Usage Pattern Analysis of e-scooter Sharing System: A Case Study in Gothenburg, Sweden

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Abstract. Swedish cities are embracing shared micro-mobility systems (SMMS) such as e-scooters sharing systems to promote sustainable travel behavior in urban contexts with corresponding infrastructure planning. SMMS is associated with various social, environmental, and economic benefits, as well as providing solutions for the first- and the last-mile problem of using public transit. This study analyzes the usage patterns of e-scooter systems, based on the scooter operation data of VOI company in Gothenburg, Sweden. The used data cover the transaction data of two and half months during the summer and include over five hundred thousand valid trip records. The result shows that most trips travel a distance between 0.5–1.8 km while the duration lasts between 4–7 min. Fridays and Saturdays are the most popular days while Sunday is the least popular day. The number of trips on Sundays decreases by about 60% compared to Fridays and Saturdays. Moreover, the e-scooters are used to varying degrees in the different areas of Gothenburg. The e-scooters are used at a much higher extent in central Gothenburg compared to areas outside the city center. This can be due to several different factors such as location, land use, and accessibility. Lastly, the results show that the e-scooters are not primarily used for commuting but rather for leisure, which can be seen in the average distance and duration of the entire zone as well as the temporal distribution.

Keywords: Micro-mobility · Shared micro-mobility · E-scooters · Usage patterns

1 Introduction

Every year more than one hundred million people are affected by climate catastrophes. According to the Red Cross [1], up to two hundred million people may need emergency aid by 2050 if the world does not act now. In connection with the climate changes that are currently taking place because of global warming, multiple countries around the world have decided to reduce their emissions. Sweden has a goal of attaining net-zero emissions of GHG into the atmosphere by 2045 [2–4]. To achieve this, Sweden must reduce their emissions from other sectors including the transport sector, which accounts

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for one-third of all greenhouse gases emitted [5]. According to a study conducted by traffic analysis [6], the majority of all journeys that take place in Sweden are carried out by car. This corresponds to 55% of all trips made in 2020. The remaining 45% were distributed rather evenly between public transport, walking, and cycling, see Fig. 1.

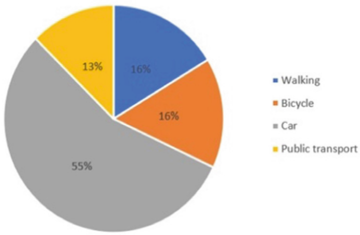


Fig. 1. Travel mode split structure in Sweden 2020.

There are several different approaches available to reduce the utilization of cars which has a negative effect on the environment. One of them is the use of shared micro-mobility systems such as electric scooter sharing mobility. According to Mansky [7, 8], electric scooters have existed for over one hundred years, but it is not until recent years that the demand for these micro-mobility devices has increased radically. The modern-day electric scooters were first introduced in the United States in 2017 and have since spread rapidly around the world [9, 10]. Electric scooters reached the Swedish market shortly after when the Swedish company VOI launched their own electric scooters in 2018. Without doubts, shared e-scooter systems (SESS) can provide convenient travel tools for users to reduce travel time or cost in many situations, as a result of its flexibility. The convenience and flexibility of shared electric scooter systems bring prosperity by implementing them in urban contexts, especially in the European Union, EU. The aim of this thesis is to answer the above-mentioned research questions based on massive real usage data of SESS. We got access to the transaction data of e-scooter systems in Gothenburg from the open API of the VOI company. Based on the unique data, we mainly investigate the spatiotemporal usage patterns of SESS in Gothenburg. Particularly, this study reveals the potential differences in the usage patterns in different urban areas with different built environments.

2 Literature Review

As urban areas throughout the world continue to expand rapidly, and the demand for the existing transportation network is increasing, micro-mobility is gaining attention as a practical alternative. Micro-mobility is defined as a short-distance transport and can be described as "Personal transportation using devices and vehicles weighing up to 350 kg and whose power supply, if any, is gradually reduced and cut off at a given speed limit which is no higher than 45 km/h" [11]. In micro-mobility, human-powered vehicles are used exclusively, such as bikes, e-scooters, skateboards, e-rickshaws, etc. Micro mobility is offering attractive solutions for "first and last-mile connectivity," as well as assisting in the reduction of traffic [12].

Moreover, the term “micro-mobility” gained popularity around the year 2016 when Dediu [10] an American analyst, connected the term to sharing vehicles such as bicycles and scooters. The term “micro,” according to Dediu [10] refers to either the short distances that are traveled by such vehicles or the vehicle itself. In recent years, the usage of micro vehicles has increased drastically in connection with the introduction of electric scooters. Many micro vehicles are owned by private individuals who utilize them for their daily trips. In addition to the privately owned vehicles, it is also common to find electric scooters and bicycles on the streets in the city that are available to rent [11]. Shared micro-mobility system (SMMS), is the system of sharing using low-speed modes such as electric scooters (e-scooters) and electric bikes (e-bikes). This innovative transportation system provides users temporary access to small modes of transportation to satisfy short-distance travel demands [12, 13] and thus has an impact on users' travel behavior and decision-making. Shared bike-sharing can be divided into station-based (docked), dockless, and hybrid bike-sharing systems. Scooter sharing, on the other hand, can be divided into standing electric scooter sharing and moped-style scooter sharing. The main difference between docked -and dockless sharing systems is that docked sharing system provides one-way station-based service, while dockless sharing system enables checking out the sharing mode and returning in any locations within a predefined geographic region [14].

Furthermore, Bielinski and Wazna [15] concluded that the availability of shared micro-mobility needs to be considered and improved to reach out to as many social groups as possible. Urban areas are increasingly affected by different issues such as traffic congestion, car accidents, space occupied by cars, air pollution and external transportation costs. Accordingly, Bielinski and Wazna [15] state that increasing the availability of these services will support municipal administrations in addressing the challenges associated with urbanized areas.

Additionally, Insurance Soved Blog [16] reports that 31% of the pedestrians in the Australian city Adelaide are uncomfortable when sharing the sidewalk with electric scooters, with a proportion increasing with the pedestrian's age. Moreover, the study shows that 29% of the pedestrians have been forced to move quickly aside to avoid colliding with electric scooters. The study also states that up to 40% of the e-scooters were not parked as per the instructions of the operator, which posed a potential safety risk to the pedestrians [16]. According to the Swedish Transport Agency [17], the number of accidents with electric scooters has risen to 1 000 accidents in the past year. In 2016–2018, approximately twenty personal injury accidents occurred per year where an electric scooter was involved. In the following years, the number of injury accidents increased, and 1 056 accidents involving electric scooters occurred from August 2021 [17].

3 Study Area and Data

The area examined in this study is the city Gothenburg located in the western part of Sweden. Gothenburg is the second-largest city, with an area of 448 km^2 and a population of 580,000 inhabitants [18]. Gothenburg is divided into 4 major urban areas consisting of Northeast, Centrum, Southwest, and Hisingen, as shown by Fig. 2.

Since the purpose of this thesis is to investigate the usage patterns of VOI's electric scooters in Gothenburg the study area will be limited to VOI's own zone which can be seen in Fig. 3. VOI has limited the use of their electric scooters to Gothenburg's inner city as well as some other adjacent areas. This area will henceforth be referred to as the "VOI zone". As presented in Fig. 3 the zone lies within major roads such as E20, E6 and E45. The zone also contains all the major districts that lie within Gothenburg's inner city. The zone has an area of 152.2 km^2 and a circumference of 71 km.

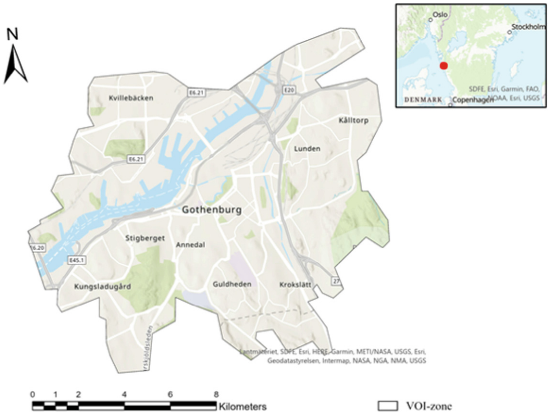


Fig. 2. Map of the study area.

Fig. 3. Land use in central Gothenburg [20].

The different zones in Gothenburg include the inner city and the middle city. The inner city is the most central part of Gothenburg and constitutes most of our study area, while the middle city is directly adjacent to the inner city. These areas consist mainly of mixed urban development that hold housing, workplaces, offices, trade, facilities, and various public services. In addition to buildings, mixed urban areas also include local streets, pedestrian, and bicycle paths, as well as public places such as squares and parks [20]. Furthermore, Fig. 3 illustrates that there are several important public transport hubs, marked as red dots, within the study area. Other areas of interest are parks and sports grounds, marked in green, as well as university campuses which are marked with many small red dots. Moreover, even though there are residentials/housing in all areas the proportion of households is much smaller in the city center compared to the rest of the zone as there is a greater focus on, for example, trade within the city center [21, 22].

3.1 Extracting Trip Transactions from Position Data

The raw data provided by VOI was downloaded from open API data in form of positioning data. Meaning it only contained the GPS information about the electric scooters that were not in use. Once an electric scooter was in use it was excluded from the list. Moreover, the data was downloaded at a frequency of 10–15 s, making it possible to record many trips to provide a fair representation of the situation. By downloading the data at such high frequency, it was ensured that the start and end coordinates of each trip were included in the dataset. It also made it possible to extract the distance based on the position data. Lastly, by knowing the download frequency the time stamps of each trip could also be extracted. In total, approximately two months' worth of positioning data was transformed into transaction data which was then used to perform the different analyses. The dataset contained 762 565 trips. Some trips were, however, abnormal, indicating the need of clearing the dataset from outliers. This was done by limiting the travel distance, duration, and speed. According to VOI's terms of service, users can only travel for 45 min continuously at a maximum speed of 20 km/h, thus setting the maximum duration to 45 min and limiting the speed to 20 km/h. The distance was also limited to a maximum of 10 km. Once all the outliers were cleared out of the transaction data, the number of trips were reduced from 762 565 to 532 938. The analysis was then performed using the new cleared dataset.

4 Results

4.1 Usage Demand and Trip Characteristics

The result is based on data that begins on the 14th of May and ends on the 20th of July. Figures 4 and 5 show the number of trips that have taken place in each zone. The dark red color in Fig. 4 indicates that many trips have taken place in that specific area while yellow indicates that the number of trips in that area is small and lastly orange is somewhere in between. The exact intervals can be seen in Fig. 4. From the figure and the diagram, it is clear that the areas with the largest number of trips are Olivedal-Haga, Inom Vallgraven and Johanneberg in descending order. On the other hand, the areas with the lowest number of trips are Skår, Delsjöområdet, and Tingstadsvassen-Hisingsbron in descending order. The other areas are somewhere in between. Nevertheless, a clear pattern is distinguished where the areas located in the city center have a high number of trips while the areas towards the edges have a much smaller number of trips. Furthermore, an exception to this trend is the area Kvillebäcken that has a larger number of trips despite being at the edge of the zone as well as being surrounded by zones that have a smaller number of trips.

Based on the approximately two months' worth of data, the distribution of trip distance and duration was calculated as well as the temporal distribution for all the

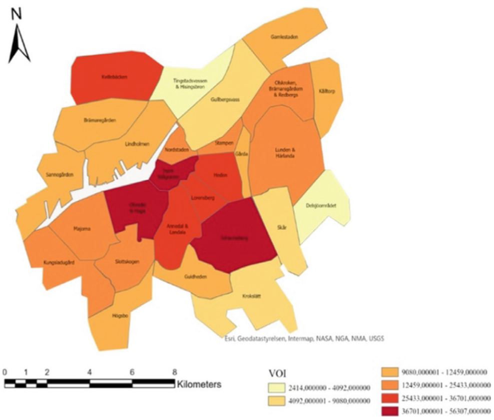


Fig. 4. Number of Voi trips for different zones.

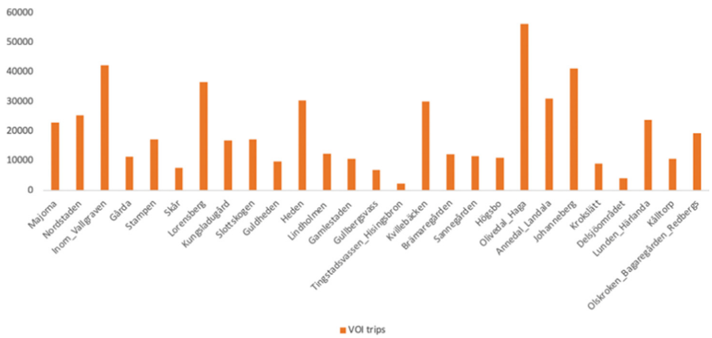
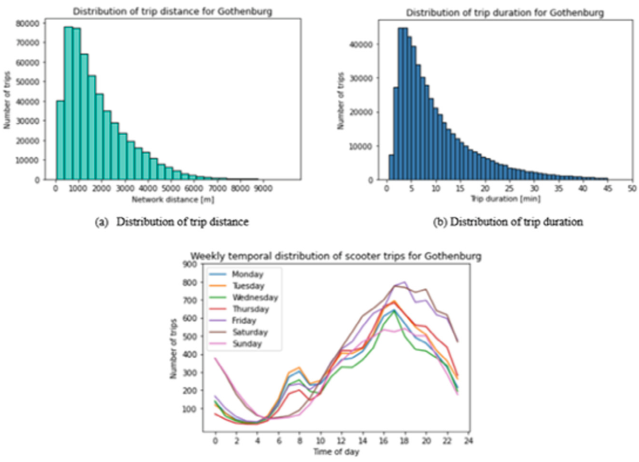


Fig. 5. Number of VOI trips in Gothenburg for different zones based on transaction data.

zones within the VOI zone. Figure 6 shows the result of each of those calculations. For the network distance, the results show that most trips travel a distance between 0.5–1.8 km, and the number of trips decreases gradually with the distance. Furthermore, most trips have a duration between 4–7 min. Similar to previous mentioned pattern, most trips are shorter rides, and the number of trips decreases as the duration increases. Lastly, the temporal distribution shows during what day of the week and what time of the day most of the users ride the e-scooters. Figure 6 (c) shows that the most popular days are Fridays and Saturdays where the number of trips is around 800, while the least popular day is Sundays where the number of trips decreases by about 60% compared to Fridays and Saturdays. Furthermore, the graph also shows that the number of trips increases during the day. The least number of trips occurs in the morning between 06.00–09.00 with about 200–300 trips. During noon, the number of trips has increased by about 150% to around 500 trips. The maximum peak hour occurs in the afternoon between 15.00–19.00 with around 600–800 trips where the number of trips has increased by 300–350% compared to the morning peak hour. Additionally, it can also be observed that the afternoon peak hour has a longer duration during the weekends (Friday and Saturday nights) and lasts until 22.00.



(a) Distribution of trip distance

(b) Distribution of trip duration

(c) Temporal distribution of scooter trips

Fig. 6. Spatial and temporal distributions for the entire Voi zone.

4.2 Differences of Using SESS Different Zones

Figure 7 shows that all areas have a trip distance distribution that is skewed to the right except Delsjöområdet. This areas distribution reminiscent of the right-skewed shape however because of the bar standing out to the left it deviates from the traditional shape. The right-skewed distribution indicates that the number of trips decreases as the distance increases.

A clear difference regarding the travel distances, as well as the number of trips, can be seen between the areas that have a high demand compared to the areas with a small demand (top three and bottom three). Areas with a high demand tend to travel very short distances between 0.8–1.5 km. For instance, in Fig. 7 (b), about 5000 of all trips that take place in Olivedal Haga are between 0.8–1.2 km. Similar occurrences can also be seen for Inom Vallgraven and Johanneberg, see Table 4. Trips that take place in the three low demand areas tend to have slightly longer distances ranging between 1–2.5 km apart from Delsjöområdet, see Fig. 7 (e). In this area, most trips are about 1.5 km, followed by a distance between 3–4 km. In addition, the number of trips in the low demand areas is significantly less than the number of trips that take place in high demand areas. Among the low demand areas, Tingstadsvassen illustrated in Fig. 7(d–f) has the highest number of trips occurring at distances between 0.8–1.5 km where the number of trips amounts to approximately 1400. For the other two areas, the number of trips amounts to approximately 500 respectively. This means that there are almost eight times more trips occurring in the three high demand areas compared to the three low demand areas. Moreover, VOI has limited the trips to a max distance of 10 km. However, the results show that the longest distance among all the areas was approximately 9.3 km which yet again occurred in Delsjöområdet.

Since all the distributions have a right skew, the average value is a little larger than the median value. By comparing the different values with the figures for both trip distance and trip duration, it may be considered that the median is more representative than the mean. For example, the average trip distance for Johanneberg is 1701 m while the median is 1391 m, and Fig. 7 (c) shows that there are more trips occurring at 1400 m compared to 1700 m. Nevertheless, the most correct parameter is the mode value of all trips. The modes for the different areas can be seen in Table 4, which shows that trips in Delsjöområdet have the longest travel distance of 1500 m while Skår has the shortest travel distance of 600 m.

Small values of standard deviation indicate that the dispersion of the data from the mean value is small, while high values indicate that the data has a great variance which obtains more uncertain results. The standard deviation for both the trip distance and duration is high for all areas, thus indicating that the data has a large dispersion. The area with the lowest value for standard deviation is Skår since most of the values are on the left side of the data, while Delsjöområdet has the highest standard deviation, which is expected since its data is very dispersed.

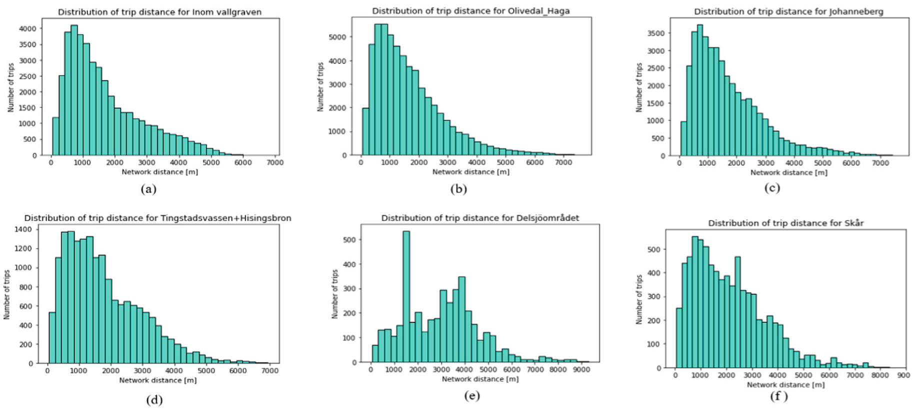


Fig. 7. Trip distance for the three areas with the biggest and smallest demand.

The percentiles show how the data is distributed within different intervals. In this study, it has been chosen to report for the 25th, 50th and 75th percentiles. For trip distance, it appears that 25% of all trips for the three high demand areas have a distance less than approximately 800 m, while 50% of all trips are shorter than approximately 2000 m. Lastly 75% of all trips are shorter than 2350 m. For the three low demand areas, there are slightly larger differences between the different areas. This is due to Delsjöområdet, which as previously mentioned, deviates from the traditional right-skewed distribution. However, in general, it can be said that about 25% of all trips are shorter than 1130 m while 50% of all trips are shorter than 2140 m and lastly 75% of all trips are shorter than 3140 m.

Table 4. Statistical parameters for trip distance.

Area	Nr of trips	Mean	Mode	Std	Min	25%	50%	75%	Max
Inom vallgraven	42 274	1676	800	1178	52	770	1343	2344	6778
Olivedal-Haga	56 307	1649	1000	1172	49	760	1374	2232	7568
Johanneberg	41 251	1701	800	1215	51	779	1391	2334	7614
Tingstadsvassen-Hisingsbron	17,330	1763	800	1187	49	830	1491	2511	6931
Delsjöområdet	4092	2978	1500	1597	54	1591	3066	3951	9289
Skår	7738	2107	600	1431	53	961	1864	2950	8349

5 Conclusion

Based on the transaction data of e-scooter sharing system in Gothenburg, this study investigates the usage patterns of the systems in both spatial and temporal dimensions. The main findings can be summarized as:

- The results show that e-scooters are used to varying degrees in the different areas of Gothenburg. E-scooters are used to a much higher extent in central Gothenburg compared to areas outside the city centre. This can be due to several different reasons such as location, land use, and accessibility.
- When e-scooters were first introduced, they were described as a means to solve the problem of the first and last mile. However, the results show that e-scooters are not primarily used for commuting but rather for leisure. This can be seen in the average distance and duration of the entire zone as well as the temporal distribution.
- The average distance and duration for the entire zone are 1.8 km and 10 min, which indicates that it is mainly very short trips that occur. Furthermore, the e-scooters are used mainly during weekday afternoons and especially during late weekend evenings when the demand for commuting is insignificant.

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