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FREE-FLOATING SHARED E-SCOOTERS USERS' PERSPECTIVE IN LUND AND MALMÖ - SWEDEN

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To everyone that took part in this journey,

What is the city but the people?

William Shakespeare

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ABSTRACT

Sustainable urban development is nowadays one of the greatest achievements that urban planners are ambitious for. The automobile dependency-related problems of congestion, pollution, and safety have been decreasing the quality of life of the cities. While, at the same time, the transportation demand has been increasing, resulting in a complex challenge. New mobility concepts are trying to solve these problems by increasing transport alternatives in urban areas. Emerging micromobility vehicles, such as free-floating shared e-scooters, are recent modes of transport that are conquering cities all around the world.

Shared e-scooters related studies are still scarce which makes it difficult for the cities to make evidence-based strategies for accommodating e-scooters. Therefore, many problems related to e-scooters services usage appeared, such as vandalism, safety, and conflicts over space. Debates around the role of e-scooters in future urban mobility are common and usually, opinions diverge into two sides - some endorse e-scooters as eco-friendly solutions, and others report contradictory findings.

The objective of the dissertation is to investigate the role of free-floating shared e-scooters for future mobility from users' perspective, based on Lund and Malmö, Sweden. Firstly, it provides a literature background focused on micromobility services and free-floating shared e-scooters. A brief market overview analysis in Europe of these services was also done. Based on the travel survey data carried out in Lund and Malmö, the results show that respondents use e-scooters mainly for leisure activities while using a bicycle as their daily mode, they also tend to use e-scooters more to go to train/metro stations rather than bus/tram stops. Frequent e-scooters users tend to be man between 26 and 39 years old, who have a higher income and education level, spend more per month on regular travel, and live less than 3km away from the city center - suitable distance to go to the city center or the central station using e-scooters. The users who use e-scooters as the substitute mode for cars represent a specific niche – they are older, expend more on travel, tend to live further away from the city center, and are less frequent e-scooter users.

The study concludes with the sustainability of e-scooters and its potential role for future mobility. In a few words, e-scooters are substituting mostly walking, biking and transit in both Lund and Malmo. According to its current performance, it shows insufficient potential to be a disruptive innovation for sustainable urban mobility. More future studies are required for creating scientific evidence to support the policy-making for shaping e-scooters towards a more sustainable mode.

KEYWORDS: Micromobility service, Free-floating shared e-scooter, Frequent users, User characteristics, Future mobility.

RESUMO

O desenvolvimento urbano sustentável é, nos dias de hoje, um dos grandes objetivos que os planeadores urbanos ambicionam. Os problemas ligados à dependência automóvel como o congestionamento, a poluição, e a segurança, tem vindo a diminuir a qualidade da vida das cidades. Enquanto que, ao mesmo tempo, a procura por transporte tem vindo a aumentar, resultando assim, num complexo desafio. Novos conceitos de mobilidade têm vindo a tentar resolver estes problemas, através do aumento das alternativas de transporte nas áreas urbanas. Serviços de micromobilidade, como as e-scooters, são modos de transporte recentes que tem vindo a conquistar cidades no mundo inteiro.

Estudos relacionados com serviços de e-scooters são ainda escassos, o que dificulta às cidades planearem estratégias direcionadas e focadas para estes serviços. Por este motivo, diversos problemas têm vindo a surgir relacionados com as e-scooters, tais como, vandalismo, segurança e conflitos pelo espaço público. Debates relacionados com o futuro da mobilidade envolvendo e-scooters são comuns, e, usualmente, as opiniões divergem em dois sentidos – alguns defendem as e-scooters como soluções amigas do ambiente, e outros argumentam com factos contraditórios.

O objetivo desta dissertação é o de investigar o papel dos serviços de e-scooters no futuro da mobilidade, tendo em conta a perspetiva dos usuários nas cidades de Lund e Malmö, na Suécia. Primeiramente, é providenciada uma revisão da literatura focada nos serviços de micromobilidade e posteriormente nos serviços de e-scooters. Uma análise breve do marcado Europeu destes serviços é também apresentada. Baseados nos resultados oriundos de um inquérito de mobilidade realizado em Lund e Malmö, os resultados mostram que este serviço é maioritariamente utilizado pelos seus usuários para atividades de lazer, sendo que estes tendem a usar a bicicleta como o modo de transporte no seu dia-a-dia. Os usuários também tendem mais a usar as e-scooters para irem para as estações de comboio/metro do que para as paragens de autocarro/elétrico. Os usuários frequentes tendem a ser homens entre os 26 e os 39 anos de idade, que tem um salário e níveis de educação superior, que gastam mais por mês em transporte, e tendem a viver a menos que 3km de distância do centro da cidade. Os usuários que usam e-scooters como substituto do carro representam um grupo muito específico – tendem a ser mais velhos, a gastar mais em transporte, e a viver mais longe do centro da cidade. São, também, usuários menos frequentes destes serviços.

Este estudo acaba com a sustentabilidade das e-scooters e o seu potencial papel para o futuro da mobilidade. Em poucas palavras, as e-scooters, nestas duas cidades, tendem a substituir maioritariamente modos mais sustentáveis de transporte, tais como, andar a pé, de bicicleta e de transportes públicos. Tendo em conta a performance atual destes serviços, estes mostram um potencial insuficiente para se poderem tornar numa inovação disruptiva para a mobilidade urbana sustentável. Mais estudos são necessários para criar evidência científica para suportar a criação de políticas que possam tornar e-scooters um modo de transporte mais sustentável.

PALAVRAS-CHAVE: Serviços de micromobilidade, Serviços de partilha de e-scooters, Usuários frequentes, Características dos usuários, Mobilidade no futuro.

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INTRODUCTION

1.1. Preamble

Sustainable urban development is nowadays one of the greatest achievements that urban planners are ambitious for. The automobile dependency-related problems of congestion, pollution, and safety have been decreasing the quality of life of the cities (Gössling 2020). While, at the same time, the transportation demand has been increasing, resulting in a complex challenge.

Through the past few decades, different approaches were carried out to solve these problems. For example, building new infrastructure, implementing congestion charges, etc. However, due to its general lack of success, new practices are now focusing their attention on voluntary behavioral change by, for example, increasing the transport alternatives (Gössling 2020).

Recently shared micromobility services changed the urban mobility reality by increasing the mode alternatives and inter-modality in the cities. The sharing economy allied to the emerging technologies provided new transport possibilities and a way to facilitate transit use: connecting conventional transit nodes such as subway stations with the trip destination (last-mile connection) or the trip origin (first-mile connection) (Baek et al. 2021).

In recent years, free floating shared e-scooters – an emerging form of micromobility service - have been conquering cities all over the world. Some studies in the fields of safety, city policies, users' characteristics, generated trips, and others were conducted (Christoforou 2021; Herrman 2019a; Baek et al. 2021; Bai and Jiao 2020; H. Yang et al. 2020; Mitra and Hess 2021; Moran, Laa, and Emberger 2020; Fearnley, Johnsson, and Berge 2020). However, due to the novelty of this form of mobility, the research is still insufficient and requires further investigation.

1.2. Objective

The objective of the dissertation is to investigate the role of free-floating shared e-scooters for the future mobility from users' perspective, based on the cities of Lund and Malmö, Sweden. The research objective is addressed by investigating three research questions:

- 1st Which is the users' segment and travel pattern in Malmö and Lund?
- 2nd What are the characteristics of frequent e-scooter users in Malmö and Lund?
- 3rd What are the substitute modes of e-scooters in Malmö and Lund? And why?

1.3. Overview

This dissertation is divided into seven chapters. The first chapter presents an introduction and announces the objective and the research questions of this thesis.

In Chapter 2, a literature background about sharing mobility services and micromobility services is presented. Chapter 3 focuses on free-floating shared e-scooters. This chapter introduces the history of e-scooters, their problems and benefits, a review of previous studies, and a market overview. Followed by Chapter 4, it provides a description of the methodology, the characteristics of the cities of Lund and Malmö, as well as their e-scooters market. It also introduces the Swedish governance and the regulations for e-scooters in Sweden. The methods for data collection and data analysis is also explained in this chapter. Chapter 5 presents the results of the statistical analysis. In the sixth Chapter, the discussion of the results is made. In the end, Chapter 7 summarizes the conclusions that have been drawn from the developed studies and suggests ideas for future researches in the studied area.

2

LITERATURE BACKGROUND

2.1. Sharing mobility services

Shared Mobility is characterized by the sharing of a vehicle, i.e., car, bicycle, e-scooter, etc., instead of ownership, and the use of technology to connect users and providers (Santos 2018). This innovative transportation strategy enables users to have access to short-term transportation modes based on their needs (S. A. S. Shaheen et al. 2017) and it is now a growing sector of the sharing economy.

The constant growth of the motorization rate and the low occupancy rates on daily trips allied to the global tendency for the population to live in urban areas results in a huge challenge for the urban transportation systems. Nevertheless, sharing mobility services are now having an important role due to their enormous disruptive potential over this market (Machado 2018).

What makes cars have a clear advantage over other transport modes? According to Martinez e Viegas (2017) there are three key characteristics: flexibility, comfort and availability. Services of sharing mobility can also offer them but in a more sustainable way, possibly allowing the reduce of traffic congestion and CO2 emissions (Santos 2018). Although, it is important to mention that these advantages will depend on the type of shared mobility.

Shaheen et al. (2017) categorizes key areas of shared mobility depending on the service, i.e., services that enable a sharing of a vehicle, services that facilitate passenger rides, and services that enable the use of private vehicles for delivery trips. In the first category, we include carsharing, e-scooter sharing, and bikesharing; in the second, ridesharing, on-demand ride services and microtransit, and in the latter courier network services.

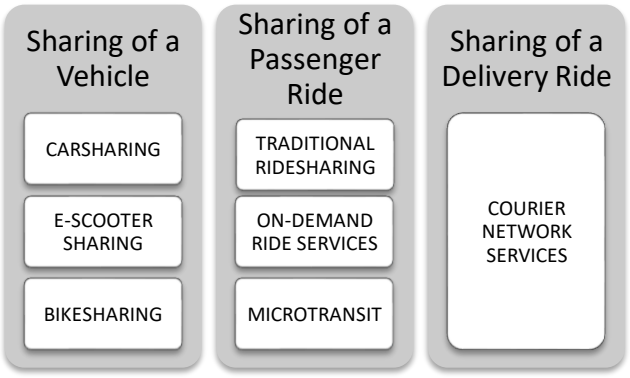


Fig. 1- Key areas of shared mobility depending on the service (based on (S. A. S. Shaheen et al. 2017))

It is now important to briefly explain each shared mobility area stated above:

- **Carsharing** is an automobile renting service that has its main objective to substitute vehicle ownership. Besides its affordability and convenience, it is possible to rent a car for short periods of time- the price is usually calculated by hour (Litman 2000). There are three different carsharing business models: Roundtrip Carsharing, One-Way Carsharing, and Personal Vehicle Sharing.
- **E-scooter sharing** is the main topic of this thesis and refers to a service that allows short-term rentals of e-scooters for mobility services in two main different forms: free-floating, also known as dockless, and, the ones with docking stations. These services are provided by different operators.
- **Bikesharing** allows users to access bicycles on an as-needed basis between bikesharing stations or a certain area (free-floating) (S. A. S. Shaheen et al. 2017). Although the most usual service is offered by operators, there are some examples of P2P systems where private owners rent their bicycles for short-term periods.
- **Traditional ridesharing** is based on shared rides between travelers with the same origin and/or destination. Vanpooling and carpooling are part of this type of shared mobility.
- **On-demand ride services or ridesharing** is a service similar to the previous one, but, in this case, the traveler requests a ride through a mobile app, for example, *Uber*. In this area, there are three different business models: ridesourcing, ridesplitting, and e-Hail services.
- **Microtransit** is a service between a traditional fixed-route/schedule transit and on-demand ride services. This service is based entirely on rider demand, making schedules and routes dynamic. Usually, the main target of microtransit is commuting trips by connecting main residential areas with job centers. An example of this service could be *Bridj* in Boston – its app allows users to ask for a ride in some neighborhoods, and then the App selects a central meeting point taking into account the clients' requests.
- **Courier network services** is a service that provides delivery services upon request. The client by using an online app/website connects with the couriers using their personal vehicles. The food delivery is the biggest market in this service, but other goods are also requested.

However, we can also categorize some of the types of sharing mobility services considering the trip length break that they can provide (CB Insights 2020). Between zero to five miles, under the micromobility umbrella, we have bikesharing and scooter sharing; between five to 15 miles, i.e., medium distance trips, we have ridesharing; and finally, for more than 15 miles, i.e., long-distance trips, we have carsharing. Some previous studies point that e-scooters tend to be used for different travel lengths, but mostly for distances lower than 4km (Hardt and Bogenberger 2019; Noland 2019; Edel, Wassmer, and Kern 2021; Degele et al. 2018).

2.2. Micromobility services

As an innovative urban transport solution, micromobility provides short-distance travel options, e.g. first and last mile trips (Abduljabbar 2021), while giving a flexible and cost-effective transport alternative that reduces reliance on using private cars (S. A. S. Shaheen et al. 2017).

Christoforou (2021) states that there is no concrete definition for micromobility, differing the most common ones from vehicle to business-oriented. While Shaheen (2019) defines micromobility as "various service models and transportation modes that meet the diverse needs of travelers, such as

station-based bikesharing and dockless bikesharing and e-scooter sharing", Dediu (2019) defines it considering the weight of the vehicle by stablishing a maximum of 500kg for this category. CRIST Philippe *et al.* (2020) goes further and defines it as "vehicles with a mass of no more than 350 kilograms and a design speed no higher than 45 km/h.". Christoforou (2021) proposes a more mobility-oriented definition: "micromobility includes all transportation modes that allow their users to make a hybrid usage and behave either as a pedestrian or a vehicle at their convenience (e.g. to cross a road or board on a bus) or when necessary."

To help categorize the different types of micromobility services and to facilitate the regulation that cities may want to implement usually there is a separation between vehicles unpowered or powered up to 25 km/h, and vehicles powered with a top speed between 25-45 km/h (Crist Philippe *et al.*, 2020) – for example, e-bikes that can reach speeds up to 45km/h are usually excluded from bike lanes and subject to further safety regulations (Kastrup Marie *et al.*, 2018).

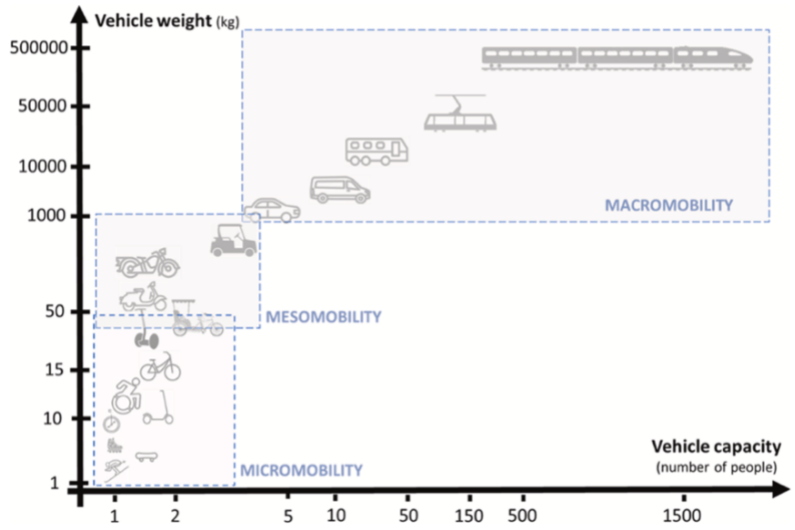


Fig. 2: Scales of mobility as a function of vehicle weight and capacity (Christoforou 2021)

2.2.1. Emerging Shared Micromobility Services

In the past few years, shared micromobility services of e-scooters, e-bikes and bikes rapidly gained popularity and are now available in two different modes: dockless (free-floating) and docked. Even though there is a good research background in docked shared bikes, the same doesn't happen for shared e-bike services and shared e-scooter services, of which the latter is even more scarce (Reck and Axhausen 2021).

2.2.1.1. Demand-side research

It is possible to divide the research in shared micromobility services into supply- and demand-side topics (Reck et al. 2021). This study will focus on the demand-side research that can be categorized according to the factors that influence demand, i.e., internal factors (user social-demographics, etc.); external factors (urban form, weather, etc.); and trip-related factors (final destination, distance, etc.) (Reck and Axhausen 2021).

Age, gender, income, and education are the most common internal factors identified in several studies as influencing docked shared bike usage. Below are stated some conclusions drawn in some studies (Reck e Axhausen, 2021; Fishman *et al.*, 2015; Fuller *et al.*, 2011; Shaheen, 2019; Machado, 2018) that were conducted in different countries:

- Users of docked shared bikes are more likely to be younger;
- Male users are usually the majority;
- Commonly the higher the income, the higher the usage of docked shared bikes;
- Generally, users of docked shared bikes have higher levels of education.

According to several studies, population density, workplace density, social and leisure center density, public transport density, elevation difference, and weather, combined with different times of the day/week/year, are external and trip-related factors that influence docked shared bikes demand (Reck *et al.*, 2021). Below are stated some conclusions drawn in some studies (Reck *et al.*, 2021; Fishman, Washington e Haworth, 2014; Ricci, 2015; Shaheen, 2019; Zhao, 2015) that were conducted in different countries:

- Workplaces have a positive effect on the usage of docked shared bikes during weekdays;
- It is usually observable a pick demand during specific morning and afternoon periods - possibly correlated with commuting trips;
- Adverse weather conditions harm the usage of docked shared bikes;
- Docked shared bikes commonly substitute public transport and walking trips;
- Shifts between public transport and docked shared bikes tend to be more common in lower-density areas on the urban periphery – possibly correlated with first and last-mile trips;
- In high-density areas with better public transport, docked shared bikes tend to be used as transit substitutes.

The factors that influence shared docked bikes and shared e-bikes demand can have similarities with the ones that influence free-floating shared e-scooters. However, aside from more general patterns, conclusions taken for one mode shouldn't be generalized to others (Reck and Axhausen 2021). For instance, McKenzie (2019) concluded that shared bikes tend to be used more for commuting purposes than shared e-scooters, and Younes (2020) reported that shared e-scooters users are less sensitive to weather than shared bike users.

2.2.1.2. Urban Policies

Another important topic when talking about emerging shared micromobility services is urban policies. The fast-growing demand for these services is confronting cities with new challenges in regulating their use. The early implementation without field trials of shared micromobility services resulted in a number of unexpected consequences, e.g. safety, liability, operational, and infrastructure-related problems (Herrman 2019a). It is then relevant to invest in proper planning and relevant regulations to increase micromobility accessibility (Abduljabbar 2021).

Since the micromobility *boom*, sidewalk and curb space management policies are having a fundamental role in reducing cluttering while maintaining curb access operational, safe, and accessible to all transportation users (S. Shaheen 2019). These type of policies is typically allocated through formal processes such as regulations, or through pilot programs and negotiated approvals (S. Shaheen 2019). The most common policies include:

- **Device caps –** limiting the number of micromobility vehicles, either by limiting the number of vehicles per category, e.g. bicycles, e-scooters, etc. or by limiting the number of vehicles per operator.
- **Service area limitation –** establishing geographic access zones where operators can/cannot operate.
- **Designated Parking Areas –** setting up designated parking areas for micromobility vehicles.
- **Fees –** charging operators with trip taxes, application fees, annual fees, permit review fees, etc., in return for the use of public right-of-way spaces.
- **Equipment and Operational Requirements –** establishing speed limits, and permissible areas of operations for example, prohibition from operating in sidewalks, bicycle lanes, etc.

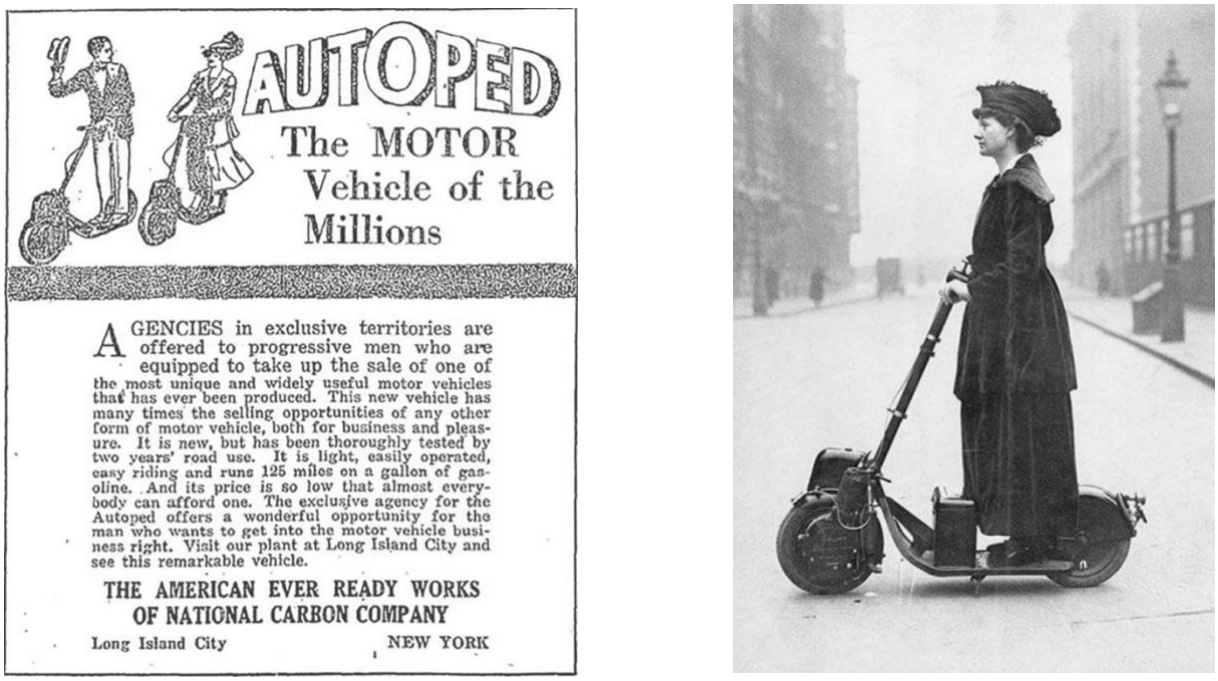
3

FREE-FLOATING SHARED E-SCOOTERS

3.1. History

Although the majority of people see scooters as a new form of transportation the first mass-produced motorized scooter dates back to 1915. This 19th-century model was known as the *Autoped* and it could reach speeds of 35 miles per hour. Some years later, a battery coil was implemented to the previous version turning it into the first electric scooter (Mansky 2019).

The *Autoped* was advertised as "The Motor Vehicle of the Millions" due to its suitability to be used by different economic classes, ages, and genders. The New York Postal Service used it as a delivery vehicle and the Police used it for the patrols (Hanlon 2016). Nevertheless, one of the main target markets was the new generation of independent women.



a) b)

Fig. 3: a) Autoped advertisement; b) Lady Norman Florence travelling to work on her motor scooter in London in 1916.

A few years later, in 1921, due to its lack of commercial success, the U.S company ceased production while in Europe, a German company called *Krupp* manufactured them from 1919 until 1922. However, after the Great Depression, this vehicle was back in fashion, possibly as a result of the increase of the public environmental consciousness and the coincidence with the Golden Age of Hollywood (Fruit 2020). At that time, these vehicles were used in military bases, airports, across urban areas, and even on Hollywood studio lots.

Fig. 4: Four delivery postmen from the U.S. Postal Service trying out new scooters in the mid-1910s.

More recently, in 1986, and after a period of decadence, a new model was invented – the *Go-Ped*. This scooter was cheap, low profile, and fast, which led to the beginning of this vehicle's second wave (Fruit 2020).

Fig. 5: Original 1987 California Go-Ped.

During the 1990s, companies like *Micro* and *Razor* allowed the world's spread of scooters even if these models were still commonly seen as toys. Wim Ouboter -founder of *Micro Mobility Systems* - changed that by reinventing scooters as an adult vehicle to travel short distances.

Since 2000 due to the battery's cost drop and its better efficiency, the new lighter materials, and the new technologies involved, the models slowly became similar to the current ones.

Until 2016 the market was fed by the private e-scooters market. In 2017 this reality changed with the appearance of two shared e-scooters companies - *Bird* and *Lime* – that have become quickly popular and

rapidly expanded through the world (Ma, Yang, Ma, et al. 2021). In the past few years, several other companies entered the market.

Fig. 6: Motorized scooters parked in Lund, Sweden *(photo by Catarina Sales).*

3.3. Benefits

In the existing literature, some benefits of free-floating shared e-scooters services are pointed:

- In some cities, for example, Munich, the majority of daily trips can be done using e-scooters (Hardt and Bogenberger 2019).
- Free-floating shared e-scooters due to their dockless nature are suitable for limited parking areas (Fong, McDermott, and Lucchi 2019)
- Promotes travel time savings (Christoforou 2021).
- E-scooters can achieve zero C02 emissions when electricity from renewable energy sources is used (Bishop et al. 2011).
- E-scooters don't require a driving license (Roca 2019).
- E-scooters are compact and light, making them easy to move (Roca 2019).
- It is a cost-effective and on-demand transport alternative. (Abduljabbar, Liyanage, and Dia 2021)

3.2. Problems

Since the beginning of the operation of shared e-scooters, problems started to appear. Only one year after, during the spring and summer of 2018, a wave of deployments began in several cities (Herrman 2019b). According to Ma *et al.* (2021), there are five main reasons for e-scooters ban: operational concerns; safety concerns; communities inconvenience; obstruct pedestrian or vehicular traffic; and physical disability barriers/ public infrastructure barriers.

Gössling (2020) identified a list of common issues related to shared e-scooters services:

- **Safety –** One of the most important factors when talking about a city is its safety (Herrman 2019b). Depending on the e-scooter, speeds can reach up to 53,3 km/h (Y.-P. Yang 2011), which makes them an issue for public health (Ma, Yang, Mayhue, et al. 2021). One of the reasons why the number of accidents is so high is because users and non-users were never educated on the usage of e-scooters (Herrman 2019b). (H. Yang et al. 2020) pointed out two causes for severe accidents: riding without protective helmets and riding under the influence

of alcohol. Due to the previous stated, several local authorities established speed limits on sidewalks, compulsory use of helmets, prohibition to use e-scooters under the influence of alcohol, etc. Nevertheless, Gössling (2020) suggests there is a high subjectivity when talking about e-scooter safety.

- **Conflicts over space, irresponsible riding and cluttering –** There is a competition between pedestrians/bicycles and e-scooters, i.e., competition for public space. This problem has two main reasons: the unused e-scooters cluttering public space and obstructing pedestrians, and the users of e-scooters that disrespect traffic rules and have careless driving (Tuncer et al. 2020). In consequence, city debates question if e-scooters should be banned from sidewalks and pedestrian areas (Gössling 2020). Yet, the issue of space distribution has a big role in this problem – public space is still mostly dedicated to cars for both parking and riding (Laa and Leth 2020).

Fig. 7: Example of unused e-scooters cluttering public space in Lund, Sweden (*photo by Catarina Sales).*

- **Vandalism and theft –** Short lifetime of e-scooters is mainly a consequence of vandalism (Gössling 2020). Common actions are throwing e-scooters into bodies of water; slashing the braking systems; tossing e-scooters into trash cans and trees; as well stealing them (Caldwell 2019; GRADY 2019). Some operators are trying to address these problems with different technologies, for example, with anti-theft systems (Frazer 2019).

Fig. 8: Example of e-scooter vandalism in Gothenburg, Sweden (*photo by Catarina Sales).*

3.3. The usage of e-scooters specified in previous studies

In the past few years, some studies were conducted in order to better understand the role of free-floating shared e-scooters in the city's urban mobility. When it comes to e-scooter related studies, excluding safety and policy studies, we can divide the results into two main categories according to the origin of the data: qualitative, based on surveys; and quantitative, based on geospatial data and trajectories (Christoforou 2021).

Table 1: Key conclusions of free-floating shared e-scooters related studies.

Study	Category	Cities	Key Conclusions
McKenzie (2019)	Quantitative	Washington D.C., USA	• E-scooter trips don't indicate commuting as a trip purpose. • 60% of e-scooter trips were within the same land use.
Hardt and Bogenberger (2019)	Quantitative and Qualitative	Munich, Germany	• E-scooter are used particularly for commuting and leisure trips, and even for business trips. • Easy parking is the biggest benefit, whether, baggage restrictions, and safety issues are drawbacks. • The average range trip has 10.6 km.
Bai e Jiao (2020)	Quantitative	Austin, TX, and Minneapolis, MN, USA	• Connection between shared e-scooters usage and downtowns, universities, recreational areas, and public transportation. • Diversity of the land-use positively affected the ridership of e-scooters. • The peak of e-scooters usage happened in the afternoons during weekends.
Jiao e Bai (2020)	Quantitative	Austin, TX, USA	• Areas with high population density, lower household income, more males, and higher education are more likely to generate e-scooter trips. • Areas near the city centre or transit stops are positively correlated to e-scooter usage.
Fearnley, Johnsson, and Berge (2020)	Quantitative	Oslo, Norway	• The majority of e-scooter trips replace walking. One quarter of the trips replace transit. • People rely on transit for travel to the city and e-scooters to travel in the city. • A considerable number of e-scooter trips is made in combination with transit.

Laa and Leth (2020)	Qualitative	Vienna, Austria	• Trips with e-scooters mostly replace walking and transit trips. • Mainly young to middle aged adults with a higher education level use e-scooters.
Sanders, Branion-Calles, and Nelson (2020)	Qualitative	Tempe, AZ, USA	• E-scooters are popular in a wide variety of ages, gender and races/ethnicities. • E-scooters are valued for their capacity to be faster than walking and more convenient than a car.
Hosseinzadeh *et al.* (2021)	Quantitative	Louisville, KY, USA	• High commercial land use and high employment areas yield to a higher density of e-scooter trips. • Industrial land use yield to lower e-scooter trips. • E-scooters peak-hours were found to be on Saturdays (1 to 5 pm) – possibly due to recreational purposes.
Christoforou (2021)	Qualitative.	Paris, France	• Most users are men aged between18 to 29 with high educational level. • The main motivation is travel time savings. • The principal travel purpose is leisure activities. • 72% shifted from walking and transit to shared e-scooters.
Almannaa et al. (2021)	Qualitative	Riyadh, Saudi Arabia	• Males use more e-scooters than females. • Most users are between 18 and 45 years old. • The income doesn't affect the use of e-scooters. • People who use other sharing services tend to show more willingness to use e-scooters in the future. • E-scooters are mostly used for entertainment reasons.
Mitra e Hess (2021)	Qualitative	Toronto, Canada	• In urban neighbourhoods, shared e-scooters tend to replace transit trips. • In the suburban areas, shared e-scooters tend to replace short car trips, and provide first and last-mile trips. • A better walkability and street safety can increase the use of shared e-scooters.

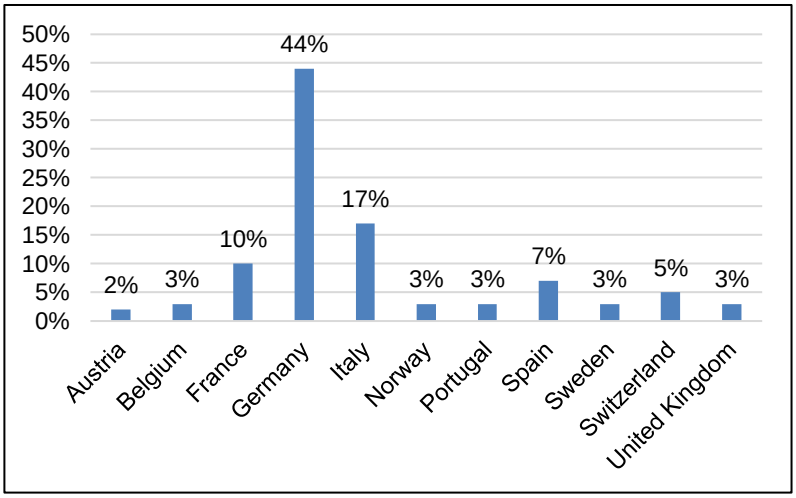
In Table 1, some key conclusions of free-floating shared e-scooters related studies were collected. By analyzing them, we can see there are common conclusions between the different studies, but also different and contrasting ones. Christoforou (2021) and Bai e Jiao (2020) argue the conclusions tend to be city-specific and due to that profiling shouldn't focus only on modes.

3.4. Market overview - Europe

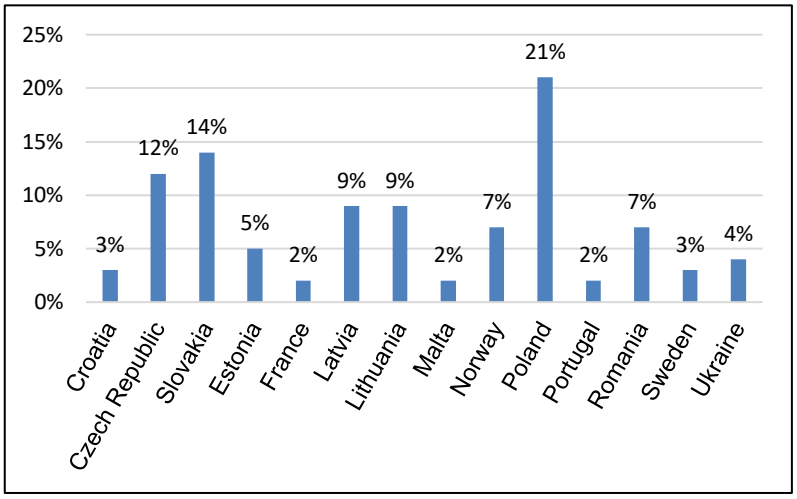
When it comes to free-floating shared e-scooters, the European market is the second-largest in the world after the North American. Until the present moment, no one studied the European market of shared e-scooters. To know how these services are spread in the continent, the websites of the biggest operators were used as a source – Bird, Bolt, Circ, Dott, Jump, Lime, Tier, Voi, Wind. It was collected information regarding the cities and countries where each operator offers a service – Jump and Circ weren't added to the study since the needed information wasn't available on their websites.

Table 2: Biggest operators in Europe – characteristics.

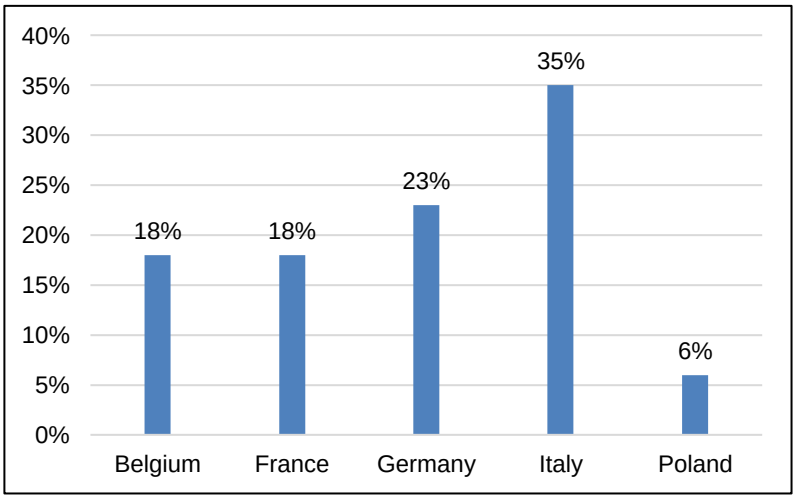
Operator	Based City/Country	Date of establishment	Areas served	Number of cities in Europe
Bird	California, USA	September 2017	Europe, Middle East, North America	61
Bolt	Tallinn, Estonia	September 2018	Europe and Asia	58
Dott	Amsterdam, The Netherlands	December 2018	Europe	17
Lime	California, USA	January 2017	Asia, Europe, Middle East, North America, Oceania, and Latin America.	62
Tier	Berlin, Germany	October 2018	Europe, Middle East	100
Voi	Stockholm, Sweden	August 2018	Europe	59
Wind	Barcelona, Spain	2017	Europe, Middle East, and Asia	18



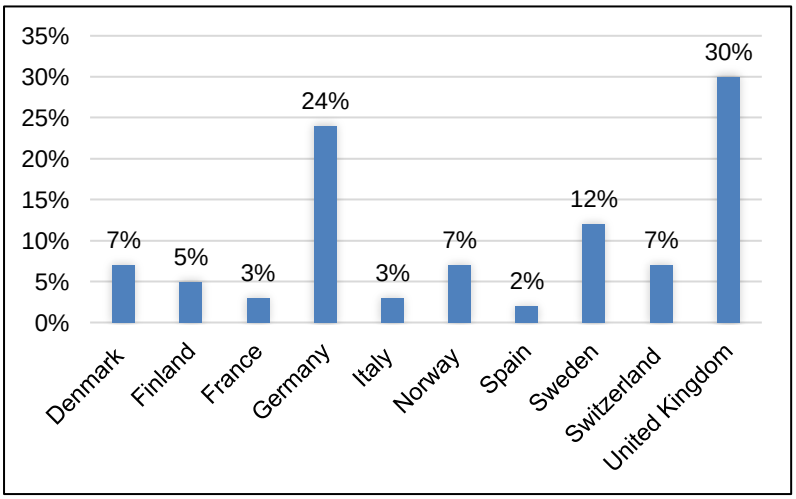
a) Bird



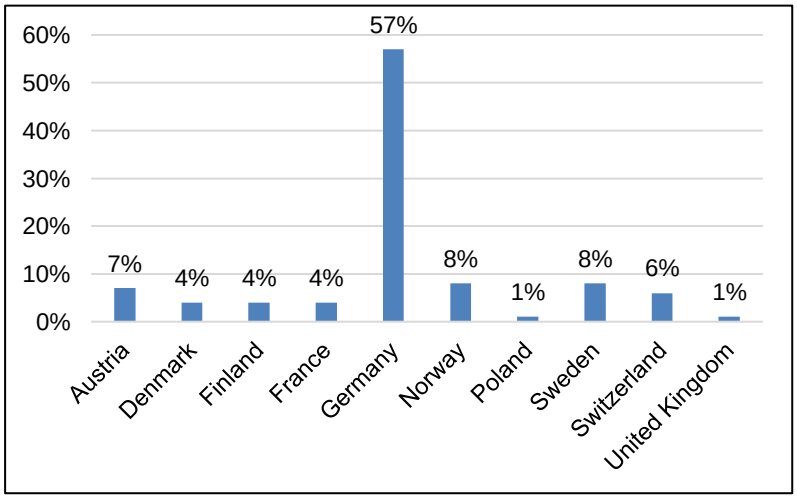
b) Bolt



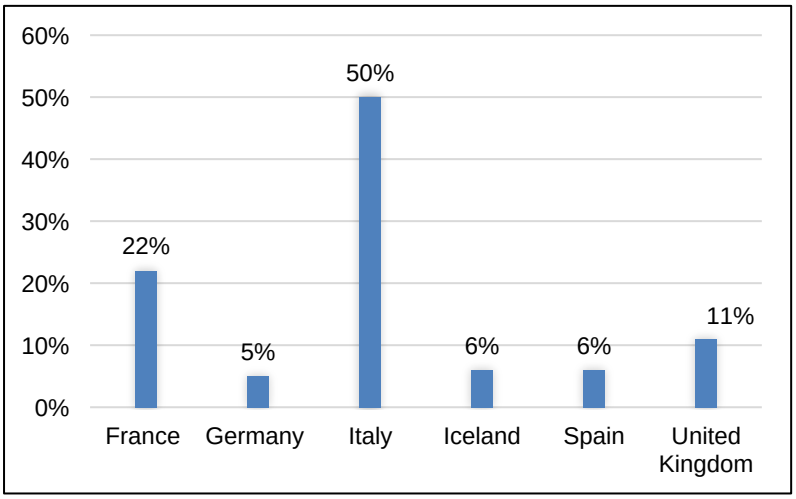
c) Dott



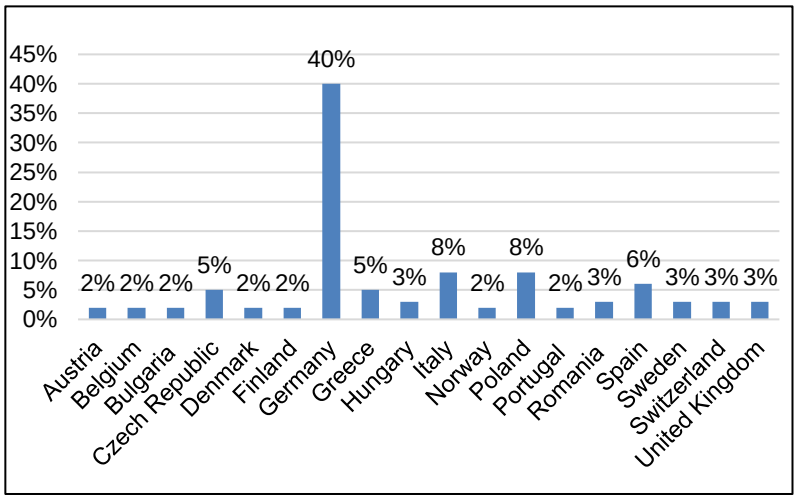
d) VOI



e) Tier



f) Wind



g) Lime

Fig. 9: Distribution of shared e-scooter services per operator in European cities by country - a) Bird; b) Bolt; c) Dott; d) VOI; e) Tier; f) Wind, g) Lime

In Europe, shared e-scooters services are present in 28 countries and 239 cities. The operator present in more cities is Tier – in 100 cities – and afterwards, the US operators follow it – Bird and Lime, respectively, in 61 and 62 cities. Still, Lime is the operator present in more countries – in 18 – followed by Bolt – in 14. Germany is the first/second-biggest market in all the studied operators, excluding Bolt and Wind, for example, represents 57% of Tiers' market. It is also, by far, the country with more cities with shared e-scooter services - 69 cities. The United Kingdom is the second European country with more cities with these services -23 cities. Bolt is the only operator that offers services of shared e-scooters in Croatia, Slovakia, Estonia, Latvia, Lithuania, Malta, and Ukraine; Wind the only one that offers services in Iceland; and Lime the only one that offers services in Greece.

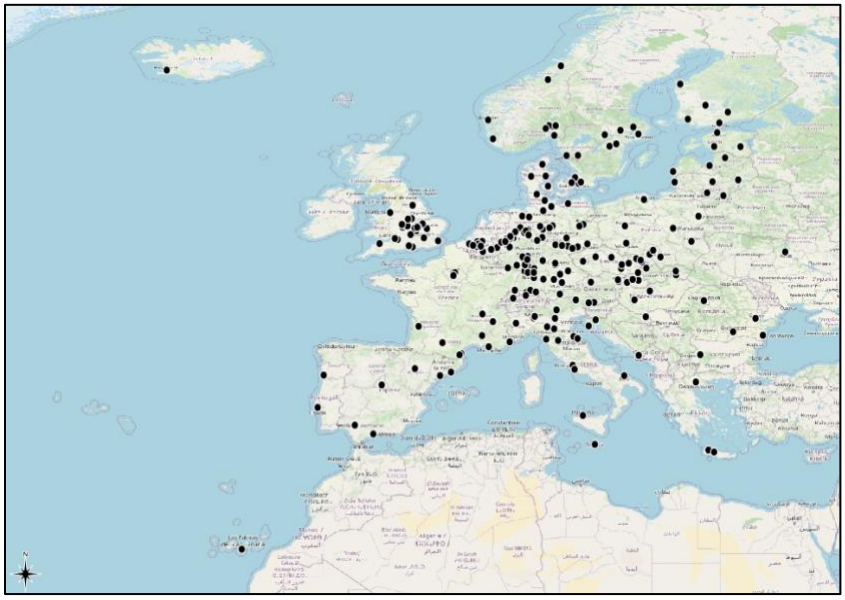


Fig. 10: Free-floating shared e-scooters services in Europe.[1]

[1] Each dot represents one city.

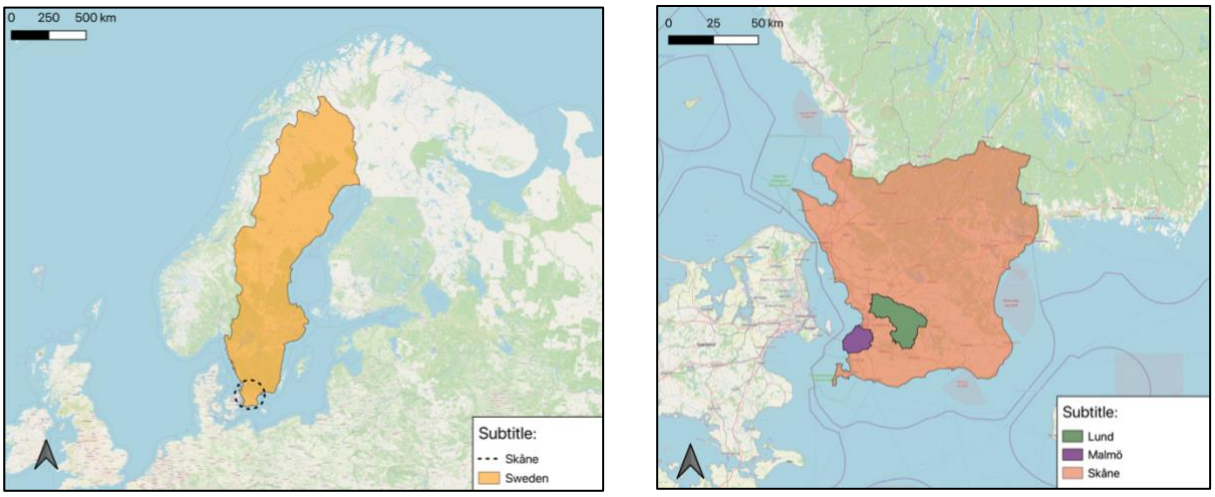
4

STUDY CASE AND METHODOLOGY

4.1. Study case context

Sweden is a large country with 450295 km^2(compared to 92212 $km^2$for Portugal), and a population of 10.23 million people (compared to 10.28 million people for Portugal), making it a low-density population country. The majority of the population lives in the south of the country. Stockholm, Gothenburg, and Malmö are the three biggest cities, with a population of 1515017, 572799, and 347949, respectively. Skåne is the southernmost county in Sweden. It contains 33 municipalities, of which Malmö and Lund are the first and third most populated, respectively. Lund municipality has 125941 inhabitants.

In this study case, it is going to be studied the free-floating shared e-scooters users' perspective of both cities of Lund and Malmö.



a) b)

Fig. 11: Maps identifying the study area.[2]

4.1.1. MALMÖ AND LUND – CITY CHARACTERISTICS

The ratio between men and women in Lund and Malmö is around 51%/49%. Also, the average age in both cities is 39 years. The average income before taxes is 25 875 SEK in Lund and 23 800 SEK in Malmö. In Lund, 40.6 % of citizens aged between 20–64 have at least three years of post-secondary

[2] In Map b) Lund and Malmö are represented by their municipality area.

education, comparing with 50,7% in Malmö. When it comes to where their inhabitants were born, in Lund 77,5% were born in Sweden, and in Malmö 65,4%.

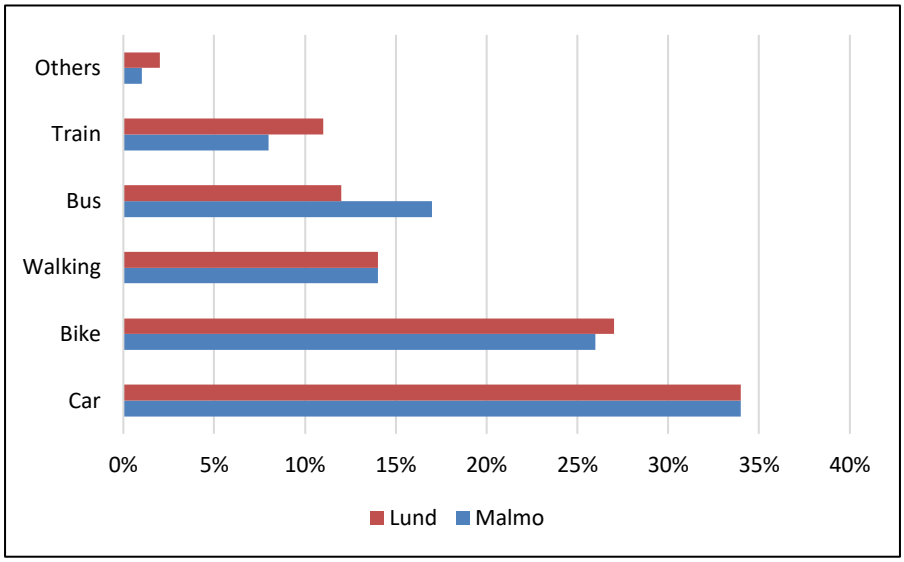


Fig. 12: Modal share in Malmö Municipality and Lund Municipality in 2018 (based on (Morin et al. 2018)).

In 2018, Skäne County conducted a survey to study the travel habits in this region. Apart from many other conclusions that are not relevant for this dissertation, it was possible to estimate the modal share in all municipalities in the county. Lund and Malmö have a similar modal share – 14% for walking, 26/27% for biking, and 34% for car mode. However, the train and bus share have a slight difference – 11% for train mode in Lund and 8% in Malmö; and 12% for bus mode in Lund and 17% in Malmö. In Lund, if we only consider the urban area, the modal share changes a bit - 16% for walking, 31% for biking, 27% for car mode, 13% for train mode, and 13% for bus mode. Both cities have been prioritizing walking, biking and public transport, making it possible to achieve a sustainable transport system.

The number of trips per day between Malmö and Lund (both directions) is about 68708 - making it the biggest flow between two municipalities in the county.

The climate of Malmö and Lund is Baltic, with cold winters and mild summers and an average temperature around 9ºC. The topography in Malmö, especially in the city center, is rather flat (Hamidi and Zhao 2020). Lund city has the highest area in the eastern part (max≈85m) and the lowest area in the western part (min≈12m) with a distance of around 6 km between both areas.

Concerning population density, Malmö municipality in 2019 had 2190 habitants per km^2, and Lund 293 habitants per km^2. However, in Malmö municipality, all the area is urban land, and in Lund, there is a big rural area around the city. When taking into account only the city's population, the difference ends up being not that big – the density in Lund is 3459 habitants per km^2, and in Malmö 4049 habitants per km^2.

Regarding the number of persons per household, the average number, both in Lund and Malmö, is 2.1 persons ("Finding statistics- Sweden").

Both Malmö and Lund have universities that attract a considerable amount of national and international students per year. In 2015, the number of students in the autumn term in Lund was 29831, and in Malmö was 14999 ("Skåne - Facts and Key Trends" 2017).

4.1.2. E-SCOOTERS SERVICES IN LUND AND MALMÖ

The operators that have services in Lund are Tier and Lime, and in Malmö are Tier, Lime, and Voi. In both cities, the perimeter where is possible to rent and park e-scooters is limited and identified on the operators' apps. There are also areas inside the perimeter where is not allowed to rent or to park e-scooters, for example, on *Stadsparken* in Lund and on *Pildammsparken* in Malmö. The majority of e-scooters are available in the city center. The total fee is a sum of two values: the unlock fixed fee – 10 SEK – and the fee calculated according to the total travel time– that varies between 2,5 SEK and 2,7 SEK per minute.

4.2. Transport administration in Sweden

In Sweden, the public transport was always seen as the key for economic growth, while being an essential public service. All parties are committed to fight against climate change throw the use of sustainable modes of transport.

There are three levels of government – local, regional and national – each one of them with distinct responsibilities. With respect to urban mobility and transportation, the national government is responsible for transport legislation and large transport investments, it is also the owner of the road and rail network; the regional government is responsible for managing public transport (PT), allowing a better connection in the entire region; and, the local municipalities have the control of land use planning ("The Scandinavian way to better Public transport")

In Skäne, the public transport authority (PTA)- *Skänetrafiken*- has the task of offering sustainable public transport (bus and train) in the county, enabling modal shift (car to PT) and the spread of economic development.

4.2.1. SWEDISH E-SCOOTERS REGULATIONS

The Swedish Transport Agency classifies e-scooters as bicycles, i.e., the traffic rules for bicycles are also applicable for e-scooters. However, the electric scooter must have a maximum speed of 20 km/h and have an engine power of maximum 250W, if not the vehicle will no longer be considered a bicycle "but will probably be considered a moped with other requirements and conditions for use in traffic" (Transport Styrelsen 2013). Both Lund and Malmö municipalities follow this regulation – in some rules, there are slight differences.

Below, some of the rules that users of e-scooters must obey are stated:

- The use of helmet is not required when using an e-scooter (Transport Styrelsen) However, *Lunds Kommun* website says: "People under the age of 15 must wear a helmet".
- E-scooters can be used in the same places as bikes can be ridden, i.e., on bake lanes and on the right side of the road.
- An e-scooter must be parked in a bicycle rack. In Lund "incorrectly parked electric scooters must then be redeemed by the owner, i.e., the company that owns them, for a fee" ("Electric scooter - Lunds Kommun" n.d.). On *Malmö Stad* website the fee isn't mentioned.

4.3. Data Collection

In this study, the chose research design was a qualitative research method. The data used in this study comes from a survey conducted in September 2020 for two weeks in several cities – Copenhagen, Gothenburg, Lund, Malmö, Oslo, and Stockholm. This survey was sent to the subscribers of one operator by email, both in English and Swedish, and was part of a research project carried out by Lund University, and K2 – Swedish Knowledge Center for Public Transport, Sweden.

The survey has different questions that are divided into three main sections:

1. Socio-demographic profile;
2. Travel Profile, users' experiences, and attitudes towards the service before Covid-19;
3. Travel with e-scooters during Covid-19.

As previously mentioned, the study will focus on the cities of Lund and Malmö. For that, the data were filtered according to the answers of the survey's first question - "Where do you live and work/study?". A sum of 287 persons who live and work/study in Lund answered the survey. In Malmö, the number of responses was a bit higher - 360. The data analysis was only conducted on the answers of the first and second sections – pre-pandemic scenario. The variables were provided by the survey data and were based on the survey's answers of the following questions, all questions were in form of multiple choice, with one or multiple answers, and designed in the form that have been used in previous studies.

- What is your age?
- Can you tell us your gender?
- What is your monthly income range?
- What is your last finished education level?
- How many persons are living in your household?
- What is the distance between your home and your main daily destination?
- What was your typical monthly expenditure for regular travel?
- What is the approximate distance from where you live to the city center?
- How often did you use e-scooter?
- How often have you been visiting the following destinations using e-scooters?
- What would you use for transport if e-scooter was not available?
- How often had you used e-scooters for going to bus/tram stops?
- How often had you used e-scooters for going to train/metro stations?
- How far are you willing to walk to find an e-scooter that is available to you?
- What was the main transport mode in your everyday life?

It is relevant to emphasize that the sample corresponds to e-scooters users. However, it also includes users that only used the service once or twice – 33% in Lund and 20% in Malmö.

4.4. Data Analysis

The data were analyzed using descriptive statistical analysis. This analysis was used to reveal the characteristics of free-floating shared e-scooters users' in Lund and Malmö, i.e., their socio-economic, demographic and travel pattern characteristics. The descriptive analyses focused on answering the three research questions:

- Which is the users' segment and travel pattern in Malmö and Lund?
- What are the characteristics of frequent e-scooter users in Malmö and Lund?

- What are the substitute modes of e-scooters in Malmö and Lund? And why?

Bar charts, as well as tables with frequency distributions were used to help the visualization of the data results. It is also important to mention that the analysis was conducted separately by city since previous studies show conclusions tend to be city-specific.

5

RESULTS

In this chapter, the results of the survey are presented. Firstly, it summarizes the survey outputs that show the main characteristics of the respondents. Secondly, the characteristics of the frequent e-scooter users in Malmö and Lund are described. Lastly, the modes that substitute e-scooters in Malmö and Lund are presented as well as the users' characteristics that chose "car" as one of the substitutes of e-scooters. It is also important to mention that the study is not intending to compare the results of two cities, rather for presenting the empirical studies based on a broader context, therefore the results were analyzed separately by city.

5.1. Who are the users?

Table 3 presents a summary of the distribution of respondents in gender, age, monthly average income, average month expenditure for regular travel, education level, and the number of persons per household. Despite having a sample of 360 answers in Malmö and 287 in Lund, only 306 and 232 were considered valid, respectively.

Table 3: Demographic and socio-economic statistics of the respondents ($n_{Lund} = 232; n_{Malmö} = 306$)

Respondent characteristics	Frequency Lund	Percentage (%) Lund	Frequency Malmö	Percentage (%) Malmö
Age:				
15-18	7	3%	8	3%
19-25	106	46%	61	20%
26-39	70	30%	145	47%
40-64	49	21%	90	29%
65-84	0	0%	2	1%
>84	0	0%	0	0%

Gender:				
Female	99	43%	117	38%
Male	133	57%	188	62%
Other	0	0%	1	0%
Monthly income:				
<20000 SEK	119	51%	59	19%
20000-30000 SEK	28	12%	64	21%
30001-40000 SEK	28	12%	85	28%
40001-50000 SEK	22	10%	43	14%
50001-60000 SEK	9	4%	13	4%
60001-80000 SEK	12	5%	11	4%
80001-90000 SEK	1	0%	2	1%
>90000 SEK	3	1%	7	2%
prefer not to tell	10	5%	22	7%
Expenditure for travel:				
<500 SEK	111	48%	113	37%
501-1000 SEK	72	31%	105	34%
1001- 2500 SEK	34	15%	52	17%
>2500 SEK	9	4%	24	8%
I do not know	6	2%	12	4%
Education level:				
Public School	4	2%	9	3%
High School	77	33%	105	34%
Technical School	62	27%	59	19%
Bachelor	46	20%	77	25%
Master degree	37	16%	52	17%
Ph.D. degree	3	1%	4	1%

Household (nº persons):				
1	69	30%	83	27%
2	74	32%	116	38%
3	28	12%	48	16%
4	37	16%	38	12%
5	17	7%	15	5%
>5	7	3%	6	2%

When it comes to age distribution, almost 50% of the respondents in Lund are between 19 and 25 years old, comparing to only 23% in Malmö. The largest group of survey respondents in Malmö is between 26 and 39 years old (47%). In both cities, the sample of respondents that are more than 65 years old is almost null. In Lund and Malmö, 56% and 62% of the respondents identifies as male, respectively. Regarding the average monthly income, in Lund, 51% earns less than 20000 SEK, comparing to 19% in Malmö. In Malmö, almost 50% earns between 20000 and 40000 SEK. Salaries bigger than 80000 SEK represent only 5% of Lund's sample and 10% of Malmö's sample. In Lund, the average monthly expenditure for regular travel is predominantly less than 500 SEK (48%). Still, expenditures between 501 SEK and 1000 SEK represent 31%. In Malmö, the same values represent 37% and 34%, respectively. In Lund and Malmö, 60% and 53% of the respondents, respectively, have a high or technical school diploma. 37%, in Lund, and 43%, in Malmö, have a university degree (Bachelor, Master or Ph.D.). Concerning the number of persons per household, in Lund, 62% of the respondents live alone or with one person. In Malmö, the percentage is 65%. In Lund, 10% lives with 4 or more persons, and in Malmö 7%.

5.2. Travel pattern of the users

Figure 13 presents the main travel modes for going to the mail daily activities. In Malmö, 30% of the respondents use a bicycle as their main transport mode, in Lund 35%. Also, in Malmö, 30% uses the car. The second most common choice, in Lund, is public transport – 23%. E-scooters are used by 4% of the sample as their main transport mode in Malmö, and in Lund by only 1%.

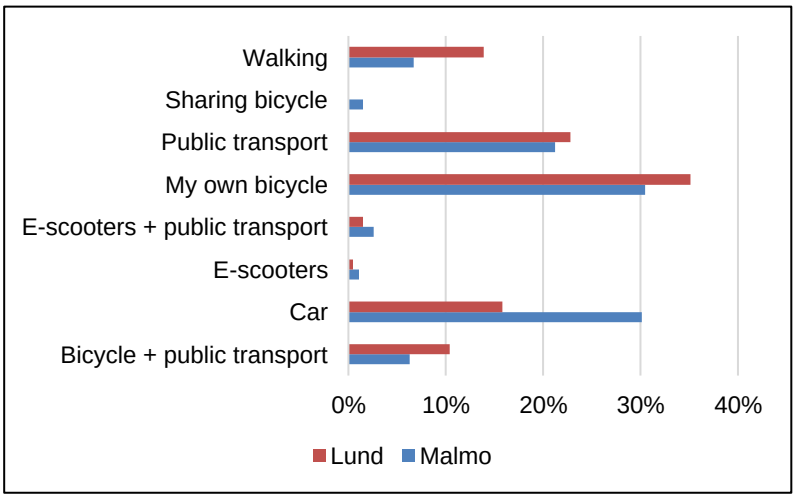


Fig. 13: Distribution of main travel modes for everyday life in Lund and Malmö

Figure 14 represents the distribution of the respondents' distance between home and their main daily destination. In Malmö, the distribution is quite even, however, the distance between 1 and 3 kilometers is the most common (32%). In Lund, 50% of the sample lives less than 3 kilometers away from their main daily destination.

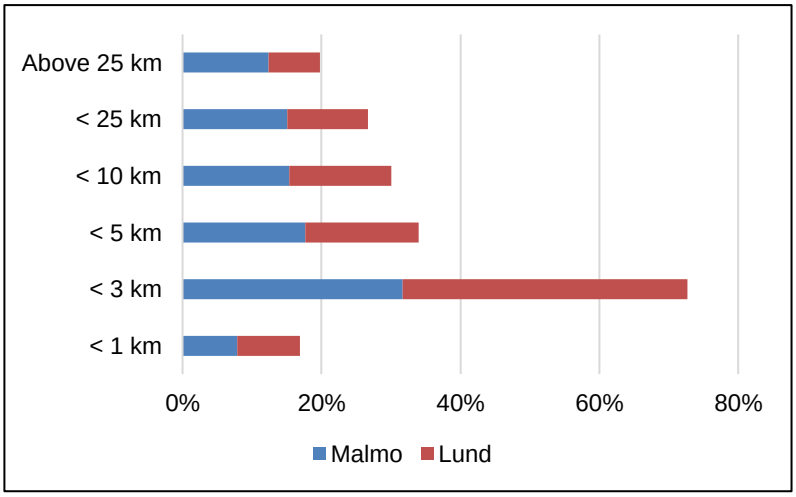


Fig. 14: Distribution of distance between users' home and main daily destination in Malmö and Lund.

Figure 15 shows the distribution of the respondents' distance between their house and the city center. On both cities, the distribution is similar. However, there is a slight difference- in Malmö, 7% lives between 3 and 4 kilometres from the city centre, and 14% above 5 kilometres; and in Lund 11% lives between 3 and 4 kilometres from the city centre, and 7% above 5 kilometres.

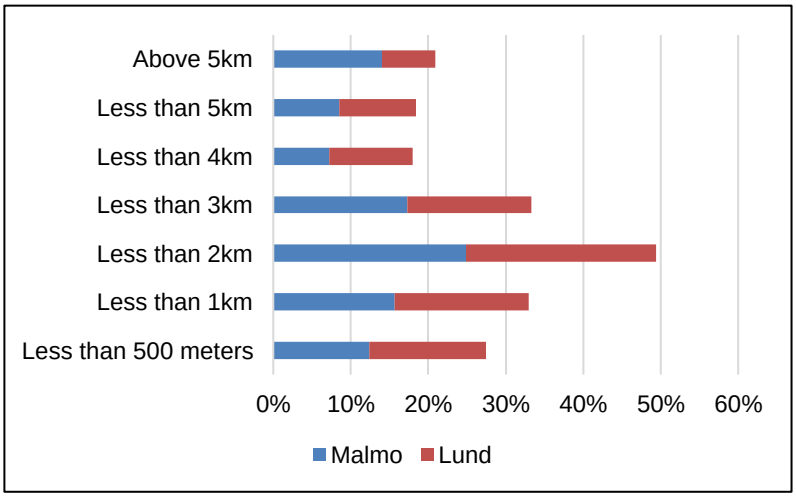


Fig. 15: Distribution of distance users' home and city centre in Malmö and Lund

Figure 16 identifies the distance the respondents are willing to walk to find an e-scooter. Both cities have similar distributions. The most common answer in Lund and Malmö is "maximum 150 meters" – 36% and 40%, respectively - and "maximum 300 meters" – 37% in both.

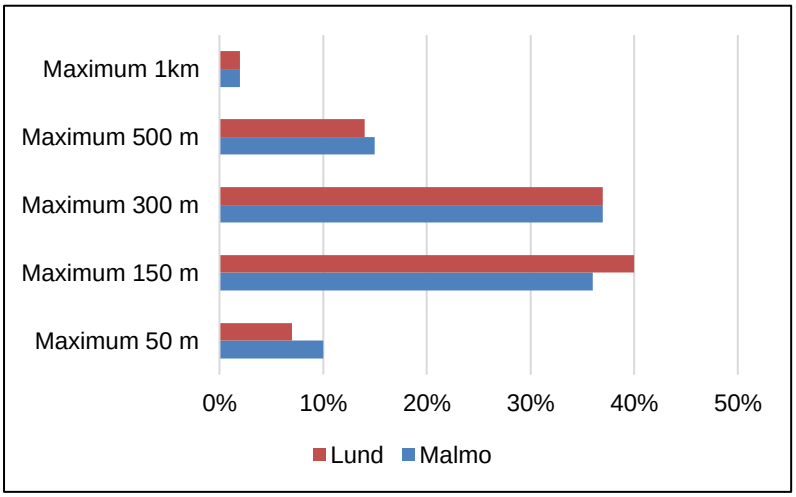


Fig. 16: Distribution of distance users are willing to walk to find an e-scooter in Malmö and Lund

5.3. How e-scooters are used: Where and how often

Table 4 shows the summary of the surveys' results related to the frequency of using e-scooters for different travel purposes. In Malmö, 59% of the respondents use e-scooters to go to leisure activities once in a while, and 15% use them often. In Lund, the same values correspond to 56% and 10%, respectively. 87% of Malmö's respondents and 74% of Lund's respondents never used an e-scooter to go to school. In Lund, 75% and 82% of the respondents never used an e-scooter to go to daily groceries and go to work, respectively. Nevertheless, in Malmö, 27% use this service to go to work, and 29% use it to go to daily groceries once in a while. In Malmö, 10% of the respondents use e-scooters often and very often to go to work, in Lund 6%.

Table 4: E-scooter travel purpose in a) Malmö and b) Lund.

a)

	Go to work	Go to school for education	Go to daily grocery	Go for leisure activities
Very often	4%	2%	1%	7%
Often	7%	3%	6%	15%
Once a while	27%	9%	20%	59%
Not at all	62%	87%	73%	20%

b)

	Go to work	Go to school or education	Go to daily grocery	Go for leisure activities
Very often	2%	2%	1%	3%
Often	4%	3%	3%	10%
Once a while	19%	21%	14%	56%
Not at all	75%	74%	82%	31%

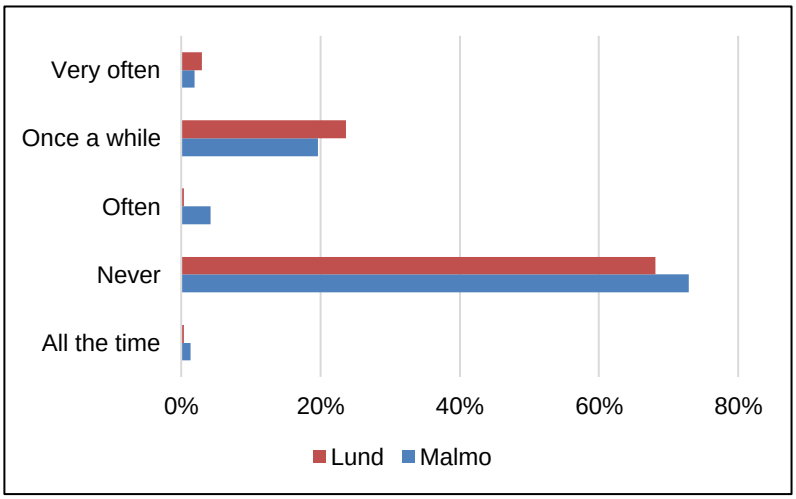


Fig. 17: Distribution of the frequency users go to bus/tram stops using e-scooters

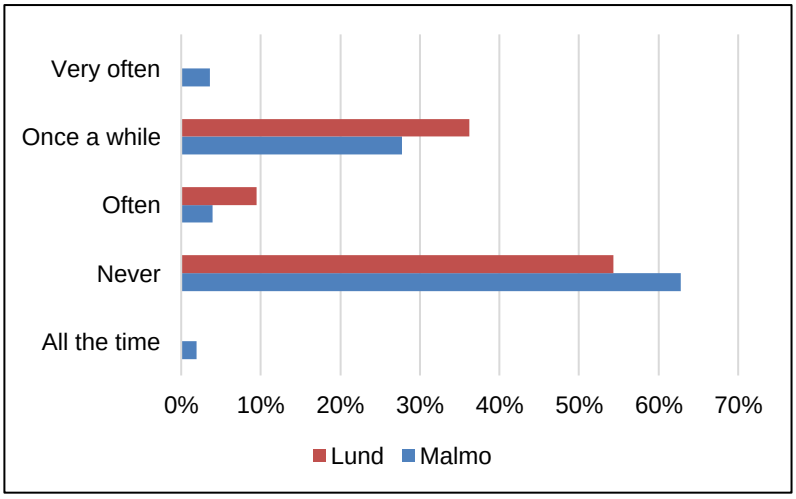


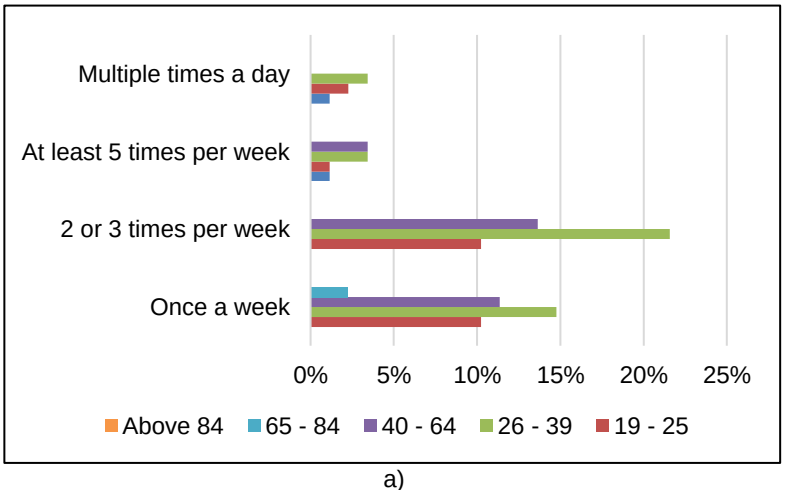
Fig. 18: Distribution of the frequency users go to train/metro stations using e-scooters

Figures 17 and 18 identify the distribution of the answers in two different questions: "How often had you used e-scooters for going to bus/tram stops?" and "How often had you used e-scooters for going to train/metro stations?". In Malmö, 20% of the respondents use e-scooters to go to bus/tram stops once a while, and in Lund, 24%. In Lund, 36% use e-scooters to go to train/metro stations once a while, and in Malmö, 28%. To go to bus/tram stops, in Lund and Malmö, e-scooters are used "Often" and "Very often" by 3% and 6 %, respectively. And to go to bus/tram stops, by 9% and 8%, respectively.

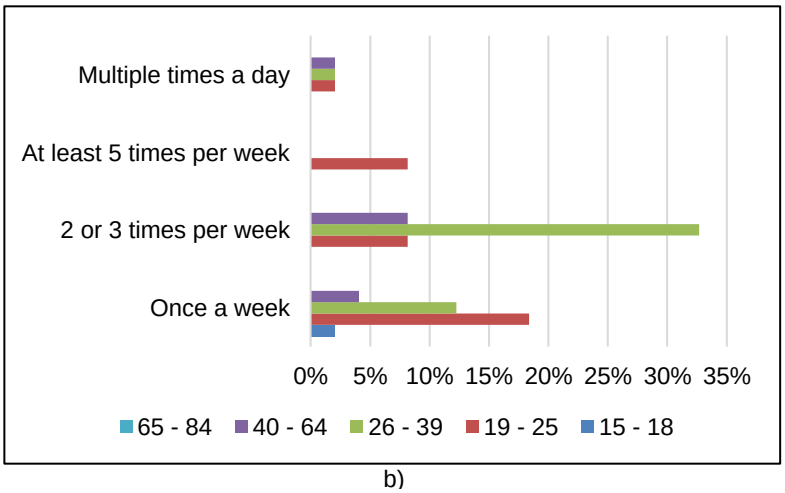
5.4. Characteristics of frequent e-scooters users

The frequent e-scooter users are defined as those who stated using e-scooter "multiple times a day", "at least five times per week", "2 or 3 times per week" and "once a week". In Lund, 51% of the respondents only used e-scooters once or twice or used them less than once a month. In Malmö, the same value corresponds to 32%.

Figure 19 shows the distribution between the frequency of e-scooter usage and the age of the respondents. In both cities, most of these users are between 26 and 39 years old – 43% in Malmö and 47% in Lund. The second most common age range for frequent e-scooter users in Malmö is between 40 and 64 years old and in Lund between 19 and 25.



a)

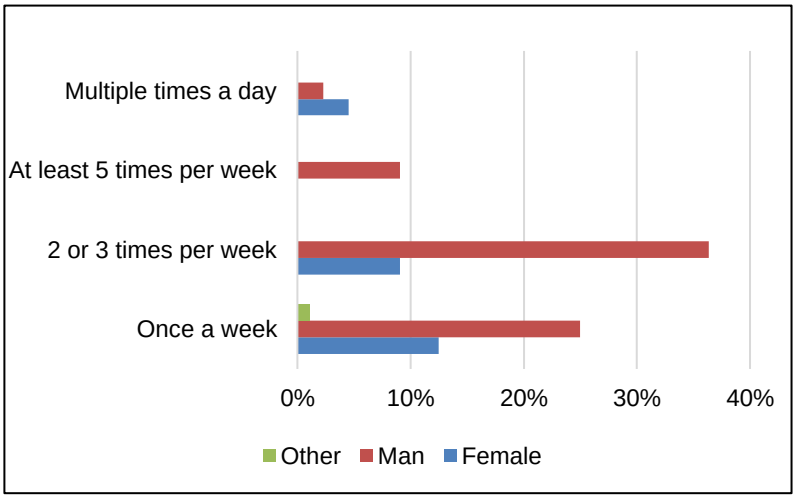


b)

Fig. 19: Distribution of the frequency of e-scooter usage and the age of the respondents in a) Malmö and b) Lund.

Figure 20 shows the distribution between the frequency of e-scooter usage and the gender of the respondents. In Malmö and Lund, 73% and 71% of the frequent e-scooter users are male, respectively. In Lund, only males use e-scooters "multiple times a day" or "at least 5 times per week". In Malmö, only males use the service "at least 5 times per week". The "multiple times a day" frequency, in Malmö, is more common among females.

In both cities, the most frequent users of e-scooters are males between 25 and 39 years old. Thereby, the sample was reduced to include only respondents with these two characteristics - Group 1. After that, the characteristics of this group were analysed, for example, average income, higher level of education, etc. In Malmö, this group represents 9% of the total sample and 32% of the frequent users, and in Lund, represents 7% and 33% respectively.



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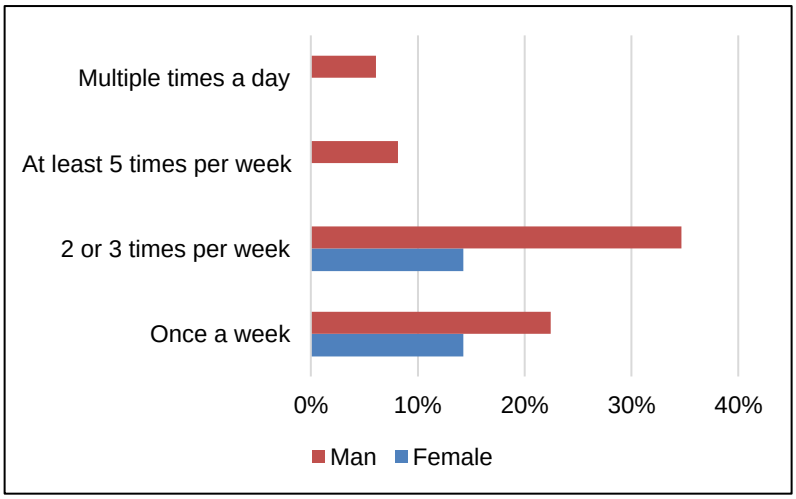
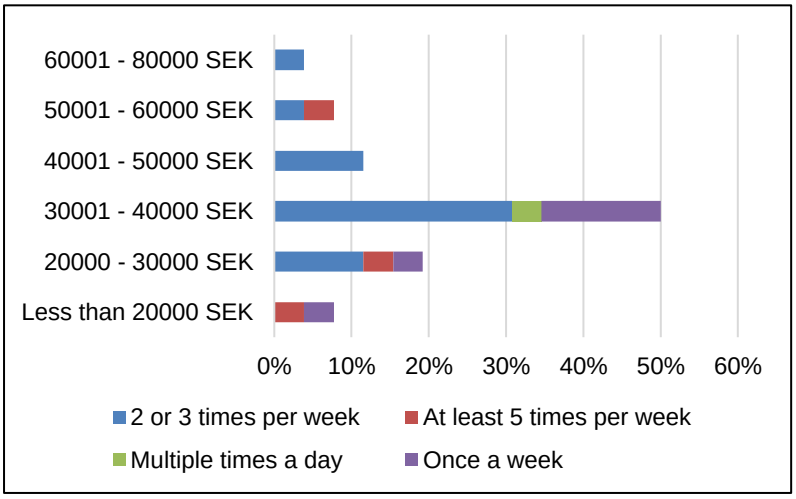


b)

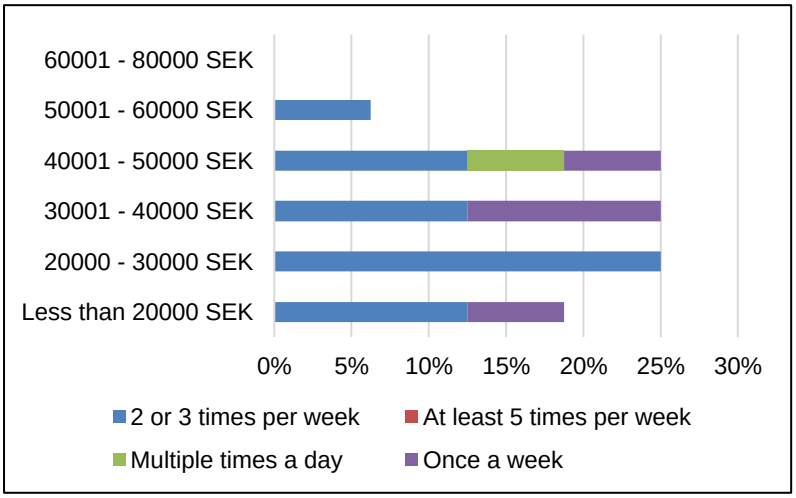
Fig. 20: Distribution of the frequency of e-scooter usage and the gender of the respondents in a) Malmö and b) Lund.

5.4.1. MAIN USERS: MEN BETWEEN 25 TO 39 YEARS OLD

Figure 21 identifies the distribution of the average income among males between 25 and 39 years old that are frequent e-scooter users. In Malmö, 50% of this sample earns between 30001 and 40000 SEK. In Lund, there isn't an average income that stands out in this sample. In Lund, the most common range of salary among this group of users that rent e-scooters "2 or 3 times per week" is between 20000 and 30000 SEK.



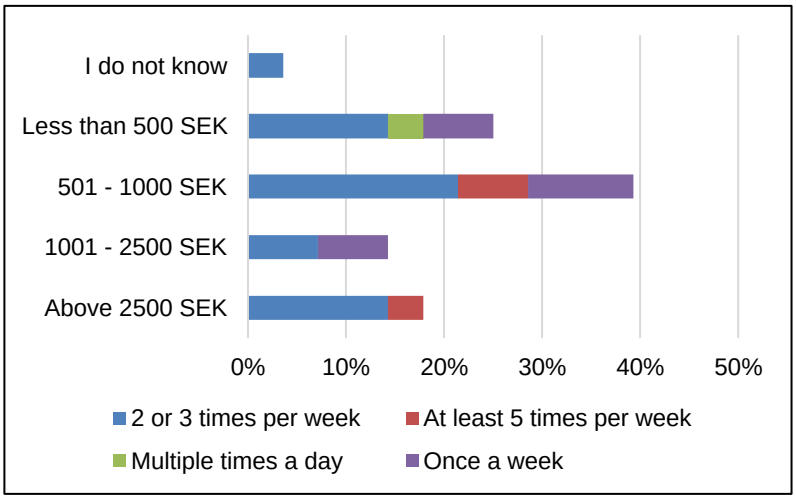
a)



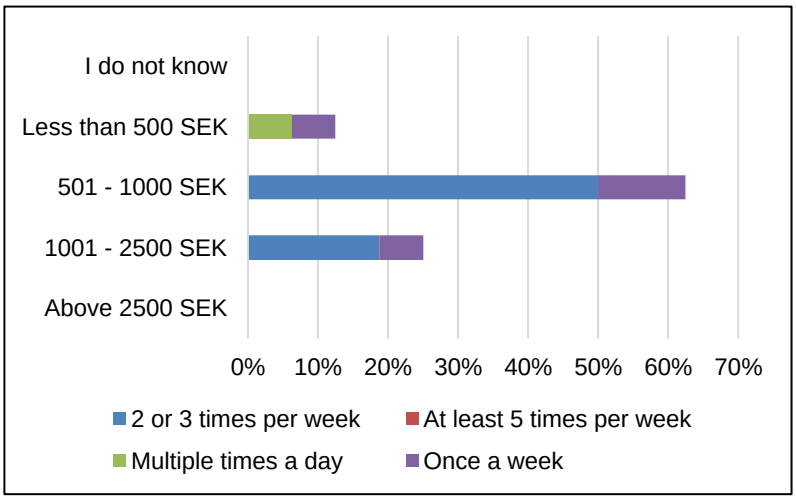
b)

Fig. 21: Distribution of the frequency of e-scooter usage and the average income in a) Malmö and b) Lund – Group 1.

In both cities, the most common monthly expenditure on regular travel among males between 25 and 39 years old that are frequent e-scooter users (Fig.22) is between 501 and 1000 SEK – 39% in Malmö, 63% in Lund. In Malmö, 18% of this group expends more than 2500 SEK per month on regular travel. "Multiple times a day" users in Lund and Malmö expend less than 500 SEK per month.



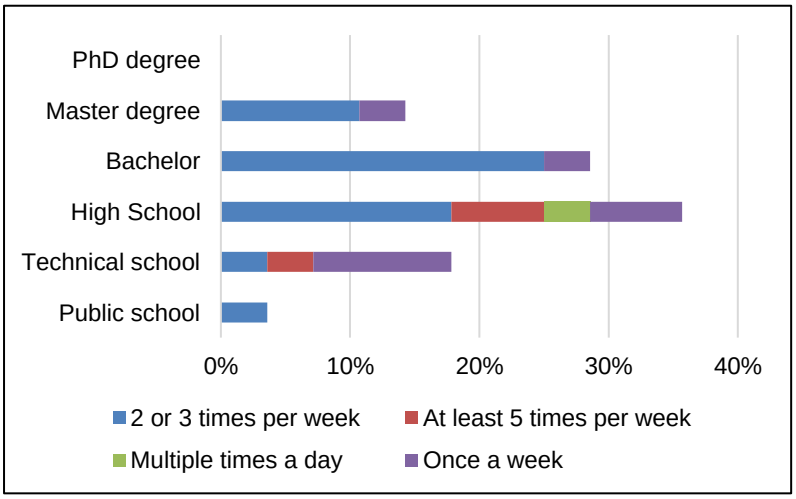
a)



b)

Fig. 22: Distribution of the frequency of e-scooter usage and the average month expenditure on regular travel in a) Malmö and b) Lund – Group 1.

Regarding the distribution of the higher level of education in the group, in Malmö, 43% have a university degree (bachelor or master), and 36% have a high school diploma. In Lund, 69% have a university degree (bachelor, master, or Ph.D.). The lowest education level in Lund is High School (31%), and in Malmö is Public school (4%). In Lund, the "multiple times a day" user has a Ph.D. degree.



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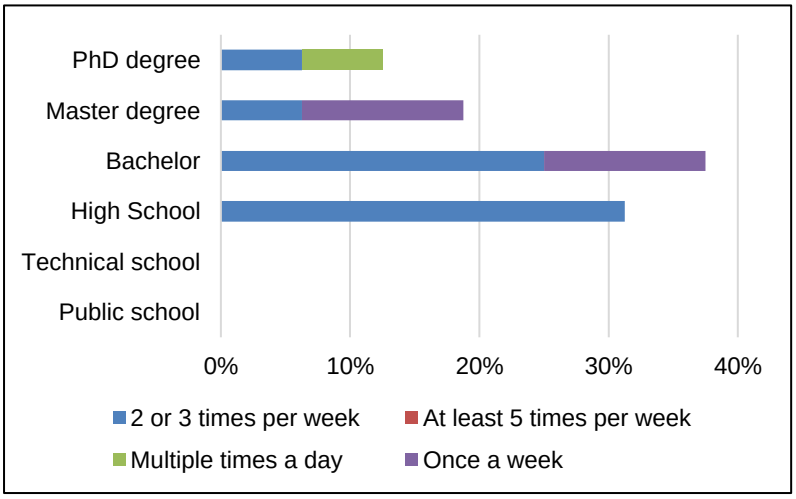
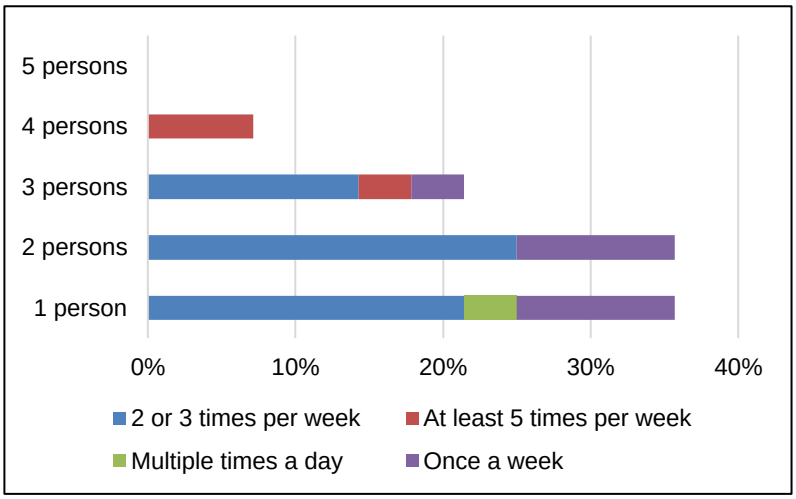


b)

Fig. 23: Distribution of the frequency of e-scooter usage and the higher education level in a) Malmö and b) Lund – Group 1

Figure 24 shows the distribution of the number of persons per household among males between 25 and 39 years old that are frequent e-scooter users. In Malmö, 71% of this group lives alone or with another person, comparing to 56% in Lund. In Lund, 44% live with two or more persons, comparing to 28% in Malmö. The percentage of respondents living with 4 persons is 6% in Lund, and in Malmö 0%.



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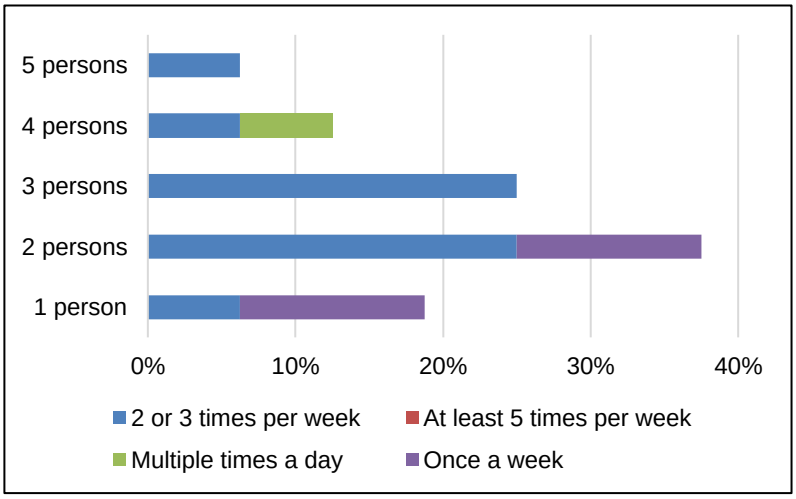
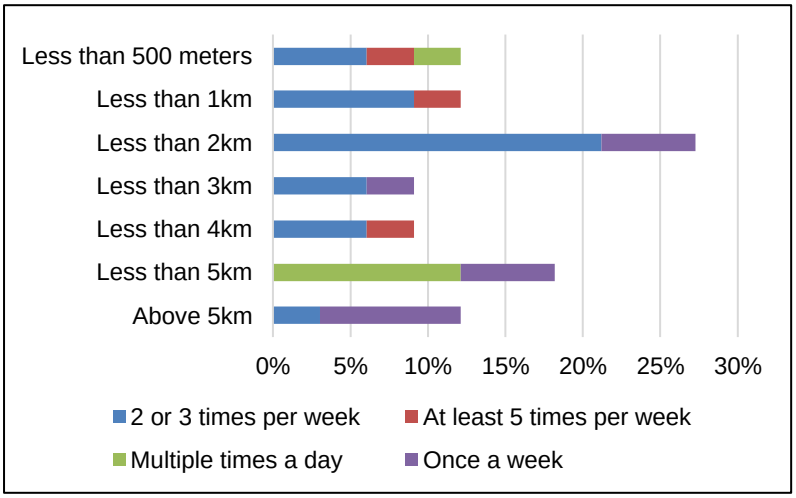


b)

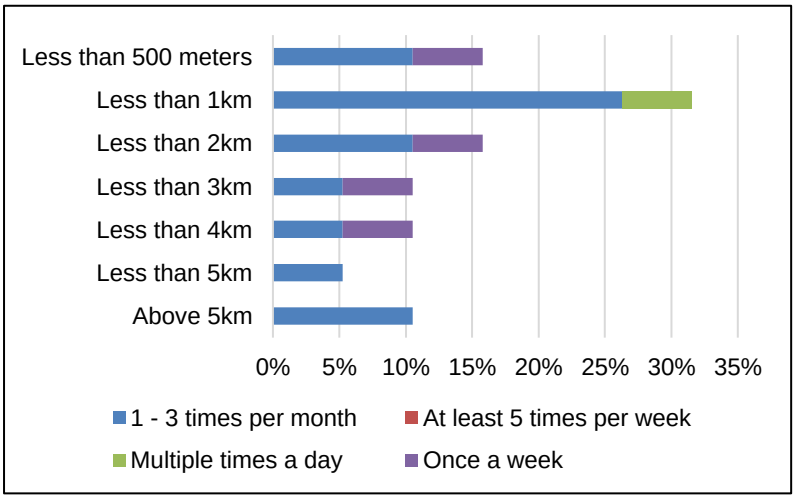
Fig. 24: Distribution of the frequency of e-scooter usage and the number of persons per household in a) Malmö and b) Lund – Group 1

Figure 25 identifies the distribution of the distance between home and city centre among males between 25 and 39 years old that are frequent e-scooter users. In Malmö, the most common distance between home and the city centre is between 1 km and 2 km – 27% - and in Lund is between 500 meters and 1 km - 32%.

The distributions of travel purpose and distance a user is willing to walk to find an e-scooter in Group 1 was not presented since the frequencies were similar to the ones identified for Lund's and Malmö's entire sample (Table 4 and Figure 16).



a)



b)

Fig. 25: Distribution of the frequency of e-scooter usage and the distance between home and city centre in a) Malmö and b) Lund – Group 1.

5.5. Alternative modes of transportation for e-scooter users

After analysing the answers of the respondents to "What would you do if an e-scooter was not available" it was possible to conclude that the three most common answers in Malmö and Lund are "Walking", "Cycling" and "Buses". It is relevant to mention that on this question the respondents could choose more than one mode for substituting e-scooters.

In Malmö, the option "car" was the fourth most chosen – by 36% of the sample. In Lund, this option was chosen by less than 30% of the respondents. In Malmö and Lund, the option "Car+PT" was chosen by 5% and 6%, respectively. Walking and cycling were the two most chosen in both cities – 62% and 58% in Malmö, and 72% and 68 % in Lund, respectively. In both cities, no one would not travel if e-scooters were not available.

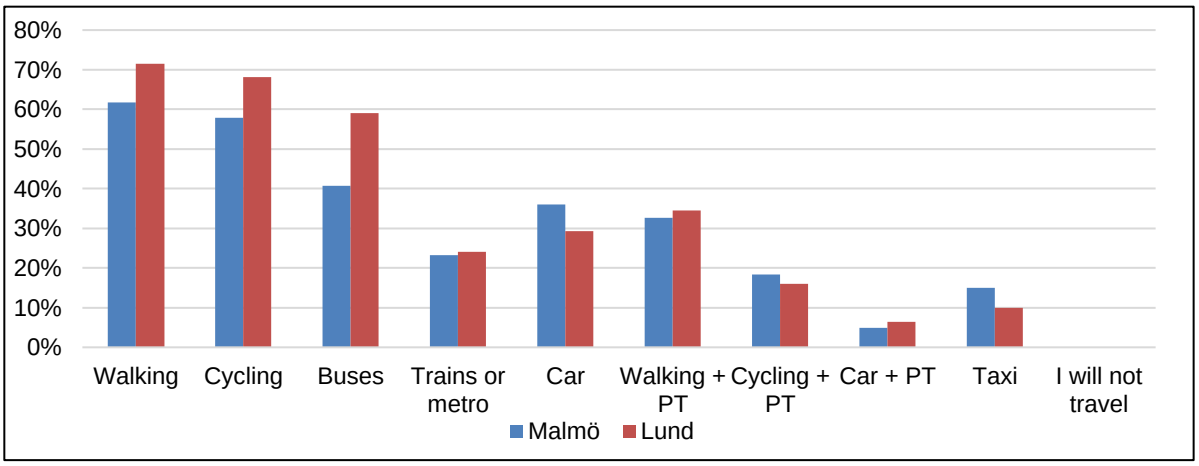


Fig. 26: "What would you do if e-scooter was not available?"

5.5.1. USERS WHO USE E-SCOOTERS AS THE SUBSTITUTE MODE FOR CARS

The data were filtered to study the users' characteristics that chose the car as a possible substitute if e-scooters are not available. Only the answers of the respondents that chose "Car" and/or "Car+ PT" as one of their options were analyzed (Group 2). This group represents 35% of Lund's sample and 41 % of Malmö's sample. In Malmö and Lund, 56% and 37% of this group, respectively, uses the car as the main transport mode in their everyday life (Figure 27).

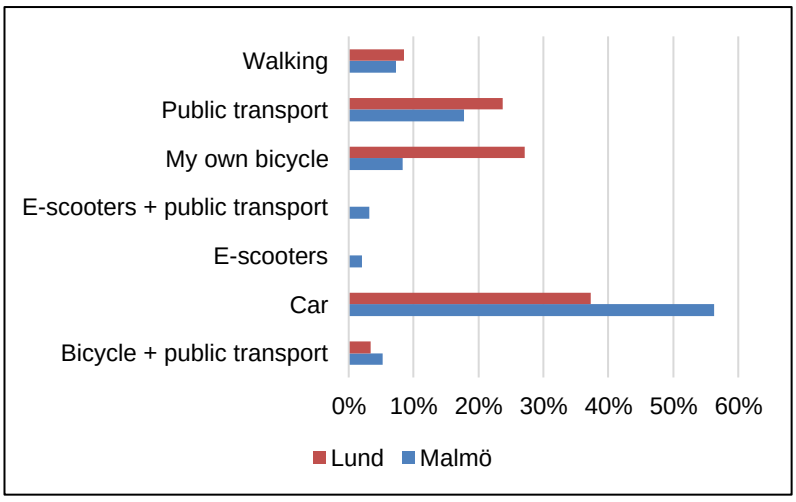


Fig. 27: Main transport mode distribution in Group 2.

Figure 28 identifies the distribution of the frequency of e-scooter usage among Group 2 respondents. In Malmö, 41% of the group only used e-scooters once or twice or used them less than once a month. In Lund, the same value corresponds to 62%. In Malmö and Lund, the frequent users correspond to 25% and to 17% of the group, respectively. The most common answer in Lund is "I have only tried once or twice" – 45% - and in Malmö is "1-3 times per month" – 34%.

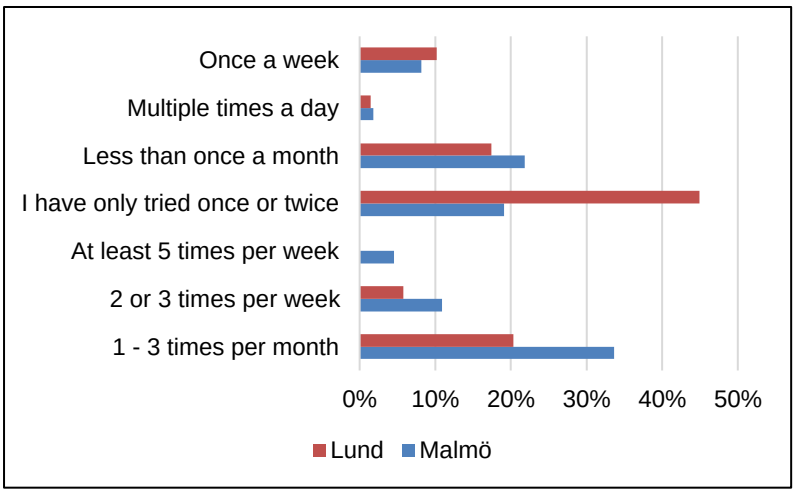


Fig. 28: Distribution of the frequency of e-scooter usage in Group 2.

Regarding age distribution of Group 2, in Lund, 41% of the respondents are between 19-25 years old, and 30% are between 40 to 64 years old. In Malmö, 44% are between 26-39, and 32% between 40 to 64 years old (Fig.29).

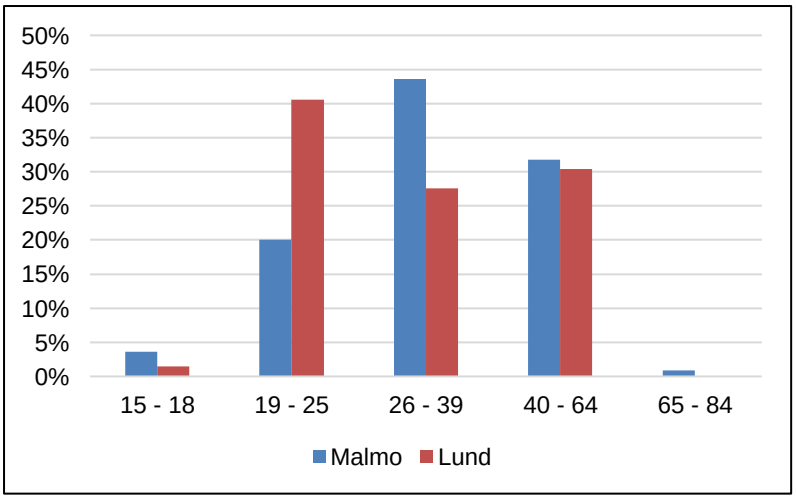


Fig. 29: Age distribution in Group 2.

Figure 30 shows the average income distribution in group 2. In Malmö, the distribution is similar to the overall one (Table 3). In Lund, 42% earn less than 20000 SEK, and 40% between 20000 and 40000 SEK. Incomes higher than 80000 SEK represent 4% of Group 2.

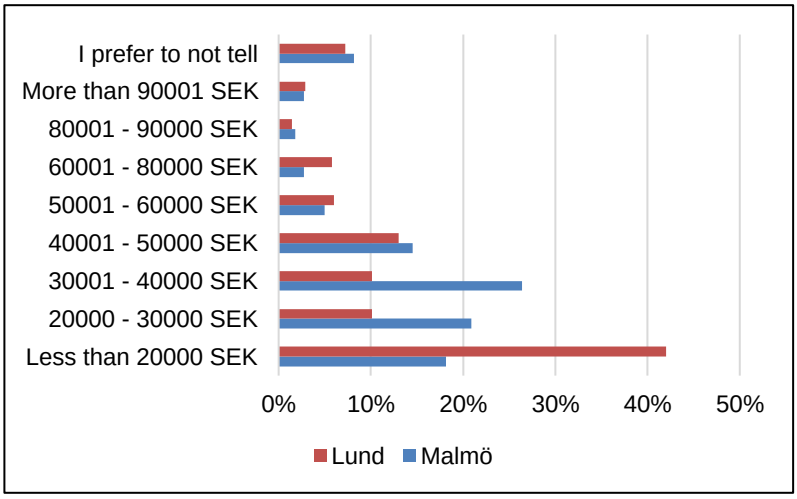


Fig. 30: Average income distribution in Group 2.

Figure 31 identifies the average month expenditure distribution on regular travel of Group 2. In Malmö, 27% of this group expends less than 500 SEK, and in Lund 42%. Average month expenditures between 1001 and 2500 SEK represent 27% of Malmö's Group 2 respondents, and 22 % of Lund's Group 2 respondents. In Lund and Malmö, 6% and 8% of the respondents expend more than 2500 SEK.

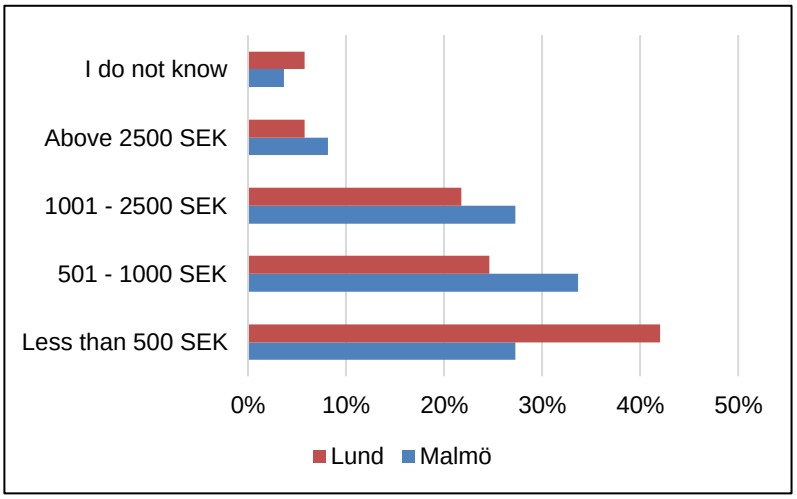


Fig. 31: Average month expenditure distribution on regular travel in Group 2.

Figure 32 shows the distribution of the distance between home and city centre in Group 2. In Lund, 61% lives less than 2 km away from the city centre, and in Malmö 49%. Almost 20% lives more than 5km from the city centre in Malmö. In Lund, almost 30% lives between 500 meters and 1km away.

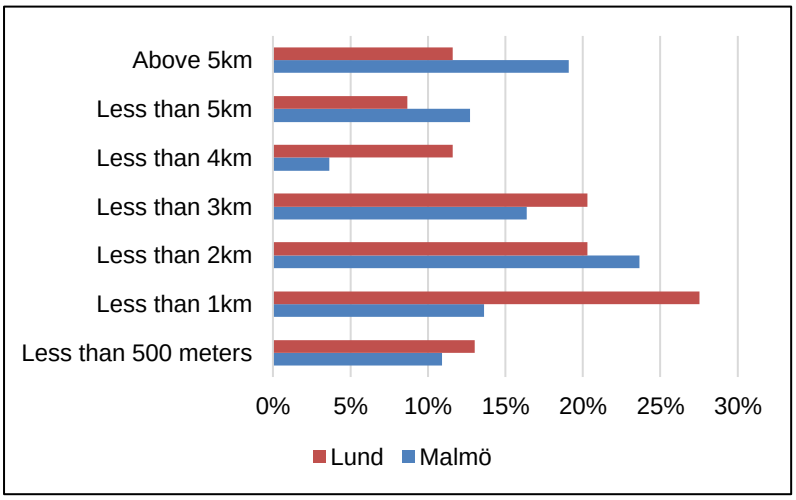


Fig. 32: Distribution of the distance between home and city centre in Group 2.

The distribution of gender, education level, number of persons per household, travel purpose, and distance a user is willing to walk to find an e-scooter in Group 2, was similar to the ones identified for Lund's and Malmö's entire sample (Table 3, Table 4 and Figure 16).

6

DISCUSSION

Knowledge on free-floating shared e-scooters usage remains scarce. This study is one of the firsts to characterize free-floating shared e-scooters users in two different cities in Sweden and the first (according to the stated references) to focus the study on frequent e-scooter users. It is also the first study (according to the stated references) to characterize users that use e-scooters as a car substitute.

This study investigates the usage of e-scooters in Lund and Malmö using the results of a travel survey sent to several users of one operator. The findings suggest important implications for future urban transport planning that can help, for example, city councils to elaborate more targeted policy guidelines.

6.1. Users' segment and travel pattern in Malmö and Lund

According to the sample, in Lund, free-floating shared e-scooters users are mostly men aged between 19 and 25 years old, and in Malmö, mostly men aged between 26 and 39 years old. These findings are consistent with previous studies that show that most e-scooter users are young to middle-aged men (Christoforou 2021; Almannaa et al. 2021; Laa and Leth 2020). But also match with conclusions drawn in some docked shared bikes related studies (Reck e Axhausen, 2021; Fishman *et al.*, 2015; Fuller *et al.*, 2011; Shaheen, 2019; Machado, 2018).

In Lund, the users' income is mostly lower than the average income of the city - 51% earns less than 20000 SEK. And, in Malmö, the users' income is mostly slightly higher than the average income of the city - only 19% earn less than 20000 SEK. Two previous studies showed inconsistency on this matter: Jiao and Bai (2020) concluded that areas with low household income tend to generate more e-scooter usage; Almannaa et al. (2021) argued that income doesn't seem to affect e-scooter usage. At the same time, docked shared bikes studies show that the higher the income, the higher the usage (Reck e Axhausen, 2021; Fishman *et al.*, 2015; Fuller *et al.*, 2011; Shaheen, 2019; Machado, 2018). These differences may be explained by each city's specificities.

When it comes to education level, the users have a lower level of education comparing to the average of both cities – 37% and 43% have at least three years of post-secondary education, in Lund and Malmö, respectively. Contrarily, in previous studies, there is a common correlation between higher free-floating shared e-scooter and docked shared bikes usage, and a higher level of education (Laa and Leth 2020; Jiao and Bai 2020; Christoforou 2021, Reck e Axhausen, 2021; Fishman *et al.*, 2015; Fuller *et al.*, 2011; Shaheen, 2019; Machado, 2018). However, it is relevant to mention that a higher level of education depends on the city/country the study refers to and should be compared to the average level of the area.

Regarding the monthly expenditure on regular travel, the sample pointed that most users spend less than 1000 SEK per month in both cities – around 80%. In Lund, almost half of the sample spends less than 500 SEK.

In Lund, the distribution of the monthly expenditure on travel, the average income, the education level, as well as the age, seems to point there is a considerable number of university students between the users of e-scooters in the city – most aged between 19-25 (46%), with a high-school diploma or bachelor degree (53%), that have less than 20000 SEK per month (51%), and expend less than 500 SEK per month on regular travel (49%). This correlation is plausible due to the high number of students in Lund University – 43700 in 2020 (Lund University 2020).

The average number of persons per household among e-scooter users in Lund and Malmö is higher than 2,5 and 2,4 persons, respectively, which consequently is higher than the cities' average (2,1 persons).

In Malmö, the respondents use bicycles (30%) and cars (30%) as the main transport mode in their everyday life. In Lund, the main transport mode is the bicycle (35%). Comparing the main transport mode distribution among users with the modal share of each city, in Lund, 16% of the users use a car as their main transport mode compared to 27% in Lund's modal share, and in Malmö, 7% walk compared to 14% in Malmo's modal share.

E-scooter users in Malmö and Lund tend to live closer to their main daily destination – 64% and 58% live less than 5km away, respectively. This finding shows that in Lund and Malmö, most of the main daily trips are suitable for e-scooters (Hardt and Bogenberger 2019; Noland 2019; Edel, Wassmer, and Kern 2021; Degele et al. 2018).

E-scooter users tend to live closer to the city center – 53% in Malmö and 56% in Lund live less than 2km away from the city center. The greater concentration of available e-scooters near the city center may be an explanation for these results. Once more, this shows that most of our respondents live within a suitable distance to go to the city center or the central station using e-scooters. Nevertheless, empirical evidences show the shorter the distance to the city center, the higher the probability of walking being replaced by e-scooters (Kopplin, Brand, and Reichenberger 2021; James et al. 2019).

Regarding the distance that a user is willing to walk, it shows similar preferences in both cities. In Lund and Malmö, 7% and 10% of the respondents answered they are willing to walk a maximum of 50 meters, 40% and 36% a maximum of 150 meters, and 37% a maximum of 300 meters. The distance of 300 meters is likely to be the acceptable distance for travellers to fetch an e-scooter.

The travel survey revealed this service is used particularly for leisure activities – 59% and 56% use it once in a while, in Malmö and Lund, respectively. Once in a while, go to work is a travel purpose for 27% of e-scooters users in Malmö. In Lund, once in a while, go to school or education is a travel purpose for 21% of e-scooters users. Once more, the latter conclusion corroborates the possible influence of Lund University in e-scooters usage. These findings seem to point out leisure activities are the principal travel purpose when using e-scooters, and commuting is a travel purpose for ¼ of the users in these two cities, which corroborates two previous studies' conclusions (Hardt and Bogenberger 2019; Christoforou 2021).

These findings seem to indicate that e-scooters have a role when served as a connection mode to PT: Train stations and metro stations tend to be concentrated in one place or in one area, and bus and tram stops tend to be more dispersed in the territory. This implies that a bigger percentage of houses is covered by bus and tram stops and just a small percentage by metro and train stations. Therefore, e-scooters can feed a niche, for example, persons that do not live far from a train station to use a bus/car to reach the

station but don't live close enough to go walking.

When analyzing the frequency of e-scooter usage, it was possible to conclude that 51% of the users in Lund and 41% of the users in Malmö only used the service once or twice or use it less than once a month.

6.2. Frequent users' characteristics

Two characteristics stand out among frequent e-scooter users:

- 43% in Malmö and 47% in Lund are between 26 and 39 years old;
- 73% in Malmö and 71% in Lund are males.

Man, that are frequent e-scooter users and are between 26 and 39 years represent 33% of Lund's and 32% of Malmö's total number of frequent e-scooter users. In this group, the respondents have similar characteristics in both cities:

- Use mostly e-scooters "2 or 3 times per week";
- Have a higher income – in Malmö, 50% earn between 30001 and 40000 SEK compared to 10% in the overall sample;
- Spend more per month on regular travel – 63% in Lund expend between 501 and 1000 SEK;
- Have higher level of education – in Lund, 69% have a university degree (bachelor, master or Ph.D.);

These findings evidence that even though the users' characteristics were not concordant between Lund and Malmö in the overall sample, the characteristics of the frequent e-scooter users are the same independently of the city.

In this group, two users' characteristics differ in the cities:

- In Lund, the average number of people per household in this group is two persons (lower than the city average and the overall sample average), and in Malmö is 2,5 persons (higher than the city average and the overall sample average).
- In Lund, users tend to live even closer to the city center – 63% live less than 2km away comparing to 56% of the overall sample- and in Malmö, users tend to live further away from the city center – 45% live less than 2 km away comparing to 53% of the overall sample.

Travel purpose, distance a user is willing to walk to find an e-scooter and distance from the main daily destination, are three variables that showed the same distribution in this group when compared to the overall sample. This may imply that these variables are independent of the frequency of e-scooter usage in Lund and Malmö.

6.3. Alternative modes of transportation for e-scooter users

According to the sample, most e-scooter users would replace the use of e-scooters for more sustainable modes of transport, such as walking, biking, or public transport. In Malmö and Lund, 36% and 29% of the users chose "car" as a possible e-scooter substitute, respectively. However, it is relevant to remember that not all of these respondents would use a car as an e-scooter substitute since this question allowed respondents to choose more than one option. These findings are consistent with previous studies that

show that e-scooters tend to replace walking, biking, and transit (Hardt and Bogenberger 2019; Fearnley, Johnsson, and Berge 2020; Laa and Leth 2020; Christoforou 2021; Mitra and Hess 2021; Curl and Fitt 2019). E-scooters seem not to generate new trips since no one chose the option "will not travel" if e-scooters aren't available.

Users that chose "Car" or/and "Car+PT" as one of their options represent 35% of Lund's sample and 41 % of Malmö's sample. In Malmö and Lund, 56% and 37% of this group use the car as the main transport mode in their everyday life, respectively. In Lund and Malmö, 62% and 41% of this group only used the service once or twice or use it less than once a month, respectively. These values evidence that users that might choose the car as an e-scooter substitute are mostly persons that are not regular e-scooter users. Therefore, it is reasonable to presume that in these two cities car use is not being significantly substituted by e-scooters services. Still, in Malmö, this mode swift seems to be higher. Regarding age distribution, this group has a slightly bigger percentage among users between 40 and 64 years old – 30% in Lund and 32% in Malmö. The average monthly expenditure on regular travel, in this group, is also higher – 27% and 22% expend between 1001 and 2500 SEK in Malmö and Lund, respectively. In Lund, this group has, on average, a higher income than the overall sample – for example, incomes higher than 80000 SEK represent 4%. The distance between home and city center, in this group, in Malmö, is higher: 32% live more than 4 km away compared to 23% of the overall sample. Due to this, we can conclude e-scooters play a more positive role for this group of people who live more than 4km away from the city center. These findings also imply that users who use e-scooters as the substitute mode for car, in general, tend to be older and expend more on travel.

7

CONCLUSION

The lack of scientific knowledge when talking about free-floating shared e-scooters services has been compromising the efficient management of these services in several cities. This study focused on analyzing the users' perspective in Malmö and Lund. The results were collected using a travel survey that was sent to several e-scooters users and afterward were analyzed using descriptive statistical analysis. The overall findings give relevant insights about e-scooters services that can help to fill the existing research gap in this field. In addition, it was conducted a brief market overview analysis of the free-floating shared e-scooters services in Europe.

The findings suggest that free-floating shared e-scooters users in Malmö and Lund tend to:

- Be young to middle-aged men;
- Spend less on regular travel;
- Live with more persons per household;
- Live closer to the city center, as well as their main daily destination - suitable distance to go to their main daily destination using e-scooters;
- Walk up to 300 meters to find an available e-scooter;
- Use the service for leisure activities;
- Use bicycle as their main transport mode;
- Use e-scooters more to go to train/metro stations rather than bus/tram stops.

In Lund, it seems there is a considerable number of university students between the users of e-scooters in the city.

Moreover, the findings argue frequent e-scooters users tend to:

- Be man between 26 and 39 years old;
- Have a higher income;
- Use the service for leisure activities;
- Spend more per month on regular travel;
- Have higher level of education;
- Live less than 3km away from the city center - suitable distance to go to the city center or the central station using e-scooters.

Cities have introduced e-scooters for a range of different reasons, but mostly with the intuit to diminish car use and to help them become more sustainable. Herewith, it is pertinent to try to answer what will be the role of e-scooters in future mobility, and if this role lies in contributing to more sustainable cities. The study findings indicate that in Lund and Malmö e-scooters usually replace the use of more sustainable

modes of transport, such as walking, biking, or public transport. Moreover, it was possible to conclude that users who use e-scooters as the substitute mode for cars represent a specific niche – they are older, expend more on travel, tend to live further away from the city center, and are less frequent e-scooter users. This indicates e-scooters are not contributing to provide a sustainable travel mode in Lund and Malmö. Furthermore, it seems that free-floating shared e-scooters services have insufficient potential to be a disruptive innovation for sustainable urban mobility with its current performance. Nevertheless, there is still a big research gap, especially in Europe. Cities like Rome, Milan, and Lisbon, due to their low urban mobility performance (Lerner 2011), can have more sustainable behaviors when implementing free-floating shared e-scooters services.

The conclusions that were taken in this study allowed to corroborate previous studies. And consequently, conclude e-scooter users, in more general patterns, behave the same. Only in more specific characteristics, it was possible to evidence differences between Lund and Malmö.

City councils have a crucial role when it comes to e-scooters proper management, for example, by implementing targeted policies. Still, the existing literature is not yet enough to support these institutions. More future studies are required for creating scientific evidence to support the policy-making for shaping e-scooters towards a more sustainable mode.

7.1. Limitations and suggestions for future studies

This study has some limitations that are important to discuss. First, the sample could have been bigger. Even though the total number of respondents corresponds to a good representation of the population, when analyzing more concrete groups the sample was quite small – for example, in Group 1 or Group 2. Furthermore, in both Lund and Malmö, between the users, there are surely tourists. This makes part of the comparisons of the results with the characteristics of the city not that accurate. The lack of research in countries with similar characteristics as Sweden also made it more difficult to conduct the analysis and make conclusions out of it.

Future research in this field is still crucial. Considering the cities that were studied until now, it is clear there is a big research gap in some types of European cities. These cities, due to their cities' specificities, can behave differently and contradict the e-scooters usage pattern that has been drawn until now. It is then relevant to study other cities with these mobility services. Moreover, more studies focusing on frequent e-scooters users and users who use e-scooters as the substitute mode for cars are crucial. Using different statistical models to try to corroborate these study findings is also relevant. Regarding the market overview analysis, the number of vehicles of each operator and its distribution in each country/city can give a better insight into its dimension and its market power. However, as the objective of this dissertation wasn't investigating the market of shared e-scooters services this research wasn't done. It may be a relevant topic to study in future researches.

All in all, it is essential to understand the role of this service in future urban mobility, and to help city councils to make the best out of e-scooters services in the most sustainable possible way.

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