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SHARED E-SCOOTERS

– Overview on the strengths, weaknesses, opportunities and threats for sustainable urban mobility

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BACHELOR'S THESIS | ABSTRACT

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SHARED E-SCOOTERS

- Overview on the strengths, weaknesses, opportunities and threats for sustainable urban mobility

This thesis takes a look at shared e-scooters in the context of sustainable urban mobility. The topic is very relevant from the climate change mitigation and urban mobility policy points of view because e-scooters and other forms of micromobility are suggested to contribute to modal shift away from private cars. In addition to decreasing urban CO_2 emissions, congestion and noise, shared e-scooters (also referred to as electric kick-scooters and powered standing scooters) are promoted complementing the existing public transportation networks and thus being a great opportunity for cities to reach their climate targets and solve mobility challenges.

This qualitative study is based on online sources ranging from news articles to policy papers, industry analyses, e-scooter service operator press releases and academic research until September 2020. The study approaches sustainable urban mobility and shared e-scooter services through an adaptation of a fourfold SWOT analysis: internal strengths of the e-scooter technology can lead to positive effects (opportunities), while certain weaknesses of the vehicle or business model can lead to threats for the overall mobility and liveability of a city. In this study, the dimensions of sustainability are drawn from the Sustainable Urban Mobility Plan (SUMP) framework, a tool promoted by the EU and used by cities in their policy planning. The study also discusses how the use of e-scooters has been regulated in a range of countries and cities.

According to early studies most e-scooter trips are short, occur during the afternoon hours and are related to work or school commuting. Students and affluent executives are well presented among the clientele which mostly consists of young males. Major e-scooter service operators have developed their vehicles and operational practices from sustainability point of view, which has lowered the total life-cycle emissions of some e-scooter services to the level of public transport. Major operators also promote safe and responsible use of their vehicles with informational campaigns, virtual driving schools and a range of technological solutions. Despite these positive developments, careless use and parking of shared e-scooters remain a challenge for the traffic safety and liveability of many cities.

One of the key findings of the study is that active strategic cooperation between local public authorities, public transportation agencies and operators of shared e-scooter services is mot likely required in order to turn the strengths and opportunities of shared e-scooter services into practise. Furthermore, minimising the potential threats for the local traffic safety, urban space and environment also requires active engagement from all the key stakeholders. Finally, the thesis calls for more research on the topic of shared micromobility and suggests legal reforms empowering cities to regulate the terms under which shared micromobility is allowed on their streets.

KEYWORDS:

electric scooter, e-mobility, micromobility, regulation, modal shift, shared mobility

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YHTEISKÄYTTÖISET SÄHKÖPOTKULAUDAT

- Katsaus vahvuuksiin, heikkouksiin, mahdollisuuksiin ja uhkiin kestävän kaupunkiliikenteen näkökulmasta

Opinnäytetyö tarkastelee yhteiskäyttöisiä sähköpotkulautoja (skuutteja) kestävän kaupunkiliikenteen näkökulmasta. Aihe on erittäin ajankohtainen ilmastonmuutoksen hillitsemisen ja kaupunkiliikenteen kehittämisen kannalta, sillä sähköpotkulautojen ja muiden ns. pienliikkumisen muotojen ajatellaan voivan edesauttaa kulkutapasiirtymää pois yksityisauton käytöstä. Hiilidioksidipäästöjen lisäksi sähköpotkulautojen mainostetaan vähentävän kaupunkien ruuhkia ja melua sekä täydentävän olemassaolevia joukkoliikenneverkostoja. Alan yritykset kuvailevat yhteiskäyttöisten sähköpotkulautojen auttavan kaupunkeja saavuttamaan ilmastotavoitteensa ja ratkaisevan muitakin kaupunkiliikenteen ongelmia.

Tämä laadullinen tutkimus perustuu internetissä vapaasti saatavilla oleviin uutisartikkeleihin, linjapapereihin, toimialakatsauksiin, sähköpotkulautapalveluita tarjoavien yritysten tiedotteisiin ja akateemisiin tutkimuksiin. Tutkimus tarkastelee yhteiskäyttöisten sähköpotkulautojen kestävyyttä SWOT-analyysistä sovelletun nelikentän kautta: sähköpotkulautoihin liittyvän tekniikan ja palvelun vahvuudet voivat johtaa positiivisiin vaikutuksiin (mahdollisuuksiin), kun taas laitteen ja liiketoimintamallin heikkoudet voivat uhata kaupungin liikennettä ja asuttavuutta. Tässä työssä kestävyyden ulottuvuudet on johdettu EU:n suosimasta kestävän kaupunkiliikenteen suunnitelmasta, jota kaupungit voivat käyttää suunnittelutyönsä tukena. Lisäksi tutkimuksessa tarkastellaan sähköpotkulautoja koskevaa sääntelyä eri maissa ja kaupungeissa.

Muutamien aiheesta jo tehtyjen tutkimusten mukaan useimmat yhteiskäyttöisillä sähköpotkulaudoilla tehdyt matkat ovat lyhyitä, tapahtuvat iltapäiväaikaan ja liittyvät työ- tai opiskelumatkoihin. Opiskelijat ja hyvin toimeentulevat johtajat ovat vahvasti edustettuna sähköpotkulautapalveluiden käyttäjäkunnassa, jonka enemmistö koostuu nuorista miehistä. Tekniset parannukset ja hyvin suunnitellut operatiiviset toimintamallit ovat laskeneet joidenkin sähköpotkulautapalveluiden elinkaaren aikaiset päästöt samalle tasolle julkisen liikenteen kanssa. Lisäksi palveluoperaattorit kannustavat laitteidensa turvallista ja vastuullista käyttöä erilaisin kampanjoin, virtuaalisin ajokouluin sekä teknologisin keinoin. Hyvistä kehitysaskeleista huolimatta sähköpotkulautoja käytetään ja pysäköidään edelleen tavoilla, jotka aiheuttavat vaaratilanteita ja haittaa kaupunkitilassa.

Opinnäytetyön keskeisin päätelmä on, että yhteiskäyttöisiin sähköpotkulautoihin liittyvien positiivisten mahdollisuuksien toteutuminen ja mahdollisten uhkien välttäminen todennäköisesti edellyttävät tiivistä strategista yhteistyötä paikallisten päättäjien, julkisen liikenteen toimijoiden sekä sähköpotkulautapalveluyritysten kesken. Tutkielman lopputuloksissa ehdotetaan lisää tutkimusta jaetun pienliikkumisen palveluihin liittyen sekä suositellaan lakimuutoksia, jotka mahdollistaisivat kaupungeille oikeuden sanella ehdot pienliikkumisen palveluiden toteuttamisesta alueellaan.

ASIASANAT:

sähköpotkulauta, sähköinen liikenne, pienliikkuminen, sääntely, kulkutapasiirtymä,
jaetun liikkumisen palvelut

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1 INTRODUCTION

This thesis takes a look at shared e-scooters in the context of sustainable urban mobility. The topic of micromobility is very relevant from the climate change mitigation point of view because it is suggested to reduce the need for private cars, which are attributed to some 11 % of the total CO_2 emissions in the EU (Transport & Environment 2018, Transport & Environment 2019). In addition to emissions, private cars also contribute to urban congestion and noise, thus compromising the livability of cities.

According to the International Transport Forum (2018), the most effective way to decarbonise urban passenger transport is to promote shared vehicles which are powered by clean electricity and integrated with existing public transportation. Introducing new and clean mobility options is indeed one important measure for cities on their path to reaching their climate targets in the spirit of the so called Paris Agreement of 2015 (European Parliament 2019). E-scooters are promoted as a perfect opportunity for cities because the service can be operated using renewable energy and the e-scooters are touted as a great last-mile extension to public transportation. For individuals, e-scooters are advertised as a convenient, quick and fun way to travel short distances (Voi Technology 2020a, 2020b.)

The topicality of individual micromobility has been further underlined by global coronavirus (COVID-19) pandemic. The threat of virus contagion has decreased the use of traditional mass transit and increased the need for such mobility solutions that allow social distancing as recommended by the health authorities. For the operators of shared e-scooter services the coronavirus has proven to be a double-edged sword: during spring and summer 2020 some e-scooter operators suspended their service, while others kept their operations running promoting shared micromobility as a safe way to commute maintaining adequate distance to others (Shrivastava 2020, Sung & Monschauer 2020.)

Dockless e-scooters were first introduced in Santa Monica, California, in September 2017 (Hawkins 2018). Since then, the service operator startups have spread their e-scooters to cities all around the world; in Finland and many other European countries dockless e-scooters emerged during 2019. The sudden appearance of hundreds or thousands of free-floating e-scooters can be a challenge for the urban infrastructure and divide the citizens' opinions. Indeed, the launch of e-scooter services is often followed by a heated debate on the practical consequences, such as thoughtless parking and questionable driving culture. Some citizens and local authorities might therefore like to prohibit shared e-scooters once and for all. However, if the vehicles are street-legal, then the city fathers might find themselves short of regulatory means to control how and where free-floating e-scooters use the public space. As a consequence, the profileration of shared micromobility seems to call for many regulations and legislations to be refined.

Despite the debates, controversies and open questions around the topic, there are still many research gaps on shared e-scooters. This thesis aims to contribute to the discussion by providing an overview on the various sustainability aspects of shared e-scooter services and pointing out differencies in national and local regulations. More exactly put, this study approaches the topic through following research questions:

- What are the strengths and opportunities of shared e-scooters in the context of sustainable urban mobility?
- What are the weaknesses and threats of shared e-scooters in the context of sustainable urban mobility?
- How can the manifestation of opportunities be supported and threats avoided through regulation and policies?

This qualitative study approaches the topic through secondary online sources ranging from news articles to policy papers, industry analyses, e-scooter service operator press releases and academic research until September 2020. Most of the academic research material covered is in the English language, while other source materials were found also in Finnish, Swedish, German and French. Some examples of national and city level e-scooter regulations from the U.S.A. and Europe are also discussed in order to understand the frameworks under which e-scooters have entered the streets.

This paper is divided into six main chapters. Chapter two introduces the concepts of the e-scooter and micromobility. In addition to the birth and introduction of shared e-scooter services, some insight on the uses and users of these services are discussed in the second chapter. Chapter three focuses on the sustainability aspects: international climate agreements push cities to develop policies on cutting carbon dioxide (CO_2) emissions and develop their mobility mix less car-centric. Also the e-scooter service operators' views on sustainability are shortly introduced. Chapter four focuses on the regulatory frameworks of e-scooter use and sharing services by proviving a few examples from different national and city level regulations. Chapter five analyses the phenomenon of shared e-scooters in the context of sustainable urban mobility using the four dimensions of a SWOT analysis: strengths, weaknesses, opportunities and threats. Finally, conclusions are drawn and avenues for further research are proposed in chapter six.

This thesis got its inspiration from ERDF funded project "BSR electric - Fostering e-mobility solutions in urban areas in the Baltic Sea Region" which took place between October 2017 and September 2020. The project aimed to enhance the utilization of e-mobility in urban transport systems around the Baltic Sea Region by demonstrating potential applications of various types of urban e- mobility such as electric city logistics, e-Bikes, e-Buses, e-Scooters and e-Ferries. It is worth noticing that in contrary to the topic of this study, in the context of the Latvian Use Case 6 of BSR electric project e-scooters refer mainly to different types of fourwheeled mobility assistance vehicles, which were tested in transport of elderly people and people with particular mobility requirements (BSR electric, 2020.) The author of this thesis worked as a part-time student assistant for the BSR electric project from November 2017 to June 2020.

2 EMERGENCE OF SHARED E-SCOOTERS IN THE URBAN MOBILITY MIX

This chapter begins with general definitions of the e-scooter and micromobility. The second subchapter takes a look at the emergence and spread of shared e-scooter services and subchapter 2.3. gives an overview on the early research findings on the uses and users of shared e-scooters. Finally, subchapter 2.4. discusses the introduction and current state of shared e-scooter services in Finland.

2.1 Defining E-Scooter and Micromobility

One definition for an e-scooter is suggested by the U.S.-based, globally active professional association and standards developing organisation called SAE International. In their SAE J3194™ Standard (2019) a *Powered Standing Scooter* is defined as a vehicle that

- Has a center column with a handlebar;
- Is controlled by the operator using the accelerator/throttle and brakes for speed and is steered with handlebar;
- Has a foot platform for the operator (and passenger) to stand on;
- Is powered partially or fully by a motor;
- Is manufactured primarily for transportation of not more than one person, except for specifically designed vehicles; and
- Is composed of two or three wheels held in a frame in the longitudinal direction of travel.

In addition, it is mentioned that the speed of the device may also be controlled manually by human power, for instance by the operator kicking to accelerate or using a foot to decelerate. (Ibid.) This kind of operation is typical for classic motorless kick-scooters and hence the e-scooters are also sometimes called *electric kick-scooters*.

The 55 page SAE J3194™ Standard goes to great detail in defining various e-scooter subcategories according to their respective physical measures, motor power and other technicalities. However, for the purpose of this paper the general definition above is useful with the exception of leaving three-wheeled e-scooters out because the typical shared e-scooters have only two wheels.

When discussing e-scooters, it is worthwhile to also mention the wider concept of *micromobility*. The concept, also spelled as micro-mobility, is yet another novel term lacking one single definition. The concept was originally popularised by an American industry analyst and investor Horace Dediu who has described the origins of the word beautifully:

> It comes from the combination of “micro,” or extremely small, and “mobility,” which means the ability and freedom to move. Micro can refer to the vehicles used but it also can refer to the distances traveled. It turns out that they are related: small distances are better traveled with small vehicles. (Dediu 2019.)

In addition to e-scooters, *micromobility* can refer to the use of a range of vehicles with a mass of less than 350 kg and a design speed of 45 km/h or less. (OECD / ITF 2020, 10). The wide range of micro-vehicles can be further divided into four subtypes based on their speed and mass. A micro-vehicle can be privately owned or shared. These devices are either motorless or they have a motor, which means that for instance both ordinary bicycles and electrically assisted ones fall under this definition. (Ibid.) The previous definition does not exclude combustion engines from the micromobility vehicle category, while in some other contexts micromobility is understood as the use of either human-powered vehicles or ones that are equipped with an electric drive (Institute for Transportation and Development Policy 2020). In this work the latter definition is used.

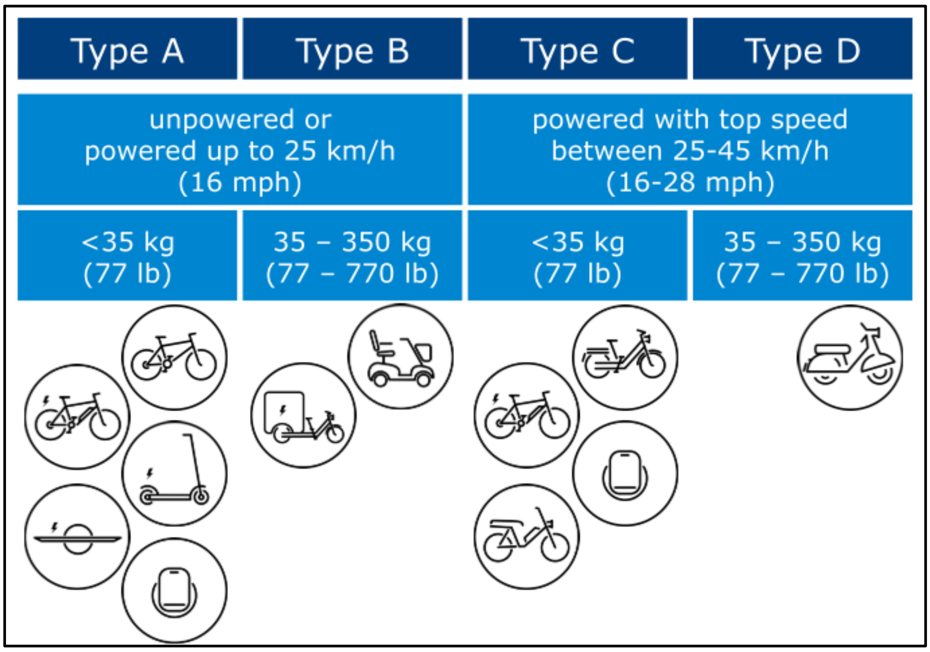

Figure 1 Proposed definition and classification for micro-vehicles (OECD / ITF, 2020, 15)

As we can see from above, e-scooters usually fall under the micro-vehicle category A. The vehicles in this category have a mass of up to 35 kg and their power supply (if any) is electronically limited so the vehicle speed does not exceed 25 km/h (15.5 mph) (OECD / ITF 2020, 10.)

2.2 E-Scooter Sharing Startups Create New Mobility Business

The American micromobility startup Bird is credited as the starter of the current e-scooter sharing phenomenom. Showcasing true startup mentality, Bird acted before asking for permissions as they distributed the first e-scooters to the streets of Santa Monica, California, in September 2017. Since then Bird, Lime and other e-scooter sharing operators have expanded their services to cover over 100 cities worldwide. The growth has been funded by numerous venture capital investors who see great potential in the micromobility service market. Thanks to the hype and very successful funding rounds Bird reached valuation of one billion dollars in May 2018, making it world’s fastest startup to reach the so called “unicorn” status. Already in June 2018 Bird’s valuation doubled into two billion which was yet another world record (Hawkins 2018.)

In the U.S.A. people took approximately 84 million trips on shared micromobility during 2018, which is more than double the number of trips taken in 2017. According to the U.S.-based National Association of City Transportation Officials, a lion’s share of this growth is due to the addition of shared e-scooters into the mobility ecosystems of U.S. cities. During 2018 e-scooters became the most popular form of shared micromobility with 38,5 million trips, while station-based bike share systems were used 36,5 million times and dockless shared bikes approximately 9 million times (National Association of City Transportation Officials (NACTO) 2019, 4-7.)

Shared e-scooters indeed are a global phenomenon: according to the latest global estimate by the New Urban Mobility Alliance, e-scooter sharing services are currently available in 246 cities across 44 countries (NUMO 2020). According to another estimation, as of March 2020 there were approximately 150 000 e-scooters in 177 cities around the US and Europe alone. Despite a number of newcomer startups to the U.S. markets, the first-movers Bird and Lime have kept their leading market position in the American market and expanded also to Europe and other regions. In Europe, the field is described more fragmented with local operators such as German TIER Mobility and Swedish Voi Technology having a strong foothold (Mobility Foresights 2020.)

The market is expected to keep growing. According to estimations, the market potential for shared e-scooter services is expected to reach at least 12−15 billion dollars by 2025 in Europe alone, while in one estimation the total market of shared micromobility[1] in China, European Union and United States is expected to reach 300−500 billion dollars in 2030 (Heineke *et al.* 2019, Schellong *et al.* 2019, Statista 2020.)

Pay-for minute business model, free-floating e-scooter fleets

The devices used by different operators vary but the operating principle is often the same: E-scooters are scattered around a city and people can activate one for their use through a designated smartphone application. Through the app the user can locate the nearest e-scooter, unlock it and start driving. Once the journey is over, the user parks the e-scooter and locks it via the app. The price of a trip consists usually of two elements: a fixed unlock fee (typically 1 $ or 1 €) and a time based rate. Depending on the service provider the minute rates can vary according to demand or day of the week. In addition, operators have discount campaigns and some also provide subscription services, such as daily and monthly passes.

Perhaps the most distinctive feature of shared e-scooters is their free-floating nature. In other words the user does not have to take the device to a designated physical docking station but can leave it almost wherever they please.

Maintenance & charging matters

Maintenance, rebalancing and recharging of the e-scooter fleet can be carried out in several ways. If an e-scooter features a built-in battery, then the whole vehicle has to be transported somewhere to be charged. While some operators use their own staff or subcontractors for charging and maintenance operations, others, especially in the US markets have outsourced most of these operations to the public, thus creating yet another unsecure freelance job, which rewards the chargers (called *Juicers* for Lime and *Flyers* for Bird) by free rides and money (Carpenter 2019, Bird 2020a, Lime 2020a.) This gig economy kind of operational model is not only questionable from the labor rights point

[1] In the McKinsey analysis shared micromobility included shared electric bicycles, electric scooters, and electric mopeds, either in station-based or free-floating offerings.

of view but it might also increase the carbon footprint of the service because the freelancers probably do not use the least polluting vehicles while hunting for more e-scooters to be charged. Also the circumstances where the freelancers carry out the actual charging might be substandard or even hazardous (Carpenter 2019.)

Starting with TIER in October 2019, many operators have introduced new e-scooter models featuring swappable batteries. This development allows using smaller electric vehicles, such as electrically assisted cargo bikes instead of clumsy vans for the maintenance and recharging operations and is expected to improve the sustainability of the service (TIER Mobility 2019, Brennan 2020.) Also swapping of batteries can be conveniently outsourced: TIER has recently announced to be experimenting with a new operational model in which e-scooter users can swap depleted vehicle batteries for charged ones at a network of charging stations hosted by local businesses such as cafes and convenience stores. In this model the users are rewarded free rides but no money for the effort. The new operational model called Energy Network is piloted in Tampere since beginning of September 2020 and TIER expects to expand it Europe-wide in the near future (TIER Mobility 2020a.)

2.3 Uses and Users of Shared E-Scooters

Due to the novelty of shared e-scooter services, there are not many comprehensive studies on the uses and users available. One much quoted European study was conducted in April 2019 by the *6-t bureau de recherche* in France. The American perspective can be found in a few cities' e-scooter pilot evaluations. Some of the key findings of these studies are presented in the following.

The French online questionnaire (N=4382) was conducted among the users of the Lime e-scooter service in Paris, Lyon and Marseille. According to the respondents, the local users of the e-scooter service were predominantly male (66 %) and aged 25-34 (28 %). Furthermore, students (19 %) and wealthy executives were found to form two main user groups among the local users of the e-scooter service. Among the respondents the most typical reasons to use an e-scooter were commuting (19 %) and leisure (10 %), i.e. riding around with no specific purpose. Leisure use (also called e-scooter strolls) were undertaken mainly by visitors, particularly foreign ones. The median duration of an e-scooter stroll was 21 minutes, while the median for all e-scooter trips was 11 minutes.

Throughout the week, afternoon hours were found to be the busiest time for e-scooter use while Saturdays were the busiest day (6t-bureau de recherche 2019.)

The findings in the U.S.A. are for most parts similar to the French. According to the U.S. studies featured in OECD/ITF report (2020, 30-32), most e-scooter trips are short, occur during the afternoon hours and are related to work or school commuting. Furthermore, shared e-scooter trips peak on Saturdays and substitute most often walking. The findings of an e-scooter pilot survey in Santa Monica resonate with the French findings: a clear majority of e-scooter service users are young (64 % aged 25-35) males (67 %) who can be described as affluent (City of Santa Monica 2019, 3-4.)

2.4 Shared E-Scooters in Finland

The new e-mobility phenomenom arrived in Finland in summer 2019 when five operators started their dockless e-scooter services in the capital region (Helsinki and Espoo) and cities of Tampere and Turku. The Finnish markets are dominated by Swedish Voi and German TIER, who started operations in all of the above mentioned cities, while U.S.-based Lime, *Float* and Finnish *Hoop* started their operations only in Helsinki. At the end of July 2019 many operators announced they were actively looking for options to expand to other Finnish cities as well (Rytkönen 2019).

Despite those earlier ambitions, none of the mentioned companies expanded their Finnish service network during the summer season of 2020, probably due to the challenges caused by the global coronavirus (COVID-19) pandemic. The summer's only new city launch took place in July when Finnish startup SUN Scooters introduced their service under the international brand *Hop Scooters* in the city of Jyväskylä (Kaski 2020). Another interesting e-scooter service announcement from July came from TIER and the Helsinki Regional Transport Authority (HSL) who launched a pilot project allowing customers to buy HSL tickets through the in-app store of the TIER app, providing them with additional benefits (TIER Mobility 2020b).

With the exception of some ambiguous figures given in newspaper interviews[2], none of the operators have published exact data of the use of their services in Finland. For the time being, the best Finnish information on the uses of shared e-scooters comes from a 2019 pilot project which was conducted in cooperation with HSL and the Russian

[2] see eg. (Kempas 2019)

micromobility startup Samocat Sharing (HSL 2019a). Comparison between Samocat and the others is however difficult due to the major differences in the operation model and the limited geographical scope of the pilot. The pilot is shortly discussed in the following.

Finnish rental e-scooter pilots featuring docking stations

The Moscow-based startup Samocat piloted their scooter services already in 2017 at the Aalto University campus in Espoo. After winning HSL's IdeaLab competition for smart mobility and securing a 500 000 euro public funding, Samocat Sharing was able to carry out a larger pilot featuring 38 docking stations in the Vuosaari district of Helsinki. The service differed from the market-based services in three major ways: i) The 2019 pilot was conducted in cooperation with the regional transport authority, ii) in addition to e-scooters the service also featured traditional kick-scooters and iii) the service featured physical docking stations which charged the batteries of the e-scooters and helped keeping the parked scooters in neat order. (Mavromichalis 2019, HSL 2019a).

During the pilot period of mid-May till end of October 2019 there were some 17 000 rides made using Samocat's scooters. According to an user questionnaire (N=178), 44 % of the rides were recreational. In the question of modal transfer the answers were the following: 46 % of the rides substituted walking, 28 % bus, 20 % cycling and only 12 % of the rides substituted riding by car. Having physical docking stations divided the opinions of the users, as others found them useful, while some thought they limited the usefulness of the service too much. Negative feedback was also given due to the many technical problems with the service. (HSL 2019b). All in all, it seems that the pilot did not quite meet the expectations and HSL has decided to continue developing their existing citybike services, as citybikes are more robust and also provide healthy exercise (Niemelä 2019).

3 SUSTAINABILITY DRIVING A PARADIGM SHIFT IN URBAN MOBILITY

This chapter begins with introducing international agreements and goals related to global warming and limitation of carbon dioxide (CO_2) emissions. The second subchapter takes a look at the future aspects of urban mobility and what role shared vehicles like e-scooters could have in it. In the third subchapter, the sustainability and social responsibility promises of four major e-scooter service providers are shortly introduced. Finally, the fourth subchapter draws five overarching sustainability aspects that build the framework of this study.

3.1 From Paris Agreement to International and Local Policies

Sustainability is a wide concept and has various interpretations. Via the multinational organisation the United Nations, the international community has agreed upon 17 goals which aim to transform the world more sustainable (United Nations 2020). Out of these 17 Sustainable Development Goals the following are relevant when it comes to mobility and technology used in cities:

- Goal 11: Sustainable Cities and Communities
- Goal 12: Responsible Consumption and production
- Goal 13: Climate Action

In December 2015 the first-ever universal, legally binding global climate change agreement, the so called Paris Agreement, a global framework to avoid dangerous climate change was set (European Commission, 2020; United Nations Framework Convention on Climate Change, 2020). The main target of the Agreement is to limit global warming to well below 2°C and pursue efforts to limit it to 1,5°C. The agreement also aims to strengthen countries' ability to deal with the impacts of climate change and support them in their efforts. (Ibid.)

In the Paris Agreement so called "Nationally determined contributions" were defined, after which countries have decided upon local implications on national, regional and municipal levels. One of the main means to address the Paris Agreement goals is to cut on carbon dioxide (CO_2) emissions. (Ibid.)

As part of the efforts to reduce CO_2 emissions, the EU has set a goal of reducing emissions from transport by 60 % by 2050 compared to 1990 levels (European Parliament 2019). Introduction of fossil fuel free means of mobility is one way to address the CO_2 emission reduction targets. Tailpipe emission free e-scooters can be seen as one solution to develop urban mobility more sustainable in the spirit of the Paris Agreement.

The Paris Agreement stresses the importance of reducing emissions and underlines the role of cities, regions and local authorities in the process towards a more sustainable future. The European Union is an active supporter of the Paris Agreement Goals and has created numerous policies and instruments in order to further the cause. When traffic and mobility is concerned, cities within EU are suggested to implement a development tool called Sustainable Urban Mobility Plan (SUMP):

> "A Sustainable Urban Mobility Plan is a strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practices and takes due consideration of integration, participation, and evaluation principles"
> (Rupprecht Consult (editor) 2019, 9)

A Sustainable Urban Mobility Plan presents, or is linked to an existing, long-term strategy for the future development of the urban area and, in this context, for the future development of transport and mobility infrastructure and services (European Commission 2013).

Within the SUMP framework, a sustainable transport system

- Is accessible and meets the basic mobility needs of all users;
- Balances and responds to the diverse demands for mobility and transport services of residents, businesses and industry;
- Guides a balanced development and better integration of different transport modes;
- Meets the requirements of sustainability, balancing the need for economic viability, social equity, health and environmental quality;
- Optimises efficiency and cost effectiveness;
- Makes effective use of urban space and of existing transport infrastructure and services;
- Enhances the attractiveness of the urban environment, quality of life, and public health;

- Improves road safety and security;
- Reduces air and noise pollution, greenhouse gas emissions and energy consumption; and,
- Contributes to better overall performance of the trans-European transport network and Europe's transport system as a whole.

As the focus of this work is to discuss the role of shared e-scooters in the context of sustainable city planning and development, some of the dimensions of the above mentioned SUMP definition are not relevant. For instance trans-European transport network falls out of the scope. In chapter 3.4 the sustainability aspects most relevant for e-scooters are discussed in more detail.

3.2 Future Aspects of Urban Mobility

Urban mobility problems and climate targets can be addressed simultaneously through new kinds of policy approaches. According to the International Transport Forum policy brief, the most effective way to decarbonise urban passenger transport is to promote shared vehicles which are powered by clean electricity and integrated with existing public transportation (International Transport Forum / OECD 2018, 1).

The first step in the process is to take the existing capacity into better use and thus mitigate CO_2 emissions in urban areas. It has been estimated that doubling car occupancy through ride-sharing would allow to provide today's level of mobility with less than 10% of the current number of cars. The next step would be supporting the adoption of electric mobility, thus lowering the emissions even further (Ibid., 3.)

Other important steps include reducing travel demand, facilitating the use of high-occupancy mobility, and encouraging walking and cycling. Furthermore, better public transport network coverage, greater accessibility to these networks, and improved connectivity between mobility options are also essential in making low-carbon travel the new default (Ibid., 4.)

In addition, the new mobility revolution will require reducing space for cars both in terms of lanes and parking. This development is suggested to have a twofold positive effect: on one hand, limited city space will make sharing a necessity. On the other hand, urban space can then be repurposed to serve more favourable modes of mobility: buses, cycling, walking and the new mobility as a service (MAAS) offerings, like shared bikes or e-scooters (Transport & Environment 2019, 4-5, 23.)

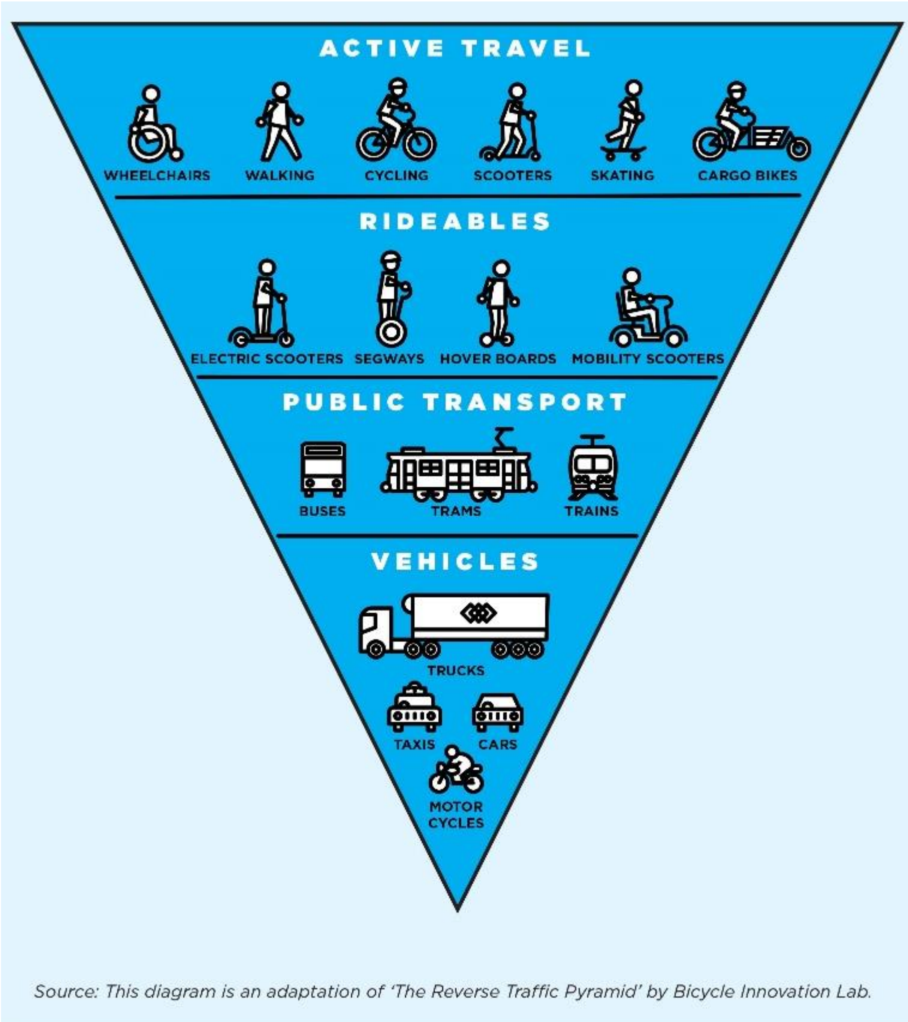

Figure 2 The reverse traffic pyramid puts active travel to the top and separates e-scooters and other rideables as their own category (Bicycle Network 2019)

The emphasis of the new urban mobility approach can be visualised for example by a reverse triangle where pollution free, active travel modes are at the top and vehicles like cars form the smallest portion at the bottom (Figure 2). In this adaptation of the Reverse Traffic Pyramid of Bicycle Innovation Lab, each mode of transport was rated across categories of cost, space, health and time so that active travel scored high for short trips, while public transportation or vehicle scored high for long trips.

3.3 Sustainability and Responsibility Aspects of E-Scooter Operators

Many e-scooter operators market their service with green aspects. For instance, the four major operators Lime (2020c), Bird (2020a), Voi (2020c) and TIER (2020e) all announce their service to be carbon or climate neutral. The operators have reached this state by innovative e-scooter and service development on one hand and emission compensation schemes on the other.

These companies' take on the wider interpretations of sustainability and social responsibility varies more than the strategies on energy usage. While Lime promotes community engagement and charity, Bird praises their dedication to the wellbeing of their own staff (Bird 2020c, Lime 2020c, Lime 2020d). Out of the four operators Voi has dedicated most web space to emphasising their willingness to cooperate with cities, their stance as pro-regulation and the safety of their customers, while TIER seems to have the most technological approach as many of their technological innovations have been industry firsts (TIER Mobility 2019, Voi Technology 2020a, Voi Technology 2020d, TIER Mobility 2020d, TIER Mobility 2020e.)

Together with Dutch Dott, TIER and Voi have recently announced a commitment to raise the bar for e-scooter sustainability even higher. In their joint release of 22nd July 2020, the three operators call all other service providers to join them in meeting ten defined environmental and social commitments which cover the full lifecycle of an e-scooter (TIER, VOI & Dott, 2020.)

3.4 E-Scooters in the Context of Sustainable Urban Mobility

Drawing from the United Nation's Sustainable Development Goals and the principles of Sustainable Urban Mobility Plans (SUMP) of the EU, five overarching themes relevant for e-scooters in the context of sustainable urban mobility can be defined. These themes and some examples of relevant questions are:

I. Energy efficiency, noise and emissions
   - How much energy does an e-scooter need to drive certain distance?
   - Carbon footprint / life-cycle analysis of the e-scooter service

II. Traffic flow and integration of mobility modes
   - Can e-scooters mitigate congestion?

- What kinds of modal shifts are caused?
- Do e-scooters support multimodal mobility?

III. Traffic safety and public health

- How are e-scooters treated in traffic code and other regulations?
- What's the occurrence of e-scooter related injuries and how can it be lowered?
- Does the city infrastructure support safe use of e-scooters?

IV. Urban environment & use of urban space

- Is there a need for dedicated e-scooter parking areas?
- How do the e-scooters affect other functions in the city, i.e. maintenance of the streets?
- How does the presence of free-floating e-scooters affect the use and feel of public spaces?

V. Accessibility & social equity

- Are e-scooters equally available to different groups of people?
- Does the e-scooter service acknowledge different geographical areas equally?

These five themes are discussed in the context of shared e-scooters in 5.

4 REGULATORY FRAMEWORKS OF E-SCOOTER USE & SHARING SERVICES

The way e-scooters and other forms of electrically powered micromobility are seen in national legislation varies from country to country even within the European Union. Some countries like Finland have allowed e-scooters on their streets already before the boom of e-scooter sharing services, while other governments' wait-and-see attitude has allowed them to gain more insight from the earlier adopters.

In many traffic codes e-scooters are treated more or less similarly to ordinary bicycles if they meet certain country-specific criteria. The maximum speed and the power of the e-scooter's motor together with safety features and physical dimensions of the device are some of the key attributes that are defined in many legislations.

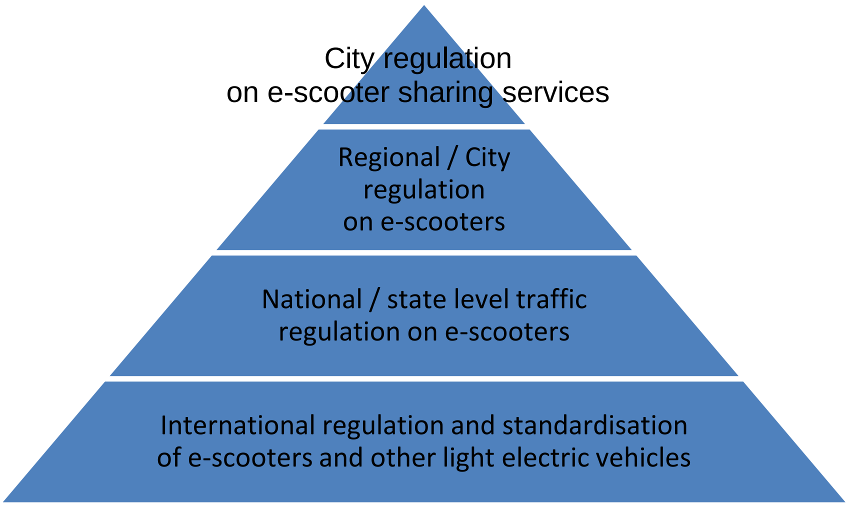

Figure 3 Different layers of e-scooter regulation.

In addition to e-scooter use in general, there are also different regulations on e-scooter sharing services at cities. The ways in which cities regulate e-scooter sharing operators varies greatly, ranging from less binding letters of intent to highly detailed, legally binding contracts.

The regulatory patchwork quilt is discussed in the following subchapters through few examples from different countries and cities.

4.1 Examples of National Traffic Codes

Finland

In Finland e-scooters have been road-legal since 2016, i.e. already before the current boom of shared e-scooters (Traficom 2019). In the Finnish traffic code *electric personal transportation devices* are divided in three categories:

i) Electric personal transportation devices to assist or replace walking
ii) Light electric vehicles
iii) Electrically assisted and motorised bicycles

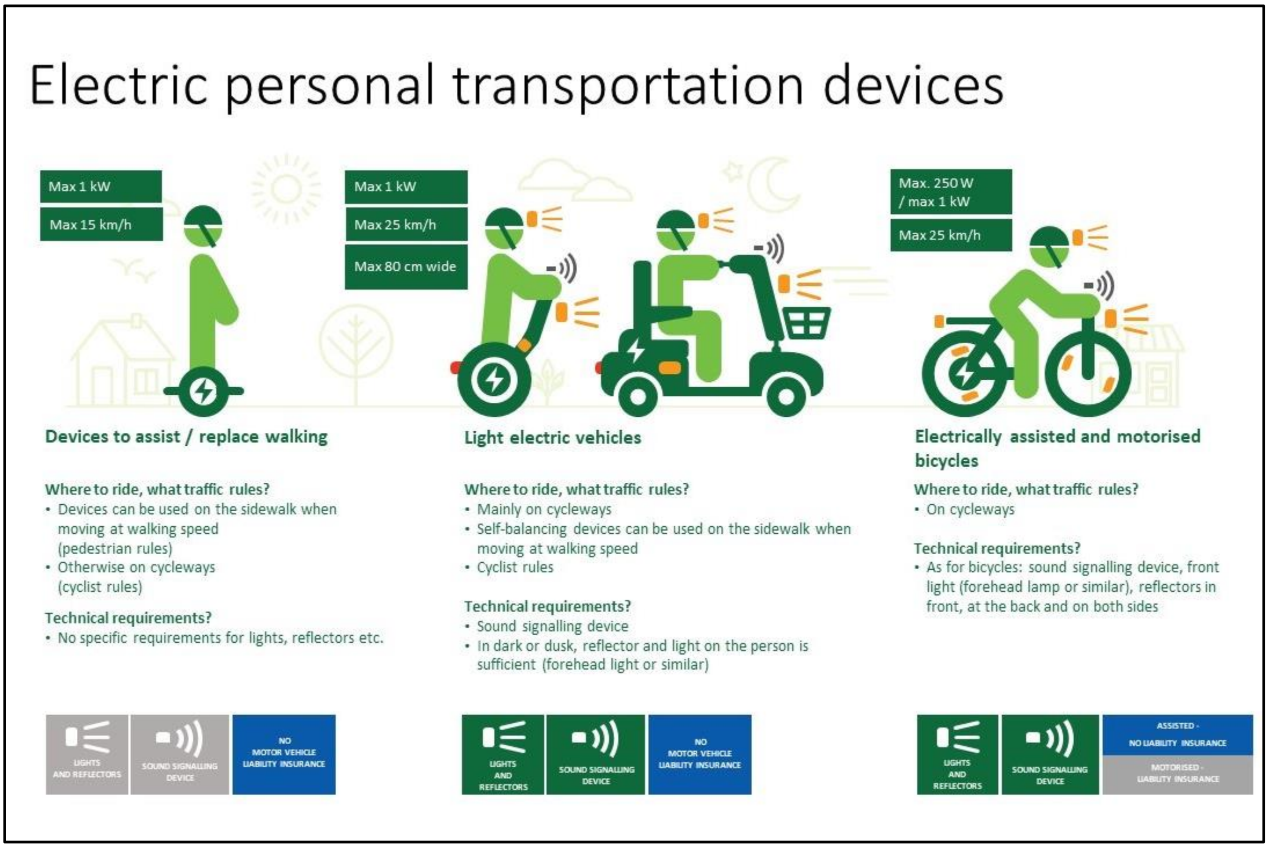

Figure 4 Electric personal transportation devices in Finnish traffic legislation (Traficom 2019)

In this classification shared e-scooters fall into the category of *light electric vehicles*, and are bound by the same traffic rules as ordinary bicycles. In other words, the driver should drive either on cycleways or among other traffic in the road. Driving on pavements is only allowed for children up to 12 years of age and those drivers who are using a self-balancing device at walking speed. In the Finnish legislation the maximum speed for light electric vehicles is between 15-25 km/h and the maximum power of the motor is 1 kW (Traficom 2019.)

Figure 4 above lists required safety features for each device category. Even if all the people in the image wear helmets, such protective equipment is not obligatory by the law. (Ibid.)

Germany

In Germany e-scooters have been street-legal only since 15 June 2019 after the approval of the *Small Electric Vehicle Ordinance* (Elektrokleinstfahrzeuge-Verordnung, eKFV). This law introduced a new micromobility category of *Personal Light Electric Vehicles*, which includes motor vehicles with electric drive without seat, such as e-scooters. Also self-balanced vehicles with or without seat are covered if they have a steering or holding rod of at least 500 mm for motor vehicles with seat and of at least 700 mm for motor vehicles without seat (BMWI 2019.)

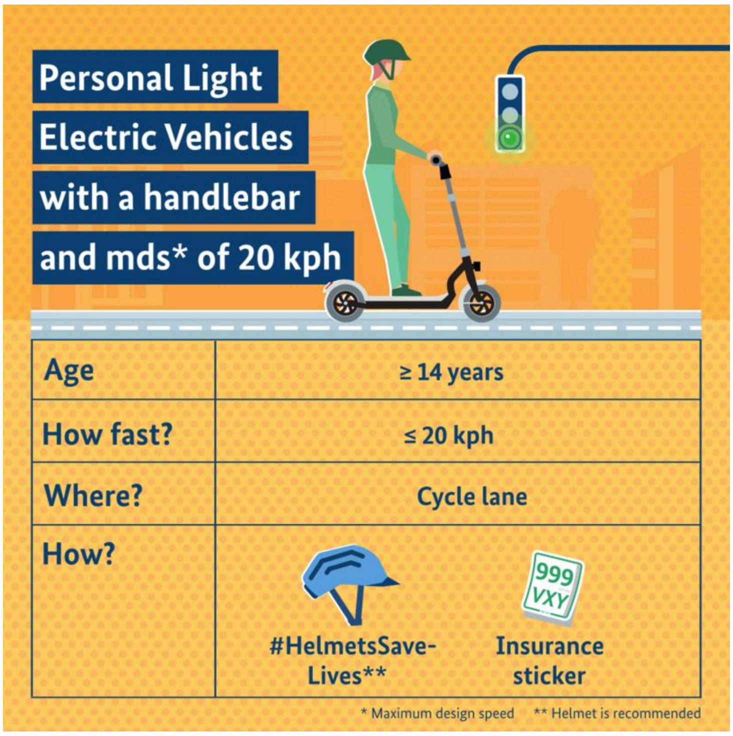

Figure 5 German regulation on *Personal Light Electric Vehicles* in a nutshell (BMWI 2019)

As we can see in Figure 5 above, the maximum speed of a *Personal Light Electric Vehicle* is set at 20 km/h in Germany. For a vehicle in this category, continuous rated power of no more than 500 W (1400 W for self-balancing vehicles) is allowed. As a general rule, these vehicles must be operated on traffic spaces for cyclists where such spaces are available. In the absence of specific cycle infrastructure, Personal Light Electric Vehicles can also be used on the carriageway. Use of a helmet is recommended but not obligatory (Ibid.)

There are some unique features in the German legislation. First of all, only e-scooters with type approval by the Kraftfahrt Bundesamt (KBA), the German Federal Motor Transport Authority, are allowed on public streets and all Personal Light Electric Vehicles are subject to compulsory insurance and must therefore bear an insurance plate. Secondly, limits and consequences regarding drunk driving with Personal Light Electric Vehicles are the same as by car or other ordinary vehicle (Ibid.) Thirdly, driving on sidewalks, in pedestrian zones and in one-way streets against the direction of travel can be allowed by using the new traffic sign featured below.

Figure 6 A new sign allows riding *Personal Light Electric Vehicle* on areas where it would normally be forbidden (Elektrokleinstfahrzeuge-Verordnung vom 6. Juni 2019 (BGBl. I S. 756))

In addition to naming general driving instructions, the German law goes into further detail by especially forbidding riding *Personal Light Electric Vehicles* with another person or objects on the footboard and to driving hands-free. It is also pointed out that these vehicles should be driven after each other instead of next to each other (BMWI 2019.)

Sweden

Unlike in Finland or Germany, in Sweden the current traffic code does not yet recognise all forms of micromobility. For now e-scooters are equated with ordinary bicycles as long as the maximum speed is 20 km/h and the maximum power of the motor is 250 W. In addition to brakes and a sound signaling device, the vehicles in the bicycle category are required to feature reflectors and lights at the front and back. A helmet is required only for children under 15 years of age (Transportstyrelsen 2019.)

The Swedish Government is currently in the process of redefining laws on light electric vehicles. Increasing safety of urban mobility and securing good order on the Swedish streets are named as main goals of the reform. Among other things, it will be considered whether renting (sharing) light electric vehicles should be subject to permission and whether communities should be empowered to define local regulations on the use of light electric vehicles, such as e-scooters (Regerinskansliet 2019.)

The U.K.

The traffic code of the United Kingdom is even more laggard than Sweden’s. For the time being "motor vehicles" in the U.K. have been defined by the Road Traffic Act dating back to 1988 (Department for Transport 2020a). In the absence of a specially-designed legal regime for e-scooters and other novel personal transport devices, also these “powered transporters” have fallen under the same laws, regulations and requirements that apply to more traditional motor vehicles. These requirements range from tax to licensing and regular MOT safety tests, and inability to comply with them makes driving a motor vehicle out in the public unlawful. In either case some people do drive their private e-scooters even in the UK and take a change of being fined (Giles 2020.)

During spring and summer of 2020 the global coronavirus pandemic (COVID-19) affected public transportation also in the U.K. and underlined the need for such ways to travel which allow social distancing. Therefore the government decided to allow trials of rental e-scooters to commence more rapidly and in more areas than initially planned. These trials began after public consultations in July and are due to last for 12 months, during which the government assesses the e-scooters’ impact on public spaces and the environment (Department for Transport 2020b, Department for Transport 2020c.)

During the trials the maximum speed of the e-scooters is limited to 15,5 mph (25 km/h) and they are allowed to be used on roads and cycle lanes. At least 16 years of age and a driver’s lisence of some sort is required from the users. Use of helmet is recommended but not obligatory. Despite the trials, individually owned e-scooters will remain illegal on public roads (Ibid.)

4.2 Examples of City Level Regulation on E-scooter Sharing Services

In a report on shared mobility planning practices, choosing between the following three policy tracks is suggested (Cohen & Shaheen 2016, 6):

- Shared Mobility as a Social and Environmental Benefit
- Shared Mobility as a Sustainable Business
- Shared Mobility as a Business

These model approaches provide a framework for the allocation of public rights-of-way, fees and permits, signage, impact studies, and public and stakeholder involvement based on varying degrees of governmental support. Whichever strategy local governments and public transit operators decide to choose, they are suggested to be proactive (Ibid.) This is the recommendation also in the discussion paper by Polis, the network of European cities and regions cooperating for innovative transport solutions (Polis 2019).

However, as the following examples from different cities clearly point out, the negotiating power of cities and municipalities varies between national legislations.

Finland

In Finland the cities have only little say on e-scooter sharing services. When a group of Helsinki City Council members called the city to take stronger action in order to keep wild parking of e-scooters in check, the vice-mayor is reported to have responded that the city has neither appropriate regulation mechanisms nor legally binding contracts with the e-scooter service operators in place (Parikka 2019). In other words, unless Finnish cities are warranted more authority to rule over what happens on their streets through legislative reforms, goodwill seems to be the key ingredient of the talks.

France

A text by Alexandre Gauquelin (2020) gives an example of how an European metropolis has step-by-step proceeded tightening the regulation of shared e-scooter service: After the first e-scooter service arrived to Paris in June 2018, others soon followed and by

2019 there were altogether 12 different operators and some 20 000 shared e-scooters. It soon became clear that some more rules were necessary. Since then, regulation of e-scooter use and service provision in Paris have been developed in two major steps. In the first wave as of April 2019 Paris sanctioned riding and parking on pavements, implemented 2500 e-scooter parking spots, adopted a license fee of 50€ / scooter / year for the operators and obliged them to sign a chart of good conduct. However, it was soon found that even more regulation was needed, so as a next step the city council decided to announce a Request For Proposal (RFP) and award three winning operators a two year tender to operate 5000 e-scooters each. In the RFP process the evaluation criteria were sorted in three main categories:

- User safety – 30% of the final mark
- Operations (management, maintenance and charging) – 30%
- Environmental responsibility 40%

In July 2020 Lime, TIER and French *Dott* were announced as winners and the rest of the operators were obliged to remove their e-scooters from Paris by mid-September. Due to the COVID-19 pandemic Paris has expanded cycle lanes which also facilitates the safe use of e-scooters. (Abboud 2020)

Germany

Due to a parking chaos on the pavements, the Berlin Senate announced in October 2019 plans to create specific parking zones for e-scooters and cargo bikes by remodeling car parking spaces suitable for the smaller vehicles (Berlin.de 2019). Further, the State of Berlin went on to propose a federal legal reform which would have allowed cities to decide whether shared e-scooters are allowed to be parked freely on the pavements. This reform would have given German cities more negotiation power towards the e-scooter sharing service operators and allowed them to set different operational conditions for the operators ranging from fleet sizes and quotas to different fees. The six largest operators Lime, Voi, TIER, Jump, Bird and Circ joined forces to oppose the bill as it would have challenged the very core of their business model. (Schwär 2020). In the plenum of 14th February 2020, the German Federal Council overruled the bill and so the operators were allowed to continue their free-floating business as usual (Potor 2020).

The U.S.A.

In order to regulate e-scooters there of course needs to be a definition for one; according to a 2019 study on the regulation practices of e-scooters among U.S. cities it was found that state level definitions were so rare that a majority of the studied U.S. cities had to make their own definitions (Herrman 2019, 16).

Different forms of regulation provide a city with varied levels of stringency in e-scooter control but also the time and effort required for the preparation of given mechanisms varies greatly. According to the 2019 study, the most usual mechanism to regulate e-scooters in U.S. cities was *ordinance:* 48 % of the cities in a study sample of 50 cities used the ordinance mechanism, while *pilot programs*, *agreements* and *permits* were used in 20 %, 18 % and 10 % of cities (Herrman 2019, 14). Some of the cities used a combination of the mentioned mechanisms and seven cities had some other form of a regulating mechanism or no regulation mechanism at all. Out of the mentioned alternatives, ordinances presents the highest level of control over the e-scooter sharing services and were often highly detailed ranging from *legal* to *operational* and *financial* points of view (Ibid., 12, 14.)

As safety and liability concerns are major factors driving American cities to impose different types of regulations on shared e-scooters, it follows that legal and financial security aspects are addressed for instance through insurance policy requirements covering different kinds of liabilities. In order to cover for e-scooter related expenses and the cost of development and maintenance of public space used by e-scooters, cities may gain financial revenues through different fees, fines, and bonds (Ibid., 17-18, 43.)

From the e-scooter and city space users' point of view, operational requirements are perhaps the most tangible matter which can also be defined in the contract between the city and the service provider. For instance, size and geographical division of the e-scooter fleet and availability of local customer service fall under this category. Also features of the user interface, such as educational aspects, data privacy and sharing can be defined in detail. (Ibid., 23)

5 STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS OF SHARED E-SCOOTERS FOR THE SUSTAINABLE URBAN MOBILITY

Shared e-scooters can affect a city in various ways. Some effects can be seen as positive, while others are troublesome. In the context of a fourfold SWOT table, internal strengths of the e-scooter technology can lead to positive effects (opportunities) in a city, while certain weaknesses of the vehicle or business model can lead to threats for the overall mobility and liveability of a city. Figure 7 below illustrates this SWOT framework.

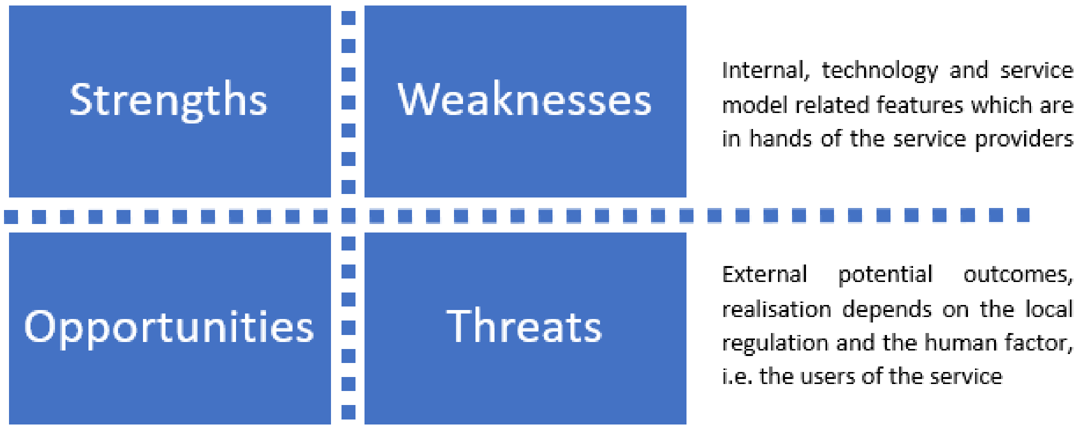

Figure 7 SWOT framework

In the following, some of the strengths, weaknesses, opportunities and threats of shared e-scooters for sustainable urban mobility are discussed through the five sustainability themes presented in chapter 3.4. The outcome oftentimes depends on local regulation practices and finally on individual users of the service. Due to the interrelatedness of the actual and potential results, the four dimensions are discussed in following subchapters in pairs as follows: 5.1. Strengths and opportunities and 5.2. Weaknesses and threats.

5.1 Strengths and Opportunities

The newest e-scooter technologies and highly developed operational models of the sharing service feature many strengths regarding promotion of sustainable urban mobility. One significant strength is the commitment of the major service operators to partner with cities and continuously develop their operations. These sustainability and responsibility aspects of e-scooter operators were already briefly introduced under chapter 3.3.

Energy efficiency, noise and emissions

Small and efficient electric motors are one of the key strengths of shared e-scooters. As electric drives cause neither tailpipe emissions nor noise, the potential outcome can be a city with less noise pollution and better air quality especially if a modal shift away from fossil fuel driven vehicles, like private cars, occurs. Simultaneously, the energy consumption of transporting a person from one place to another would diminish.

One way of comparing the energy efficiency of different vehicles is to calculate the range each vehicle can drive per one kilowatt hour of energy. When German thinktank Agora Verkehrswende (2019, 10) compared the ranges of four types of motorised vehicles, the results were the following:

- Small gasoline car *VW Golf 1.0 TSI* = 2km
- Small electric car *VW e-Golf* = 6 km
- Electric moped scooter *Unui Standard Classic* = 35 km
- Shared e-scooter *Bird One* = 100 km

In other words, an e-scooter is calculated to drive 50 times further than a small ordinary car with the same amount of energy. In addition to the amount of energy needed, the source of energy effects the sustainability of a ride: Some e-scooter operators claim to only use electricity from renewable sources, while some others are less precise on the origin.

In order to properly scrutinise the life-cycle impact of an e-scooter service, a thorough life cycle analysis (LCA) is needed. LCA measures both direct and indirect environmental impacts related to transporting one person for one kilometer on an electric scooter. In a rapidly developing field, the operators of course have the best knowledge of their service and independent scientific research inevitably lags behind. For the time being, the most up-to-date and thorough analysis of the environmental impacts of an e-scooter service is probably provided in the Voi-sponsored report of the international consultancy agency EY (2020).

In the report, Voi’s service in Paris is estimated to emit 35g of CO_2 equivalent per person per kilometer. For the sake of comparison, the following figures for other mobility modes are presented (Ibid., 26):

- Metro = 12–23 g of CO_2 equivalent per person per kilometer
- Electric Bus = 16–48 g
- High-speed vs. regional train = 50–60 g
- Diesel Bus = 45–93 g
- Electric Car = 85–300 g
- Petrol Car = 200–350 g

In other words, in Paris the CO_2 impact of Voi’s service is estimated to be similar to that of public transport and much lower in comparison to private cars. This can be seen as a great strength and opportunity in the quest for more sustainable mobility especially if e-scooter use can be proven to substitute more emitting alternatives.

It has to be noted, however, that multiple factors influence the emissions range for each mobility mode, including energy mix, vehicle models and average occupancy rate. Furthermore, the calculations feature the most recent model of the Voi e-scooter which is equipped with a swappable battery. According to the report, swappable batteries enable 51 % reduction in emissions in comparison to older type of e-scooter fleet featuring fixed batteries. The lifetime emissions are also lowered by more durable design: the newest model of Voi e-scooters are expected to have an operational lifespan of 24 months. (Ibid., 23, 26)

The findings of the EY report discussed above showcase great advancement in reduction of emissions in comparison to previous studies. For instance, in a study focusing on an e-scooter service in Brussels the environmental impacts were estimated being almost fourfold (131 g of CO_2 equivalent per person per kilometer) in comparison to the 35g of the EY analysis (Moreau *et al.* 2020). In an earlier Raleigh, North Carolina, based study the average value of life cycle global warming impacts were found amounting 202 g CO_2 equivalent per person per mile (Hollingsworth *et al.* 2019). Both of these independent studies stressed the effect of the e-scooter lifetime and the emission reduction potential through product and service development.

Traffic flow and integration of mobility modes

Thanks to the small size of an e-scooter, street infrastructure of certain size can accommodate a multitude of micromobility vehicles in comparison to private cars. For example, one car parking space can accomate at least 10 e-scooters. Picture 1 illustrates how e-scooters can be parked tightly. Increasing use of e-scooters can lead to less congestion and better traffic flow in dense urban areas. Furthermore, e-scooters have a great potential in complementing the existing public transportation network and improving the integration of different mobility modes.

Picture 1 Tightly parked shared e-scooters and citybikes in downtown Turku. Picture by the author (August 26, 2020)

According to the French study, free-floating e-scooters were quite often used in intermodal ways: 23 % of the trips combined either using public transportation (66 %) or walking (19 %). Further, 44 % of users rented out an e-scooter only to take a one-way trip, returning with another transportation mode (or vice versa). In 57% of those cases, public transportation was the other mode used, and walking in 37% of the cases (6t-bureau de recherche 2019.)

Multimodal use of shared e-scooters and public transportation can be promoted through active cooperation between the shared e-scooter operators and local public traffic agencies. The following three factors should be especially addressed: availability of the scooters in right places, combined pricing of e-scooter and public transportation use, and digital integration of those two services (Agora Verkehrswende 2019, 14.)

In order to seize the opportunity of smooth multimodality, public transportation agencies and shared e-scooter operators should develop attractive pricing models for the combined use of their services, such as monthly subscriptions or bulk purchase discounts. Furthermore, the two services should be available through same navigation apps and booking platforms and the availability of e-scooters at the stops of the public transportation should be guaranteed (Ibid.)

Traffic safety and public health

Safety of a traffic mode can be assessed for instance by counting the road traffic death ratio and the number of injuries that require hospital visits per one or ten million trips. Whether or not e-scooters are dangerous and risky vehicles is a question of much debate and the topic has inspired quite a bit of research. One reason for the lack of consistent data lies in the way e-scooter related hospital visits are reported. In the absence of a separate e-scooter code in the International Classification of Disease system (ICD-10), it is very challenging for researchers to collect data on the patient records systematically (OECD / ITF 2020, 33). For example, at the Töölö Hospital in downtown Helsinki e-scooter related injuries have so far been counted using manual tallying (Kantola 2019).

In some countries, like Australia, helmet use is obligatory by the law and for instance e-scooter operator Lime has provided helmets together with their e-scooters in that market area. However, according to one Australian study 39 % of observed e-scooter riders failed to wear head protection (Layt 2019.) Due to challenges related to loose traditional helmets TIER has developed a so called *integrated helmet solution,* which means equipping their newest e-scooter model with a locked box that contains a reusable foldable helmet (TIER Mobility 2020d).

In addition to providing helmets and guidance on safe driving, the e-scooter service providers can promote safe use of their vehicles by various technical means. For instance, the operator can remotely lock their whole fleet during the night or potentially dangerous weather conditions. Further, the operator can adjust the operating region of their e-scooter fleet in a given city. This technology is called geofencing. It is also possible to force e-scooters to drive at slower speed within certain areas, such as busy shopping streets, traffic junctions or touristic areas. Likewise the operator can prohibit or promote parking within marked areas. (OECD / ITF 2020, 59-60) These different types of zones can be highlighted on the e-scooter application’s map using different colors or symbols.

A recent Finnish assessment of the traffic safety of e-scooters concluded that shared e-scooters are probably safe for an experienced driver if they abide by traffic regulations and all the e-scooter service provider’s instructions (Lahtinen 2020). The findings of the Finnish study are in line with a recent international report by the OECD and ITF (2020). According to the current understanding, it seems that making a trip by a shared e-scooter is no more likely than a bicycle trip to result in a road traffic fatality. Another important finding was that car traffic seems to form the largest threat to e-scooters like it does to bicyclists as well: Over 80% of cyclist and e-scooter rider fatalities result from crashes with heavier vehicles. When hospital admissions are concerned, it seems that e-scooters are riskier than bicycles. However, it has to be noted that firm conclusions cannot be drawn until there is more solid data available. (OECD / ITF 2020, 20, 62)

The global coronavirus (COVID-19) pandemic has affected people’s lives and urban mobility all around the world since spring 2020. On one hand, commuting and recreational driving has decreased significantly due to lockdowns, social distancing and remote work. On the other hand, many people still need to commute but probably prefer to avoid public mass transit. As a consequence, the need for mobility solutions allowing people to maintain sufficient distance to others as recommended by health authorities has increased. For the operators of shared e-scooter services, the coronavirus has proven to be a double-edged sword: While some e-scooter operators suspended their service, others kept their operations running promoting shared micromobility as a safe way to commute. In order to address the public worry on the hygiene of shared e-scooters, service operators increased the cleaning of their e-scooters and TIER trialled anti-bacterial copper handlebar surfaces which are expected to kill 99,8% of all viruses in just a few minutes. Furthermore, some micromobility operators showed their eye for the game by launching discount campaigns for people working in critical sectors, such as healthcare (Lawrence 2020.)

Urban environment & use of urban space

Introduction of shared e-scooters in a city most likely promotes discussion on the safety and functionality of the urban street infrastructure. Active city planners or public pressure on the topic could lead cities to create e-scooter suitable traffic routes. Furthermore, investments in e-scooter related infrastructure can benefit also pedestrians and users of other types of micromobility ranging from ordinary bicycles to e-skateboards, and for this reason the effect of e-scooters to urban mobility can be considered positive. According to experiences from Portland, the better the bicycle infrastructure, the smaller share of e-scooters were illegally driven on pavements (Portland Bureau of Transportation 2019, 24). Proliferation of e-scooters and other forms of micromobility pushes cities also to reconsider parking infrastructure: reallocating parking spaces that are now dedicated to cars could encourage increasing use of micromobility modes and reduce wild parking on the sidewalks (Agora Verkehrswende 2019, 27.)

Developing street infrastructure is often costly. Therefore cities are prone to collect different fees from the e-scooter service providers in exchange for a operating license. However, due to differences in national legislations, not all cities have the power to shift the expenses of urban space development to the e-scooter service providers.

Accessibility & Social Equity

One of the major strengths of a shared e-scooter service lies in the free-floating nature of the system. Laws and regulations permitting, it is up to the e-scooter service operator to decide how they distribute their fleet within a city. In an optimal case, shared e-scooters are provided not only in downtown areas but also in so called mobility deserts, i.e. areas underserved by public transportation (DuPuis *et al.* 2019, 6). Further, the system ought to be easy to use and pricing models should allow even people with lower income to use the service. Introduction of such less business oriented practices that serve the wider public good most likely require close cooperation between the city leaders and the e-scooter service providers (Rose *et al.* 2020.)

Examples of a pro equity discount programmes are provided by American operators Lime and Bird: both operators offer significant discounts for low-income individuals who are eligible for certain public benefits programmes (Lime 2020e, Bird 2020d). Furthermore, the operators provide service access even without smartphones or credit cards. However, there’s no data on how wide the use of these benefits programmes is and whether they will be expanded to all European markets as well.

5.2 Weaknesses and Threats

Public decision-makers were reminded of the risks and threaths of shared micromobilty in a 2019 discussion paper by Polis, the network of European cities and regions cooperating for innovative transport solutions (Polis 2019). Also an American advocacy organisation National League of Cities (2019, 25) points out that unprepared cities are essentially relinquishing control of public assets to private companies, while simultaneously taking on the implementation costs of incorporating a new mode of mobility. At the end of the day, venture-capital backed international micromobility operators are profit-seeking private actors and might therefore be unpredictable, if left unregulated (Polis 2020, 8-9). Up-to-date traffic codes and regulations setting the boundaries for e-scooter sharing services in a city are necessary but on the other hand, there are also cases of overregulation and e-scooter service providers leaving cities due to tightening of the requirements of operational licenses (Meiling 2020).

Energy efficiency, noise and emissions

As discussed earlier, the average e-scooter lifetime has a significant effect on the overall sustainability of an e-scooter sharing service. The lifetime of an e-scooter can be seen as a sum of the following four parameters: eco-design, usage, vandalism, and maintenance (Moreau *et al.* 2020, 8) Out of these parameters, the design of the e-scooter and the maintenance practices are fully in the hands of the service operator, while the usage and vandalism fall under the mercy of the service users and other people.

Even if the e-scooters themselves were energy efficient, the fleet management and maintenance operations might be carried out by less efficient vehicles, such as ordinary vans or pick-ups. Furthermore, if these operations are not centralised and well planned, they most likely cause excess driving and emissions.

Vandalism of e-scooters causes extra trouble and costs for the e-scooter service operators but also thins down the sustainability of the service as a whole and burdens the local community and nature with unpleasant externalities. Especially e-scooters that end up in waterbodies can be harmful for the environment due to the lithium batteries which might leak. Reports of tens of e-scooters in a single waterbody are not rare, and in the case of a French river over 100 e-scooters have been dragged up by local volunteers (Ho 2018, Coste 2019.) In the annual volunteer cleaning operation of the river Aurajoki in Turku, Finland, fifteen e-scooters were dragged up together with other scrap in September 2020 (Koivunen 2020). Some of those findings are featured in Picture 4. The volunteer diving operation however only covered a small fraction of the river in downtown Turku so the muddy river bottom most likely houses even more two-wheelers.

E-scooters are very silent as they drive on the streets. This feature of electric motor is definitely good in terms of urban traffic noise emission reduction, however, silence of e-scooters can also be seen as a weakness from the traffic safety point of view: especially pedestrians can be at risk if faster e-scooter users quietly weave their way at pavements. Therefore, the importance of safety features like a sound signaling device are stressed by concerned practicers of medicine, some of whom fear that the injury burden from e-scooters will soon exceed other pedestrian- or bicycle-related trauma (Nisson et al. 2020, 178.)

Traffic flow and substitution of mobility modes

If a city is planned mostly for private cars and e-scooters enter the picture, then it is likely that there will be friction and even collisions between different types of road users. As a consequence, the traffic flows will suffer.

When French users of Lime e-scooters were asked which form of mobility they would have chosen if an e-scooter had not existed, 44 % of the respondents mentioned walking and 30 % public transportation. Only 9 % would have used a shared bike and 3 % their own bike. Furthermore, Uber and similar ride-hailing services would have been used by 4 %, own car by 3 % and taxi by 1 % of the respondents. (6t-bureau de recherche 2019). Among its key sustainability targets for 2020 the Swedish operator Voi has mentioned increasing the car substitution rate through their services (Voi Technology 2020c). Unlike for the other rigorous development goals of their sustainability statement, for this one Voi has not provided more concrete steps or metrics.

In other words, the French respondents substituted more often sustainable mobility modes (walking and public transportation) than car. The rate of car substitition can be considered very low, which is in stark contrast with the aimed modal shift and therefore a weakness for the sustainability of the e-scooter services as a whole. In regard to car substitution rates, OECD / ITF report (2020, 30-32) shows a clear difference between

Europe and the U.S.A.. In the featured 11 American studies the substitution of personal car and ridesourcing (i.e., Uber and Lyft) was found more common: if a shared e-scooter (or shared bike) had not been available, 30-50% of the respondents would have driven a personal car or hailed a taxi, Uber or Lyft.

When the above discussed findings are concerned, it has to be remembered, however, that those studies only cover certain cities. Furthermore, each city is an unique sum of its population, road infrastructure, geography, tourist attractions and lack of thereof plus several other factors. Especially the availability, pricing and coverage of public transportation services plays a significant role in the overall mobility habits; in major European cities like Paris public transportation is a real alternative to private car usage, which might not be the case in most U.S. cities. In other words, shared e-scooters are most likely used differently in one city than in another. This was also one of the key findings of a recent comparative study on usage patterns of dockless e-scooters between two rather similar American cities (Bai & Jiao 2020). It is also suggested that utilization of e-scooters evolves over time: as the service matures and people get more accustomed to shared e-scooters in their neighborhood, it is increasingly likely that e-scooters will be used for functional trips (communiting and errands) rather than leisure (EY 2020, 16.)

Increasing multimodal use of public transportation and shared e-scooters requires active cooperation between the public transportation agencies and e-scooter service providers. Changing status quo of course requires work and can be seen as a political challenge in some municipalities. However, without strategic policies and cooperation between the key stakeholders it is unlikely that multi-modal use of the two services will proliferate: for instance the price of combined use might be considered too high and there might also be other practical obstacles hindering the integration of the two mobility modes (see eg. Agora Verkehrswende 2019, 14).

Traffic safety and public health

In order to educate the public in safe e-scooter use, e-scooter sharing companies should provide substantial help to people who are not familiar with the vehicles or the rules of the road. While most legislations do not impose helmet use, the shared e-scooter operators should nevertheless continue promoting the use of helmets, as helmets are known to mitigate the severity of head injuries in some crash types (OECD / ITF 2020, 56).

Major e-scooter service operators have already done many developments in the right direction, such as providing announcements of safe driving to their customers. Voi has even launched a virtual driving school and awards users with free rides if they complete the school which is localised according to the traffic rules of each country (Voi Technology 2020e).

Unfortunately e-scooter operators' efforts to promote safe e-scooter driving can only do so much, while the human factor together with local culture also have their influence on the actual traffic culture. According to early studies on Finnish e-scooter accidents it seems that drunk driving is a real threat for public health. A Helsinki-based Finnish study on e-scooter accidents found that a majority (53%) of all 74 accidents took place during the evening and night hours between 20 and 04 o'clock and 51 % of all the patients had been under the influence of alcohol or drugs (Lahtinen 2020, 33). A Turku-based recent study gives an even worse picture of the Finnish e-scooter driving culture: 21 out of 23 e-scooter patients (91 %) who landed at the head trauma ward of the Turku University Hospital had been under the influence of alcohol. Three quarters of these accidents had occurred between 00 and 06 o'clock and the majority of patients were males while the average age of patients was 30. The study covered a timeframe of some seven months between the lauch of shared e-scooter services in summer 2019 and the end of the year. (Pihkala 2020).

One solution to reduce accident-prone driving would be to issue a night-time curfew for e-scooters. However, such approach might seem disproportionate, as it would prevent also the lawful utilisation of shared e-scooters (OECD / ITF 2020, 56). Secondly, business-driven e-scooter operators are probably unlikely to voluntarily limit their service hours.

Law enforcement can reduce the temptation of risky driving behaviour and fine violations of traffic code, such as drunk driving. However, comprehensive e-scooter control might be challenging considering the size of e-scooter fleets and limited police resources. For example, the police unit specialised in overseeing light traffic in the Finnish capital was only five officers strong when it was founded in September 2019 (Poliisi 2019). In addition to the likelihood of one driving into a police raid, the consequences of traffic violations also vary between countries. As mentioned in chapter 4.1 German traffic code takes a strict stand on driving under the influence of alcohol by applying the same rules to e-scooters as to cars.

In addition to the behaviour of the e-scooter user, the quality of street infrastructure is also important for road safety. Vehicles with small wheels require very smooth surfaces and precisely beveled edges on crossings. Some cities have already invested in high quality bicycle infrastructure but for instance cobble stone areas of historical European downtowns are far from comfortable and potentially unsafe for the users of e-scooters (Zagorskas & Burinskienė 2019, 6).

From the public health point of view it has to be also remembered that substituting so called active modes of mobility, such as walking and cycling, with more passive e-scooter usage is an unfavourable trend. As illustrated in Figure 2, active mobility should remain the default choice in short trips due to the positive health effects of everyday exercise.

Urban environment & use of urban space

Wild and thoughtless parking is perhaps the most visible weakness of shared e-scooters. Carelessly parked and fallen e-scooters might disturb pedestrians, other traffic, maintenance of streets and buildings, deliveries, emergency transport and other activities taking place in urban environment. Examples of incorrectly parked e-scooter can be seen in Picture 2 and Picture 3.

Especially disabled people have found e-scooters challenging in their daily lives. For example, in the U.S.A. an advocacy group has filed a lawsuit against the city of San Diego and e-scooter brands Lime and Bird alleging the ubiquitous motorised vehicles are violating the Americans with Disabilities Act (ADA) by impeding and blocking access to city streets and sidewalks (James *et al.* 2019).

Picture 2 E-scooters as a token of intermodal mobility and challenging parking behaviour at Turku railway station. Picture taken in the middle of the main train platform by the author (August 21, 2020).

In the northern hemisphere there has been much discussion around the suitability of e-scooters to the challenging winter conditions. The roadworthiness of e-scooters during slippery winter months is one question, and whether the vehicles cause problems for the winter maintenance of streets is another worry especially for the northern city officials. E-scooter service operators have addressed these worries in different ways: some operators halt their service completely during winter season while others keep at least a reduced fleet in operation and promise either limiting or pausing their service upon adverse weather conditions and send their users safety tips for winter riding (Griswold 2019). Furthermore, at least in Finland the e-scooter service operators have promised to clear their fleet out of road maintenance operators way (Eronen 2019). Apparently the system has worked well as there were no Finnish news reporting major challenges caused by the e-scooters last winter, which was the first of shared e-scooters in Finland. However, it is worth noting that winter 2019 was the warmest on record for Europe, which means there was less snow and need for road maintenance than usually (World Meteorological Organization 2020).

Picture 3. E-scooter blocking a clearly marked driveway. Picture taken in downtown Turku by the author (August 21, 2020).

In addition to varying weather conditions, also vandalism challenges the maintenance of shared e-scooter fleets on one hand and the liveability of a city on the other. Apart from being stolen, e-scooters have for instance been burned and tossed in trash cans, trees or bodies of water. Operators usually do not disclose the scale of vandalism but they complain the losses and wish the communities to respect their property. However, only few operators work with community groups in seeking measures to curb environmental damage. (Ho 2018). In other words, unpleasant externalities like discarded e-scooters in waterbodies become trouble of the local municipality and community. Picture 4 Picture 4below features some of the 15 e-scooters and other scrap that were dragged up from the river Aurajoki in Turku, Finland by volunteer divers on September 20th, 2020 (Koivunen, 2020).

Picture 4 Unpleasant externality: free-floating e-scooters have a tendency to end up in waterbodies. Picture by the author (September 20, 2020).

Despite the high frequency of angry news headlines the scope of improper e-scooter parking, research on the matter gives a less chaotic view of the situation: In one study, 16 % of 606 observed e-scooters were not parked properly and 6% were blocking pedestrian right-of-way (James *et al.* 2019). Another study observed parking behaviours of over 3600 bikes, e-scooters and cars in five American cities concluding that less than one percent (0,8%) of bicycles and e-scooters were improperly parked, while the share of improperly parked motor vehicles was nearly one-quarter (24,7%) (Brown *et al.* 2020).

In the policy recommendations for local governments, German Agora Verkehrswende (2019) counts managing use of shared spaces as one of the most essential elements of e-scooter policy. In order to reduce conflict over congested public spaces, cities are suggested to allocate and clearly designate parking spaces for e-scooters and other forms of shared micromobility (Ibid.)

Accessibility & Social Equity

Shared e-scooter service can only contribute meaningfully to the transportation goals of a city if the vehicles are accessible to a broad spectrum of individuals, across many demographics (Agora Verkehrswende 2019, 12). Furthermore, barriers and opportunities for widespread transportation access can be classified under five categories: spatial, temporal, economic, physiological, and social (Shaheen *et al.* 2017, 22).

For a private e-scooter service provider the noble principles of equitable service might not be the first priority as they most likely conflict with the ultimate aim of profit-seeking. Some cities have therefore included social equity related requirements among the conditions of their e-scooter pilot programmes, thus ensuring at least certain level of service for all members of their community. However, as findings from Portland suggest, even despite contractual demands, service providers have not always met the set requirements (Portland Bureau of Transportation 2019, 7).

Like in any scalable business model, also in e-scooter sharing services localisation efforts mean extra expenses for the service provider. Therefore, as Finland is only a tiny market for the international startups, it is unsurprising that none of the foreign operators provide their smartphone application in the Finnish language. From an accessibility point of view, however, the operators should remember that also the service language matters and can create a barrier for some prospective users.

6 CONCLUSIONS

In this concluding chapter the findings of the study are briefly discussed. Finally, avenues for future research are suggested at the end of this chapter.

This thesis aimed to provide an overview on the various sustainability aspects of shared e-scooter services and point out differencies in national and local regulations. More exactly put, this study approached the topic through following research questions:

- What are the strengths and opportunities of shared e-scooters in the context of sustainable urban mobility?
- What are the weaknesses and threats of shared e-scooters in the context of sustainable urban mobility?
- How can the manifestation of opportunities be supported and threats avoided through regulation and policies?

Since the first launch of shared e-scooter services in California, U.S.A. in 2017, the market has grown and evolved tremendously. Rapid development of both e-scooter technology and operational practices has been possible thanks to generous venture capital investments in the startups who predict huge growth potential in the field of shared micromobility. Today many of the major e-scooter service operators name sustainability as one major driver of their business. Indeed, after several technology and service development phases it seems that shared e-scooters can be labelled as a sustainable urban mobility alternative thanks to climate-neutral operational practices and the low life-cycle emissions of the newest e-scooter versions featuring swappable batteries. However, despite these many positive developments, shared e-scooters remain a hot topic at newspapers' opinion section because of their nonchalant use and parking.

Major strengths of the leading shared e-scooter services include their low total life-cycle emissions, the compact size of the vehicles and their free-floating distribution within a city. Shared e-scooters provide an easy and fun way to move short distances and they can be used as an extension to public transport services. Social equity can be addressed by providing discounted e-scooter rides to people of low income and by serving mobility deserts, i.e. areas which are not covered by public transport networks.

From emission reduction perspective the greatest opportunity of shared e-scooters lies in modal shift away from more polluting mobility modes, such as fossil fuel driven private cars. Lower amount of private cars would also allow cities redesign public spaces more suitable for mass transit, different forms of micromobility and pedestrians. According to early research findings, car substitution rates vary significantly between European and U.S. cities, perhaps due to differences in public transport services and other variables.

Reckless and careless use of shared e-scooters is one of the major weaknesses of e-scooter services. Unawareness of and disrespect towards traffic regulations threaten general traffic safety and the overall image of shared e-scooter services. Indeed, many weaknesses of shared e-scooters are related to the so called human factor and the inability of the service providers and law enforcement to prevent or stop careless use, parking and vandalism of the vehicles. Because the devices are equated with ordinary bicycles, the users are usually not required to have any formal driving licence. Inexperienced drivers equipped with an e-scooter that can reach speed of 20 or 25 km/h with the bend of a finger can indeed put their own and others' health at risk – especially if the e-scooter is used under the influence of alcohol or drugs. In addition to driving also parking of shared e-scooters requires consideration for other users of the public space. Carelessly parked and fallen e-scooters have unfortunately become a daily nuisance in many cities. In some cases free-floating shared e-scooters face vandalism and are for example tossed in water bodies where they compromise the safe use of those waters and are potential threat for the biota as the e-scooters' lithium ion batteries might leak.

In order to answer the third research question, the thesis went through different e-scooter regulation and policy practices from Europe and the U.S.A.. It was found out that the nyances of traffic codes related to micro-vehicles vary between countries and in some countries, such as the United Kingdom, the legal reforms aiming to legalisation of e-scooters have only begun. Such legislative procrastination allows the laggards to learn from the experiences of the earlier adopters of e-scooters. Another policy related main finding of the study was that the degree to which municipalities can have a say to the ways how shared e-scooter services use the public space varies from highly defined control and legally binding agreements to less binding letters of mutual understanding. In addition to local politics, the municipal scope of action is of course also subordinate to national laws.

According to the findings of the thesis it seems like regulation practices and local policies are in decisive role when the overall effect of shared e-scooter services to urban mobility is concerned. Turning the mentioned strengths and opportunities into practise requires active cooperation between local public authorities, public transportation agencies and operators of shared e-scooter services. For instance, in order to seize the opportunity of smooth multimodality, public transportation agencies and shared e-scooter operators should develop attractive pricing models for the combined use of their services. Furthermore, both services should be available through one single mobile application and the availability of e-scooters at the stops of the public transportation should be guaranteed.

Adequate new policies and infrastructure investments are needed also to avoid the inherent weaknesses of e-scooter services that cause threats for the public health, livability and environment. For instance the temptation to illegally drive on pavements can be addressed by developing proper separate lanes for micromobility. Both the local authorities, law enforcement and e-scooter service providers should cooperate in order to find ways to prevent driving under the influence of alcohol or drugs which, according to early studies, has been found to compromise the traffic safety of shared e-scooters especially in Finland. Annoying and potentially dangerous wild parking of free-floating scooters can be reduced by geofenced no-parking zones and promotion of well-planned e-scooter parking corrals. Environmental damage caused by vandalised e-scooters in waterbodies should be minimised jointly by local authorities, law enforcement and e-scooter service providers.

All in all it seems that the use of electrically powered micro-vehicles will keep increasing in the future. Micromobility sharing operators are likely to broaden their vehicle portfolios from e-scooters to a range of devices which all fit on bicycle lanes. This development will change urban mobility and the use of public space. Cities are therefore encouraged to be proactive in the development of micromobility friendly infrastructure and regarding the operators of micromobility services. In order to enable strategic long term mobility development in cities, local authorities should probably be legally empowered to regulate the terms under which shared micromobility is allowed on their streets. The commitment of the stakeholders should most likely be secured by proper contractual means.

Avenues for Future Research

There are many research gaps around the topic of shared e-scooters in Finland and internationally. In order to provide more insight for public decision-makers and the wider audience, at least following questions could be addressed in future research:

- How has the cooperation between Finnish (Nordic) cities and e-scooter service operators worked so far? Would cities benefit from more authority over the micromobility operators?
- What are the experiences of winter street maintenance providers on shared e-scooters?
- Are cities prepared to reallocate public space, such as car parking space to serve different types of micromobility in order to promote good parking behaviour and multimodality of urban transportation?
- Development of standardised tool to measure modal shift in cities

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