transport. The same applies for transportation at which shared and on-demand mobility are now one of the most notable shifts in the 21st century. Recently, an increase in the demographic trends, private vehicles, climate change and environmental impacts led to some suggestions that actions should be taken against private vehicle use. Simultaneously, these trends have led to the growth of mobility on demand (MOD) modes (Shaheen and Cohen 2020). Mobility is defined as the ease of accessibility to the places necessary for living and healthy life. These places might be school/workplaces, sporting facilities, groceries and markets. The basic definition of "on demand" is where users have access to various goods and on demand services (Shaheen and Cohen 2020). In other words, maintaining accessibility to an increasing demand service. MOD various approaches and innovations have appeared such as bike sharing, carsharing, MODs transport and pooling service companies (Shaheen and Cohen 2020).MOD makes concrete changes if the following concepts are satisfied:

1- The commodity of transportation. i.e., presenting transportations as a commodity where all transport modes have cost in terms of waiting times, in vehicle times, fleet sizes and other parameters.
2- The aggregation of user needs: i.e., embracing all types of passengers having special purposes and disabilities. Services shall include all people with different needs.
3- A strategy for improving the efficiency of the transportation network. Including management of the supply and demand. Allowances for investors to introduce new approaches that compromise with all stakeholders' needs and transportation policies and based on these three concepts, mobility on demand is built and implemented.

On the other hand, the aggregation and introduction of the previously mentioned services by one enterprise is defined as mobility as a service (Maas). An example of Stockholms lokaltrafik (SL)-The Stockholm public transport authority- which a variety of subscribed services are offered to the users. The figure below illustrates the difference between the MOD and Maas and where both meet.

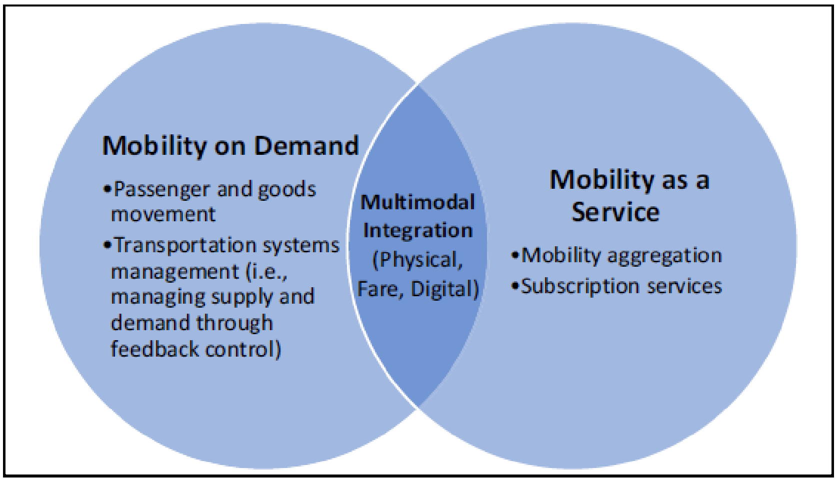


Figure 1: Definitions of mobility on demand versus mobility as a service (Maas) , from Shaheen and Cohen (2020)

1.1.2. Shared micro mobility concept, impacts and evaluation methods.

The shared micro mobility concept enables individuals to have access to lower speed modes for last mile trips. These forms of micro mobility can either be station-based electric bicycles, dockless electric bicycles or E-scooters. Since the introduction of micro mobility forms over the last decade, the trend has been growing which increased the demand for curb access. The development of micro mobility forms will change travel and delivery methods which might affect other public facilities on the other hand, thus thoughtful planning should include full understanding of these impacts to balance between public and commercial interest and maximize the social and environmental benefits at the same time (Shaheen and Cohen 2019).

Studies have been conducted on the GHG mitigation by shared mobility (car sharing, bike sharing and ride sharing). Impacts on environment were found to be significant (Roukouni and Homem 2020). For micro mobility, potential results in a significant decrease in greenhouse gas (GHG) emissions and minimizing other environmental impacts of other forms such as noise, pollution and low air quality (McQueen, MacArthur, and Cherry 2020).

The shared mobility concept has been a back-to-back objective for policy makers and individuals within the community. It has been adopted in all major cities around the world and defined as the seek of destination rather than using private modes (Roukouni and Homem 2020). Forms of shared mobility are wide and varied such as bike sharing, car sharing as shown in the figure 2. One of the fast-growing organisations in the last decade was Uber which has adopted the concept by ensuring mobility among people using their private cars.

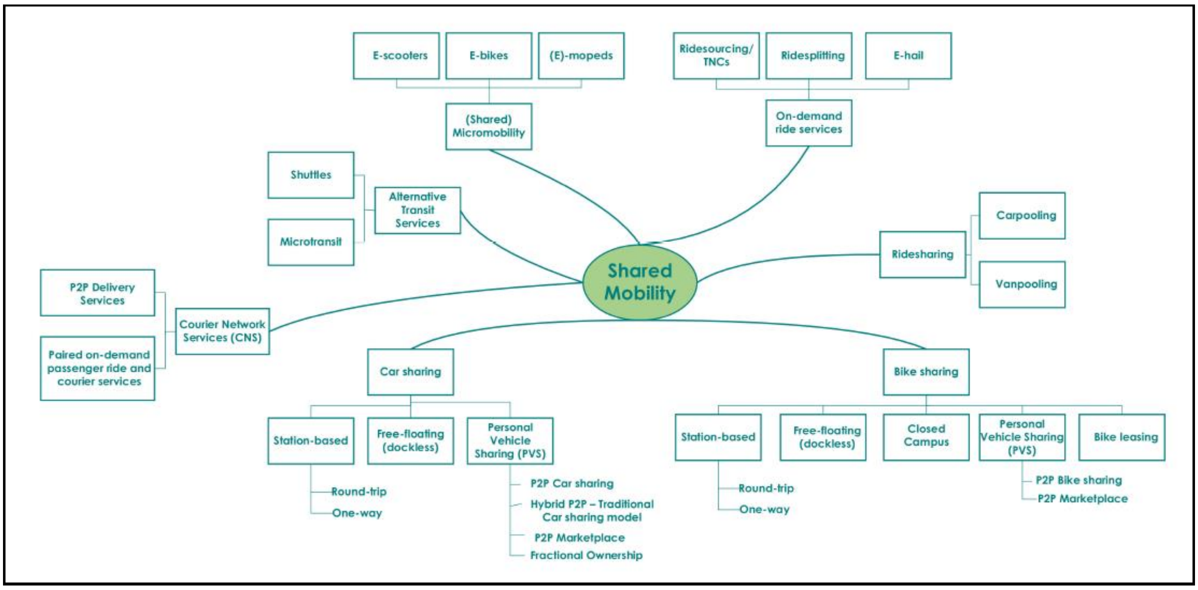


Figure 2: Different forms of shared micro mobility systems

from (Roukouni and Homem 2020)

1.2. E-scooters mode overview

Electric shared scooters are considered one of the shared micro mobility services. It has been in high demand over the past few years and have been largely spreading in most of the world's major cities including Stockholm. The users have access to the service using mobile phone applications. Variety of models are also available in addition to parking spaces and day to day maintenance. All these services are open to the public in exchange for fees paid electronically.

1.3. Operation of E-scooters:

Operation of E-scooters is defined as managing a fleet of E-scooters distributed over a specific region. Region areas vary from one to another and have a specific number of E-scooters. These scooters have no docking stations because they are equipped with a self-locking system. E-scooters run on lithium batteries. The expiry of such batteries is limited to the number of miles covered over the day which can be set back for these scooters. Nevertheless, this shortage is compensated by providing several scooters at the same place, so the user has the liberty to choose another scooter in case of power issues. At the end of the day, all E-scooters are collected by the supplier of the service to be powered by charged batteries, then all E-scooters are distributed again to their specified regions. The operation scheme consists of three main phases which are relocation, collection and distribution as shown in the figure below.

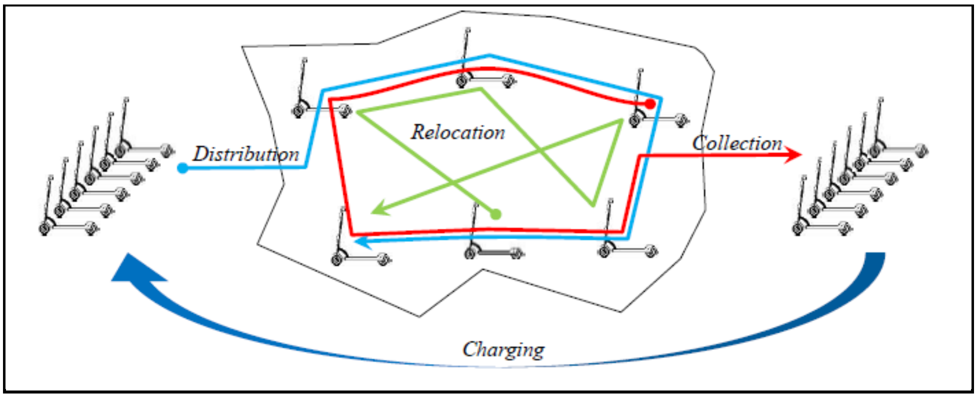


Figure 3: Schematic drawing shows E-scooters operation phases: relocation, collection and distribution, from Badia et al. (2021)

All scooters have special ID and GPS receivers that make them more accessible and easier to find and reported which is one of the major contributions to their success and good prevention from theft. However, some can be located at unattractive destinations which significantly reduces users' frequency which will later affects the service vehicle's productivity because scooters at these locations will last for longer time to have their batteries changed. As an approach to overcome this, vehicles are usually deliberately placed at attractive destinations and the fleet size is always adjusted to suit the use in these destinations. Collection, charging, and relocation activities are performed by the supplier or some subcontractors which can be a private firm or an individual. Subcontractors impose some conditions for the drivers. So, a driver should be over the legal age and should have a driving license and a social security number. The standard wage for charging an E-scooter ranges from $3 to $5. However, the wages are subject to increase according to the demand (Campbell, 2018).

1.4. Usage of E-scooters:

After creating a personal account, users can access a map on their smartphone applications which shows the locations of the neighboring scooters. The time taken by the user to find a scooter is known as the access time. Once located, the user scans the QR code found on the scooter to unlock it. A couple of skate-like leg pushes are needed to start up the engine. At this stage, the system considers that scooter is being used and disappears from the map. After reaching the desired destination, the scooter is parked and locked by the user. Now the scooter becomes available again on the map.

1.5. Fare systems

1.5.1. The common fare

The fare system consists of two fares, fixed and variable fares. The fixed fare is imposed once the scooter is unlocked, and it is mostly the same amount (10 SEK) among all operators in Sweden (see table 1). The varying fare on the other hand is imposed per minute based on the travel time consumed and it usually ranges between 2,25 SEK per minute and 4 SEK per minute. The total travel time is rounded to the nearest minute and the final fare is calculated accordingly as the summation of the two fares. Fare rates are shown in the table 1 below (Tatty 2020).

Table 1: Fixed and variable fare prices according to E-scooter operators in Stockholm, from Tatty (2020)

Company	Fixed fare (SEK)	Time dependent fare (SEK)/minute
Voi	10	2,5
Lime	10	3
Tier	10	2,25
Bird	10	3
Moow	-	20 SEK for 10 minutes
Bolt	10	3
Wheels	10	4

1.5.2. Monthly pass

E-scooter operators have recently launched a new fare system that offers a monthly subscription for unlimited number of trips. In Stockholm, some operators such as VOI and lime offered a 30-day pass that enables the user to travel as many times as possible except the trip should not exceed 45 minutes. For the more than 45-minute trip, the application counts it as a normal fare. The monthly pass might not be available in some markets, but it costs around 550 SEK in Sweden; however, this amount decreases to 14 SEK per day for a six-month subscription period.

The monthly pass is only valid for the city it was purchased, and the user has the liberty to cancel the pass within 14 days of purchase with total or partial refund depending on the usage ("VOI-Payments, Credits and loyalty", n.d.).

1.6. Research objectives

Travel behaviors were considered the main reason for introducing new transport policies and other decisions made. Thus, it is crucial to know who the users for E-scooters are and to explore their travel attitudes, travel preferences, travel frequencies. In short, the research objectives will be as follows:

1- To analyze travelers' behavior using E-scooters as a mode of transport by knowing their demographic data, travel preferences, travel frequencies, their motives, and barriers towards using the mode.

2- Reporting the statistical analyses of the gathered data.

3- Validating the findings of the survey by analysing one of Stockholm's operator dataset.

1.7. Background

E-scooters are one of the mobility on demand forms that nowadays are used and considered by some users in tackling daily transport congestion. E-scooters were launched in 2017 in Santa Monica, United States of America. Since this introduction, the business started to rise and the competition and top sales rates among firms became the primary motive. This resulted in rapid increase of E-scooters in the cities (Roukouni and Homem 2020). The service undoubtedly has ensured mobility among individuals and tackled some transportation problems such as congestion in addition to other positive impacts on the environment.

Positive impacts on mobility have been experienced because of the vast introduction, e-scooters has tackled congestion and other transport problems. The presence of dockless shared E-scooters have led to reduced individual trips using the private car. People started to consider the mode as an alternative for highly frequent short individual trips made by private cars on daily basis. The ease of operating, navigating and stable maneuvering attracted many users to access E-scooters. This accessibility was for different trip purposes as many times per day since the cheaper fare required compared to fares of other modes that cover the same distance. (Bai and Jiao 2020). The location of E-scooter stations around the city has encouraged physical activity to many users. This has resulted in improved health and social attitude among other people within the society. Dockless electric shared scooters resulted in reduced GHG emissions compared to the shorter trips made by private cars (Lo et al. 2020).

In Paris, personal interviews were conducted to investigate passengers' perspectives regarding the main differences between E-scooters and cycling, whether E-scooters can compensate for vehicles and the concrete differences when E-scooters were used as an alternative. The findings suggested that E-scooters would be an effective tool in modal split. Also, E-scooters would fill the limitations created by public transit or as a contingency mode in case of delays caused by buses due to repairs, road maintenance or facility failures (Tuncer and Brown 2020).

However, negative impacts were controversial among scholars. Several studies revealed the impacts of E-scooters as a result of passenger behaviours and the lack of supply and/or demand of E-scooters, etc. Some companies have encountered challenges in making profit. The E-scooter companies need to find support from many cities in seeking less competitiveness and more stable markets to be able to have some market power and thus contribute positively to the local economy (Button, Frye, and Reaves 2020). Moreover, cities within California and the neighbouring states were supplied by many devices. The massive spread of E-scooters led to many drawbacks to pedestrians and other traffic modes such as cars and public transport (Todd et al. 2019). One of the main drivers that led to these drawbacks were the lack of censorship by the government and the absence of transport policies required to control the new service. The Scooter sharing system (SSS) and bike sharing system (BSS) operators on the other hand, have entered the cities on a larger scale with a main objective to ensure projects' feasibility rather than the actual mobility. "*An argument can be made that SSS and BSS are examples of companies using public space to generate corporate profit, and that stated environmental and equity benefits often are not realised."* (Lo et al. 2020).

Results of a real-life test which was performed in Munich, Germany are presented in this study. It was found that E-scooters were mainly used for commuting and leisure trips within Munich. Respondents revealed that commuting and business trips can be covered by E-scooters while leisure trips can be partly covered (Hardt and Bogenberger 2018). In Vienna, statistics had raised a suspicion that E-scooters did not offer an advantage in terms of mobility gender equity. However, results revealed that E-scooters replace the short trips that are most likely to be covered by a sustainable mode e.g walking or cycling as well as a potential increase in the number of cyclists (Laa and Leth 2020). Similarly in Arizona, USA where walking was found to be the major mode that replaces E-scooters. Consequently, E-scooters were considered faster than walking admittedly by most of the respondents (Sanders et al., 2020)

Another study aimed to explore the intention of E-scooter users located in Ontario, Canada. It was found that 21 % of the users were amenable to considering E-scooters in their daily trips. 60 % would replace the mode by walking and 55 % would use public transit instead (Mitra and Hess b 2020). However, in a French study, the main motivation in using electric shared scooters was found to save time rather than monetary savings or playfulness. 72% of the respondents shifted mainly from walking and public transit to E-scooter use. 16 % replaced a motorized mode by E-scooter. Leisure activities were found to be the major travel purpose however, the study revealed that older users were likely to use the mode for longer distances usually for commuting and not for leisure activities (Christoforou et al. 2021).

Dockless E-scooters have on the other hand raised concerns regarding road safety. The introduction of the new form of micro mobility has led to conflicts among roadways and sidewalks which resulted to externality issues, congestion and visual pollution. Sharing car lanes and cutting major intersections were observed by pedestrians in the inner cities which has led to major injuries and deaths (Lo et al. 2020). This has encouraged some scholars to conduct research questions on the description of users' behaviours using E-scooters compared to their behaviour when using shared bicycles (Todd et al. 2019). These users might have shown lack of confidence in operating the facility despite being given a driving license to use their private cars. The rising numbers of E-scooters in addition to the demographic trends has prompted the governmental representatives to introduce policies and regulations to tackle the consequences of this massive increase (Todd et al. 2019). The introduced policies had mitigated the current situations but had as well other impacts. Regulations such as mandatory helmet use, traffic speed limit, prohibition of riding on sidewalks and specific parking locations have resulted in a remarkable decrease of E-scooter usage among users (Lo et al. 2020). The rate of use was directly proportional to the rate of temperature decrease. Safety issues have been a research area also to consider. A case study in Rosslyn, Virginia discussed a main issue which was how pedestrians experience their safety from E-scooter users when walking down the sidewalks. 16 % out of 606 observed E-scooters were misplaced in the city. The consequences found were E-scooters had blocked sidewalks despite replacing some trips performed by other modes such as taxis, bicycles, busses and cars. 4-10 % of the parked E-scooters have blocked pedestrian access (James et al. 2019). In shanghai, China, the risky behaviors were assessed by comparing the similarities in riding behaviors of E-scooters and motorized bikes. A strong relationship was found between the availability of vehicles and the risky behaviors adopted by two-wheeler modes (Rodon and Ragot-Court 2019).

2. METHODOLOGIES

2.1. Site overview

Stockholm city is the capital and the largest city in Sweden. The total city area is 188 km^2 which makes it one of the largest cities in Scandinavian countries. The main geography of the city is different from other cities. Stockholm is based upon 14 different islands and considered a population-growing city. In 2013, the total population was 1,439,000 inhabitants. However, in 2019, the total population is 1,656,571 inhabitants (United Nations 2019). Due to the large population, travel times vary with different times depending on if its weekdays, weekends, days or nights.

2.2. Survey: Questionnaire preparations, design and considerations

This section includes questions regarding travel preferences, motives and barriers that can influence E-scooters ridership. There are different types of transport research surveys such as land-use surveys, surveys of transport system inventory, travel pattern surveys and transport system performance surveys. Each type of the mentioned surveys has a specific purpose but, in this study, survey was used to measure demographical trends, main travel parameters of E-scooters, represent the variations of users' preferences, choices and to forecast the potential transport conditions and the impacts of system changes.

2.2.1. Survey design procedures

In reference to the literature papers, surveys included various sections based on the research question. There was misclassification of sections in the beginning, but questions were then updated to focus on mainly three sections.

The first section included some questions regarding gender, residency, age, household status, income level etc., general travel preferences and access frequency of all modes. The second section covered the E-scooter last trip parameters and modal splits. Finally, the third section included discussion questions regarding the driving license possession, main reason for trying the E-scooters for the first time, motives that would make the user use E-scooters as a main mode, barriers that discourage using E-scooters, whether E-scooters would replace private car use.

Continuous revisions were performed on the accuracy of questions as well as the variety of choices. The last revision was thorough on the entire survey to find unclear information. Some questions were interconnected to each other through a feature the 'question logic'. This feature makes a change based on the users' answers. For example, the respondents were required to have used the E-scooters at least once. The logic option was used in a question that asked whether the user have tried an E-scooter before or not. The survey is terminated if the answer was 'No'. So, the logic options were set at selected questions to avoid irrelevant sections being asked. Then some scientific-related terms were swapped by simpler terms to be understood by the user. The survey was not distributed directly to the users but it was sent to close friends for a general feedback and assessment. There was no remarkable limitation in the questions in terms of language and structure of the choices. Finally, an invitation message was customized, and the survey was ready to be sent.

2.2.2. Data collection

Questionpro had variety of communication means. The survey link could be sent to the users by invitation emails and social media platforms. The start page link also was in the form of URL and QR code. The first method of communication which is sending invitation emails to the users was adopted but found to take some time for the respondent to receive it as well as the possibility of categorizing the invitation email as junk. The target sample respondents were decided to be over 200 respondents in order to avoid false representation and bias. Data collection phase lasted for 17 days. The first week involved remote communication through private messages, social media platforms. These were WhatsApp, telegram, Facebook, Instagram and slack. Each respondent was contacted privately with some greeting messages then an invitation message including a brief description of the study followed by the survey URL. The respondents were able to press the URL and easily fill in the survey using the mobile camera scanner or the computer. Questionpro automatically counts the respondents by counting the URL clicks, the total surveys completed and the total survey dropouts.

Eight days were dedicated for distance communications, then additional respondents were required to reach an acceptable sample size. There were some methods proposed to deliver the survey to as many respondents as possible. One idea adopted was to print a kind message and a brief description of the study of an A4 document followed by the QR code.

Communication was performed remotely without any approaching which make it convenient under the current COVID-19 regulations in public places. Respondents meeting places were different, but spots were mainly within the E-scooter permitted areas which was Stockholm central areas. Respondents invited were either pedestrians, waiting passengers at bus stations or passengers inside the public transportation modes (tunnelbana, pendeltåg, tvärbanan etc..). Uuniversity and personal identifications were firstly shown to the passengers then a brief oral description on the study was introduced and ended by a question of whether the user is interested to fill the survey or not. If the passenger agreed, the QR code was scanned by the smartphone using the built-in camera then by clicking on a pop-up link which redirects the user to the survey's start page. It is important to mention that social distancing was followed during this phase to avoid any contact with the respondents. As a part of the process, each interested respondent was given a free drink as an incentive to participate and answer the survey questions.

2.2.3. Methods of data analyses:

Total number of respondents were 203 counted as completed comprised of 80 surveys gathered by internet communication and 123 gathered on site meetings. Analysis methods for the preliminary results were performed using MS-Excel software in addition to the ready-made statistics by Questionpro software. In the first section, a general statistic regarding demographic data, users' general transportation parameters, users' travel preferences, E-scooter travel purpose and frequency, E-scooter travel preferences etc… percentages for each section were imported into an excel table. Then question responseswere clustered into sections and the corresponding percentages were added to each section (see appendix A)

2.3. Operators' data

2.3.1. Data collection

Historical data needed to be imported from the E-scooter operator in Sweden. There were difficulties in the direct connection with the operators as well as scheduling constraints. Alternatively, this data was imported with the help of a KTH scholar in the department of transportation science. The attributes included were customer ID, start time, end time, start latitudes and longitudes, End latitudes and longitudes and the vehicle ID. The data imported was in a form of CSV file and included trips that started from the 29th of April until the 5th of May 2019. The total number of trips made during this period were around 52 000 trips.

2.3.2. First preparations

To manage this amount of data, python programming was the most optimum tool. By the help of pandas library, data has been uploaded from a CSV file in the form of pandas dataframe. The column headings have been renamed and other fields such as the vehicle ID, customer ID were removed.

2.3.3. Data analyses

From the available parameters in the dataset, three more parameters were calculated. The travelled distance firstly was calculated as a function of latitudes and longitudes. Haversine method was the selected approach by converting the starting and ending longitudes and latitudes into radians. The conversion was performed using the math.radians method then using the radius in km to compute the entire distance in km as well. The second parameter was the travel time. Operations performed was simple subtraction between the finish time and the start time however, data types were converted from date-time format to time delta then to float to be compatible for further python mathematical operations. The third parameter calculated was the average speed. Using the built-in function that loops around columns, the speed was calculated by dividing the total travelled distance over the elapsed time converted to hours to get the speed in km/h.

2.3.4. Data cleaning

After computing travel distances and travel times, it was important to clean the dataset by removing outliers in both parameters. The first step was removing the start and end date columns to make the entire set visually appealing. The second step followed was calculating the first and the third quartiles then calculating the inter quartile range as a difference between the fourth and the third quartiles. Then specifying the upper and the lowest boundaries as a function of the interquartile range. The filtered dataset has been computed by the help of dataframe.query method and the final has been decreased to 48 thousands entries. It was important to double check the dataset by showing the descriptive statistics. As a result, some large numbers in the distance travelled column appeared to be unrealistic which was then removed manually using the dataframe.drop method.

2.3.5. Data visualisation

There were three selected patterns of visualising the computed data. The first pattern was histogram which represented the frequencies of the data among set ranges (bins). Using the prepared visualising libraries, histogram plots represented travel time, travel distance and average speed parameters as shown in figures 18, 22 and 26. The second pattern was a pie chart that represents the percentages of parameters values that lie within set ranges and the third pattern was the box plot. Using the ready installed libraries, both patterns were drawn as well as graph labels, titles, axes ranges, font size and colors were customized. Bin ranges have been set from 0 to 2500 with an increment of 500 for travel times which was equivalent to the choices of time intervals in the survey. From 0 to 8 with a single increment for the total travelled distances. Regarding pie charts, travel times were classified into four ranges started from 0 to 500 till 2000+ seconds. Similarly, travel distances were classified into four ranges starting from distances less than one kilometer up until over 5 kilometers distances with 2 kilometers increment among ranges.

2.3.6. Spatial visualisation

2.3.6.1. PREPARATIONS

The gathered data required powerful interfaces for analyses. Several attempts had been performed to visualize these points using geopandas library but this method did not work due to technical issues and the big space of the data. Alternatively, ArcGIS pro has been used to visualise longitude and latitude points in the form of XY points through some procedures which will be detailed in the coming paragraphs.

2.3.6.2. DATA EXTRACTION

longitude and latitude spatial data points referred to the starting and ending points. In the CSV file, there were a total of four parameters representing the origin and destination. Number of entries in the historical data had reached 43118 points after the removal of outliers and prior to calculating distance, speed and time parameters. Due to large space of CSV file, weekend days only have been selected out of the entire data set to have a total of 11014 entries instead of 43118 entries. The selected dataset has been reconverted from a dataframe format into a CSV file using pandas preinstalled method and became ready to be imported to the GIS interface.

2.3.6.3. ADJUSTMENTS OF GIS INTERFACES

Historical data points had an unknown coordinate system. Thus, an assumption has been drawn to visualize the points using the Swedish coordinate system instead. So, the first step was setting the coordinate system from the default WGS-1984 into SWEREF99. The same system has been adjusted for the layers that have been used in the visualization.

2.3.6.4. CREATION OF LAYERS IN ORDER TO PERFORM VISUALIZATIONS

In ArcGIS, longitude and latitude entries were considered as continuous data type. However, with the ‘Display X, Y data’ command, these points are converted into coordinates and visualized based on the set coordinate system (Esri 2021). In this process, data points were extracted from the CSV file in the form of two layers for the start and end points. Layers used in ArcGIS include all data that will be visualized in addition to other data types known as attribute data. All data entries are recorded in the attribute table where the user can edit, select or add additional data. Data file was imported to the program in the form of a CSV file but was converted into a layer through selecting ‘Display XY data’ command that reads the coordinate points and visualizes it in the form of XY on a map. Base map layer had to be added for visualization. coordinate system has been adjusted also to SWEREF99 for both layers.

2.3.6.5. HEAT MAP ANALYSES

After installation of the data file and creation of layers, a visualization pattern had to be selected to help in observing the distribution of E-scooters. ArcGIS includes various tools analyzes data and perform other functions such as prediction, data management, data conversion and data summary. In this study, data summary was the most convenient to use for visualization due to the increased size of data points. Data summary included a summary of continuous data and visualizing this data over a selected region. Heat map visualization command was selected for visualizing the dataset, figure 6. In the far-right tab, the symbology option was selected from the drop-down menu and a heat map was selected to visualize the data points density which means the number of points per unit projected area. In the left menu, radius is adjusted to 25 and up to 100 units and the color scheme represents the ratio between the number of points over the projected area to reveal the degree of intensity based on the color. The ‘Method’ entry refers to color change based on the map scale. In larger scales, colors remain the same and for smaller scales colors change according to the point intensity.

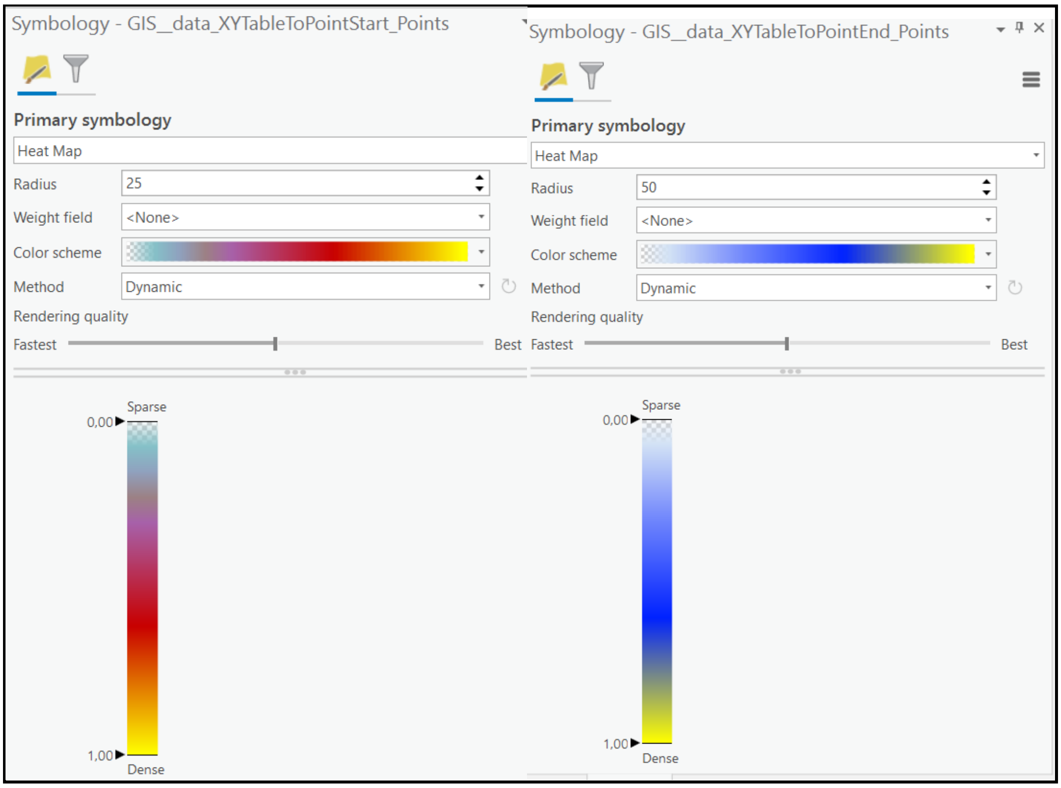


Figure 4: Choosing the symbology method and color scheme adjustments for both starting and ending point layers.

3. RESULTS AND DISCUSSIONS:

3.1. Demographic data findings:

Questions regarding demographic data show some parameters that influence the decisions made towards choosing E-scooters as mode of transport. Demographic parameters measured were age, gender, main residence, last granted degree, occupation category, monthly income and the composition of household. 44.23 % of respondents aged between 18-24 years old as shown in figure 5 with male dominance over female at 66.16% and 32.32% respectively. The majority of respondents were either inactive or students (44.56%) at an income level less than 10 thousand SEK per month (43.3%) unmarried and has lived in a single accommodation type (48.66%) and pursuing further studies as the last granted degree was a bachelor's degree (33.51%) as shown in figure 7. However, high school and master's degree respondents were the second and the third majority at 30.41% and 25,65% respectively. Stockholm's demographics in 2020 have shown that number males were slightly equal to females at 50,1 % for males compared to 49,9% for females. Stockholm age group has shown dominance for people aged between 30-39 years old while residents aged between 20-29 were nearly equal to those aged between 50-59 years old (see figures 6 A and 6 B).

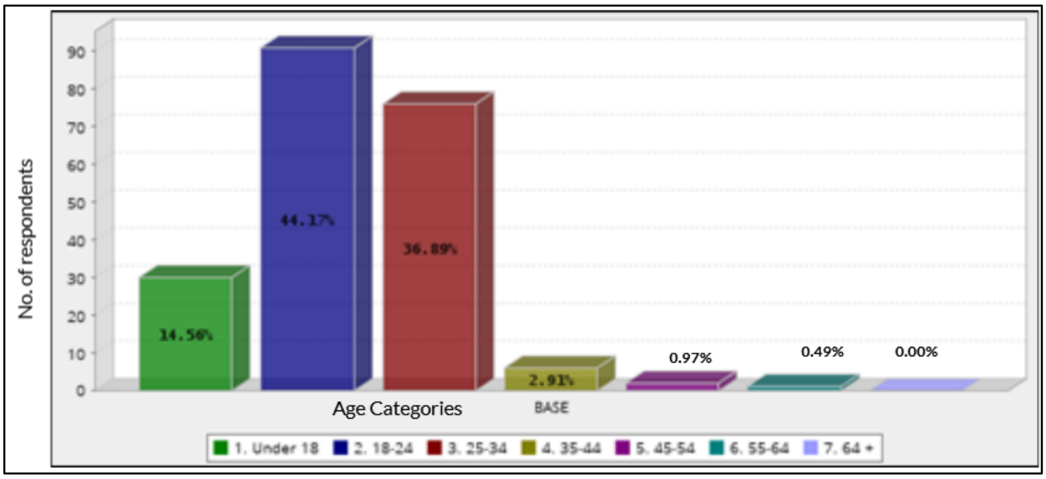
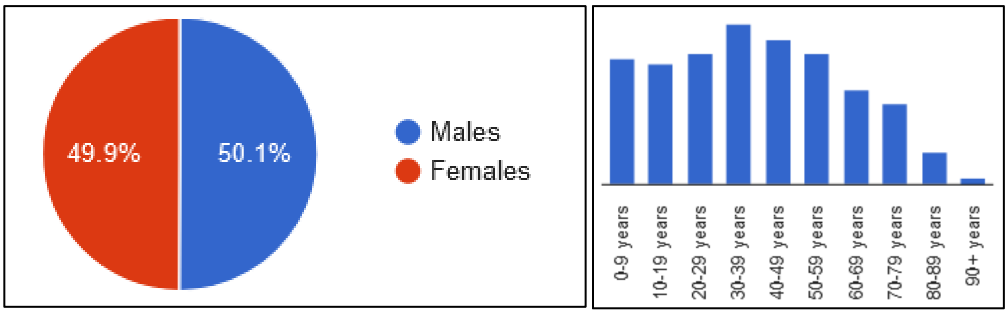


Figure 5: Age categories among survey respondents calculated and plotted by the survey software.



A B

Figure 6(A-B): gender and age trends in Stockholm, From (Brinkhoff 2020)

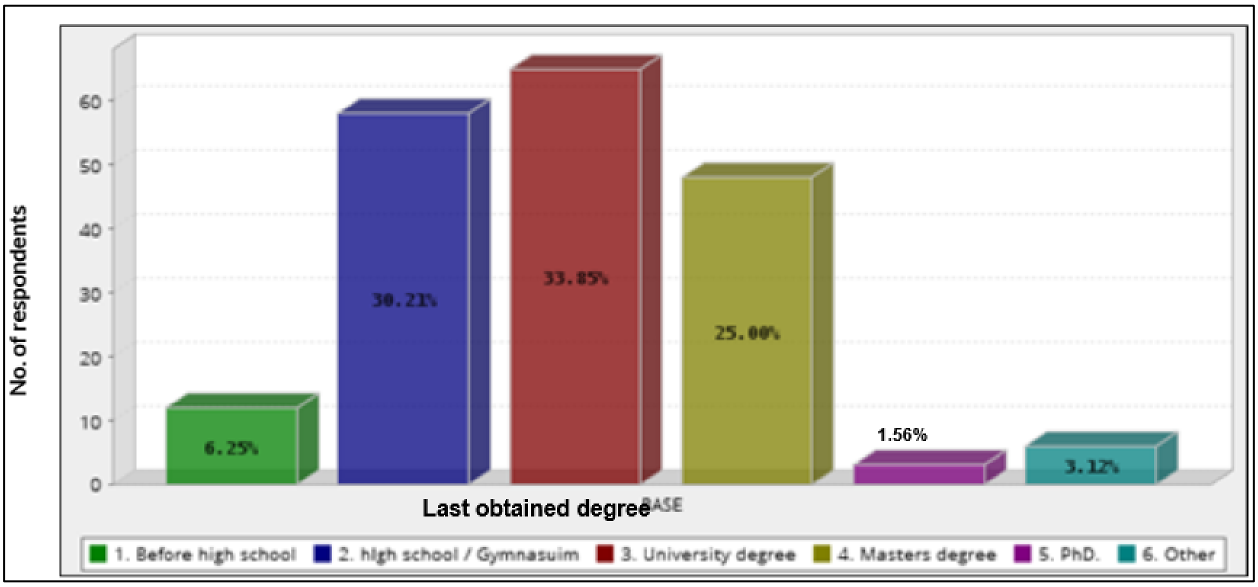


Figure 7: respondent's last degree distribution

Demographic findings have shown dominance in the younger age category (18-24 years old) in addition to lower income level and non-active/student occupation category. These findings suggest that E-scooters are mostly used by younger age males than people aged from 25 to 34 years old. In comparison to Stockholm's demographic stats, the distribution patterns for gender age group in the survey were not the same as the demographic stats. The other findings in the demographics section suggest the same inference. Findings of these parameters had some similarities with Shaheen's study. Though, demographic profiles about E-scooters users were included, and it showed that frequent users had higher education at either college or university levels. In addition to Berkeley university study, results have shown that most of the micro mobility users were 'childless' as a household status at a middle to upper income level (Shaheen and Cohen 2019).

There was a male dominance over females in E-scooter ridership which was the same case in Sanders and Nelson findings also confirm. Male respondents were more likely to be using E-scooters than females and to ride more often. Income levels varied as it showed a significant relationship in riding patterns with the highest percentages of frequent riders who earn between 55 thousand and 99 thousand on an annual basis. (Sanders, Branion-Calles, and Nelson 2020). The same for Mitra and Hess where old and retired respondents were less likely to adopt the idea of micro mobility. But single younger aged male respondents were more likely to consider the mode. However, household income showed a non-significant relationship among adoption intentions towards E-scooters (Mitra and Hess b 2020).

Respondents in Paris showed the same trends. Users were mainly males and aged between 18-24 years old. Students represented 41% of the total sample so this can explain the under-representation of the highly educated respondents. About 30% of the respondents have a master's degree or higher with over-representation of executives and students by 41% and 30% respectively while there was an under-representation of old and retired respondents (Christoforou et al. 2021). However, average income and age category were slightly different than demographic trends in Poland. Users were mostly aged between 21 and 45 years old at an average of 31 years old for E-scooter users which was even younger than bike sharing system (MEVO) users. However, Demographic findings in another study has shown that modal income levels for E-scooters were lower than electric bike users at an average of 3205 euros a month. This validates the financial status of E-scooter users as a middle class. (Bielinski and Wa˙zna 2020).

3.2. Travel preferences

3.2.1. Users' general travel preferences

Some travel preferences usually prioritized by passengers before the decisions of travel are made. Priorities often reflect part of the user's behavior regarding the choice of the mode. A detailed criteria was set as choices for the user to choose. Types of travel preferences were found to be mainly speed, time, cost, comfort and environment. Findings revealed that time and cost were considered the most important parameters for passengers.

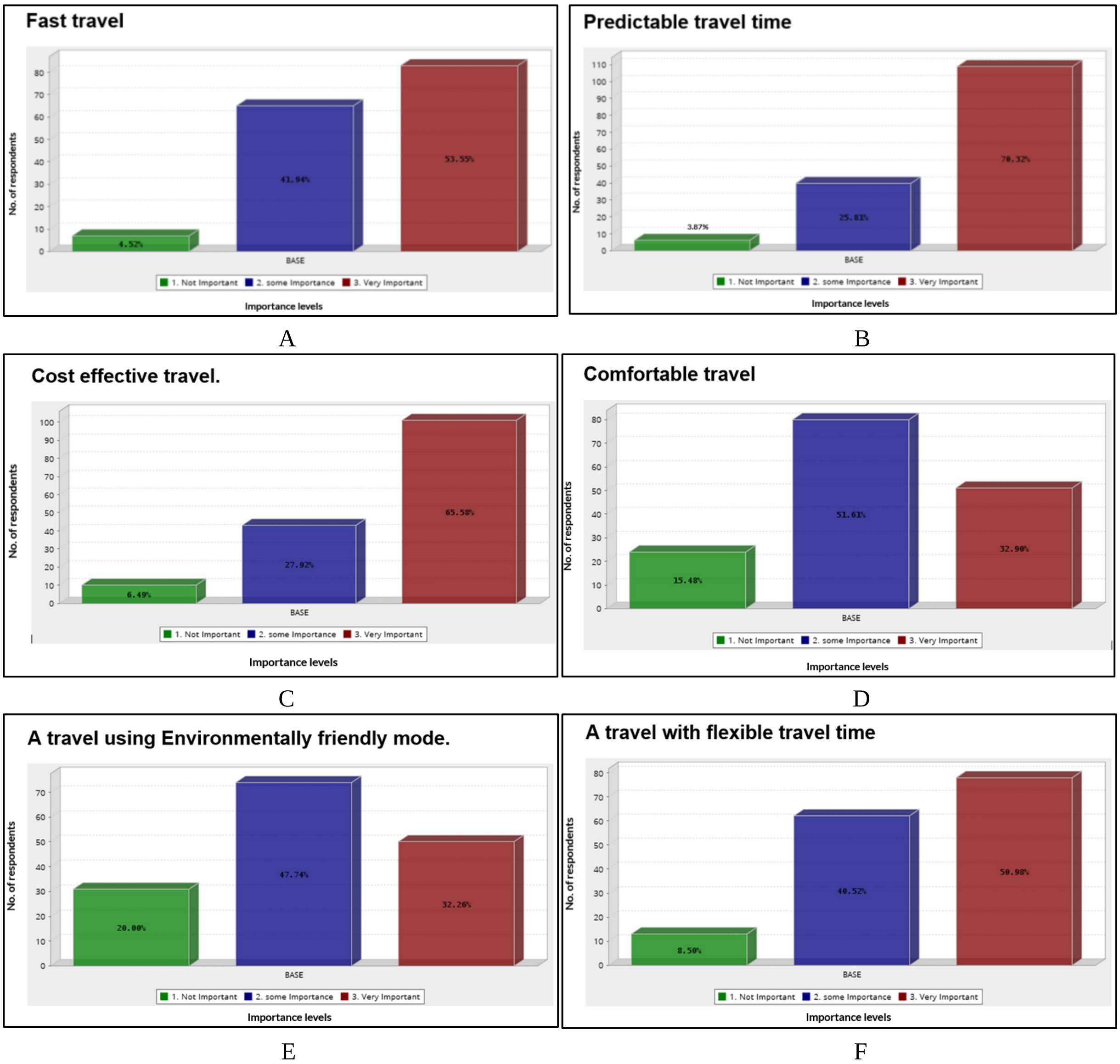


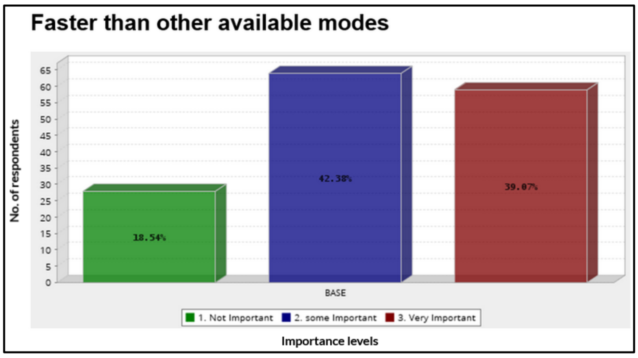
Figure 8(A-F): General travel preferences among the users showed high importance in cost and time criteria.

Criteria such as 'fast travel', 'predictable travel time', 'cost effective travel' and 'flexible travel time' were considered the most important for the respondents prior to making a trip for over 50% of the respondents as shown in figures 8A, 8B, 8C and 8F respectively. However, quality criteria such as 'comfort travel' and 'environmentally friendly mode' were counted to have some importance from passengers' point of views at 51,61% and 47,74% as shown in figures 8D and 8E. The decisions made by passengers prior to making a trip usually rely on the trip time. So, most of the respondents in this study preferred trips with predictable travel time rather than a mode of being comfortable or environmentally friendly when a trip is decided to be made. In reference to a comparative study in Canada, the purpose was to discover the modal shift behavior under the existence of bike sharing systems in North America, users' preferences were mostly associated to faster trips when respondents were found to access bike sharing systems and use public transit less frequently in large Canadian cities (Shaheen, Martin, and Cohen 2013).

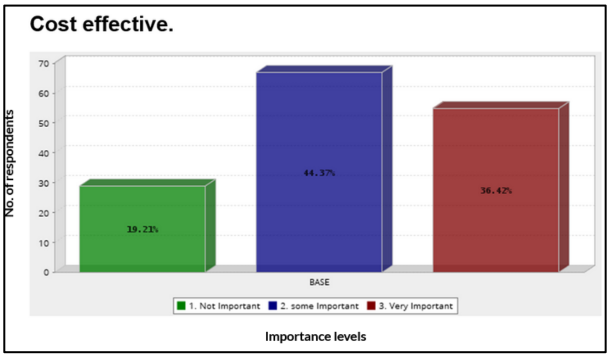
Unlike other findings in other studies where cost was a larger deciding factor than travel time. In a study of micro mobility modes in Sweden has showed that preferences were mainly limited to cost. Shared E-scooters were known to have a distinct method of driving as well as fare system which led to significant decrease in utilization compared to the alternative bicycle sharing system (Badia et al. 2021). Similarly, Mitra and Hess study findings revealed that most selected travel preferences were 'active, flexible and cost-effective' criteria. These are the respondents who were likely to adopt the use of E-scooters in their trips (Mitra and Hess b 2020).

3.2.2. E-scooters choice preferences

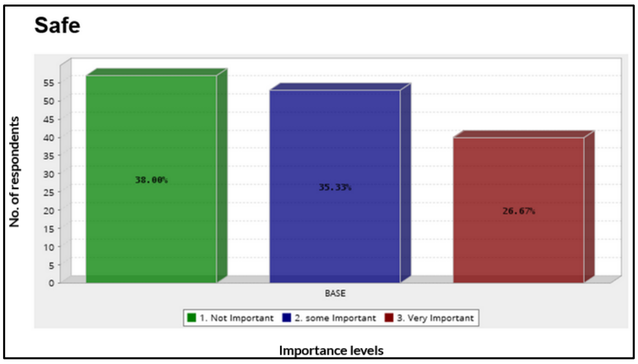
E-scooter choice preference questions included options that revealed some preferences adopted by the users prior choosing E-scooters. In other words, if E-scooters are mostly used to make trips, what would be the most important choice according to the user?



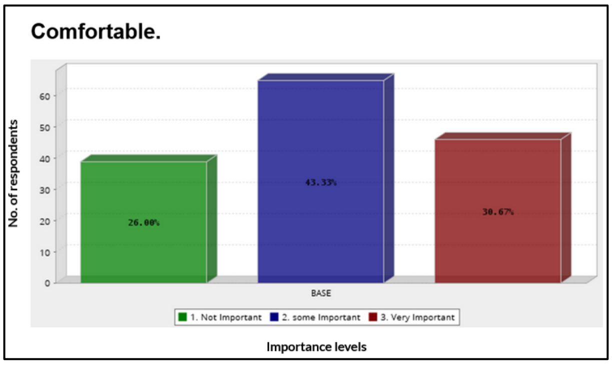
A



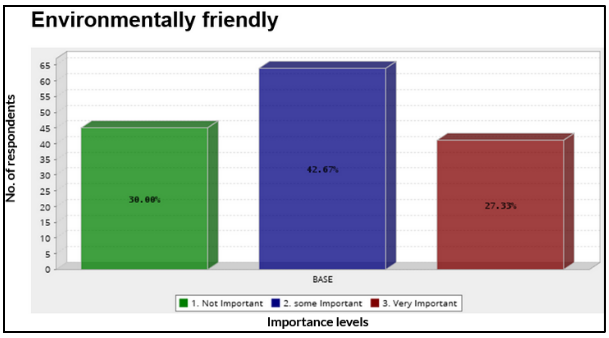
B



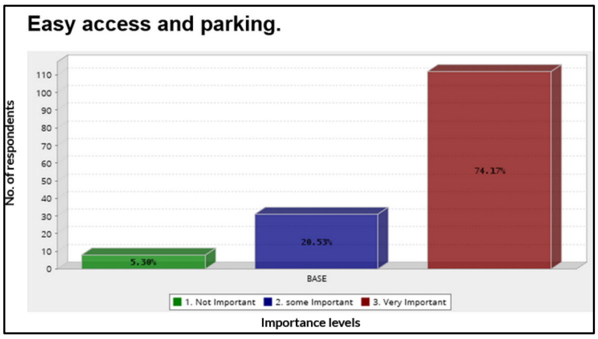
C



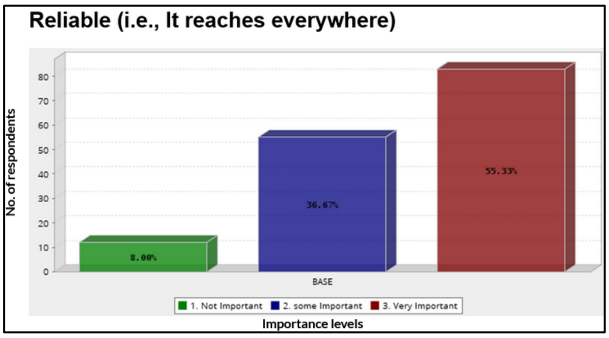
D



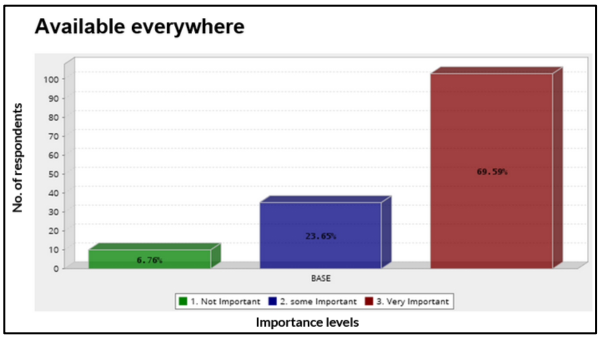
E



F



G



H

Figure 9(A-H): Importance variations of the users' choice preferences prior using the E-scooter.

Most of the respondents believed that easy access and parking are the most important preferences to use E-scooters over other available modes as shown in figures 9A and 9H respectively. It was also found that time and cost came as the second most important parameters rather than accessibility. Similarly, reliability was considered a crucial criterion according to the respondents. 70% agreed on availability as same as easy access and easy parking property as shown in figure 9H. Reliability that has been voted by nearly 55% a choice preference as in figure 9G. On the other hand, safety was considered as 'not important' unlike cost effectiveness (42,38%), faster mode (44,37%), comfort (43,33%) and environmentally friendly mode (42,67%) that had 'some important' rank as in figures 9C, 9B, 9D and 9E. Observations from the previous findings suggests that time and cost are not the main choices and might change from one user to another.

In an ethnographic French study, findings reported that different behaviors adopted by the residents regarding trying shared E-scooters. Residents and tourists have chosen the mode according to the reliability choice preference as stated that it avoids congested areas. The same choice preference also validated by some respondents, for example they agreed that E-scooters were more efficient for longer distance and save more time in addition to comfort that was also preferred by commuters in order not to sweat in the work dress. Others considered E-scooters safer due to the possibility of safely maneuvering and driving in the bike lanes (Tuncer and Brown 2020). Similarly, the most significant preferences that have been selected by all users were mostly referred to less travel time, E-scooter reliability. Over 60 % of regular riders have agreed that E-scooters are preferred over other modes due to speed, easy parking, easy accessibility as well as reliability so E-scooters can reach destinations that can be hardly reached by private cars (Sanders, Branion-Calles, and Nelson 2020).

Unlike the findings in another study in Paris when travel time was considered as the most critical factor than travel cost. Not surprisingly, other factors such as comfort, safety, playfulness and cost had high percentages as ‘Very important’ choice criteria, however, travel time had the highest importance by 75 % of respondents (Christoforou et al. 2021).

3.3. Travel frequencies

3.3.1. Users’ travel frequency using public transit.

The public transportation network in Stockholm infrastructure is counted as the largest and the most reliable among other Swedish cities because of the variety in public transit modes. Modal composition varies in the entire system with 44% trips made by the metro, 39% of trips made by buses, commuter trains contribute by 11 % and the least contribution of daily trips is by LRT systems by only 6 % (Jenelius and Cebecauer 2020). However, the remaining population have access to either bikes, private cars or other shared mobility solutions.

Survey findings showed that over 70% of respondents have access to public transit systems using the public transportation pass (SL card), While just 29,68% who used normal tickets. Tunnelbana was found to be the most frequent mode used by over 29,87% of respondents for more than three times per week compared to daily users who occupied 27%. Around 23% of the same respondents have been using the bus a few times a month. This makes buses in second place as the most frequent mode used. Whereas pendeltåg was found to be the third most frequently used mode at 30,87% of the respondents. Other modes including low speed trams and taxi were the least accessed by passengers during an entire year at 34,21% and 33,33% respectively. High speed tram which is known as the ’Roslagsbanan’ was the least used mode because stations are mainly dispersed to regions located in the north central Stockholm and fewer are in the northeast as shown in figure 10.

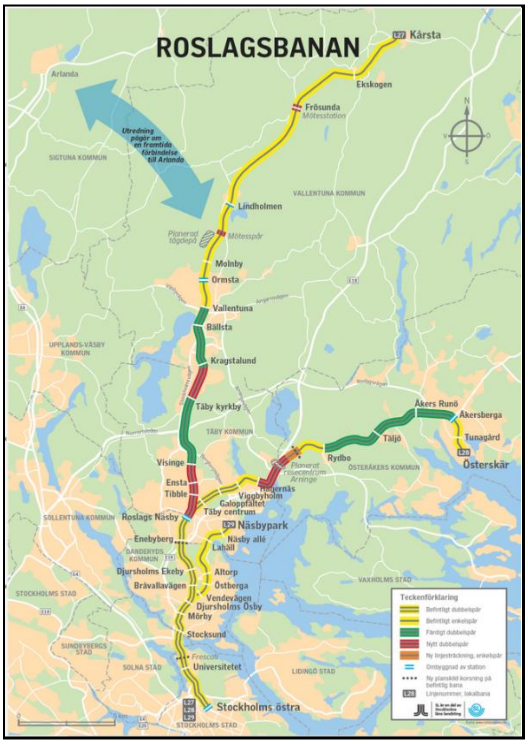


Figure 10: Roslagsbanan route map that cover northern Stockholm regions, from “Allt möjligt om Stockholmsområdet” (2015)

In other studies modes access findings showed that 77,9% of the respondents have a public transit pass or a seasonal ticket for public transportation (Garcíaa, Gomez, and Sobrino 2019). While in Paris, E-scooter frequent users also known as the 'owners' were found to use public transportation more often than renters and the occasional users (Christoforou et al. 2021).

3.3.2. E-scooter travel frequency based on trip purposes.

Detailed analyses of travelers' behaviors were conducted. A question in the survey focused on asking about travel purposes in addition to the frequency of using the E-scooter when doing such a trip. Findings of this question revealed that most commuting trips such as work, education as well as shopping and social visits were rarely made using E-scooters compared to other types of trips such as leisure activities, strolling and outings which were more likely to be made using the mode. Statistically, over 40% of all respondents have never used E-scooters in the following trips such as 'commuting', 'delivery services', 'shopping and errands' and 'social'. Whereas 'leisure' and 'strolling' trips were occasionally made using the mode and marked as 'few times a year'. These findings suggested that E-scooters fleets / stations are limited to several places within the downtown areas.

Similarly, Travel frequency based on trip purpose has been measured among the sample. Most of the findings suggested that paris residents are 'occasional' users of shared E-scooters in their daily trips. One third of the respondents make occasional trips by E-scooters for various purposes including leisure activities, strolling around the city. On the other hand, trips such as social visits, services and shopping had been recorded as 'never' made using E-scooters by the majority of respondents (Christoforou et al. 2021). E-scooters were mainly used for leisure trips at 42% of the total trips, 33% of trips were recorded as activities and fun followed by 30% of commuting trips (Sanders, Branion-Calles, and Nelson 2020). In Stockholm, most of the professional and business areas are located outside the city center (mostly Kista and Solna) which have no fleets and therefore commuting have no popularity using E-scooters. All E-scooters have no seats which make the modes less practical in longer trips or shopping and service trips.

Trip frequency is often decided by the availability of the mode. In the French ethnographic study, Users of E-scooters considered selection of E-scooter was a spontaneous event which means that some users have not planned for using E-scooters prior making the trip and E-scooters are found by coincidence. Therefore, the modes were rarely used for commuting however, it might be a choice made under timely-pressured situations beside public transit use. This had created a lack of reliability for E-scooters in some regions in Paris (Tuncer and Brown 2020).

3.4. Travel parameters

3.4.1. E Scooter last trip parameters

This section gives an insight in the utilization of E-scooters quantitatively. Trip parameters have been gathered through the survey questions and it will be compared to a part of historical data in the next section for validation. As mentioned, that travel time was considered as the most important preference to the user, travel time in this question has been classified into access time and in vehicle time. Last trip responses also included information related to trip purposes and alternative modes or the modal shift as known. According to the findings, the majority of respondents consume from 1-3 minutes to find a shared E-scooter and from 5 to 15 minutes are required to reach the final destination. Most last-time trips were made for leisure activities and the modal shift for these trips were found to be walking if the shared E-scooters were not found at that time.

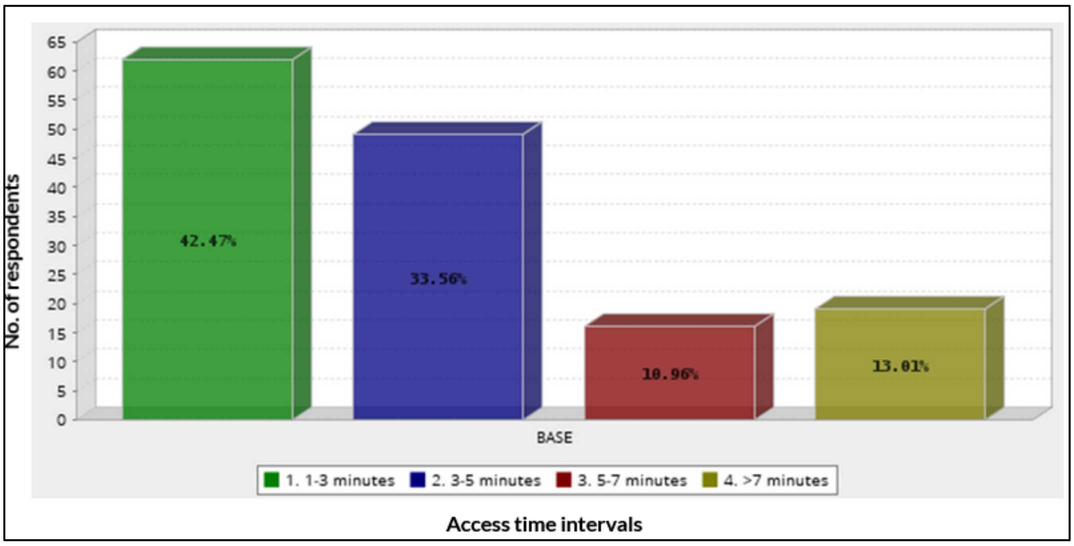


Figure 11: Last trip parameters include responses about approximate access time taken by the users.

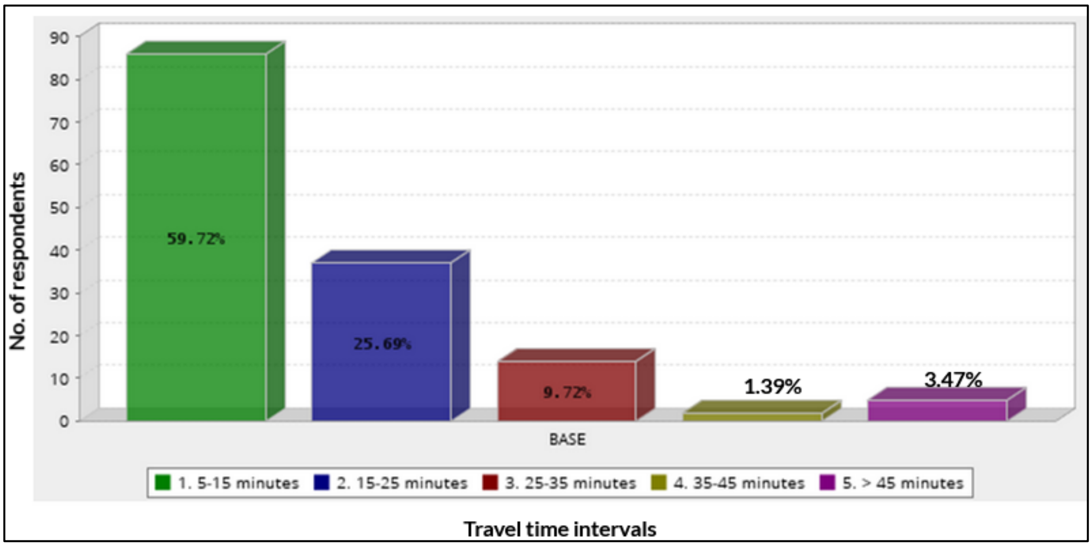


Figure 12: Last trip parameters include responses about the approximate travel time taken.

Conversely, respondents in Vienna were found to have a public transport pass or a private vehicle preferred to use the most convenient mode instead of E-scooters but the findings proved that walking showed the most replaced trips but in most situations E-scooter trips replace walking and cycling trips (Laa and Leth 2020). The French media suggested that users of private E-scooter trips are likely to replace their private cars with E-scooters, unlike renters who replace these trips by walking (Tuncer and Brown 2020). The findings interpreted the impacts of geofencing as well as the lack of mode reliability in longer distances.

Accordingly, the user prefers to use the other available modes to reach the final destination in a predicted travel time. So, these findings suggest that users evaluate E-scooters as last mile mode rather than being a main travel mode and this will be validated in later sections. Modal shifting results were slightly different than found in this study. About 25% agreed to use cars as an alternative for E-scooters in case of their absence while 57% of respondents would make the trip by walking and 8% would bike. These results were different according to the purpose of the trip. So, for commuting trips walking as an alternative has been adopted by 62% of commuters whereas only 42% of shopping enthusiasts can walk if E-scooters were not found (Sanders, Branion-Calles, and Nelson 2020)

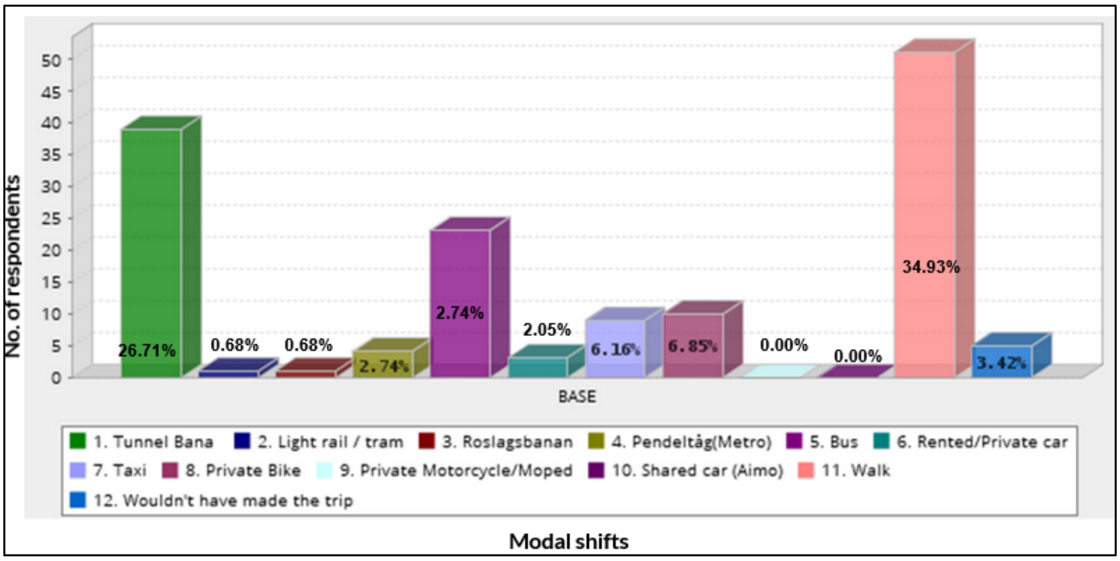


Figure 13: Responses about modal shift in case of the absence of E-scooters

The E-scooter last trip data findings stated that E-scooters are not mainly used as a last mile mode. The modal shifts to E-scooters were mainly from walking (35%), public transit (27%), private car (4%), taxi (6%) and other mobility modes by (9%) as shown in figure 13. Regarding trip parameters, access time which is also known as the walking time has rarely exceeded 3-4 minutes interval in addition to the majority of travel times that were mostly between 10 and 19 minutes (Christoforou et al. 2021). Results in a Canadian study in the city of Toronto has shown that 21% of the total sample of respondents can consider the shared E-scooter in their current trips. 59% out of this sample would replace electric shared scooters by walking. Moreover, 65% of urban residents agree to replace public transit trips with E-scooters while 46,5% would like to substitute car trips by E-scooters (Mitra and Hess b 2020).

3.4.2. General findings.

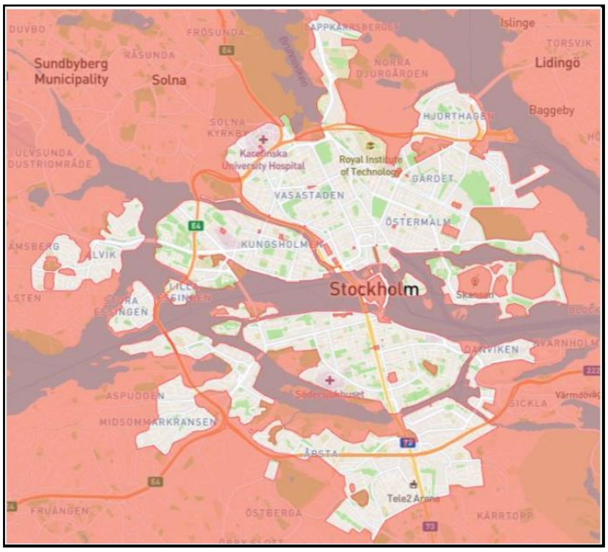


Figure 14: VOI Stockholms' service/coverage areas including the non-permitted parking areas, from Tsarapatsanis (2021)

The last part of the survey some discussion questions were included and discussed the motives, barriers, decisions against private car use and weather impacts on E-scooters ridership. Despite the mentioned choice preferences, over 50 % believed that a private car is worth using in the presence of the shared E-scooter system. This choice also justifies the majority choice of not using shared E-scooters during snowy or rainy days and worth mentioning that Stockholm weather is mostly rainy all over the year. The last section included questions that discussed the first-time motivation of using the E-scooters and it was found that over 60% of the respondents were ‘curious’ to try the mode down the streets. However, 22,54% believed that E-scooters were faster than other available modes of transportation.

These findings were slightly different than were in Paris. More enthusiastic users have completely replaced private modes by E-scooters as a result of the congestion problems and the wasted commuting time during the rush hours. One user agreed to use an E-scooter as an alternative because his moped has been broken. Another user refused to buy a new car and used an E-scooter as an alternative (Tuncer and Brown 2020).

3.4.2.1 MOTIVES AND BARRIERS

On the other hand, 24,42% of respondents agreed that lower fare cost will be the main motive for them to use E-scooters more often. All these findings might be used as reference in justifying previous choices made by the respondents regarding timely mannered travels, high frequency of public transit modes, fast and low-cost trips and leisure trips made using E-scooters. Same motives for Paris residents. Respondents were classified as locals, foreign tourists and French visitors. The main motives for riding an E-scooter were found to be time saving for locals. However, visitors preferred to value joy and fun over time. The main barriers were weather conditions, fleet size and safety concerns by the riders (Christoforou et al. 2021).

Regarding the barriers, the 17,15% of respondents agreed that shared E-scooters are not practical for longer distances, and they are only limited to certain regions (see figure 14). This percentage was nearly the same ratio for responses complained about high fare cost (17,03%). However, only 11,27% avoided to use E-scooter due to battery issues.

In other studies, barriers of riding E-scooters differed from one group to another for example safety barriers varied between men and women. Women were more worried about the fear of hitting a pedestrian when using an E-scooter, being hit by others, falling or losing control. Regarding practically criterion, results varied among the team of users. So regular and occasional users agreed that E-scooters were not practical to carry luggage and travel for longer distances. And regarding the equipment related barriers, majority of the users believed that availability, maintenance and battery issues are the main discourages for the frequent usage of E-scooters. Motives of using E-scooters were found to be broadly perceived in contrast to the barriers that have been varying among groups of respondents (Sanders, Branion-Calles, and Nelson 2020).

3.4.3. Historical data analyses:

In continuation to behavioral analysis, some parameters related to trips made were required to be analyzed and visualized. Travel time, travel distance and the average travel speed were not possible to be observed from the survey questions. Alternatively, a historical dataset for one week duration has been imported from one E-scooter operator in Stockholm. Dataset duration was one week from the 29th of April till the 5th of May 2019. Travel time, travel distance and average speed were computed and visualized using python pre-installed libraries. The main purpose was to monitor the statistical distribution of these parameters using three different plots: histogram, pie charts and boxplots. Histogram was considered a good choice for such a large dataset to show the distribution of the continuous variables through aggregating the data into bins and representing the frequency of each bin in the form of columns. Pie chart representation has been selected for better illustration. Thus, the pie chart was a good approach in addition to the entire data statistics that had to be shown. In addition to the summary statistics for each parameter, the graphical representation of these statistics was required that was the reason for choosing the box plot.

3.4.3.1. TRAVEL TIME

Data gathered have been used to generate additional parameters and travel times/elapsed times have been calculated as the difference between the end times and the start times. Data analyses included removal of outliers, graphical representation, and descriptive statistics. Histogram has shown the frequency of different travel time intervals.

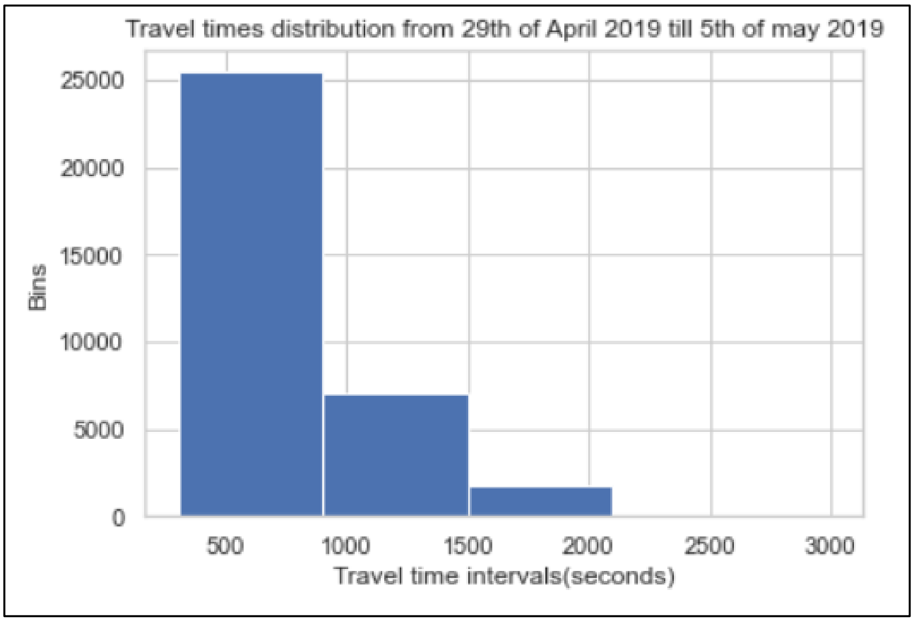


Figure 15: Histogram showing the frequency of travel time intervals along the study period.

figure 15 demonstrated various travel times that had occurred among the following time intervals: 300-900sec., 900-1500 sec. ,1500-2100 sec. ,2100-2700 sec. ,2700-3000 sec. In order to make representation more illustrative, pie chart representation has been drawn for travel times, but the values were represented in minutes instead of seconds as shown in the figure 16.

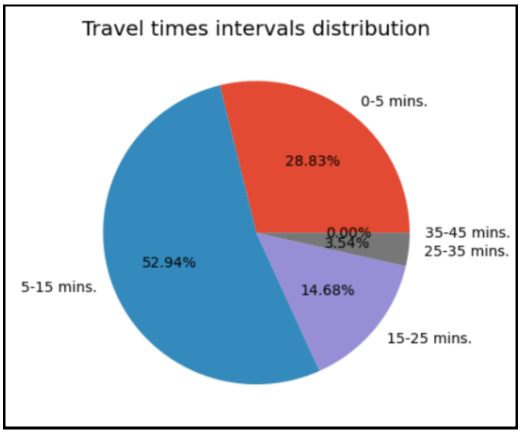


Figure 16: Pie chart showing same travel time interval in minutes.

From the previous charts, it can be demonstrated that most of travel times lie between 5 to 15 minutes or 300-900 sec. as in the first chart. However, longer trips that lasted between 15-25 minutes were considered as just 14,68% of the total trips made during this time and the longest (25-35 minutes) trips were the minority in the entire representation at 3,54%. To visualize the descriptive statistics of the data, a boxplot has been drawn to monitor the patterns of change and figure the entire parameter in form of quartiles, median, maximum, minimum values and the extremes.

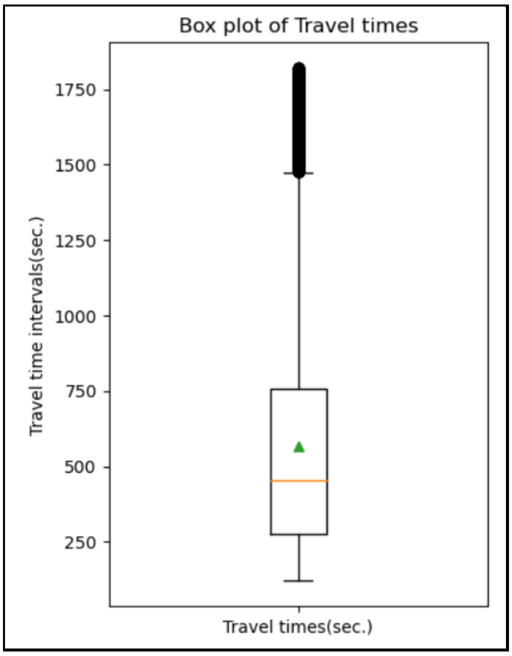


Figure 17: Box plot shows the 1st,3rd quartiles and mean values of the total calculated travel times.

Numerically, descriptive statistics have been drawn for travel time. The mean travel time during this time was 569 seconds equivalent to 9 minutes and 29 seconds. The minimum travel time was 121 seconds equivalent to 2 minutes and 1 seconds while the maximum travel time was 1820,39 seconds equivalent to 30 minutes and 20 seconds as shown in the figure 18.

count	48143.000000
mean	569.064875
std	383.772809
min	121.022007
25%	275.452753
50%	453.291775
75%	755.375240
max	1820.397944

Figure 18: Descriptive summary of the total travel time values

3.4.3.2. TRAVEL DISTANCES

Figure 19 shows the distribution of the total distance covered during the study period (one week) of the historical data. Majority of travel distances were less than 1 km while around 15000 trips lied between 1 and 2 km. All trips longer than 2 kilometers have not shown a significant frequency.

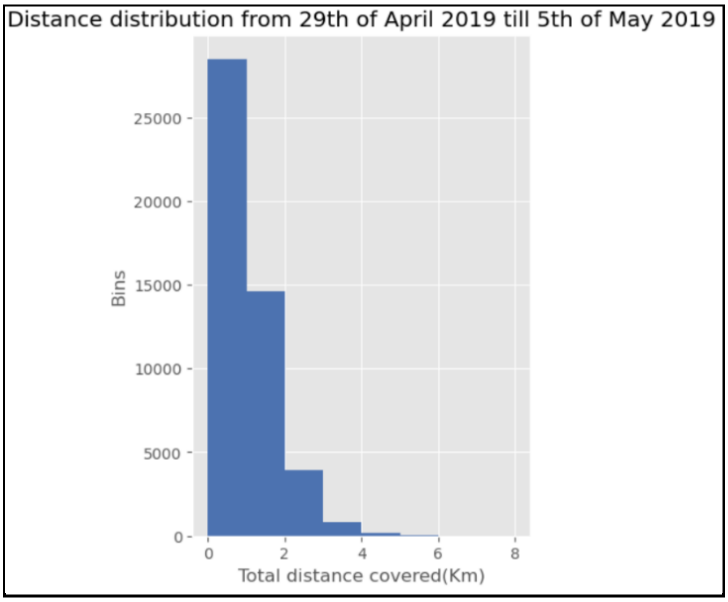


Figure 19: Histogram showing the frequency of distance intervals along the study period.

In figure 20, less than one-kilometer trips occupies 59,21% then 38,67% is the total percentage of trips between 1 and 3 kilometers. Longer trips are showing non remarkable occupation (less than 3%).

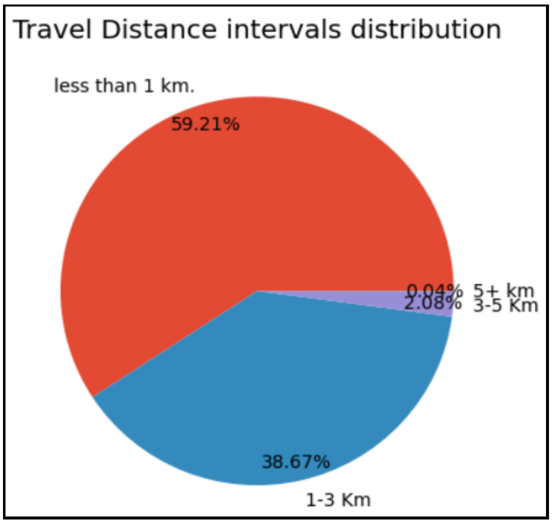


Figure 20: Pie chart showing same travel distance intervals in kilometres.

The summary statistics overview for the traveled distance reveals that the mean distance is mainly less than one kilometer. The first and the third quartiles were usually between 0,5 and 1,5 km. However, the minimum distance traveled was almost 0 km and the maximum was 7 km. More details on the travelled distance summary statistics are found in the figure 21.

count	48113.000000
mean	0.994062
std	0.764104
min	0.000000
25%	0.436704
50%	0.826421
75%	1.388804
max	6.978093

Figure 21: Descriptive summary of the total distance traveled.in km

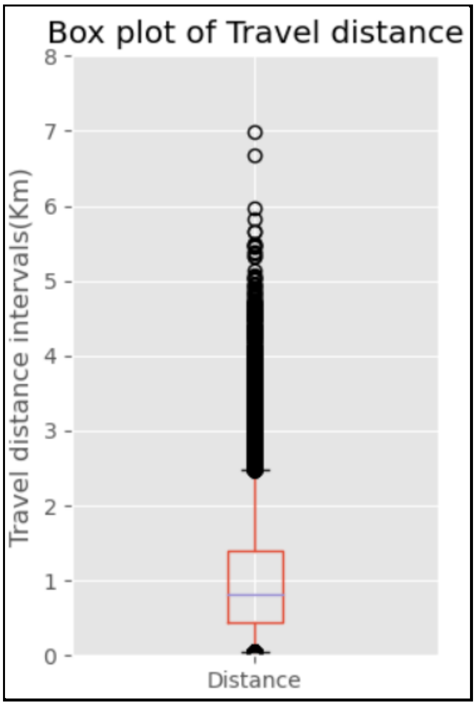


Figure 22: Box plot shows the 1st,3rd quartiles and mean values of the travel distance.

3.4.3.3. TRAVEL AVERAGE SPEED

The top speed of an E-scooter is mainly between 15 to 20 km/h. The average speed calculated varied but did not exceed 20 km/h. At first, there were some outliers in the dataset but were removed. Figure 23 demonstrates the average speed frequencies among bins that increases by 5 km/h. Figure 23 shows a predominance of trips travelled from 5 to 10 km/h. However, the least number of trips have been made at a higher speed, mainly between 15 to 20 km/h.

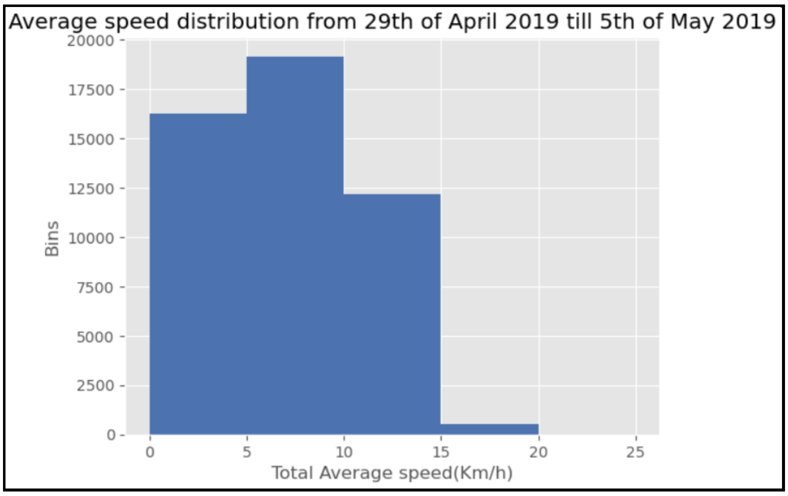


Figure 23: Histogram showing the frequency of the average speed intervals along the study period.

The pie chart visualizes the patterns at which over 70 % of the total trips were made at a speed lower than 10 km/h. Whereas only 25% of the remaining trips have been made between 10 and 15 km/h. And only 1,12% of the total trips were made at over 15 km/h.

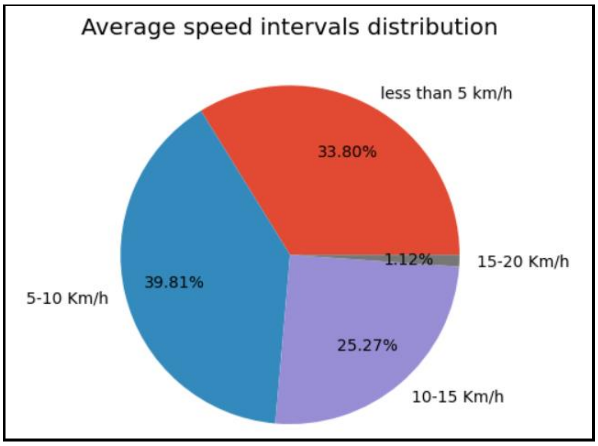


Figure 24: Pie chart showing the percentages of average speed of e-scooter trips in km/h.

Regarding the summary statistics, the box plot shows that the mean average speeds among all trips made was between 5 and 10 km/h. The minimum speed was almost 0 and the maximum average speed was 19,6 km/h. Overall summary suggests that the majority travel speeds lie mainly between 3 km/h and 10 km/h. The descriptive summary in figure 25 includes more statistical illustrations.

count	48113.000000
mean	7.017887
std	3.965481
min	0.000000
25%	3.756004
50%	7.156615
75%	10.155690
max	19.672071

Figure 25: Descriptive summary of the average speed in km/h

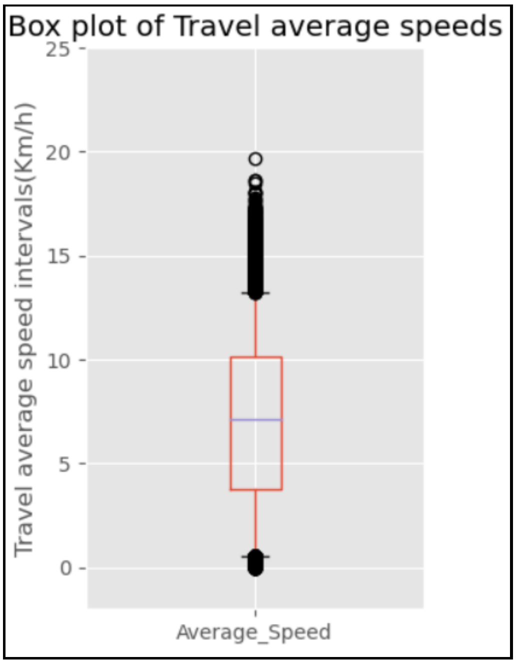


Figure 26: Box plot shows the 1st,3rd quartiles and mean values of the average speeds.

The average travel speed showed only 7 km/h which interprets that walking can be a compensation for this exerted travel speed for these types of trips. E-scooters undergo the same traffic rules as bikes and other modes which means that some wasted time at traffic signals and traffic congestion. Despite that walking can be a slower than an E-scooter, but users tend to adopt walking more often.

3.4.3.4. SPAITIAL VISUALIZATION- AREA OF FOCUS:

The main study area in this project was the central region of Stockholm in addition to some neighboring areas to see the distribution of location points for E-scooters. Data visualization approach was firstly chosen to make use of the gathered historical data and to validate some findings in the survey section. So, some conclusions are drawn regarding some findings in the survey section and the visualized section. The idea of visualizing location points was to interpret some adopted behaviours by the passengers. Data visualization is considered an initiative for future research in analyzing passengers' behaviors using advanced methodologies such as spatial regression and machine learning models that predict the anticipated destination points.

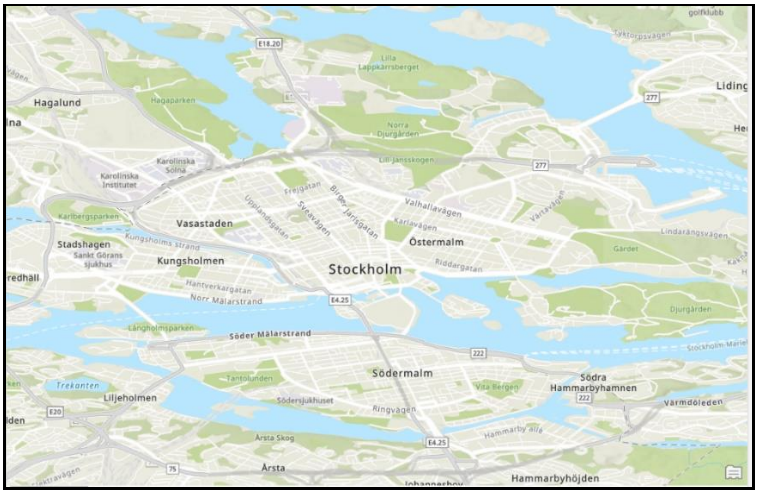


Figure 27: Central Stockholm region map: Scale = 1:60 000

After running heat map commands in Arcgis Pro, the distribution of points is shown in figure 28. The color index has been changed so starting points had a different scheme than ending point layer as it was shown in the methodology part. It was required to decrease the scale each time to determine the distribution on smaller regions and make comparisons. The following figures represent the starting (alighting) point densities at various scales.

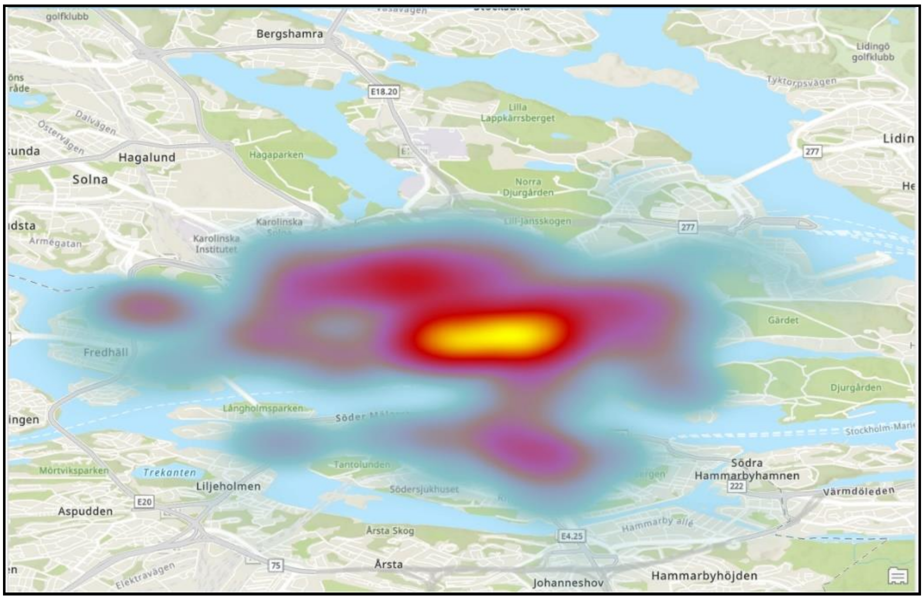


Figure 28: Starting points density distribution over Stockholm central region: scale=1:64 000

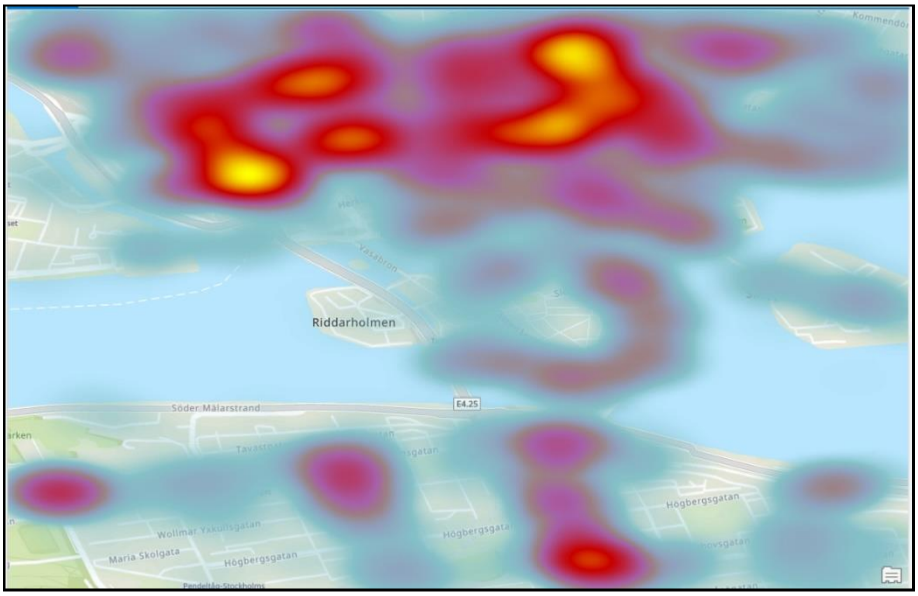


Figure 29: Start points heat map at a Scale = 1:25 000

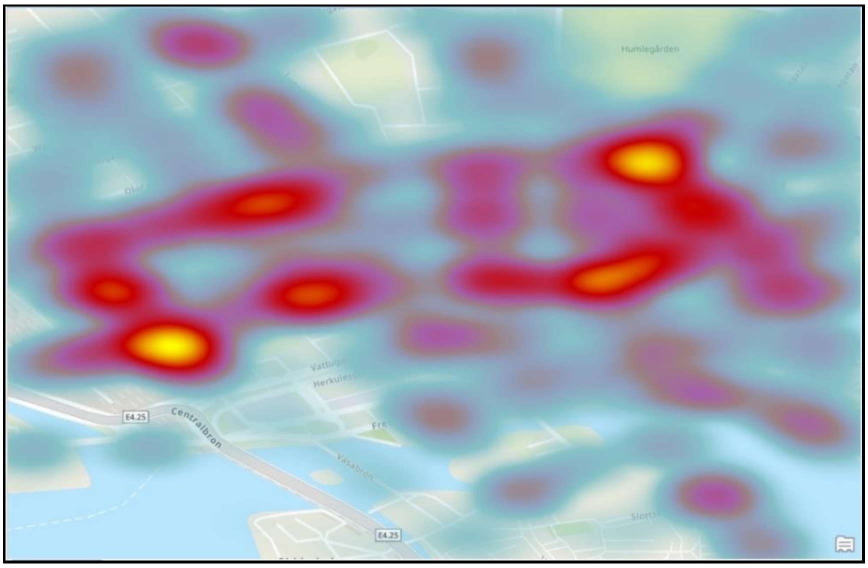


Figure 30: Start points heat map at a Scale = 1:15 000

From the previous figures, it can be determined that most of the starting points were concentrated in the downtown areas especially in the eastern and western parts rather than other locations in the south. However, distribution densities tend to be the same in the southern regions (Gamla Stan) as well as some parts in the southern areas (Södermalm), northern and western areas (Norrmalm and Kungsholmen).

The ending (destination) points were visualized as shown in the figure 31. Lighter colors represent low density while blue and yellow colors represent higher densities. In figure 31, the distribution seems to be the same as the starting points in the first figure. However, distribution densities have been changed as scale became smaller.

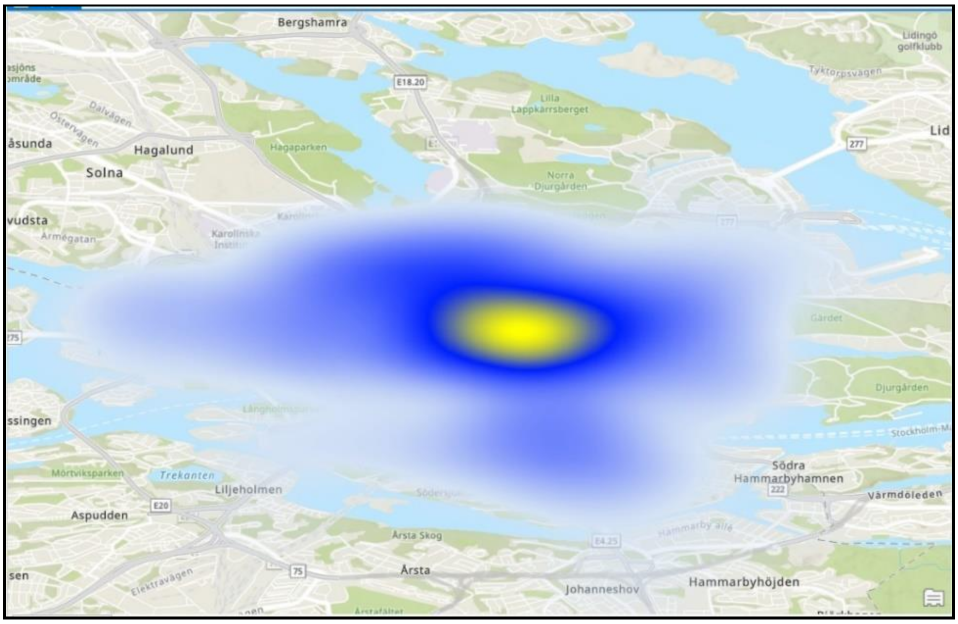


Figure 31: End points heat map at a Scale = 1:64 000

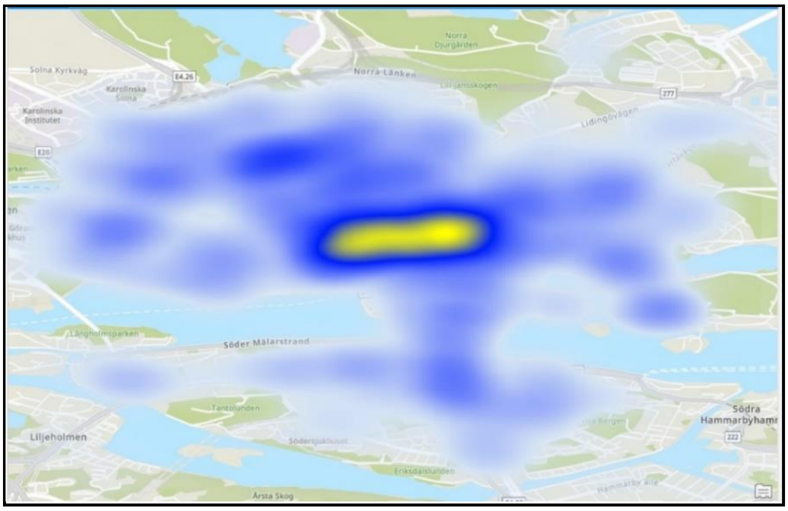


Figure 32: End points heat map at a Scale = 1:25 000

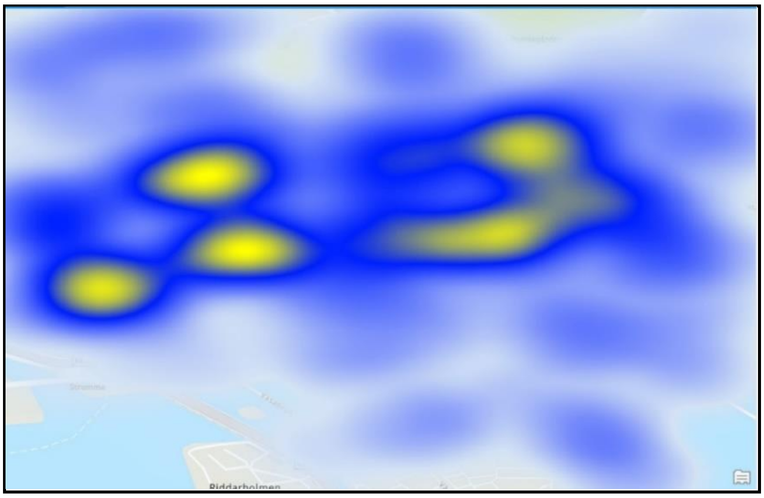
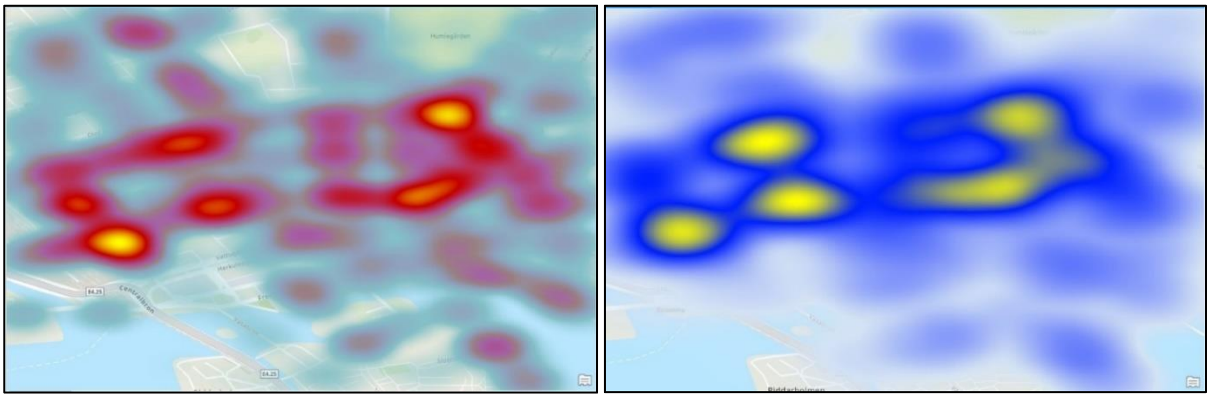


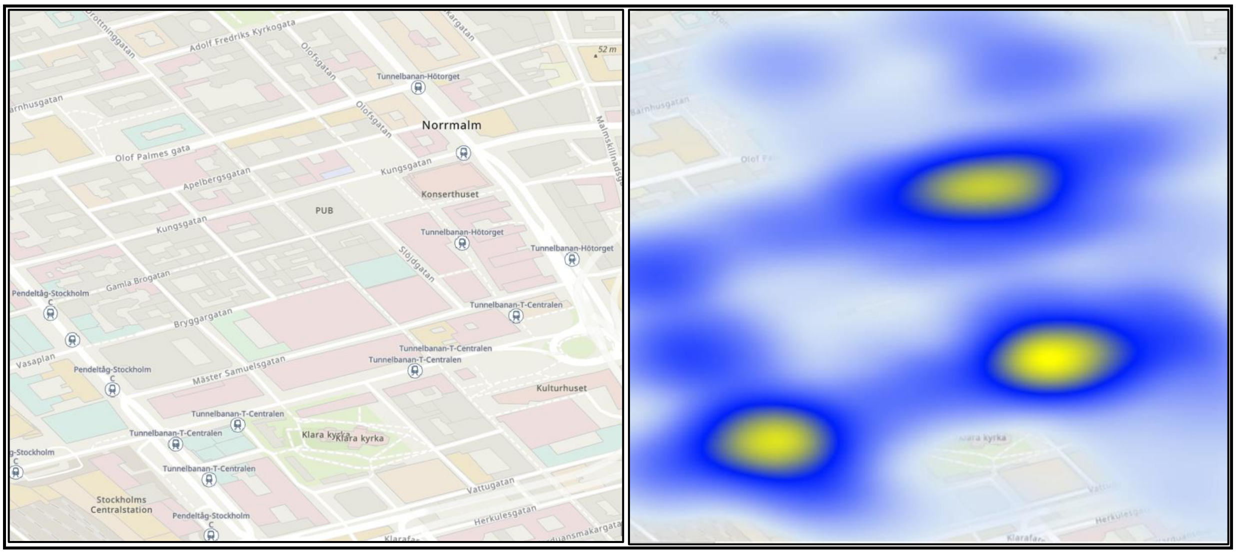
Figure 33: End points heat map at a scale = 1:15 000



A B

Figures 34(A and B): Start and end point densities at the same locations and scale = 1:15 000

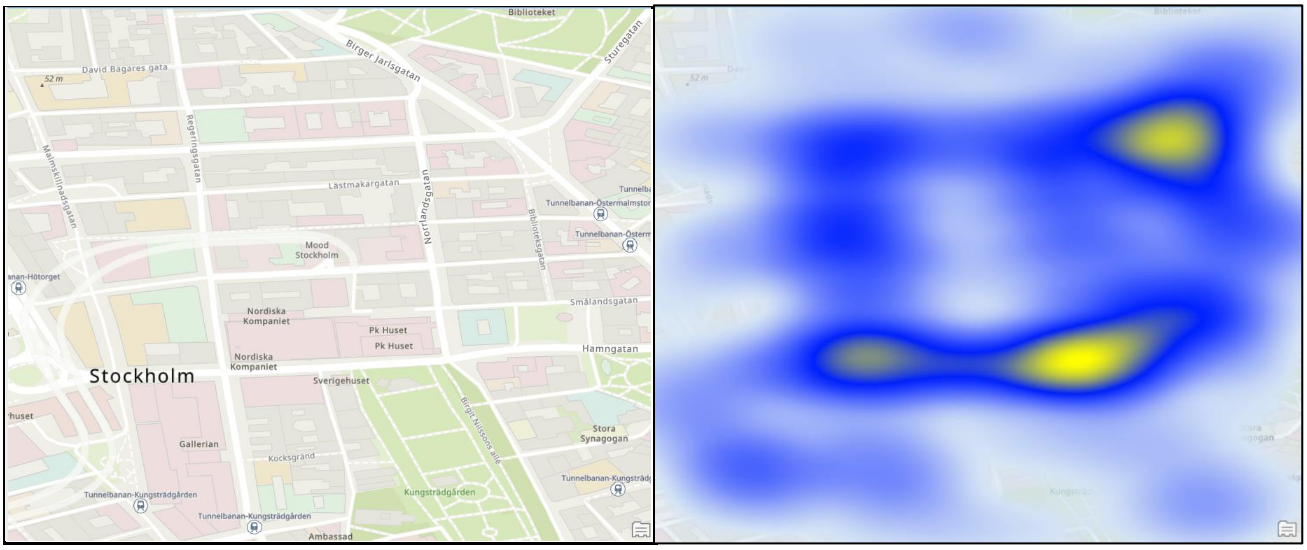
It can be observed that destination point densities were distributed at the same locations for both starting and ending points and densities were the highest in the central region. These figures reveal some travel behaviors that E-scooters are mostly used in the T-centralen areas of the city including Kungsträdgården, Sture plan, Sergelstorg and some parts in Östermalm. From these regions it can be recognized that trips mainly made for either leisure purposes. In figure 35 B, concentrations of point densities were mainly around T-centralen Metro and railway and Hötorget railway stations which are known by the presence of many restaurants, shops and other leisure facilities located there. Detailed figures of the mentioned locations are shown below. An American study has examined E-scooter users. Findings were almost using the mode in central Austin and the neighboring areas similar to other studies (Caspi, Smart, and Noland 2020).



A B

Figure 35(A-B): The end point densities at T-centralen and Hötorget

The three yellow shaded regions represent the highest densities of destination points which are dispersed exactly beyond T-centralen and Hötorget railway stations as shown in figure 35 A and 35B. Figures 36A and 36B represent the eastern part in central Stockholm where high destination densities are located there also. So, from the two figures it can be observed that Hamngatan and Östermalmstorg were the most attractive regions for E-scooter users. The highly dense regions are known by the presence of some touristic places as well as other leisure facilities which can indicate some types of trips made to these destinations over others.



A B

Figure 36(A-B): The end point densities at Östermalm and Stureplan as shown.

4. CONCLUSIONS

4.1. Study limitations

Responses were mostly from students which have shown some bias as a result, and this was due to the difficulty of communication with older respondents. Onsite meetings, passengers showed some apprehension from strangers in public transportation some time during the rush hours a day and night so presenting the study to someone interested was a little demanding. Survey data were validated by analyzing the real trip parameters. However, the dataset was recorded in the spring of 2019. This was due to difficulties in communicating with the operators in addition to the limited time allowed for the study. Uncovered topics related to impacts of covid-19 on the mode utilization as well as some safety- related questions.

4.2. Main conclusions

E-scooters were mostly used by young, aged users mainly between 18 and 24 years old who had at least a university degree and males. The income level was less than 10K SEK per month which shows that students are the dominating category over others in this study.

Travel time and cost were the most appreciated by the users over other preferences such as comfort and green travel modes. In particular, E-scooter preferences were different. Passengers emphasized on availability and reliability as the most important prior to choosing the E-scooters and these preferences had higher importance than time and cost according to their choices. On the other hand, there were high accessibility to public transportation facilities since the high percentage of SL memberships. This also has interpreted the low usage frequency of other shared mobility modes including bike, moped, car sharing etc... E-scooters were mainly used for leisure and outing trips were the most using E-scooters unlike commuting, services and social trips. In other studies, these preferences were varied. So, in Paris, travel time was the most appreciated over travel cost. However, in Stockholm, some users have preferred other E-scooter facilities and the reason for this difference is due to difference in traffic congestion level between Stockholm and Paris. Similar findings were mentioned in Mitra and Hess study where people preferred the same vehicle facilities, but timing parameters had higher advantages.

According to E-scooter last trip parameters, main findings suggested the user valuations have not significantly changed. Most of the respondents agreed that E-scooters would not replace car and walking is more likely to be adopted as an alternative mode. Main barriers summarized as limited E-scooter fleets in certain regions in Stockholm known by the technical term 'Geo-fencing' this has led to lack of E-scooter usage in longer trips such as commuting or social visits. However, improved fare system was found to be the main motive for the users to use E-scooters more often. Regarding data analyses, it can be concluded that E-scooters are used as a supplementary mode rather than a main mode. Users tend to access E-scooters not only for leisure activities -as stated- but sometimes also for compensating walking trips such as from and to public transit stations. This emphasizes the reason for not using E-scooters as a main mode or replacing the common means of transport by E-scooter. The spatial visualisations showed a great concentration of destination points at central parts of Stockholm such as (T-centralen, Hötorget and Östermalm) which reveals the nature of trips made by the E-scooter and validates their types as leisure trips.

5. RECOMMENDATIONS AND FUTURE WORK

5.1. Recommendations

The service area was found to be roughly 52,49 square kilometers while Stockholm counts to 188 square kilometers, which is 27 % of the total area as in figure 37. This suggests that future studies need to focus on different travel demands in the outskirts' regions. Findings of these studies will answer questions such as how these demands can be satisfied using E-scooters to serve in these regions and mitigate private car use. Many companies are in regions at the north of Stockholm such as Kista where more commuters are likely to use E-scooters than public transport.

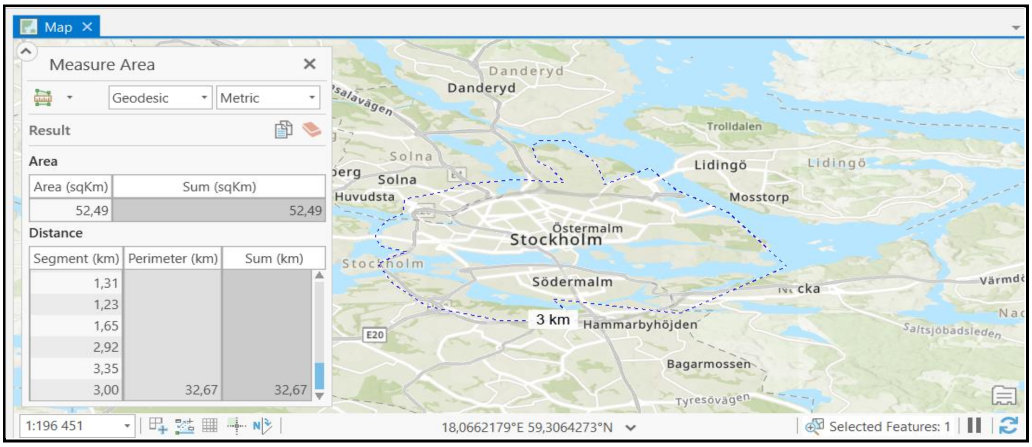


Figure 37: An approximate calculation of the total covered/service area of the shown polygon,

Fare costs were considered as one of the main barriers to access E-scooters as many respondents found that SL fare costs were more effective than hiring an E-scooter. It is suggested to increase the competition through reduced prices through offers for students and pensioners in addition to long-term payment options such as invoice payments. Another approach was found to be subsidization. A recent agreement between lime and benefits company in the US. The agreement aimed for providing E-scooter services for commuters. The initiative grants the potential positive impacts of e-scooters on society and environment. Similar initiative worth proposed in Stockholm (Holder 2021).

Transportation will play an important role in satisfying UN global goals. Since that it contributes to over 20% of energy-related CO_2 emissions. The global transport emissions were counted to 8 billion tons of CO_2. 74.5% of these emissions comes from road vehicles. Mobility was defined as the ease of accessibility of passengers and goods from one point to another (Caballero and Tanzilli 2021). The development of shared mobility utilization will therefore increase the positive impacts on environment since the accessibility to different demands now became easier and sustainable. Increased accessibility E-scooters in different regions would mitigate the GHG emissions at 13700 metric tons of carbon dioxide. This amount is equivalent to replacing 105000 cars by electric scooters around the world (lat 2018). consequently, this would have a significant contribution in achieving the United Nations global sustainability goals by 2030.

5.2. Future research work

Micro mobility modes are expected to have positive impacts on the environmental levels (McQueen, MacArthur, and Cherry 2020). To increase this probability, future studies are required to include the influential factors that affect the intention of using E-scooters. These are the findings of statistical models such as logistic regression models. Furthermore, research frameworks can be used in exploring, analyzing and changing human behaviour from the psychological point of view. Theory of planned behaviour and the transtheoretical models of change can be considered as examples.

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APPENDIX A: SUPPLEMENTARY INFORMATION-SURVEY FINDINGS

1-Demographics			
Varaible	Type	Summary statistics	Varaible ID
Gender			
Male	Discrete	65,82%	1
Female		32,65%	2
Prefer not to say		1,53%	3
Main residence			
Stockholm	Discrete	95,90%	1
Other swedish city		4,10%	2
Age			
Under 18	Discrete	14,56%	1
18-24		44,17%	2
25-34		36,89%	3
35-44		2,91%	4
45-54		0,97%	5
55-64		0,49%	6
64 +		0,00%	7
Last degree			
Before high school	Discrete	6,25%	1
hIgh school / Gymnasuim		30,21%	2
University degree		33,85%	3
Masters degree		25,00%	4
PhD.		1,56%	5
Other		3,13%	6
Monthly income			
Less than 10K SEK	Discrete	43,23%	1
10K-20K SEK		25,00%	2
20k-30K SEK		11,98%	3
30K-40K SEK		11,98%	4
40K-50K SEK		1,56%	5
> 50K SEK		6,25%	6
Occupation category			
Not active (student / retired)	Discrete	44,50%	1
Employee-Full time		26,70%	2
Employee-Part time		24,08%	3
Head of a company or Executive		0,52%	4
Business owner		4,19%	5
Houshold composition			
Single in private accomodation	Discrete	48,66%	1
Couple with no child(ren) in private accomodation		17,65%	2
Couple with child(ren) in private accomodation		7,49%	3
single with child(ren) in private accomodation		0,53%	4
Single in shared accomodation		21,93%	5
Couple with no child(ren) in shared accomodation		1,60%	6
Couple with child(ren) in shared accomodation		1,07%	7
single with child(ren) in a shared accomodation		1,07%	8

2- Users' general travel pereferences			
Varaible	**Type**	**Summary statistics**	**Varaible ID**
Fast travel	Discrete		1
Not Important		4,52%	2
some Importance		41,94%	3
Very Important		53,55%	
Predictable travel time	Discrete		1
Not Important		3,87%	2
some Importance		25,81%	3
Very Important		70,32%	
Cost effective travel	Discrete		1
Not Important		6,49%	2
some Importance		27,92%	3
Very Important		65,58%	
Comfortable travel	Discrete		1
Not Important		15,48%	2
some Importance		51,61%	3
Very Important		32,90%	
A travel using Environmentally friendly mode	Discrete		1
Not Important		20,00%	2
some Importance		47,74%	3
Very Important		32,26%	
A travel with flexibile travel time	Discrete		1
Not Important		8,50%	2
some Importance		40,52%	3
Very Important		50,98%	

3- Escooter choice perferences

Varaible	Type	Summary statistics	Varaible ID
Faster than other modes			
Not Important	Discrete	18,54%	1
some Important		42,38%	2
Very Important		39,07%	3
Cost effective			
Not Important	Discrete	19,21%	1
some Important		44,37%	2
Very Important		36,42%	3
Safe			
Not Important	Discrete	38,00%	1
some Important		35,33%	2
Very Important		26,67%	3
Comfortable			
Not Important	Discrete	26,00%	1
some Important		43,33%	2
Very Important		30,67%	3
Environmentally friendly			
Not Important	Discrete	30,00%	1
some Important		42,67%	2
Very Important		27,33%	3
Easy access and parking			
Not Important	Discrete	5,30%	1
some Important		20,53%	2
Very Important		74,17%	3
Reliable (i.e. It reaches everywhere)			
Not Important	Discrete	8,00%	1
some Important		36,67%	2
Very Important		55,33%	3
Availble everywhere			
Not Important		6,76%	1
some Important		23,65%	2
Very Important		69,59%	3

4- usage frequency of Private modes			
Varaible	**Type**	**Summary statistics**	**Varaible ID**
Car ownership			
No car	Discrete	74,68%	1
1 car		22,08%	2
several cars		3,25%	3
Driving License			
Yes	Boolean	65,81%	1
No		34,19%	2
Rented/Private car	Discrete		
Never		40,13%	1
Few times per year		17,76%	2
Few times per Month		14,47%	3
Weekly		11,84%	4
More than 3 times per week		9,21%	5
Daily		6,58%	6
Private Bike	Discrete		
Never		38,41%	1
Few times per year		21,19%	2
Few times per Month		12,58%	3
Weekly		10,60%	4
More than 3 times per week		8,61%	5
Daily		8,61%	6
Private electric scooter	Discrete		
Never		83,55%	1
Few times per year		3,95%	2
Few times per Month		7,89%	3
Weekly		1,32%	4
More than 3 times per week		3,29%	5
Daily		0,00%	6
Private Motorcycle/Moped	Discrete		
Never		91,45%	1
Few times per year		3,29%	2
Few times per Month		2,63%	3
Weekly		1,32%	4
More than 3 times per week		1,32%	5
Daily		0,00%	6
Walk	Discrete		
Never		1,34%	1
Few times per year		4,03%	2
Few times per Month		2,68%	3
Weekly		12,75%	4
More than 3 times per week		17,45%	5
Daily		61,74%	6

5- usage frequency Public Transit			
Varaible	**Type**	**Summary statistics**	**Varaible ID**
Public Transit Pass (i.e SL card)			
Yes	Boolean	70,32%	1
No		29,68%	2
Tunnel Bana	Discrete		
Never		2,60%	1
Few times per year		7,79%	2
Few times per Month		21,43%	3
Weekly		11,04%	4
More than 3 times per week		29,87%	5
Daily		27,27%	6
Light rail / Tram	Discrete		
Never		19,08%	1
Few times per year		34,21%	2
Few times per Month		27,63%	3
Weekly		9,87%	4
More than 3 times per week		6,58%	5
Daily		2,63%	6
Roslagsbanan	Discrete		
Never		50,33%	1
Few times per year		29,14%	2
Few times per Month		13,25%	3
Weekly		3,97%	4
More than 3 times per week		1,32%	5
Daily		1,99%	6
Pendeltåg (Metro)	Discrete		
Never		8,72%	1
Few times per year		30,87%	2
Few times per Month		28,86%	3
Weekly		14,09%	4
More than 3 times per week		11,41%	5
Daily		6,04%	6
Bus	Discrete		
Never		2,65%	1
Few times per year		10,60%	2
Few times per Month		23,84%	3
Weekly		20,53%	4
More than 3 times per week		20,53%	5
Daily		21,85%	6
Taxi	Discrete		
Never		32,00%	1
Few times per year		33,33%	2
Few times per Month		25,33%	3
Weekly		6,67%	4
More than 3 times per week		2,00%	5
Daily		0,67%	6

6-User travel frequency using shared mobility modes

Shared mobility systems			
Varaible	**Type**	**Summary statistics**	**Varaible ID**
Electric scooter Pass			
Yes	Boolean	7,74%	1
No		92,26%	2
Shared bicycle (Euro bike)	Discrete		
Never		86,09%	1
Few times per year		6,62%	2
Few times per Month		3,97%	3
Weekly		0,66%	4
More than 3 times per week		2,65%	5
Daily		0,00%	6
Shared car (Aimo)	Discrete		
Never		84,11%	1
Few times per year		8,61%	2
Few times per Month		3,31%	3
Weekly		3,31%	4
More than 3 times per week		0,66%	5
Daily		0,00%	6
Shared Electric scooter (Voi, Lime, etc..)	Discrete		
Never		15,89%	1
Few times per year		49,67%	2
Few times per Month		18,54%	3
Weekly		7,95%	4
More than 3 times per week		4,64%	5
Daily		3,31%	6

7- E-scooter usage frequency based on trip puropose

Varaible	Type	Summary statistics	Varaible ID
Commuting / Education (School/University)			
Never	Discrete	45,45%	1
Few times per year		22,08%	2
Few times per Month		9,74%	3
Weekly		11,69%	4
More than 3 times per week		7,14%	5
Daily		3,90%	6
Delivery services			
Never	Discrete	73,20%	1
Few times per year		5,23%	2
Few times per Month		11,76%	3
Weekly		6,54%	4
More than 3 times per week		1,96%	5
Daily		1,31%	6
Liesure and activities (e,g outings)			
Never	Discrete	29,61%	1
Few times per year		36,84%	2
Few times per Month		18,42%	3
Weekly		9,21%	4
More than 3 times per week		3,95%	5
Daily		1,97%	6
Strolling around the city			
Never	Discrete	25,83%	1
Few times per year		41,06%	2
Few times per Month		17,22%	3
Weekly		10,60%	4
More than 3 times per week		2,65%	5
Daily		2,65%	6
Shopping and errands			
Never	Discrete	52,63%	1
Few times per year		22,37%	2
Few times per Month		14,47%	3
Weekly		5,92%	4
More than 3 times per week		3,95%	5
Daily		0,66%	6
Social (Visiting friends/Family)			
Never	Discrete	40,67%	1
Few times per year		25,33%	2
Few times per Month		18,00%	3
Weekly		9,33%	4
More than 3 times per week		3,33%	5
Daily		3,33%	6

8- Escooter last trip parameters

Varaible	Type	Summary statistics	Varaible ID
Access time			
1-3 minutes	Discrete	42,47%	1
3-5 minutes		33,56%	2
5-7 minutes		10,96%	3
>7 minutes		13,01%	4
Travel time			
5-15 minutes	Discrete	59,72%	1
15-25 minutes		25,69%	2
25-35 minutes		9,72%	3
35-45 minutes		1,39%	4
>45 minutes		3,47%	5
Trip purpose			
Commuting / Education (School/University)	Discrete	17,24%	1
Delivery services		5,52%	2
Liesure and activities (e.g. outings)		31,72%	3
Strolling around the city		19,31%	4
Shopping and errands		5,52%	5
Social (Visiting friends/Family)		20,69%	6
Modal shift			
Tunnel Bana	Discrete	26,71%	1
Light rail / tram		0,68%	2
Roslagsbanan		0,68%	3
Pendeltåg(Metro)		2,74%	4
Bus		15,75%	5
Rented/Private car		2,05%	6
Taxi		6,16%	7
Private Bike		6,85%	8
Private Motorcycle/Moped		0,00%	9
Shared car (Aimo)		0,00%	10
Walk		34,93%	11
Wouldn't have made the trip		3,42%	12

9- General findings

Varaible	Type	Summary statistics	Varaible ID
first time motivation	Discrete		
Curious to try it out		64,08%	1
Environmentally friendly		5,63%	2
Look fast to get around		22,54%	3
Save some money		2,82%	4
Discovering the city		4,93%	5
private car reduction			
Yes	Discrete	10,56%	1
No		54,93%	2
No, but I've considered it.		4,93%	3
N/A, I didn't own an automobile before using e-scooters and currently don		29,58%	4
Riding an Escooter during a rainy or a snowy day			
Yes	Boolean	21,13%	1
No		78,87%	2
Barriers of riding shared electric scooters			
Worry about hitting someone or being hit	Discrete	9,35%	1
Instability while driving		8,39%	2
Not enough safe places to ride		4,56%	3
Worry about safety from crime		0,48%	4
Can't carry much / transport others		13,43%	5
Impractical for longer distances		17,51%	6
Battery not always charged		11,27%	7
Other malfunctions in the Scooter		4,56%	8
High rental price		17,03%	9
Escooters are far away from my area		7,91%	10
Have some diffuclties using the applications		1,92%	11
Too many competing companies in the same area so I'm getting confu		2,16%	12
Have no experience in using it		1,44%	13
Motives of riding shared electric scooters			
E-scooters availble in surrounding locations (outside the ci	Discrete	13,35%	1
Lower costs		26,42%	2
E-scooters with seats		6,82%	3
Improved design (carry more than one person onboard)		8,52%	4
Safer places to ride other than bike lanes		8,24%	5
Longer battery life		13,35%	6
Improved stability		11,08%	7
Fatser and more effecient motors		9,94%	8
None of the previous changes would encourage me to use e-scooters more		2,27%	9

APPENDIX B: HISTORICAL DATA ANALYSES (PYTHON CODE)

```
#Analyses
import datetime as dt
import csv
import math
import pandas as pd
pd.options.mode.chained_assignment = None
import numpy as np
#Visualisation
import matplotlib as mpl
import matplotlib.pyplot as plt
import seaborn as sns
sns.set(style="white")
sns.set(style="whitegrid", color_codes=True)
```

```
data = pd.read_csv("trip_data_20190429_20190505.csv")
df1 = pd.DataFrame(data)
df1.head()
df1.tail()
```

```
#Changing data headings, spliting data, changing data types and removing
unwanted attributes
dict = {'hashed_customer_id': 'ID',
        'start_timestamp': 'Start',
        'end_timestamp': 'End', 'start_lat': 'Start_latitudue','end_lat':
'End_latitude','start_lon': 'Start_longitude','end_lon': 'End_longitude'}
dff=df1.rename(columns=dict,inplace=True)
dff=df1.drop(['ID','md5_vehicle'], axis = 1)
print(dff.dtypes)
```

```
#changing the date from string to date time format
dff.Start=pd.to_datetime(dff.Start)
dff.End=pd.to_datetime(dff.End)
dff.loc[:, 'Distance'] = pd.Series(dtype=float)
#Calculating the distance using Haversine Formula
for i,row in dff.iterrows():
    lat1=math.radians(dff.Start_latitudue[i])
    lon1=math.radians(dff.Start_longitude[i])
    lat2 = math.radians(dff.End_latitude[i])
    lon2 = math.radians(dff.End_longitude[i])
    dlon = lon2 - lon1
    dlat = lat2 - lat1
    a = math.sin(dlat / 2)**2 + math.cos(lat1) * math.cos(lat2) *
math.sin(dlon / 2)**2
    c = 2 * math.atan2(math.sqrt(a), math.sqrt(1 - a))
    distance = 6373.0 * c
```

```
    dff.Distance[i]=distance
```

```
# Calculating the elapsed time between dates
dff.loc[:, 'Elapsed_time'] = pd.Series(dtype=object)
for i,row in dff.iterrows():
    dff.Elapsed_time[i] = dff.End[i]-dff.Start[i]
dff.head(3)
```

```
dff.Elapsed_time=dff.Elapsed_time.astype(str)
dff.dtypes
```

```
long=np.where(dff.Elapsed_time=='1 days')
long
```

```
dff['Elapsed_time'] = pd.to_timedelta(dff['Elapsed_time'],errors='coerce')
dff.dtypes
```

```
dff.Elapsed_time=dff.Elapsed_time/np.timedelta64(1, 's')
dff.dtypes
```

```
# Calculating the Average speed
dff.loc[:, 'Average_Speed'] = pd.Series(dtype=float)
for row in dff.itertuples():
    dff.Average_Speed=dff.Distance/(dff.Elapsed_time/3600)
dff.head()
```

```
# Data cleaning-removing outliers for elapsed time
#The chosen criteria is the elpased time than distance
q1 = dff['Elapsed_time'].quantile(0.25)
q3 = dff['Elapsed_time'].quantile(0.75)
iqr = q3 - q1
fence_low = q1 - 1.5 * iqr
fence_high = q3 + 1.5 * iqr
dff = dff.query('(@q1 - 1.5 * @iqr) <= Elapsed_time <= (@q3 + 1.5 * @iqr)')
dff.head()
```

```
# Data cleaning-Removing outliers for distance
q2 = dff['Distance'].quantile(0.25)
q4 = dff['Distance'].quantile(0.75)
iqr = q3 - q1
fence_low = q1 - 1.5 * iqr
fence_high = q3 + 1.5 * iqr
dff = dff.query('(@q1 - 1.5 * @iqr) <= Distance <= (@q3 + 1.5 * @iqr)')
dff.head()
```

```
#removal of outliers in the average speed
q5 = dff['Average_Speed'].quantile(0.25)
q7 = dff['Average_Speed'].quantile(0.75)
iqr = q7 - q5
fence_low = q5 - 1.5 * iqr
fence_high = q7 + 1.5 * iqr
```

```
dff = dff.query('(@q5 - 1.5 * @iqr) <= Average_Speed <= (@q7 + 1.5 * @iqr)')
dff.head()
# Data Visualisation Travel times(sec.)-Histogram
bins=[300,900,1500,2100,2700,3000]
plt.hist(dff.Elapsed_time,bins=[300,900,1500,2100,2700,3000])
plt.xlabel('Travel time intervals(seconds)')
plt.ylabel('Bins')
plt.title('Travel times distribution from 29th of April 2020 till 5th of may
2020')
plt.show()
```

```
# Data Visualisation Travel times(sec.)-Pie chart
plt.style.use('ggplot')
rang_0_300 = dff.loc[dff['Elapsed_time']<=300].count()[0]
rang_300_900 =
dff.loc[(dff['Elapsed_time']>300)&(dff['Elapsed_time']<900)].count()[0]
rang_900_1500 =
dff.loc[(dff['Elapsed_time']>900)&(dff['Elapsed_time']<1500)].count()[0]
rang_1500_2100 =
dff.loc[(dff['Elapsed_time']>1500)&(dff['Elapsed_time']<2100)].count()[0]
rang_2100_2700 =
dff.loc[(dff['Elapsed_time']>2100)&(dff['Elapsed_time']<2700)].count()[0]
labels=['0-5 mins.','5-15 mins.','15-25 mins.','25-35 mins.','35-45 mins.']
plt.pie([rang_0_300,rang_300_900,rang_900_1500,rang_1500_2100,rang_2100_2700]
, labels=labels,autopct='%.2f%%',pctdistance=0.6)
plt.title('Travel times intervals distribution')
plt.show()
```

```
# Travel times (sec.)-Box plot
plt.style.use('default')
plt.figure(figsize=(4,6))
labels=['Travel times(sec.)']
plt.title('Box plot of Travel times')
plt.ylabel('Travel time intervals(sec.)')
plt.boxplot(dff.Elapsed_time,showmeans=True,labels=labels)
plt.show()
```

```
dff.Elapsed_time.describe()
```

```
# Total distance covered (km) -Histogram
bins=[0,1,2,3,4,5,6,7,8]
plt.figure(figsize=(4,6))
plt.hist(dff.Distance,bins=bins, color='b')
plt.xlabel('Total distance covered(Km)')
plt.ylabel('Bins')
plt.title('Distance distribution from 29th of April 2019 till 5th of May
2019')
plt.show()
```

```
# Total distance covered (km) -Pie chart
plt.style.use('ggplot')
```

```
rang_0_1Km = dff.loc[dff['Distance']<=1].count()[0]
rang_1_3Km = dff.loc[(dff['Distance']>1)&(dff['Distance']<3)].count()[0]
rang_3_5Km = dff.loc[(dff['Distance']>3)&(dff['Distance']<5)].count()[0]
rang__Over5Km = dff.loc[(dff['Distance']>5)].count()[0]
labels=['less than 1 km.','1-3 Km','3-5 Km','5+ km']
plt.pie([rang_0_1Km,rang_1_3Km,rang_3_5Km,rang__Over5Km],
        labels=labels,autopct='%.2f%%',pctdistance=0.9)
plt.title('Travel Distance intervals distribution')
plt.show()
```

```
# Total distance covered- Box plot
plt.figure(figsize=(3,5))
labels=['Travel Distances(Km)']
plt.title('Box plot of Travel distance')
plt.ylabel('Travel distance intervals(Km)')
plt.ylim((0,8))
axes = dff.boxplot(column='Distance', figsize=(20,10),whis=[5,95],
return_type='axes')
plt.show()
```

```
dff.Distance.describe()
```

```
# Data Visualisation-Average travel speed-Histogram
bins=[0,5,10,15,20,25]
plt.hist(dff.Average_Speed,bins=bins,color='b')
#plt.hist(dff.Average_Speed, bins=range(min(dff.Average_Speed),
max(dff.Average_Speed) + 200, 200))
plt.xlabel('Total Average speed(Km/h)')
plt.ylabel('Bins')
plt.title('Average speed distribution from 29th of April 2019 till 5th of May
2019')
plt.show()
```

```
# Data Visualisation-Average travel speed-pie chart
plt.style.use('ggplot')
rang_0_5Kmh = dff.loc[dff['Average_Speed']<=5].count()[0]
rang_5_10Kmh =
dff.loc[(dff['Average_Speed']>5)&(dff['Average_Speed']<10)].count()[0]
rang_10_15Kmh =
dff.loc[(dff['Average_Speed']>10)&(dff['Average_Speed']<15)].count()[0]
rang__15_20Kmh =
dff.loc[(dff['Average_Speed']>15)&(dff['Average_Speed']<20)].count()[0]
labels = ['less than 5 km/h','5-10 Km/h','10-15 Km/h','15-20 Km/h']
plt.pie([rang_0_5Kmh,rang_5_10Kmh,rang_10_15Kmh,rang__15_20Kmh],labels=labels
,autopct='%.2f%%',pctdistance=0.7)
plt.title('Average speed intervals distribution')
plt.show()
```

```
# Data Visualisation-Average travel speed-Box plot
plt.figure(figsize=(3,5))
labels=['Travel average speeds(Km/h)']
```

```
plt.title('Box plot of Travel average speeds')
plt.ylabel('Travel average speed intervals(Km/h)')
plt.ylim((-2,25))
axes = dff.boxplot(column='Average_Speed', figsize=(20,10),
                   whis=[5,95], return_type='axes')
plt.show()
```

```
dff.Average_Speed.describe()
```

```
b = np.where(dff.Average_Speed < 0)
print(b)
```

```
# Visualising locations
Start_Date='2019-05-1 00:00:00'
End_Date='2019-05-3 00:00:00'
mask = (dff['Start'] > Start_Date) & (dff['End'] <= End_Date)
```

```
dff1=dff.loc[mask]
dff1.head()
```

```
dff1.drop(['Start', 'End'], axis = 1)
```

```
dff1.to_csv(r'C:\Users\taha-\GIS__data.csv',index=False)
```

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