Professional MBA Automotive
Industry

E-Scooters in Inner City Vienna
-
Deployment Prospects and Environmental Impact

A Master's Thesis submitted for the degree of
“Master of Business Administration”

supervised by
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Vienna, 08.03.2020

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Affidavit

I, **GORAN JOVICIC**, hereby declare

1. that I am the sole author of the present Master's Thesis, "E-Scooters in Inner City Vienna - Deployment Prospects and Environmental Impact", 81 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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Abstract

E-Scooters are everywhere nowadays. They seem to be well accepted by general population and are quickly gaining popularity among all ages and social classes. Lightweight, compact, easy to use, they appear to be one of the best tools for promoting the micro-mobility and environmental sustainability. On the other hand, there are many both apparent and concealed risks, limitations, and controversies associated with E-Scooters. They present a safety hazard for their own users as well as other traffic participants, mainly pedestrians. Their contribution to well-being of users is questionable, for they seem to augment the most common disease of today - sedentary lifestyle. By depriving individuals of physical activity, e.g. walking the "first and last miles", E-Scooters have potential of causing serious implications for people's health. Their practicality in winter season is uncertain. Their environmental impact is also currently unclear. Their actual CO_2 footprint is not clearly defined and is often overlooked. Short shelf and operational life, toxic batteries, poor traceability, are all factors that should be taken into consideration and are often not.

The explosion of E-Scooters seems to have caught authorities and regulators off guard. But they are rapidly starting to address the issue by creating and enforcing E-Scooter rules. No doubt that E-Scooters will survive. The question is how extensive their participation in total traffic will be after restrictions are introduced.

This Master's Thesis clarifies the future of E-Scooters in Vienna`s micro-mobility scheme and focuses on E-Scooters' potential to reduce motorized individual traffic (MIT) in the inner part of Vienna. It goes on to determine how many cars could be replaced by E-Scooters and quantifies the impact on emission of CO_2 and air pollutants.

Keywords: Micro-Mobility, e-Mobility Strategy, Safety Hazard, Health Impact, Carbon Footprint

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Abbreviation List

MIT	Motorized Individual Transport
NOx	Nitrogen Oxides, Nitrogen Oxide (NO) and Dioxide (NO_2)
$PM_{2.5}$	Atmospheric particles with diameter less than 2.5 µm
ICE	Internal Combustion Engine
E-Scooter	Electro-Powered-Scooter
WRD	Wheeled Recreational Device
EMS	Emergency Medical Services
IQR	Interquartile Range
PKM	Passenger Kilometer
PC	Passenger Car
BMVI	Das Bundesministerium für Verkehr und digitale Infrastruktur
UBA	Umweltbundesamt
GDP	Gross Domestic Product
STEP	Stadtentwicklungsplan
StVO	Straßenverkehrsordnung
EOB	End Of Business
TTM	Time To Market
ROI	Return Of Investment

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1. Theoretical Part

1.1. Introduction

1.1.1. Motivation

Recent catastrophic Australian bushfires, unprecedented in recent history for its level of destruction, but also publicity, rapidly raised both global and individual awareness regarding climate change and global warming. The most appalling fact is that, in addition to more than two dozen of human victims, more than one billion animals ended up killed in firestorms.[1] This time it was not just environmental activists and lone politicians raising their voice, the general public throughout the globe expressed their concern and impatience regarding the accelerating climate change and lack of resolve to fight it. More than ever before human race seems unified in preventing the climate apocalypse. This unfortunate event just reinforced already universal belief that humanity must end its dependence on fossil fuels.

Besides carbon dioxide and other greenhouse gasses emission, the release of pollutants causing respiratory and malignant disease, such as NOx, and Atmospheric Particulate Matter, such as $PM_{2.5,}$ is another great reason for concern. A good share of these harmful air contaminants is discharged by older ICEs, especially diesels found in both personal and light commercial vehicles. The harmful effect of these compounds is particularly evident in large cities, where there is a high concentration of ICE vehicles, and low circulation of air currents due to obstruction from high-ride buildings. The examples of such environment can be found not far from EU boundaries. Take for example city of Sarajevo, capital of Bosnia and Herzegovina, which is distanced only 100 km from EU boundary and 500 km from Vienna. Sarajevo's residents are traditionally suffocating every winter season. In recent years Sarajevo is among most polluted capital cities in the world, frequently vying for the worst place with much larger conurbations, such as Delhi of Dhaka.[2]

One additional reason for reduction of motorized traffic in modern cities is that the change in lifestyle of its inhabitants is causing the change of transportation methods in those cities. Public transportation, micro-mobility devices, and even walking are rapidly displacing individual motor transport as a preferred way of moving.

[1] (Dickman, 2020)
[2] (World Air Quality Index, 2020)

City infrastructure is being accommodated to this new reality. For instance, one of Vienna's most busy streets, Mariahilfer Strasse, has in recent years undergone a major transformation from a busy motorized traffic artery to an exclusive pedestrian zone. At the end of the same street, by Westbahnhof strain station, globally known furniture retailer IKEA is constructing a revolutionary kind of store. This new store concept is following the current megatrends and takes into consideration both changed shopping behaviors and new formula of mobility without a car. Therefore, the new store will have no parking spaces for automobiles. All purchased bulky items will be delivered straight to customers' residences straight from a warehouse located in city outskirts, far from the store and city core.[3] Deliveries will be consolidated and executed using reasonably environmentally efficient vehicles, contributing to emission reduction. Needless to say, both convenience and experience of a customer are dramatically improved - one can easily imagine a family having fun by arriving to a furniture store on E-Scooters. No doubt that the new IKEA concept will end up being a success.

In 2019 the international consulting firm Mercer ranked the city of Vienna number one in the World on their Quality of Living index. Vienna won this prestigious award for the tenth time in row.[4] Environment conditions are considered among other criteria. People of the world are paying attention to what is happening in Vienna. Decision made by Vienna city officials could positively influence development of world's current and future megacities. Despite its relatively small size, Vienna could serve as a role model to many cities around world. In addition, Vienna should continue to identify ways to even more effectively protect not just the health of its inhabitants, but also the delicate and historical architecture. Any changes to existing infrastructure, on surface level, are very limited. Most of buildings and streets within the city core are classified as cultural heritage, and as such protected from any altering. This aged layout is not well sized nor suited for volumes and forms of 21st century transportation. The result of this mismatch is traffic congestion. The goal of this research is to detect in which direction Vienna is moving when it comes to micro- mobility solutions, but also to determine whether those solutions may be viable. Another purpose of this research is to enhance Vienna's excellence, to make the great city of Vienna even greater.

[3] (IKEA at Westbahnhof, 2019)
[4] (Mercer, 2019)

One of major causes of traffic congestion and air pollution are so called last-mile trips. An example from US shows that “46% of car traffic in the US is caused by cars on trips less than three miles”.[5] Micro-mobility solutions, such as E-scooters have shown a significant potential for resolving this serious issue. But is an E-Scooter the optimal last-mile micro-mobility solution, in contrast to an E-Bicycle, or upcoming Segway S-Pod[6] for instance?

One thing is for certain, there is a renewed interest of general public in Vienna concerning the E-Scooter. The google shows the significant spike in searches of term “E-Scooter” in year 2019, coming from geographical area of Vienna.

Figure 1: Interest Over Time in Search Term "E-Scooter", in Vienna (Source)

Besides studying the feasibility of E-Scooter deployment, this research is aimed at determining the practical impact of such deployment, by mean of quantifying the actual air emission reduction.

1.1.2. Problem Definition, Hypothesis, and Research Questions

After initial successes and ample enthusiasm, E-Scooter implementation in cities has been plagued and consequently impeded by many serious problems. The major issue was the safety, E-Scooters indeed have tendency to cause injuries to its users, but also to other active traffic participants and pedestrians. In addition, E-Scooters contribute to direct environment pollution (by being intentionally disposed into bodies of water, for instance), they are congesting sidewalks, are subject to theft and vandalism - the list is long. Without resolving these issues first there are small chances that E-Scooter will emerge as a wining solution for a long-term micro-mobility. It will not happen without systemic regulation driven by city and state authorities. So, the

[5] (Ajao, 2019)
[6] (Leskin, 2020)

main problem associated with E-Scooters is the viability their concept. This research will attempt to resolve that unknown by determining the probability of long-term E-Scooter deployment. The scope will be limited to inner city Vienna.

Let's hypothesize for a moment that all issues can be resolved. Let's imagine that E-Scooter can and will mature enough to become a preferred solution for long-term micro-mobility. This hypothesis sets the stage for asking and answering the following questions: if all obstacles end up removed, what share of current MIT users will switch to E-Scooter, and what practical impact, in terms of reduction of harmful emission, will this shift have? Can this reduction be quantified and expressed in simple terms?

1.1.3. Structure of Thesis

This thesis consists of three major parts, theoretical part, practical part, and conclusions/recommendations part.

The theoretical part focuses on exploring the state of art. First, examined is the purpose of E-Scooters, very need for their existence and implementation. Some technical description and brief history follow. The important and often controversial subjects of safety, health, and environmental impact are explored next, followed by an overview of current E-Scooter mobility concept and related trends. E-Scooter-associated developments in selected European cities are also looked into. Subsequently, several sub-chapters deal with specifics of E-Scooter deployment in Vienna, essentials such as deployment volumes and operators, modal mix, environmental impact, traffic regulations and long-term strategy.

The second, practical part is an empirical study aimed on determining two aspects: 1) quantifying the annual volume of Individual Motorized Traffic in Vienna's Inner District, and 2) determining the share of drivers willing to give up their cars and swap them for a micro-mobility solution, an E-Scooter in this case. The study outline begins with a detailed description of the methodical approach and continues with results derived from vehicle counting investigation as well as from questionnaires returned from survey participants. The practical research is rounded with the interview with Vienna Deputy Mayor Ms. Maria Vassilakou and several other city officials. Finally, the data analysis, discussion, conclusions, and recommendations to future policy makers conclude the thesis.

1.2. Background information / state of the art

1.2.1. Research Methods and Literature

The background information was obtained by researching the literature. Consulted were books, journals, research papers, newspaper and magazine articles from TU Wien library, as well as various syndicated electronic libraries such as ABI/INFORM Collection of ProQuest and Direct Journals of Elsevier. In addition, great amount of facts and information came from World Wide Web. Due to rapidly changing aspects of E-Scooter micro-mobility concept, the Internet seem to be the medium best suited to keep track of fast developments.

1.2.2. The Need for E-Scooter Concept and Key Drivers

Many industry analysts are predicting the future of mobility in cities not to be the auto industry, but the micro-mobility concepts. Some even attempt to estimate the volume of micro-mobility market. Joao Peixe, a writer for Oilprice.com, predicted in 2019 that the future mobility industry presents a $7-trillion (EUR 6.36T) opportunity,[7] with increasing focus on micro-mobility. The rapid expansion of micro-mobility can be illustrated with an example from New York. Year 2010 saw 321,000 micro-mobility trips. Eight years later, in 2018, completed were 84 million micro-mobility trips.[8] The E-Scooter is emerging as a convenient and affordable solution to transportation problems, and an ideal mean to bridge the first and last mile of a trip. It seems to have already surpassed the conventional bicycle as the vehicle of choice not just for private, but also commercial users i.e. vendors. This is especially visible in Chinese cities, where traditional bikes are already hard to spot. E-Scooters, on the other hand, are everywhere.

What is driving the micro-mobility and E-Scooter market? Some of major drivers are massive marketing, explosion of internet-based technologies, soaring urban populations, unbearable traffic congestion, climate change, and fuel costs.[7]
Some other important drivers are desire to mitigate greenhouse and harmful emissions away from cities, quest for reduction of noise, and desire to free as much valuable space as possible. The chocking pollution is increasingly becoming a critical issue in many cities, especially those deprived from wind and air circulation due to

[7] (Peixe, 2019)
[8] (Descant, 2019)

geographical location and topography. Eliminating emission from internal combustion engine powered individual transports greatly reduces the air pollution, even if electrically powered micro-mobility alternatives are powered by electricity generated in coal-fired power plants. Such power plants are typically situated far away from urban areas, where environmental conditions are more favorable and allow for quicker and more efficient dispersion and dilution of harmful gasses. Furthermore, E-Scooters are very quiet by their very nature and contribute significantly to reduction of noise pollution. Currently, 65% of the European Common Market population is exposed to unhealthy levels of transportation noise, which is considered to be a modern plague.[9] Massive implementation of E-Scooter will help alleviate this issue. Finally, E-Scooters possess substantial potential for freeing more space for public transport, cyclists, and pedestrians. The streets in most cities were designed to accommodate cars. The population of those cities is growing, and the existing infrastructure is overused and overloaded. On the other hand, more and more people are increasingly opting to walk, cycle, or use eco-friendly electrified micro-mobility solution. An example from Vienna is showing that more than 65% of street surfaces are utilized for motorized traffic and parking, despite the fact that only 28% of all trips are made by car.[10] The occupancy of motorized individual transports is very low, often only a quarter, or even a fifth of designed capacity. The vast difference in size and footprint between micro-mobility devices and motorized individual transports defines vastly different space demands.

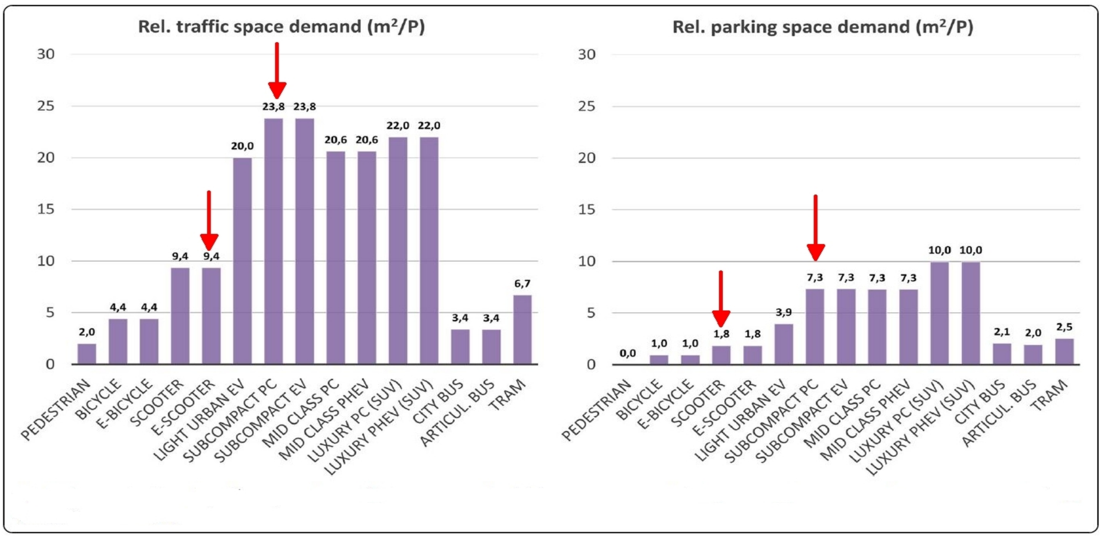

Figure 2: Relative traffic and parking space demands of various vehicles (Source)

[9] (Goines, Hagler, 2007)
[10] (MA18 Vienna, 2015)

The graph above is showing the dynamic (mean velocity 17 m/s) and static space demand of various means of transportation, in meters squared, per person.[11] The lack of space for moving and maneuvering contributes to traffic congestions, which in turn have detrimental effect on peoples' health - sitting in traffic is bad to health. The following figure illustrates the magnitudes of losses in time and money in traffic congestions.

Figure 3: Time and money lost in traffic congestions in US (Source)

Traffic congestion translates to a lot of wasted fuel, and a lot of unnecessary emitted greenhouse gases. Not to forget almost $1000 annual loss per person. And it shows an increasing tendency, in unfavorable way.

1.2.3. History and Technical Description

Contrary to popular belief, E-Scooters are not the recent invention. Automobile enthusiasts will recall that first automobiles were battery powered. The electrical

[11] (Brunner, Hirz, Hirschberg, Fallast, 2018)

propulsion is not a novelty. The first E-Scooters were not quite resembling today's designs. They were more like electrically-powered bicycles, albeit ones having two equally-sized wheels. The first patent for an electric scooter was granted to Ogden Bolton in 1895 (Patent No. US552271), with a permanent magnet DC motor housed in rear wheel hub (a modern layout even by today's standards). Scooter's 10 Volts battery could deliver up to 100 Amperes.[12] There is no evidence that Bolton ever produced a working example.

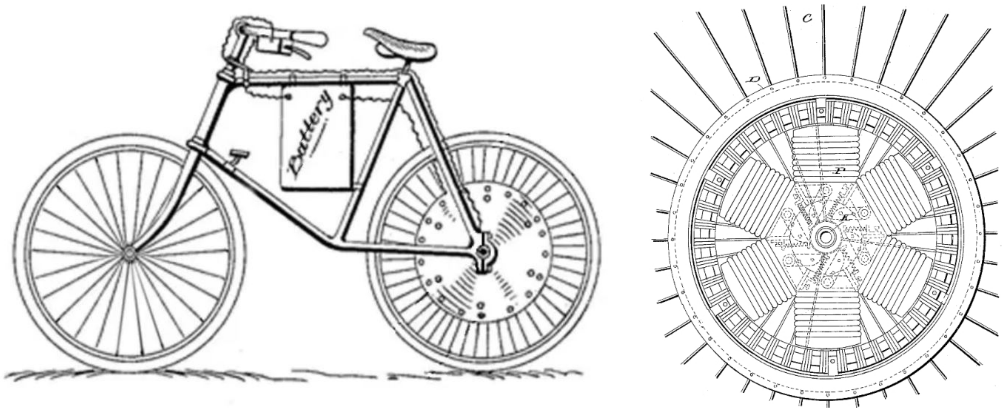

Figure 4: Ogden Bolton's electric scooter and its motor (Source)

In 1911 the famous magazine Popular Mechanics described a novelty electric motorcycle to its readership. The range specification was incredible, even by today's standards; full charge could propel this vehicle 75 to100 miles (120-160 km).[13]

The next important milestone in E-Scooter development was introduction of French-made Electrocyclette, first model available for public purchase.[14] It closely resembled today's standing E-Scooters; its seat was placed very low, encouraging the standing operations, and there was an absence of pedals. It was a large (1.8 meters long) and heavy (75 kg), it had a modest output electric motor of only half horse power, but on the other hand it had for the time decent 30km range, thanks to its large 150 Ah battery.

It was French engineers again, this time from famous company Peugeot, who were responsible for creating the first truly commercially available and mass-produced

[12] (Ron, S. 2013)
[13] (ST2, 2020)
[14] (Paolo, 2015)

E-Scooter Scoot'elec in 1996. With its nickel cadmium batteries sufficient for 40 km operating range, reasonable weight of only 115 kg, intelligent electronic controls, and very modern look, Scoot'elec outmaneuvered all contemporary competitors and laid down the foundation for E-Scooter revolution a couple of decades later.[15]

Figure 5a: 1927 Electrocyclette (Source) ***Figure 5b: 1996 Scoot’elec (Source)***

The appearance and construction of modern E-Scooters departed significantly from those of Peugeot Scoot'elec, which looked a lot like today’s gasoline powered scooters. Nowadays E-Scooters resemble classical kick scooter, they ride on a very slender and lightweight, yet durable chassis. The frame is often foldable, in sense that steering column and handlebars can fold onto the platform, making the scooter more compact and suitable for handling and carrying around, as well as for accessing the public transportation. Some public transportation companies, Wiener Linien for example, treat folded scooter as a hand-carried package, thus making it exempt from restrictions which typically apply to bicycles. The electric motor on a modern typical E-Scooter is located in the front wheel hub and it can be reversed for energy recuperation, charging the battery pack through braking. The battery pack of today is Lithium-Ion and is located either in the floor, also known as deck, or if swappable like on commercial models, on the vertical handles bar. Hard or emergency breaking is accomplished using disk brakes, frequently with anti-lock function. Tires are often of run flat type or even made of hard foam. Every E-Scooter intended for street use has appropriate safety equipment, such as modern and bright LED head, rear, and stop lamps, reflectors, and bell and/or horn. Modern E-Scooters are packed with

15 (Lanemotormuseum, 2019)

electronics, for motor and battery management, control and information panels, cruise control, connectivity (Bluetooth), and tracking (GPS). The luggage carrying capacity is very modest, if not non-existing. The concern is how a luggage might affect the stability. Some modern E-scooters do come with a mounted basket for stowing the helmet, of for carrying groceries.

Figure 6: See-through image of a modern E-Scooter, Xiaomi Mi (Source)

Contemporary E-Scooters come in different sizes, power levels, and useful ranges. The smaller size does not necessarily mean less performance or practicality. The range and charging times vary significantly from model to model.

E-Scooter Make & Model	Max Distance/Run Time	Charge Time
GLIDER Electric Scooter (Best Budget)	15 kilometers	3 hours
Xiaomi Mi Ultra-Lightweight	30 kilometers	5 hours
SWAGTRON Foldable SwagCycle E-Bike	16 kilometers	2.5 hours
Razor E100 Electric Scooter	40 minutes	12 hours
Razor Pocket Mod Min Electric Scooter	40 minutes	12 hours
Razor E300 Electric Scooter Family	40 minutes	12 hours
Razor EcoSmart Metro Electric Scooter	40 minutes	12 hours
Super 36v Turbo 1000-Elite Scooter	40 minutes	4 hours
Glion Dolly Foldable Electric Scooter	24 kilometers	3.5 hours
Ninebot Segway ES 2	25 kilometers	4 hours
Jetson Jr. Electric Bike for Kids	5 hours	14 hours
UberScoot 1000w Electric Scooter	45 minutes	4 hours
GigaByke Groove – 750W Electric Bike	40 minutes	6 hours

Table 1: Specifications of some popular E-Scooter models (Source)

Table 1 is showing useful range and charging times for some of most popular makes and models of E-Scooters. Regarding the motor output, an average electric scooter, like the Xiomi Mi, have a 250-watt motor. The top range, performance scooters, can output more than 2kW.[16] The design of E-Scooters is evolving quickly, primarily due to rapid development of batteries.

1.2.4. Safety, Health, and Environmental Concerns

Probably the most controversial issue with E-Scooters is safety. The advent of E-Scooters was so sudden and fast, hardly any safety-related subjects could have been evaluated and regulated. Suddenly there were situations where E-Scooters were mixing with pedestrians on sidewalks and motor vehicles on streets alike. In addition, E-Scooters were left by its users everywhere all over the cities, leaving sidewalks, tram and bus stations, parks and paths dangerously obstructed.

Figure 7: E-Scooter Path Obstruction* *(Source)

There were even reports of E-Scooters being left of the platforms of metro stations, or even driven through passengers waiting on them, creating a great hazard.[17] The modern commercial E-Scooters are dockless, and the rider is not required to leave the scooter at a designated place to avoid getting penalized. Fast and silent, E-Scooters are particularly hazardous for pedestrians. They typically operate in the areas with heavy pedestrian traffic, often swerving around pedestrians, Therefore the

16 (Escooterguide, 2019)

17 (Heute, 2019)

collisions happen frequently. Especially endangered are older and fragile persons. For them an impact could easily end up deadly. In 1998, in Spain, a 90-year-old woman died after being accidentally hit in the pedestrian section by an E-Scooter moving at 30 km/h and operated by a young E-Scooter rider. The ill-fated woman was in good health and was in the middle of her daily stroll. There is a possibility that the young rider was looking at his phone. Manoli, the manager of a nearby store, commented on the case: *"What happened to her could happen to anyone. When I see one of those scooters going by at full speed I get the shivers."* As a result, several cities and municipalities in Spain, such as Madrid, Valencia, and Barcelona, are introducing or have already introduced restrictions on where E-Scooters are allowed to be ridden. Sidewalks and historic city centers are getting off-limit. Moreover, the Spanish traffic authority is setting to introduce national guidelines and a 25 km/h speed limit for E-Scooters.[18]

Introducing rules and restrictions is not exclusive for Spain; More and more cities and events, such as fairs, from all over the world, are introducing restrictions or even completely banning use of E-Scooters. A perfect example is upcoming 2020 Dubai Expo, which expects 150000 guests every day during its six months duration – that is total of 25M visitors. In order to guarantee visitors safety E-Scooters will be banned from exposition premises.[19]

E-Scooters present a substantial hazard for their riders. Their center of gravity is very high, and therefore they tend to be inherently unstable. Their wheels are quite small and riding surface imperfections such as potholes, cracks, manhole covers, debris, and uneven surfaces can and do cause loss of control and crash. Their modest length also doesn't contribute to longitudinal stability. The steering mechanism is light and allows for sudden changes of directions, a challenge for new and inexperienced riders. To make things worse, most of E-Scooter riders are not particularly disciplined. Many of them are not following traffic and zoning rules and regulations, they are mixing with other motorized traffic on streets and roads not meant for scooter traffic. There are even reports of E-Scooters being ridden on motorways.[20] Majority of rider's wear earphones or headphones, and they are unable to hear sounds and signals from surrounding traffic. Some of E-Scooter riders do not pay much attention to traffic signs, and even run red lights. Alcohol is often a factor. Another study from US, from

[18] (Garcia, Congostrina, Urra, 2018)
[19] (SyndiGate Media Inc, 2019)
[20] (Heute, 2019)

Austin, Texas has shown that out of 190 injuries, originating from 936000 rides, 29 injuries were somehow related to drinking alcohol. Half of injuries were head injuries, and only a single rider wore a helmet.[21] Yes, the especially troubling fact is that majority of riders are not wear helmets. In some jurisdictions small foldable E-Scooters are not classified as motor vehicles, so the helmets are not required. Even there where helmets are required, authorities often fail to reinforce the policy. A study from Southern California, a hotbed for E-Scootering, shows that out of 249 riders admitted for a treatment in hospital only 4.4% were wearing helmets.

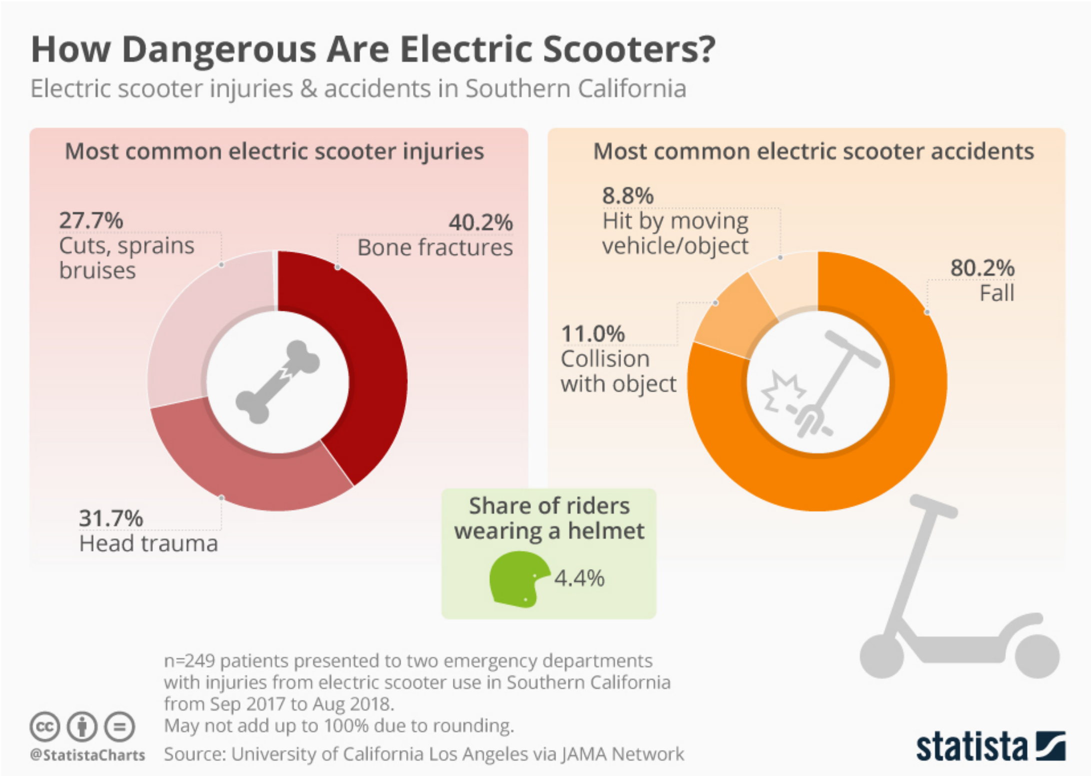

Figure 8: Electric Scooters Accidents and Injuries (Source)

The same study points to the fact that most injuries are very serious ones, head trauma or bone fractures, and that majority of those injuries are stemming from losses of control and falls.[22]

A nice study from Copenhagen is illustrating the severity of hazards and injuries associated with E-Scooters, and compared with manual, kick scooters. The data was collected between January 2016 and August 2019 (July is included).[23] It is

[21] (Schaefer, 2019)
[22] (McCarthy, 2019)
[23] (Blomberg, Rosenkrantz, Lippert, Christensen, 2019)

worth noting that Copenhagen is one of world capitals of bicycle, and that riders of WRDs are seldomly first-timers, in other words the they are mostly experienced riders. It stands to reason that Copenhagen riders can and will master E-Scooter driving/riding technique with ease. However, since the launch of E-Scooter rental services in January 2019 the accidents and injuries have skyrocketed. The criteria for injury was that to qualify an injury must be severe enough to warrant the involvement of EMS. The study population totaled 468 patients, with 43.0% / 57% male/female ratio, and with IQR resting between 9–25 years, as well as median age of 12 years.[22]

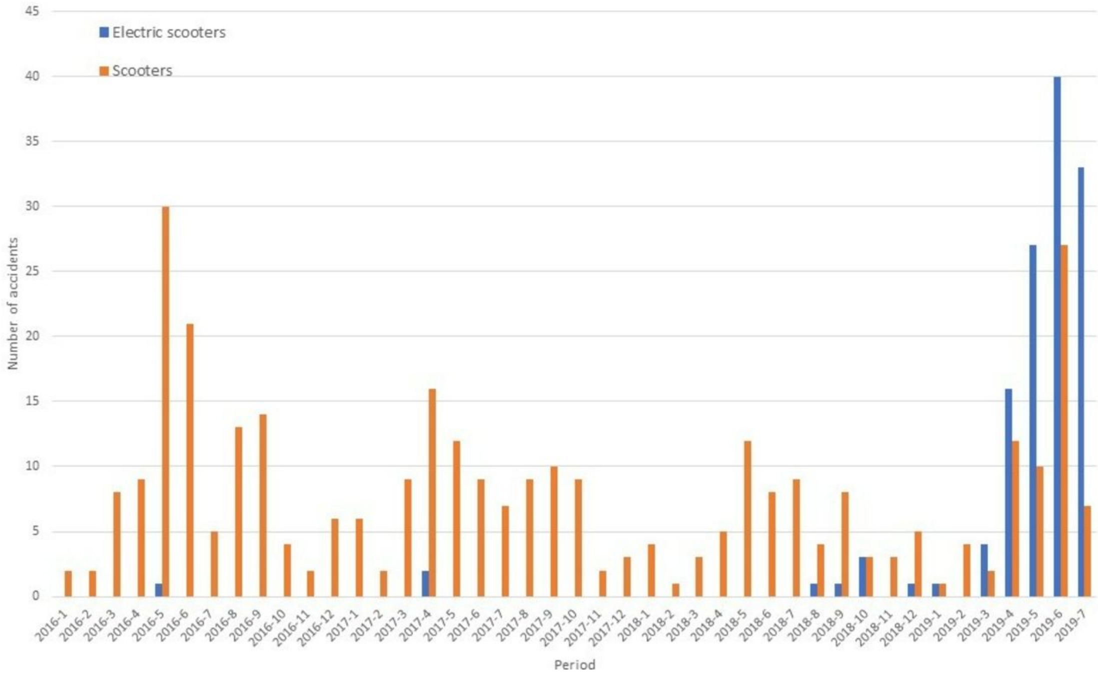

Figure 9: Distribution over time of kick and electro scooter injuries (Source)

The graph indeed shows a dramatical increase of E-Scooter related injuries, starting with the moment of their mass-introduction (blue columns). The Copenhagen study goes on to elaborate on mode of injuries, circumstances, age of injured, as well as on kind of sustained injuries. Most injuries were caused by falls, the riders of E-Scooters were much older than the general population, IQR: 22–42 years and median age 27 years, only 3.6% of those E-Scooter riders wore a helmet, but more than one third of them (36.6%) was intoxicated, either with alcohol or drugs. The severity of injuries was higher within E-Scooter riders than within kick scooter riders.

Higher were fractures (9.6% kick vs 11.6% electric), facial injuries (25.1% vs 38.4%), Lacerations requiring sutures were double (19.5% vs 44.6%), so were the head injuries (10.5% vs 20.5%). The number of non-rider injuries also surged dramatically. The number of injuries reported in first seven months of public E-Scooter service exceeded the total number of injuries in previous 3 years.[22]

One additional health-related aspect goes unnoticed, and it should be considered. Using self-propelled device such as E-Scooter for first and last mile transport deprives users from a little physical activity they would otherwise get by walking. The major disease of 21st century is sedentary lifestyle. Cities' inhabitants nowadays spend most of their time sitting, sitting at home, sitting at work, in offices, in public transportation, etc. Robbing people of this little physical activity of walking from public transportation terminal to office or home might lead to increase of sedentary lifestyle illnesses such as obesity, high blood pressure, and diabetes.

Regarding the environmental impact, (other than carbon footprint which will be addressed in further text) E-Scooters appear not to be exceptionally friendly to environment. They are often subjected to vandalism and besides being damaged, broken, set on fire[24] they often end up thrown into bodies of water, rivers, canals, even oceans. One example is French city of Marseille where hundreds of electric scooters are being tossed into water for fun.[25] Most of these E-Scooters are recovered, but those which are not, will eventually disintegrate and leak harmful chemicals, mostly from batteries, into the water, polluting the environment. The lifespan of an average E-Scooter is not long. A study was conducted in Louisville over five-months span in 2018. Deployment of 129 E-Scooters was scrutinized, and the results were somewhat discouraging: The average lifespan of an E-Scooter turned out to be less than a month, 28.8 days to be precise, and during that time E-Scooters were used only for 92 trips covering 263 kilometers.[26] This is quite a low level of utilization for a Lithium Ion battery which is both energy-intensive to produce and difficult to recycle. Numerous studies agree on the present Lithium Ion battery rate of recycling and place it at 5%.[27] Some studies place this figure somewhat hire, and the trends are positive, but the current state is that very small share or Li-Ion batteries is getting recycled.

Finally, some of E-Scooters end up in garbage, mostly due to acts of vandalism. This creates risk of soil pollution, in case garbage is sent directly to landfills, but also a safety hazard for municipal solid waste processors. Lithium Ion batteries can easily catch fire if punctured or crashed, and that fire, being

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24 (Newberry, 2018)
25 (France 24, 2019)
26 (Griswold, 2019)
27 (Jacoby, 2019)

uncontrollable exothermic reactions, is very hard to control and extinguish. There is a least one report where an E-Scooter battery pack set a garbage truck on fire. Several E-Scooters were disposed of in a dumpster, and one of battery packs ruptured and ignited when compacted, causing the load and the entire truck to burn.[28] All above listed deficiencies point to an urgent need: All aspects of E-Scooters must be better regulated.

1.2.5. Current Status of E-Scooter Mobility Concept

After initial craze, when expectations were sky-high, the enthusiasm about E-Scooters seem to be cooling down a bit. E-Scooter popularity now appears to have been something of a bubble. The riders themselves are still supportive, despite recent negative publicity (e.g. since 2017 in US alone at least eight people have died riding E-Sooters,[29] in UK Television presenter and YouTuber Emily Hartridge died in E-Scooter accident[30]), but the cities regulators do not seem to share that same enthusiasm. They are introducing more and more restrictions on use by limiting the number of vendors and the size of fleet, and even penalizing operators for overdeployment.[31] enforcing the rules and imposing the fines. UK and Ireland have decided to forbid E-Scooters from using public roads, an offence punishable by 300 Pounds penalty plus six points on driving license. Sweden capped the top speed for E-Scooters using bicycle lanes at 20km/h.[32] Politicians promoting environmental protection are reconsidering the environmental benefit of E-Scooters, reason being their very short lifespan.

The same factor, short life cycle of E-Scooters, is also troubling investors. The current generation of E-Scooters is convenient and lightweight, but also a light duty built. Also, the riders have no incentive to take care off and be gently to these scooters, so they often suffer abuse. They simply do not last long enough to turn profit. Due to high competition, the profit margin on E-Scooters is very slim, and it takes about six months just to amortize the investment and break even. The problem is that E-Scooters do not last that long, they are typically written off after only a month or two.[33] Initially excited investors are now becoming increasingly reluctant to open their

[28] (Kurt, 2018)
[29] (Benzinga Newswires, 2019)
[30] (Tapper, 2019)
[31] (Jankowski, 2018)
[32] (BBC, 2019)
[33] (Rosalsky, 2019)

purses. An example from US: total investments in micro-mobility in first six months of 2019 ($968 million) are only about a half of what was invested in year 2018 ($3.8 billion).[28] The concept continues to be promising. It is the economics behind the concept that needs a fresh scrutiny.

1.2.6. Future Trends in E-Scooter Mobility

As already mentioned, the total mobility market is now worth $7 trillion (EUR 6.36T). The micro-mobility share alone is expected to reach nearly $32 billion (€29 billion) by 2029, and it is still considered the definitive answer for first mile and last mile problem. It has the best potential to replace motorized individual transport.[34] Yes, there is a downturn ongoing, but the issues causing it are currently being resolved, and are expected to be solved in near future. The legal and social responsibility issues will be resolved by thorough regulations, and the economic sustainability issues will be self-resolved as E-Scooter mature in technical sense. They will be built to last, and will incorporate features intended to dramatically improve safety, convenience, and comfort of riders. Much enhanced reliability and customer experience of the new generation of E-Scooters will allow for expanded profit margins and longer depreciation periods.

The good example of E-Scooter technical evolution is the recent offering from a startup company called OJO. It has a big advantage over its competitors; it's got a seat. Therefore, it is more comfortable, and this added comfort together with larger battery capacity allows for longer individual rides.[33] It also features a breathtaking industrial design and its appearance is visually appealing to its target audience.

Figure 10: The lineup of all versions of OJO E-Scooters (Source)

[34] (PR Newswire, 2019)

OJO is a big improvement in technical sense. The average ride is three times longer than that one of competitors. It is as well more suitable then opponents for longer rides. It can do 16-24 kilometers effortlessly, thanks to aforementioned seat and hyper-power charger.[33] OJO’s specification list is long and impressive.

- **Motor:** 500W HyperGear hub motor
- **Battery:** 48V lithium-ion battery
- **Range:** 25 miles
- **Max Speed:** 20 mph
- **Weight:** 65 lbs
- **Brake System:** Front and rear disc brakes
- **Dimensions:** 51.5 x 24.2 x 49 inches
- **Wheels:** 8.5 inches with all weather pneumatic tubeless tires
- **Max Load:** 300+ lbs
- **Charging Time:** 0%-100% 7 hours
- **Light:** LED Headlight, LED Tail Light & LED Turn Indicator
- **Special features:** Wireless key FOB, Bluetooth speakers

***Figure 11: OJO E-Scooter Specifications** (Source)*

It has a powerful motor and capable battery, yet it weights less than 30kg. Unlike with current generation of E-Scooters that is lightweight but unsuitable for heavy loads (typically up to 90kg), OJO’s lightweight aluminum under chassis is designed for loads exceeding 135kg,[35] a minimum rating for today’s overweight population (no pun intended, the author of this work himself falls well into that category). An integrated rear basket is optional. The seat can be adjusted or even removed allowing both sit down and stand up riding position. In addition, it features the latest technological gadgets such as integrated waterproof Bluetooth speakers, interactive, non-glare touchscreen, three speed mode, and more.[34]

But where OJO really shines, and makes difference, is safety. It integrates many different passive and active safety features: With its geometry and riding position it is intrinsically stable, much more so than the standing riding position brethren. It has a powerful disc brakes front and back, as well as full suspension on both wheels (better stopping power and riding control and stability, even in wet conditions). OJO packs a long list of innovative active safety features. Its speakers are designed to sound alerts,

[35] (Steinman, 2020)

the scooter has built-in an automatic speed limiter which slows it down in areas classified as restricted, such as schools. Theft is prevented by a combination of motion activated alarm and a wireless key fob.[34]

It was an innovative technology and outstanding engineering that has drawn attention of city regulators. Previous E-Scooter haven't been met with much fervor. One could even say that they were hated. That's not the case with OJO. Thanks mainly to improvements of safety, the major drawback of up-to-date E-Scooter deployment, cities are supportive of OJO deployment. In their words "OJO plans to disrupt the disruptors, and they're disciplined enough to do it". [33]

It is also OJO's clever business model that made the difference. OJO watched carefully and learned from mistakes the early entrants made. They, the early contestants, have thrown tons of raise venture capital cash into flooding streets with short-lasting hardware, huge numbers of them, and all that without understanding first the requirements, expectations, and limitations. And they continue to do so, despite the backlash. Such business model is simply not sustainable. OJO is doing it differently. They seem to have a plan developed ahead of time by their team of experts. They involved city official and renting vendors from the very beginning and carefully considered their inputs. The goal is to contribute to turning the existing chaos into order.

Concerning the pace of deployment, OJO is very methodical. The amount of money they plan to raise is closely proportional to number of E-Scooters they can deploy. No throwing huge amounts of money in arena without having a good visibility first. OJO currently can earn $15 per day, per scooter. By the end of 2019 they projected to have 2,500 scooters deployed, for a total of $13.5 million (€12.2 million) annualized revenue. Moreover, by the end of 2020 OJO projects to have 15,000 scooters deployed, for a total of $82 million (€74 million) in annualized revenue.[33] OJO also has a creative approach when it comes to marketing and establishing new and inventive sales channels. OJO teamed up with one established player from automotive industry. In 2017, at the very beginning of OJO's endeavor, a licensing agreement between OJO and Ford Motor Company was reached. The agreement was to build an exclusive line of six Ford-branded models.[36]

It has become clear that big early entrants, such as Bird and Lime, moved in too quickly without a sound plan, and ended up burning a lot of venture capital money.

[36] (Markham, 2017)

OJO has committed itself to different and slower, but more rational and sustainable path. The expect their business model to be successful in a long run.[33]

OJO's story is a good example how good opportunities can arise from good preparation and methodical approach. Doing thorough homework simply pays off.

1.2.7. The Average CO_2 Emissions of an MIT Unit and an E-Scooter

It is already established in previous text that a lifespan of an average E-Scooter is very short, perhaps as short as 30 days. Therefore, a lot of carbon emission is embedded in the E-Scooter body, especially in its (Aluminium) frame and Lithium-Ion battery. And that is lost because of extremely short lifespan. A European study shows that the carbon footprint of E-Scooters is not much smaller than the one of cars.

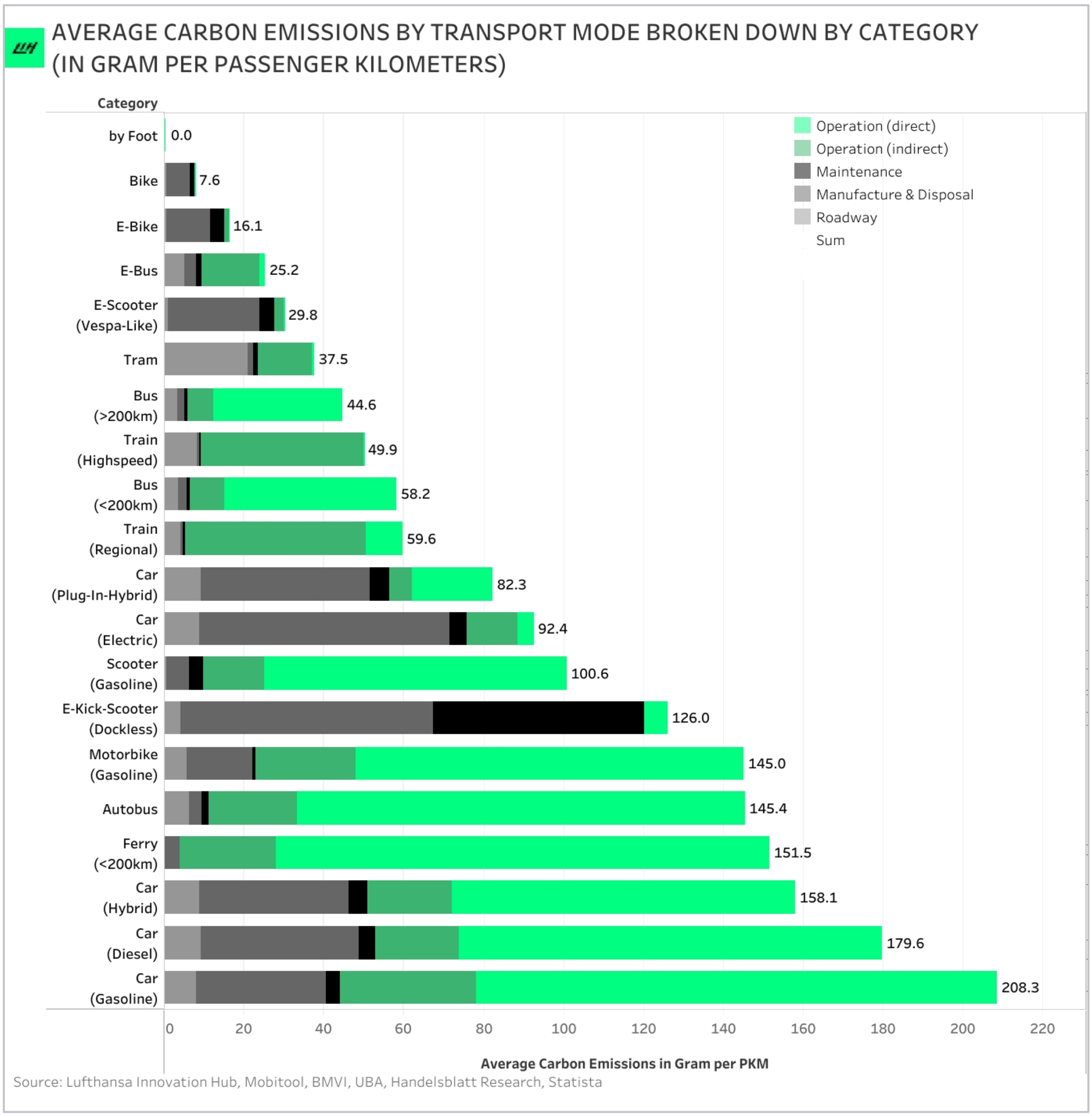

Figure 12: Average carbon emission by transport mode (g/pkm) (Source)

You will indeed notice that only a very small portion of total carbon emission of a dockless E-Kick-Scooter (compact, stand-up riding position) is originating from direct operation (green section). The most of remaining emission is discharged into the atmosphere from manufacturing and maintenance processes.[37]

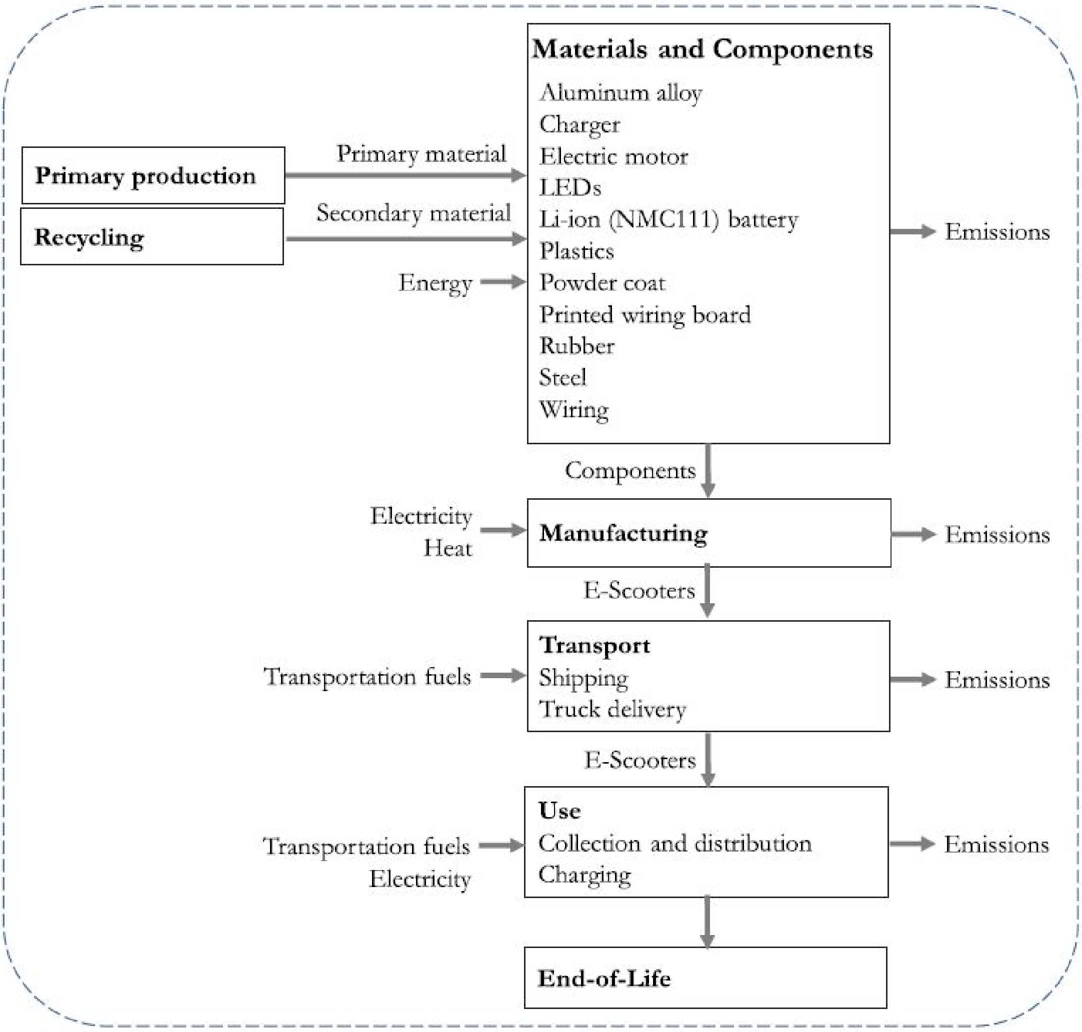

Figure 13: Sources of carbon emission throughout life cycle of an E-Scooter (Source)

Figure 13 shows that in addition to production of raw materials and manufacturing and assembly processes significant sources of emission during the life cycle of an E-Scooter are delivery of finished scooter to an end user, and collection and charging during the active and profitable phase of life cycle. Some aspects of E-Scooter environmental impact are still not fully understood. For instance, the end-of-life. How

[37] (travelandmobility.tech, 2019)

E-Scooters are recycled at the end of their useful lifecycle, and how significant is the CO_2 emission associated with it?

Let's look at direct operation carbon emission of average gasoline and diesel cars? Back at figure 12 and counting against the scale:

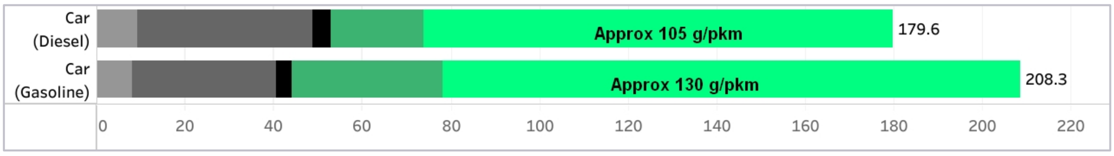

Figure 14: Estimation of MIT Carbon Emission (Source)

It comes to approximately to 105 g/pkm for an average diesel car, and 130 g/pkm for an average gasoline car. The fleet average is 117.5 g/pkm. It is important to note that the occupancy rate for both types of cars is one person.

Let's see how these European figures compare with Austrian statistics. First, what is the average fleet CO_2 emission of passenger cars registered in Austria?

	Diesel	Benzin	Flottendurchschnitt (alle Antriebe)
2000	162	176	167,3
2001	161	175	165,8
2002	161	173	164,6
2003	161	170	163,6
2004	159	168	161,6
2005	161	165	162,4
2006	164	163	163,6
2007	164	161	162,8
2008	160	155	157,7
2009	153	148	150,3
2010	145	143	144,0
2011	140	137	138,7
2012	138	134	136,2
2013	134	129	131,5
2014	131	127	128,4
2015	126	123	123,7
2016	123	122	120,5
2017	125	122	120,7
2018	129	125	123,1

Table 2: Average CO_2 emission of 1st time registered PCs in AT, 2001 – 2018 (Source)

One interesting observation: the fleet average has jumped up in 2018, after 11 years of dropping. This must be due to increased share of gasoline vehicles, in response to dieselgate scandal. The fleet average, all fuel and propulsion types combined, for year 2018, is 123.1 g/pkm.[38] What is for gasoline and diesel fueled vehicles only? We need to know the ratio between the two first.

Vorläufiger Pkw-Bestand am 31.12.2019 nach Kraftstoffarten bzw. Energiequelle
Absolut und Anteile

Kraftstoffarten bzw. Energiequelle	Dezember 2019	Anteile in %
Benzin inkl. Flex-Fuel	2,179,236	*43.2*
darunter Flex-Fuel	*5,464*	*0.3*
Diesel	2,772,854	*55.0*
Elektro	29,523	*0.6*
Flüssiggas	2	*0.0*
Erdgas	2,602	*0.1*
Benzin/Flüssiggas (bivalent)	330	*0.0*
Benzin/Erdgas (bivalent)	3,143	*0.1*
Benzin/Elektro (hybrid)	45,645	*0.9*
Diesel/Elektro (hybrid)	6,172	*0.1*
Wasserstoff (Brennstoffzelle)	41	*0.0*
Insgesamt	**5,039,548**	***100.0***

Q: STATISTIK AUSTRIA, Kfz-Statistik. - Rundungsdifferenzen nicht ausgeglichen.

Table 3: Registered vehicles in Austria by fuel type (Source)

At the end of year 2019 the ratio between gasoline and diesel propulsion in Austria was roughly 44% to 56% (hybrid types values added to respective fuel types). So, the average gasoline and diesel carbon emission is (125*0.44+129*0.56) 127.24 g/pkm. Rough fleet average from aforementioned European study is 117.5, in comparison with 127.2 figure from Austrian study, the difference of about 8%. The conclusion is that for the practical purpose results from European study are applicable for Austrian environment. Therefore, for all future considerations used will be values of **194** g/pkm for an MIT (average gross carbon footprint for both gasoline and diesel passenger cars), and **126** g/pkm for an electric scooter, with one exception – the latter value needs to be adjusted for Austrian conditions.

[38] (Schod. 2019)

1.2.8. Source of electricity in Austria and Vienna

Austria, together with Norway, lead EU28 in share of renewable energy in its electrical energy balance. At 73% (Fig 13), it more than doubles EU28 average.[39]

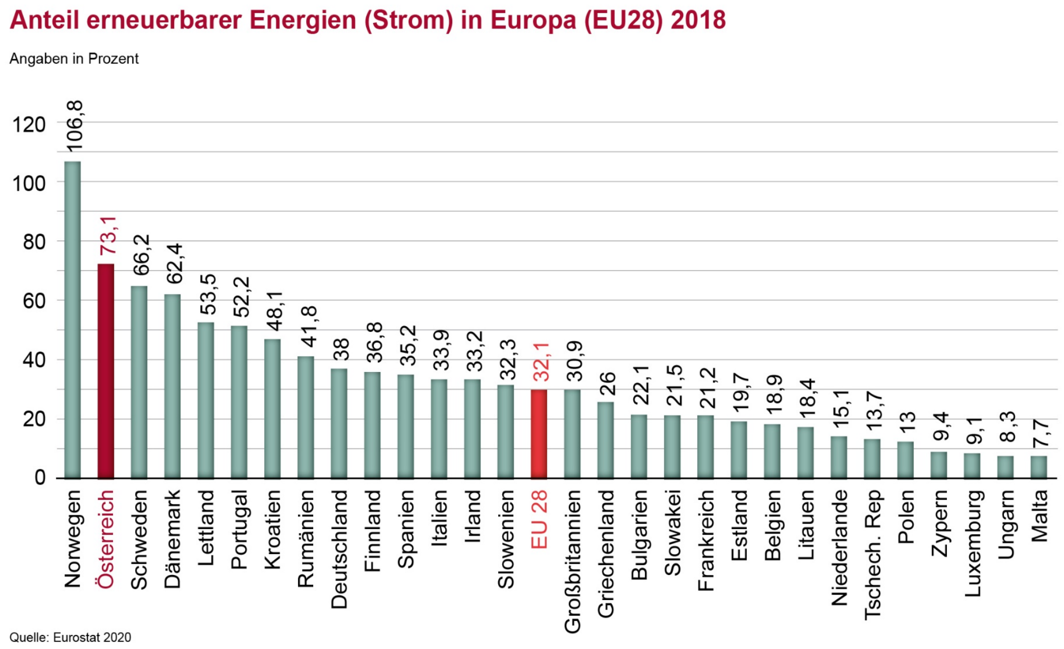

Figure 15: Share of el. energy from renewable sources in total En. Balance (Source)

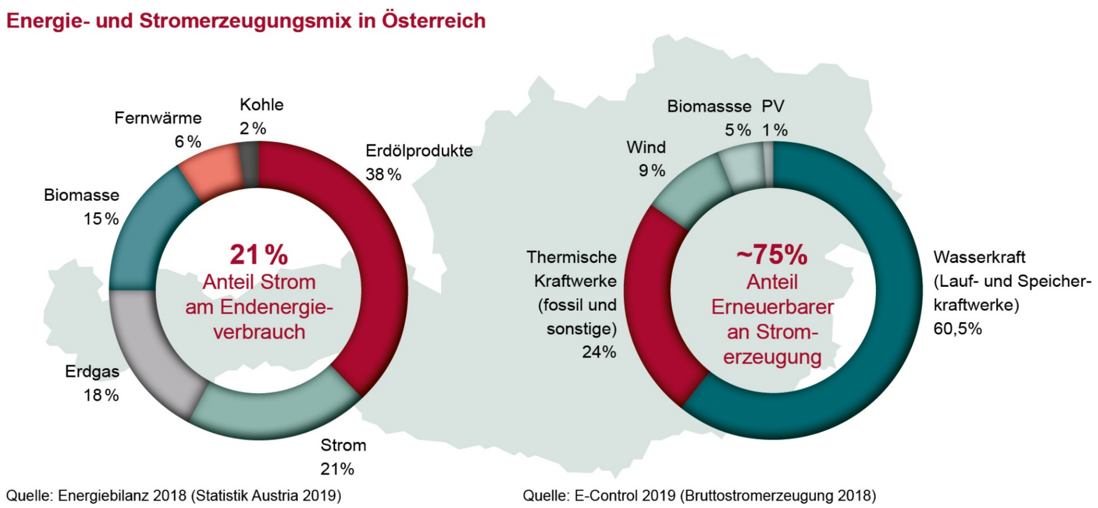

Figure 16: Energy and electricity generation mix in Austria (Source)

[39] (oesterreichsenergie, 2019)

Figure 14 shows that a share of fossil-fuel-generated electric energy in Austria does not exceed 24%. It could be that this share is even lower for city of Vienna. Below excerpt from a typical residential electrical energy bill in Vienna, section energy sources, place the share of fossil-energy sources (natural gas) in 2018 at only 11.6%:

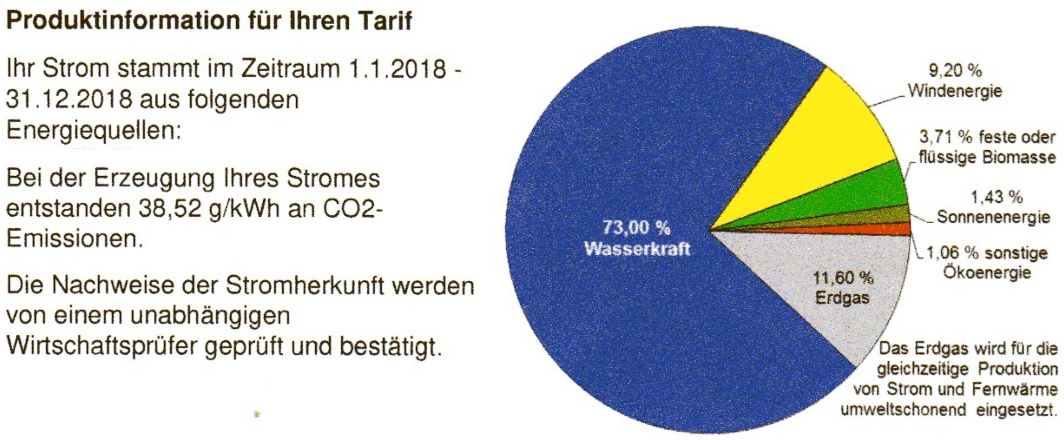

Figure 17: Wien Energy electricity bill - energy source section (Source)

Different utility companies in Austria own, maintain, and utilize different power plants. It could be that Vienna's electrical energy provider Wien Energy is profiting from nearby sources of green energy, such as Danube hydroelectric power plant, or Lower Austria wind farms. The electric energy is also hedged and traded. In any case Vienna seem to be using quite green electric energy.

Back to carbon emissions study from section 1.2.7. This study has been conducted by several German organizations and institutes, including UBA - German Environment Agency, Germany's main environmental protection agency, and BMVI – German Federal Ministry of Transport and Digital Infrastructure. The source of study info does not specify its geographical area, but since the study has been conducted by prominent German bodies, it stands to reason that study data is pertinent to German state.

What is the share of fossil fuel-generated energy in Germany? According to a study conducted by Fraunhofer ISE – for Solar Energy Systems, in year 2018 it was about 45%,[40] majority from burning hard and brown coal, but also from burning natural gas (Fig 18). It is worth noting that the share of fossil fuel-generated electric energy is being reduced sharply each year, thanks to rapid increase of solar photovoltaic and wind-power electric energy generation capacities.

[40] (Berger, B. 2019)

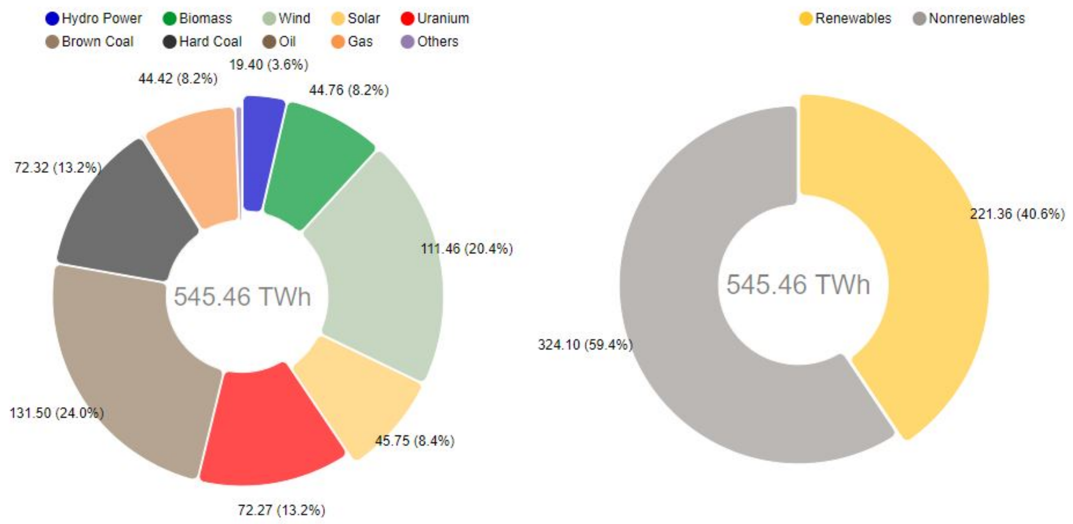

Figure 18: Net public electricity generation in Germany in 2018 ***(Source)***

The E-Scooter bar chart from German carbon emission study (Fig 12) shows that only 6 grams of CO_2 is released for each ridden kilometer, and released indirectly, through generation of electric energy.

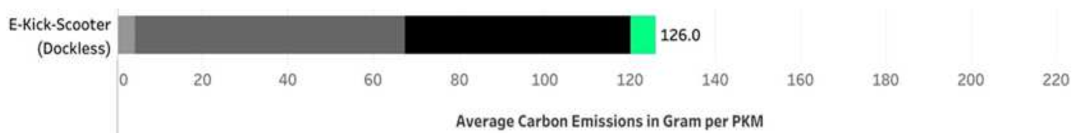

Figure 19: Structure of E-Scooter Carbon Emission ***(Source)***

Let's stick with 24% figure for Austria. E-Scooter is powered exclusively by electric energy, so if an E-Scooter indirectly emits 6 grams of CO_2 for each covered kilometer in Germany, in Austria this value should not exceed 3.2 grams (6/(45/24)) per ridden kilometer. For all future considerations in this study used will be values of 194 g/pkm for an MIT (average gross carbon footprint for both gasoline and diesel passenger cars), and 123 g/pkm for an electric scooter.

1.2.9. Status of E-Scooter Industry in Selected European Cities

Currently, the E-Scooter industry is facing an uphill battle in most European cities. The city regulators are moving rapidly to eliminate the legal grey areas and permanently regulate the E-Scooter sector. E-Scooter operators are forced to rethink their business models and strategies. E-Scooter must improve its safety and reliability record in order to achieve stronger public and social acceptance and better environmental performance, and the E-Scooter vendors must find ways to assure that their customers are staunchly and consistently obeying all laws and regulations. In addition, E-Scooters are expected to further evolve, through innovation, to be able to function better and safer in adverse weather conditions, such as rain, snow, and ice. Many experts consider the current situation just an intermission between two phases of E-Scooter deployment. "A lot of people look at scooters and think that that's kind of the end game, but it's really just the first incarnation."[41]

Degree of how smart and sustainable a city is - and consequently, how developed its E-Scooter micro-mobility concept is – appears to closely correspond to GDP of those cities.[42] Figure 20 is showing this relationship.

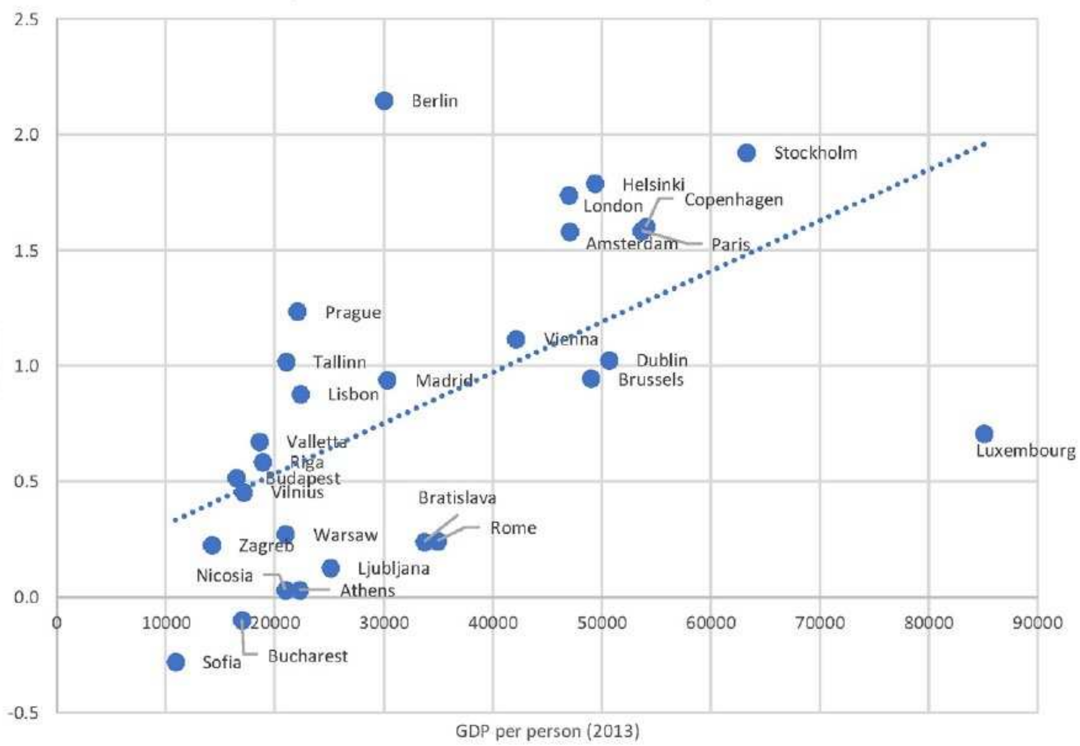

Figure 20: Smart and sustainability ranking and GDP of EU-28 capital cities (Source)

There are some exceptions to this GDP rule: Capital cities of Berlin and Luxembourg. Berlin is ranking highest in smart and sustainability rating, while having quite low GDP. It is a matter of prioritization; Berlin's city officials have recognized E-Scooters as a convenient mean to relieve the heavy traffic and congestions in the city center.

[41] (Collins, 2019)

[42] (Akande, A., Cabral, P., Gomes, P., Casteleyn, S., 2018)

Therefore, Berlin quickly moved to approve no less than five E-Scooter sharing operators (Lime, Vio, Bird, Tier and Circ), and to build infrastructure needed for convenient and efficient renting operation.[43] But at the same time Berlin and Germany quickly moved to regulate E-Scooters operation. As of June 2019, E-Scooters must not share infrastructure with pedestrians, but can use bicycle lanes or even roads when other alternative doesn't exist, its power output and maximum speed are limited, and the insurance policy is mandatory.[44]

Luxembourg, on the other hand, is showing very little interest in implementing E-Scooters, despite having very rich population. As of end of October 2019, the major of Luxembourg was firm in her decision to refuse access of market to E-Scooter operators. One of them, Bird, attempted to introduce and deploy a fleet of 250 E-Scooters without authorization. Those were quickly removed on safety grounds. Luxembourg city officials are currently working on legislations that will closely mirror German ones.[45]

With its narrow and steep streets and sidewalks, Portuguese capital Lisbon is especially sensitive to improper parking practices. E-Scooter vendors have quickly understood the importance and provided their customers with guidelines for responsible parking. Users, however, did not follow the suit, prompting Lisbon to introduce hefty fines.[46]

Out of all European capitals the city of London is perhaps the least tolerant towards E-Scooter. As of today, E-Scooters are still illegal in London and United Kingdom. They cannot be used on public roads and pavements, only on private ones. But there is a growing pressure to legalize E-Scooters, heavy scrutiny and regulations being prerequisites. The younger generation is particularly concerned: 60 % of 18 to 24-year-olds supports E-Scooter legalization. Big vendors are also lobbying by emphasizing the environmental benefits. These combines pressures seem to slowly bring about a change: British legislators are finally moving to legalize E-Scooters, albeit by imposing conditions such as restrictions on use (roads and bike lanes only), and maximum speed, weight, and power, and mandating use of safety equipment.[47]

Paris is one of pioneers of E-Scooter micro-mobility concept. It allowed public E-Scooter service in 2018, and by following year a dozen of operators offered their fleets and services to both locals and tourists. Unfortunately, the regulation activities did not

[43] (Berlin.de, 2019)
[44] (Olk, 2019)
[45] (Bauldry, 2019)
[46] (Lusa, 2019)
[47] (Dathan, 2019)

keep the pace with the rapid growth of E-Scooter services, so the chaos ensued. Soon, Paris became an example of what could go wrong with E-Scooters. 20000 poorly managed E-Scooters literally polluted the city. After initially giving chance to E-Scooter operators to clean up their act, Paris City Hall took more active role and introduced a set of regulations on speed and parking, as well as some severe restrictions on scope of deployment. The City Hall has limited the number of operators to only three and restricted the size of their fleet to 2000 devices each. In addition, the city officials have submitted E-Scooters under French highway code, effectively subjecting them to standard rules of the road.[48]

1.2.10. Status in Inner City Vienna

1.2.10.1. Deployment Volume and Operators

As of February 2020, nine operators are providing short-term hiring of E-Scooters in city of Vienna. Those are: Bird, Lime, KiwiRide, Circ (formerly Flash), Hive, Holmi / Rollmi, animal, Wind / Byke, and Max Motion. Three more providers, Arolla , Voi and Bolt, showed their interest in 2019 to enter the Viennese E-Scooter market, but their entries are still pending.[49]

Regarding the number of E-Scooters deployed on streets, the full capacity as permitted by city authorities has not yet been reached. Each operator is allowed a fleet numbering 1500 E-Scooters. Currently there are 9000 registered E-Scooters in city of Vienna, only two-thirds of permitted number.[48] Most E-Scooters are deployed close to city center, conveniently available to tourists and visitors. Most operators offer similar prices and conditions:

Provider	Base price per trip	+ Price per min.
Lime	€ 1.00	€ 0.20
Bird	€ 1.00	€ 0.27
animal	€ 1.00	€ 0.18
Wind / Byke	€ 1.00	€ 0.15
Circ	€ 1.00	€ 0.15
Hive	€ 1.00	€ 0.15
KiwiRide	€ 0.99	€ 0.19
Holmi / Rollmi	€ 1.00	€ 0.15
Max Motion	€ 1.00	€ 0.25

Table 4: Price Comparison Between Vienna E-Scooter Providers (Source)

[48] (The Local France, 2019)
[49] (Schögl, 2020)

The strong competition is resulting in reasonable prices for riders. There are other benefits from this contest: some of operators are offering special and novelty services, such as “winter service”. Three operators, Lime, Tier, Circ and KiwiRide, are allowing their E-Scooters to be rented throughout winter months, with exception of harsh winter storms.[48] This year’s very mild winter proves their strategy right. Another special provided by Circ is all-night renting option- all other operators collect their scooters at the end of day.[48]

Vienna providers all have similar requirements for renting their E-Scooters. Riders must be at least 18 years old, and must possess monetary collateral for reserving, renting, and fining expenses, collateral such as credit card, debit card, PayPal, Google Pay, and even "Sofortüberweisung" service – an option for quick transfer of funds from a bank account. In addition to short-term renting some providers are offering longer-period rents, up to a month.[48]

Needless to say, all potential users must have installed proprietary applications for mobile devices. Besides allowing for a quick and convenient renting, these apps also visualize availability and location of E-Scooters. Finally, the applications are also instructing the riders on where the E-Scooters can be ridden and parked without risking fines.[48]

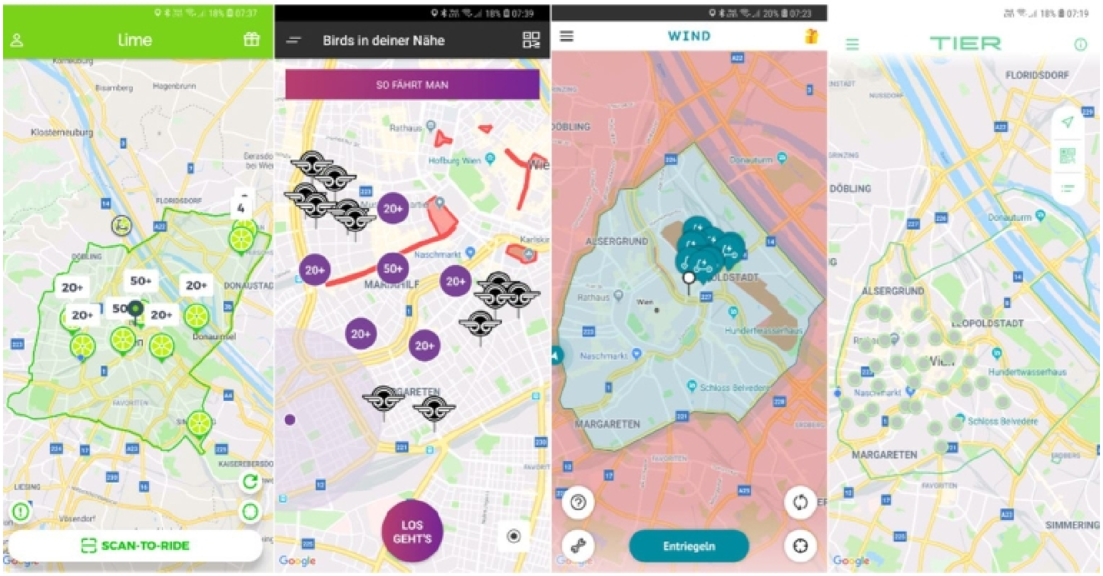

Figure 21: Samples of screenshots of E-Scooter rent applications (Source)

Figure 21 is showing examples of E-Scooter renting applications. It is interesting to note that the operators are strategically placing their fleets close of most dense pedestrian areas such as entire first district and Mariahilfer Strasse, and also in areas where their main target population – young people – are congregating, popular spots such as Sweedenplatz and MuseumsQuartier.

1.2.10.2. Service Model and Share in Current Modal Mix

Service model employed by Viennese E-Scooter vendors is so-called free-floating systems which do not require fixed locations. E-Scooters are available for spontaneous hiring and use. All E-Scooters operators in Vienna are employing so called dockless devices. That means that there is no dedicated publicly-accessible charging stations, and that therefore riders are not responsible for the charging of devices. Instead, operators collect all their scooter at the end of the day, take them to a dedicated charging and service facility, charge them overnight, and drop them off to authorized locations following morning.

Figure 22: Drop-off of E-Scooters in Vienna's first district (Source)

Let's take a look at several modal mix (a.k.a. modal share or modal split) studies. Wiener Linien study (Fig 23) from 2018 shows a sharp drop in private motor traffic and significant increase in use of public transportation since 1993. There is an increase in share of eco-friendly mode of transport, with some walking substituted by cycling. Interestingly, there is no mention of E-Scooter in this 2018 study. Vienna possesses arguably the World's best public transportation system, with fantastic degree of accessibility and availability - 97 percent of Vienna's population lived within 500 meters from a metro or S-Bahn station, or 300 meters from another form of public transportation such as tram or bus.[50] Under those conditions is there really a need for motorized (electrified) first mile-last mile mobility solution? Nothing gets eco-friendlier than walking. Could the following be the reason why E-Scooters appear omitted from this urban mobility study?

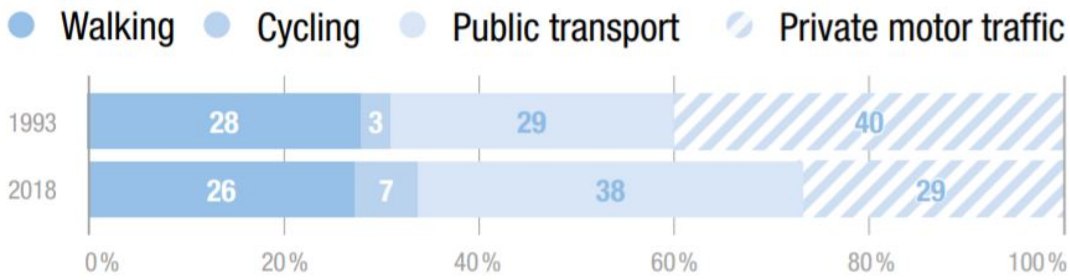

Figure 23: Vienna modal mix change 1993-2018, Wiener Linien [(Source)]

Here is another study, created by Stephan F. Steinbach using data from Vienna's municipal department for energy planning - Magistratsabteilung MA 20. The data are extrapolated to year 2030:

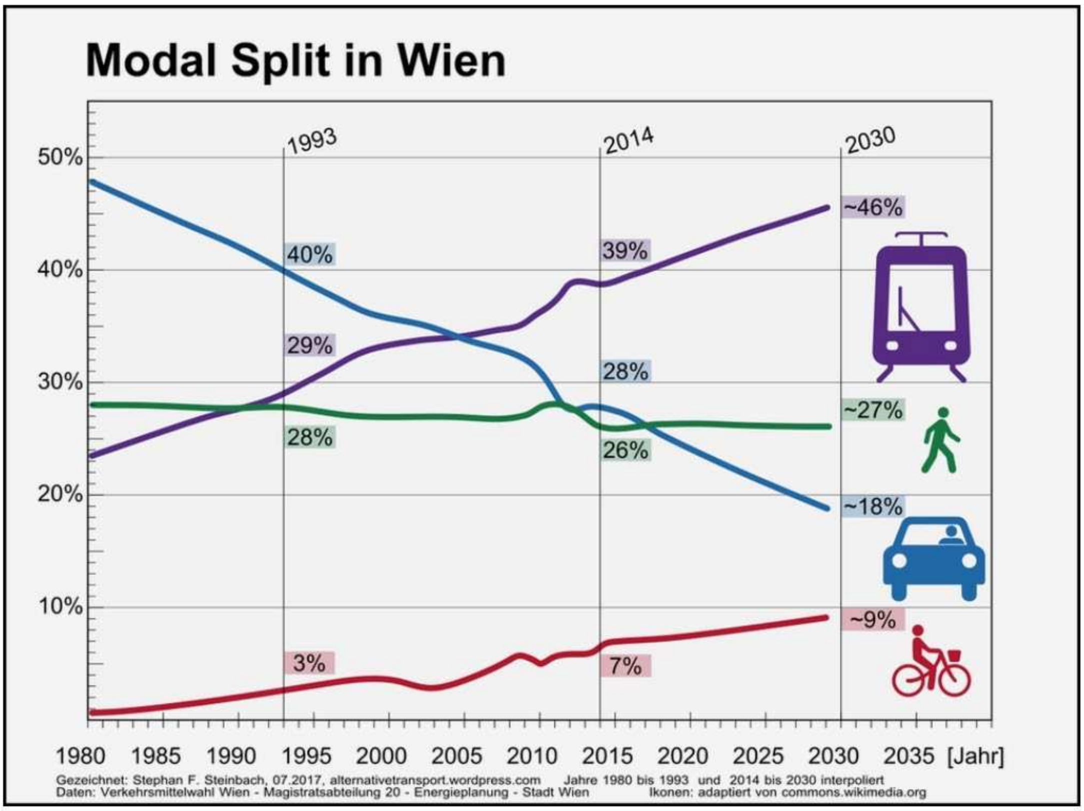

Figure 24: Vienna modal mix change 1980-2030 [(Source)]

[50] (Wiener Stadtwerke 2015)

There is very little difference between present time data from Wiener Linien and Alternative Transport studies. The share of Motorized Individual Transport should drop down to 18% by year 2030.

A major study from 2014 called STEP 2025 (STEP - short for Stadtentwicklungsplan – city development plan) laid down the foundation for urban development and urban mobility plans until year 2025.[51] According to it, by year 2025 the modal mix should be 80% / 20% mix between eco-mobility and car traffic.

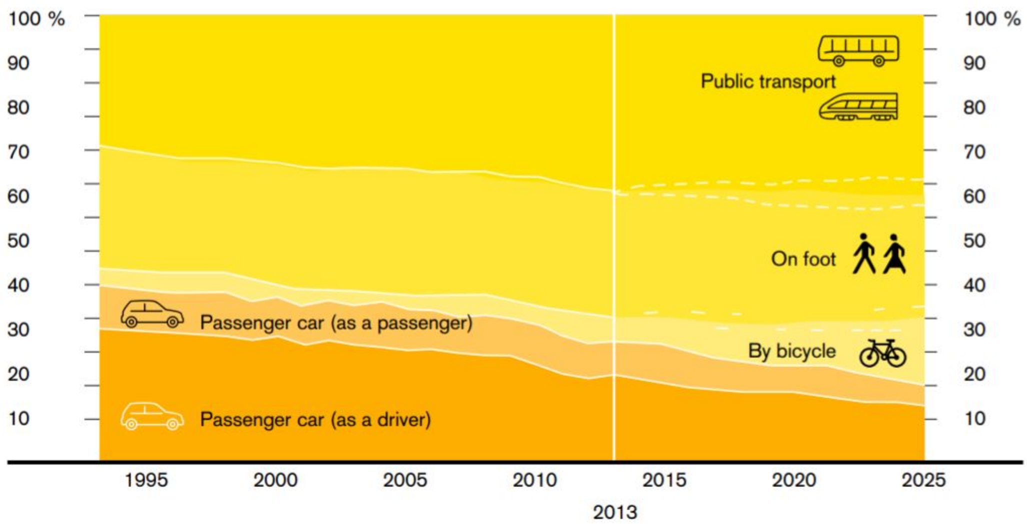

Figure 25: Modal mix in Vienna per STEP 2025 (Source)

While the focus of STEP 2025 is on "a new mobility culture" and "multi-modal transport from door to door"[50] there is again no mention of E-Scooter, or any other form of electrified micro-mobility solution. E-Scooters are relatively new phenomenon, the massive public showing in Vienna has started only a couple years ago. Most of mentioned studies predate the mass implementation of E-Scooters - could it then be that they were not recognized as a significant factor due to their anonymity?

1.2.10.3. Impact on Environment

Presently there is no publicly available data that can help quantify the effect on environment E-Scooters might be making in inner city Vienna. The assumption is that this effect is positive only in case E-Scooter rides are substituting MIT drives.

[51] (STEP 2025, 2014)

One study (Fig 26) places Vienna’s first district bicycle ridership at low 4%, or even lower. Considering the size and structure of first district, it stands to reason that most residents, employees, and visitors are either walking, using public transportation, and to a lesser extent use their private motorized individual transport.

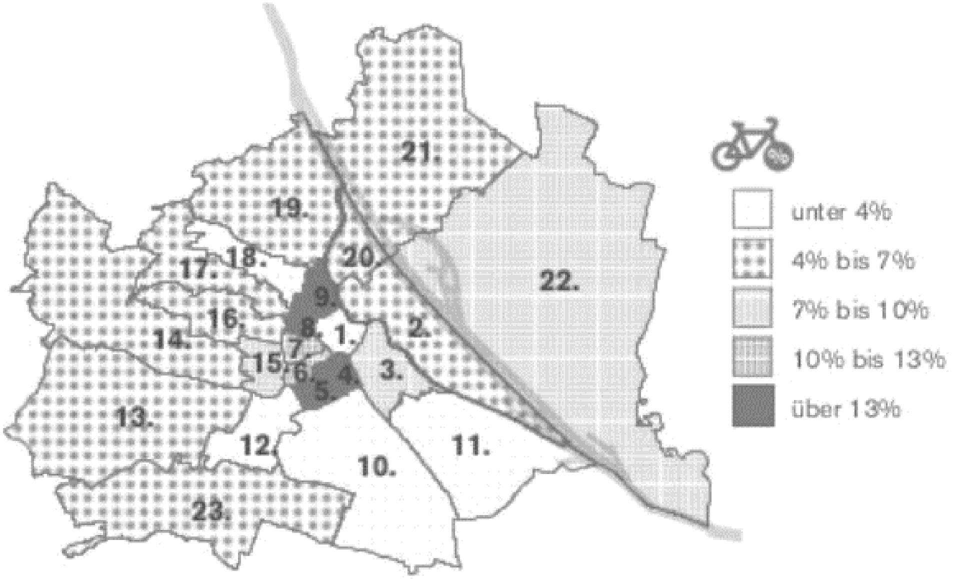

Figure 26: Share of bicycle transport among Vienna's districts (Source)

There is an interesting recent news from city of Graz.[52] The Graz city authorities still do not allow E-Scooters on their streets, reason being they are not convinced that E-Scooters have a positive impact on environment. They cite three main reasons: 1) an extremely short lifespan mandates frequent replacements that in fact have a negative impact on environment, 2) average E-Scooter user is otherwise a pedestrian or a public transportation user, and 3) E-Scooters mingle with bicycle traffic within dedicated bicycle infrastructure (paths), and by doing it they end up discouraging bike users from doing their daily routine.[51]

The practical part of this thesis will attempt to provide an answer, by determining what share of current motorized vehicles would be willing to swap their mode of transportation for an E-Scooter.

[52] (Stoyanov, 2019)

1.2.10.4. Compatibility with Current Traffic Regulations

In autumn of 2018, only a couple short months after introduction of E-Scooters in Vienna, it became apparent that some sort of regulation is necessary. E-Scooters quickly turned into obstructions for pedestrians, despite fleets from two operators being quite modest in numbers. Complaints from Vienna residents prompted an agreement between Vienna's Chamber of Commerce and the pioneer provider Lime. The objective of these rules was to, above all, regulate the sidewalk congestions and parking. As a result, no-parking zones, identified on mobile apps required for borrowing, were introduced. Penalties, enforced by providers on borrowers in form of an additional EUR 25 fee, were introduced for improper parking. Operator was also to be promptly informed when an E-Scooter is left in a non-parking zone, such as heavy-traffic pedestrian zones. Additionally, automatic speed limits, where the speed of an E-Scooter is reduced down to walking pace, were introduced for special pedestrian zones exempt from riding bans, such as Mariahilfer Straße.[53] It is important to note that these rules were proposed and voluntarily enforced by E-Scooter operators, not the city.

The first attempt to officially regulate the E-Scooters took place on June 1st, 2019, with introduction of 31st amendment of StVO (Straßenverkehrsordnung – Austrian road traffic regulations). The amendment was necessary to regulate somewhat chaotic situation with E-Scooters in Vienna. The regulation is quite broad and regulates not just the traffic use of E-Scooters, but also the mandatory technical and safety equipment they must be equipped with. In addition, the amendment is also valid in all federal states in Austria.[54]

E-Scooters were classified in two categories. Ones with installed power exceeding 600 watts, and top speed exceeding 25 km/h, were defined as motor bikes, in other words mopeds. Regulations were matching those for mopeds, meaning mandatory are minimum age of rider, set at 15 years, an appropriate driving license, registration and license plate, as well as a liability insurance. The use is permitted only on public roads reserved for motor vehicles.

The second category of E-Scooters are the small vehicles intended for use outside the roads. With installed power and speed not exceeding 600W and 25 km/h they are considered compatible with both electro-assisted and human-powered bicycles and therefore allowed to share the same infrastructure, i.e. designated

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[53] (Rachbauer, 2018)
[54] (Autorevue Online, 2019)

bicycle paths. Furthermore, all traffic rules and regulations applicable to e-bikes and traditional bikes also applies to this category of E-Scooters. If bicycle infrastructure exists, then E-Scooters must be used on it. If it doesn't exist, the streets meant for motorized traffic can be used, but in the same manner as bicycles. Driving on sidewalks is strictly prohibited, unless there is an exemption authorized by authorities (for example where only other option is unsafe use of a motorized traffic road), in which case E-Scooters can use a sidewalk at speeds that nor exceed a walking pace. E-Scooters can also be used in pedestrian zones and residential streets, but again only at speeds not exceeding the pace of a pedestrian traffic. Driving against the traffic flow in one-way streets is allowed wherever the same is permitted for bicycles. Parking on the sidewalk is permitted only a sidewalk is at least 2.5 meters wide.

The new rules and regulations are also defining the behavior and responsibilities of E-Scooter riders. The passengers are prohibited; only the person operating the scooter is allowed to ride. As with bicycles, use of telephones is not allowed; hands-free devices are exempt. Age limit for road use of E-Scooters is 12. Younger children are allowed to accompany riders older that 16, and the use of safety helmet is mandatory for those children younger than 12. Regarding the alcohol limit, the same rules as for bicycles apply: the blood alcohol content may not exceed 0.08%. One departure from bicycle traffic rules is that hand signals when turning are not required, reason being that taking one hand from handlebars can lead to loss of control and accident. Legislators are working on a solution for this problem.[52]

Mandatory E-Scooter equipment is also defined in new rules. Applicable are the same rules that apply to bicycles, and they are mostly focused on safety of riders and other traffic participants. E-scooters must be equipped with an effective braking device and set of lights, reflectors, and/or reflective foils, white in front, yellow on side, and red in rear.[52]

It soon became obvious that the present set of rules and regulations, despite seeming comprehensive and robust, still does not address all aspects of E-Scooter use. Therefore, a revision of regulations will be rolled out soon.

1.2.10.5. Upcoming Regulations and Their Expected Effect

First six months of E-Scooter regulations of E-Scooters in Vienna revealed some shortcomings. Problems related to improper and reckless use of E-Scooters persisted. Therefore, a new, 9-points set of additional rules is planned to become effective in April 2020.[52]

A major reduction of fleet size is planned. Providers will be required to drastically downsize their fleets in several city districts, including first, to only 500 E-Scooters, down from 2000. The parking rules will be tightened: minimum width of a sidewalk appropriate for parking will be increased from 2.5 meters to 4 meters. The duration of parking will be limited to two hours, down from current 4-12 hours. Designated, marked park spaces will be introduced, a pilot project in district Neubau is ongoing. A new rule concerning noise pollution will be introduced: Parked E-Scooters will no longer be permitted to emit acoustic location signals.[52]

A special emphasis will be on enhancing connectivity and communication. E-Scooters operators will be required to share important information with its clients. This includes, for example, instructions about correct use of the vehicle, available and restricted parking, speed limits, prohibited driving zones, temporary driving bans, etc. E-Scooters will also be equipped with an automatic electronic speed control capable of enabling mandatory speed limits in certain areas.[52]

The updated regulation is expected to have a diverse and positive effect. The accumulation of E-Scooters in districts will be reduced, and with it visual, physical and noise pollution. Level of vandalism will probably be diminished. Pedestrian safety is also likely to get improved.

1.2.10.6. Strategy (within Vienna Smart City Framework)

When judged by publicly available facts only, at this time it is unclear in which direction the E-Scooter concept is heading in Vienna. E-Scooter prospects don't not seem to be investigated in any recent city development study. It is thesis author's opinion that share of E-Scooter in modal mix in Vienna's inner city will continue to shrink, due to following reasons: Because of modest distances and great coverage of public transportation, walking and riding public transportation will remain preferred mode of last and first mile transportation. Another reason is that E-Scooters do not mix well with pedestrians, and therefore Vienna authorities will continue tightening the rules and reducing the scope for E-Scooters used by tourists and visitors. Finally, unless and until the carbon footprint of an E-Scooter is drastically reduced, the environmental factor alone will not warrant the reversal of present course.

2. Practical Part

2.1. Analysis of MIT Reduction Potential

The following empirical research will focus on answering three main research questions:

1. What is the annual volume of motorized individual transport in inner city Vienna – Vienna's first district – in number of movements per year?

2. What percentage of commuters - both residents and visitor workers that usually depend on motorized individual transport - would be willing to change their behavior and switch to eco-friendlier E-Scooter for their daily travel within limits of Vienna's first district?

3. Will there be an opportunity for E-Scooters to make a positive impact on environment and lives of Vienna's residents? Are E-Scooters here to stay?

To obtain those answers, three separate studies were conducted. For traffic volume, the actual traffic movement were observed, and quantitative data collected. For behavior probe, both quantitative and qualitative data were collected using a questionnaire distributed in and returned from first district. Data from two studies is used to calculate potential annual reduction of CO_2 emission in inner city Vienna. Finally, questions regarding E-Scooters' role in Vienna's mobility strategy are answered with a help from Vienna city officials.

2.1.1. Description of the Methodical Approaches

The data for the annual volume of motorized individual transport in inner city study was collected by a counting and recording number of vehicles entering and exiting the first district on 33 entrances/exits along Ringstraße and Franz-Josefs-Kai. The counting was conducted over the specific period of time and resulting figure extrapolated into one-year period.

The potential for change in behavior of current MIT users was surveyed using a traditional printed questionnaire. A ten-questions form was distributed to alleged MIT users within first district, to be mailed back for evaluation.

The issues related to Vienna mobility strategy, sustainability, and long-term effect were addressed in an interview with Vienna city officials. More details on all three methodical approaches can be found in following subchapters.

2.1.2. Determination of current MIT Volume in Inner City Vienna

2.1.2.1. Vehicle Count Study

In order to have this quantification study properly interpreted and understood, a couple assumptions must be accepted:

- What comes in must come out, the number of vehicles entering the first district must match the number of vehicles exiting it in a long run. To reflect this entries and exits were counted and recorded without making distinction and recorded as simple vehicle movements. However, the distinction was made between two categories of vehicles, motorized individual transport - personal private vehicles - and commercial vehicles. Because E-Scooters cannot substitute commercial vehicles for activities those commercial vehicles are designed to fulfil, the study is dealing only with MIT movements. Following types of vehicles are classified as commercial, and thus excluded from the count: taxis, vehicles for hire such as passenger vans and limousines, public busses, ambulances, fire brigade vehicles, police cars and vans, municipal and utility vehicles (Wiener Linien, Wiener Netze, Wien Energy etc.), garbage trucks, and any other commercial and delivery vehicle. Excluded from the study were electric vehicles (mostly Teslas, some Nissan and Hyundai EVs), and Car Sharing services vehicles (car2go, DriveNow, etc.).

- The variations in throughput are proportional, but at different times. For instance, a surge in inflow in the morning will result in a surge in outflow in the afternoon. The fact that no distinction is made between inflow and outflow, and that only the combined movement of cars is recorded, allows for “transplantation” of traffic volume curve from an established metering point to any other metering point, under condition that the recipient metering point contains one reference value. It is also due to practicality; It is virtually impossible to collect data from all metering points for all times of the day, or all days of the month, or all months of the year. Therefore, the solid baseline was established using the data from one prevalent metering point, namely the Kärntner Straße. Again, it stands for reason that traffic volumes on the rest of metering points is proportional to traffic on these four points, so the baseline percentage profile was duplicated on the rest of metering points. The vehicle counts were performed on both weekdays and weekends. Day values were then extrapolated into months and year, with holiday months reduced by 20%.

Single measurements were taken at weekdays and weekends at each one of 33 metering points (entry/exit points), at locations shown below:

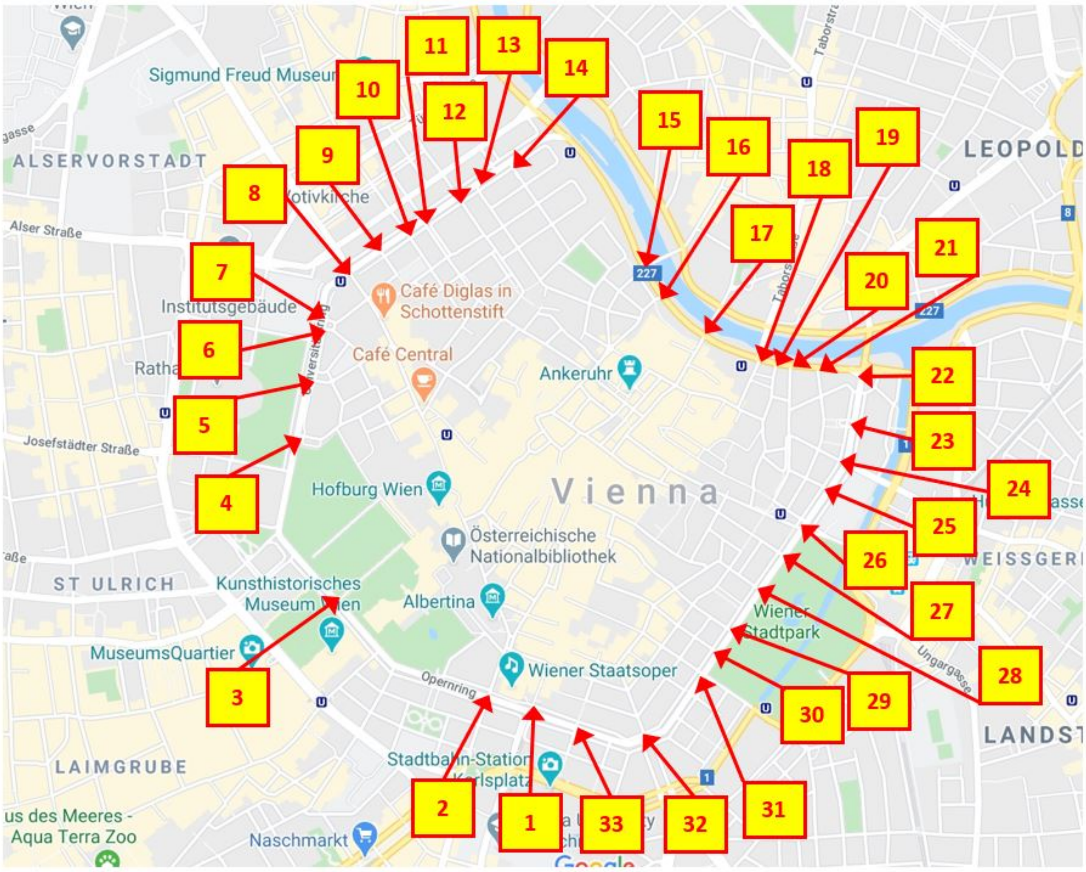


Figure 27: Observed metering points along 1st district's perimeter (Source)

The metering points were located on intersections between Ringstraße and Franz-Josefs-Kai, and following streets:

1. Kärntner Str.
2. Operngasse
3. Heldenplatz /Burgtor
4. Josef-Meinrad-Platz
5. Löwelstraße
6. Schreyvogelgasse
7. Mölker Bastei
8. Schottengasse
9. Heßgasse
10. Hohenstaufengasse
11. Wipplingerstraße
12. Börsegasse
13. Neutorgasse
14. Gonzagagasse
15. Salztorgasse
16. Morzinplatz
17. Rotenturmstraße
18. Laurenzerberg
19. Postgasse
20. Dominikanerbastei
21. Biberstraße
22. Julius-Raab-Platz
23. Georg-Coch-Platz
24. Rosenbursenstraße
25. Falkestraße
26. Dr.-Karl-Lueger-Platz
27. Zedlitzgasse
28. Liebenberggasse
29. Weihburggasse
30. Himmelpfortgasse
31. Johannesgasse
32. Schwarzenbergstraße
33. Max-Weiler-Platz

A 30 minutes vehicle count was performed at all these locations, except the Kärntner Straße, which was subjected to much more detailed scrutiny. Counts were taken on different times of the day, and separately on workdays, Saturday, and Sunday. These measurements served as reference points for applying the baseline profile delivered from detailed Kärntner Straße count.

Kärntner Straße count was taken over period of four-week days, and one weekend, both days. Many 30-minute counts were made, at different times of day, different ends of spectrum, very early, very late, midnights and middays, mornings and evening, traffic peak hours and lulls. The chronological density of obtained data was good, therefore there was no need for intensive intrapolation to get the accurate traffic volume vs. time curve. The results are shown in tables below.

Average on weekdays:

Kärntner Straße	Monday	Tuesday	Wedneday	Thursday	Average	% of Peak
00:00 - 00:30	35	40	31	38	36	14%
00:30 - 01:00	37	33	37	24	33	12%
01:00 - 01:30	18	18	21	19	19	7%
01:30 - 02:00	22	16	18	20	19	7%
02:00 - 02:30	15	12	16	18	15	6%
02:30 - 03:00	12	13	9	11	11	4%
03:00 - 03:30	9	10	7	8	9	3%
03:30 - 04:00	7	6	4	8	6	2%
04:00 - 04:30	8	6	12	7	8	3%
04:30 - 05:00	34	40	38	41	38	14%
05:00 - 05:30	50	46	49	52	49	19%
05:30 - 06:00	78	77	80	74	77	29%
06:00 - 06:30	117	122	120	117	119	45%
06:30 - 07:00	148	155	147	152	151	57%
07:00 - 07:30	175	174	180	171	175	66%
07:30 - 08:00	215	212	220	221	217	82%
08:00 - 08:30	198	202	189	212	200	76%
08:30 - 09:00	184	192	185	199	190	72%
09:00 - 09:30	152	162	155	157	157	59%
09:30 - 10:00	146	147	154	155	151	57%
10:00 - 10:30	124	121	117	127	122	46%
10:30 - 11:00	113	111	107	122	113	43%
11:00 - 11:30	134	133	142	130	135	51%
11:30 - 12:00	143	147	140	150	145	55%
12:00 - 12:30	150	154	147	148	150	57%
12:30 - 13:00	147	144	137	152	145	55%
13:00 - 13:30	124	123	119	122	122	46%
13:30 - 14:00	138	142	133	142	139	53%
14:00 - 14:30	165	170	154	172	165	63%
14:30 - 15:00	151	147	150	144	148	56%
15:00 - 15:30	172	180	202	199	188	71%
15:30 - 16:00	181	190	208	174	188	71%
16:00 - 16:30	189	192	204	168	188	71%
16:30 - 17:00	212	201	218	208	210	79%
17:00 - 17:30	248	256	296	257	264	100%
17:30 - 18:00	198	202	187	203	198	75%
18:00 - 18:30	229	241	202	222	224	85%
18:30 - 19:00	172	182	178	184	179	68%
19:00 - 19:30	167	170	182	157	169	64%
19:30 - 20:00	150	147	139	157	148	56%
20:00 - 20:30	165	172	154	166	164	62%
20:30 - 21:00	187	188	201	194	193	73%
21:00 - 20:30	199	202	203	208	203	77%
21:30 - 22:00	145	154	143	154	149	56%
22:00 - 22:30	125	134	133	127	130	49%
22:30 - 23:00	104	108	102	97	103	39%
23:00 - 23:30	65	58	68	71	66	25%
23:30 - 00:00	48	43	37	49	44	17%

Table 5: Averaged count of MIT traffic through Kärtner Straße on weekdays (Source)

Average on weekend days:

Kärntner Str.	Saturday	Sunday	Average	%
00:00 - 00:30	52	46	49	24%
00:30 - 01:00	45	48	47	23%
01:00 - 01:30	22	32	27	13%
01:30 - 02:00	25	31	28	14%
02:00 - 02:30	23	18	21	10%
02:30 - 03:00	18	16	17	8%
03:00 - 03:30	12	18	15	7%
03:30 - 04:00	11	16	14	7%
04:00 - 04:30	9	12	11	5%
04:30 - 05:00	7	24	16	8%
05:00 - 05:30	18	28	23	11%
05:30 - 06:00	33	42	38	18%
06:00 - 06:30	27	56	42	20%
06:30 - 07:00	47	53	50	24%
07:00 - 07:30	73	65	69	33%
07:30 - 08:00	87	60	74	36%
08:00 - 08:30	112	74	93	45%
08:30 - 09:00	115	77	96	47%
09:00 - 09:30	137	85	111	54%
09:30 - 10:00	145	76	111	54%
10:00 - 10:30	155	72	114	55%
10:30 - 11:00	167	87	127	62%
11:00 - 11:30	175	98	137	66%
11:30 - 12:00	187	98	143	69%
12:00 - 12:30	199	99	149	72%
12:30 - 13:00	197	112	155	75%
13:00 - 13:30	206	114	160	78%
13:30 - 14:00	176	108	142	69%
14:00 - 14:30	165	116	141	68%
14:30 - 15:00	154	118	136	66%
15:00 - 15:30	157	122	140	68%
15:30 - 16:00	144	131	138	67%
16:00 - 16:30	167	128	148	72%
16:30 - 17:00	177	122	150	73%
17:00 - 17:30	184	108	146	71%
17:30 - 18:00	278	117	198	96%
18:00 - 18:30	301	110	206	100%
18:30 - 19:00	257	102	180	87%
19:00 - 19:30	189	98	144	70%
19:30 - 20:00	175	101	138	67%
20:00 - 20:30	195	87	141	68%
20:30 - 21:00	201	81	141	68%
21:00 - 20:30	225	74	150	73%
21:30 - 22:00	176	83	130	63%
22:00 - 22:30	165	64	115	56%
22:30 - 23:00	154	52	103	50%
23:00 - 23:30	147	41	94	46%
23:30 - 00:00	126	31	79	38%

Table 6: Averaged count of MIT traffic through Kärntner Straße on weekends (Source)

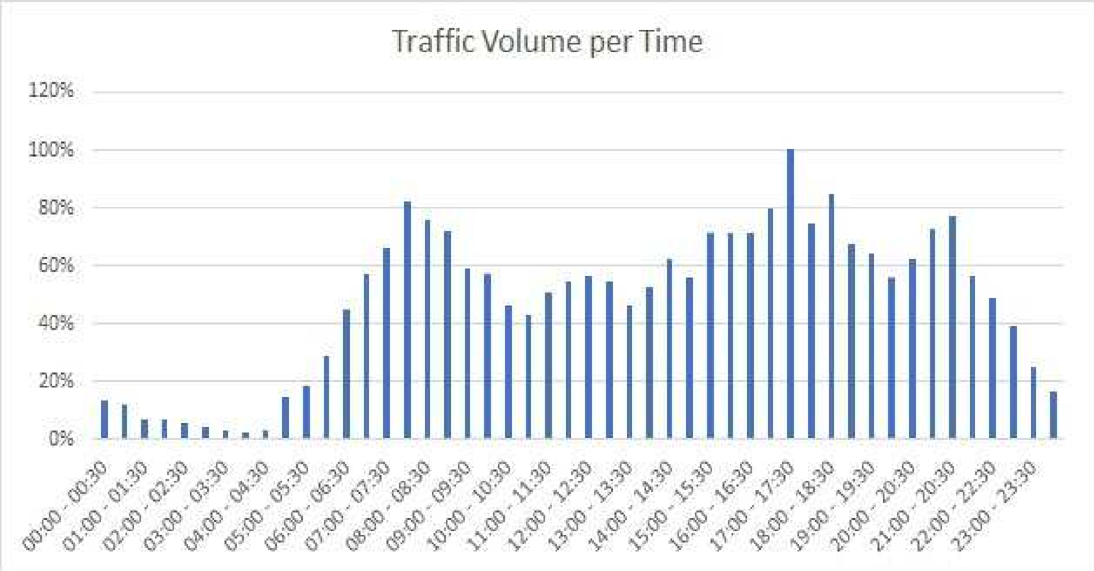


Chart 1: Traffic Volume Kärtner Straße Weekday (Source)

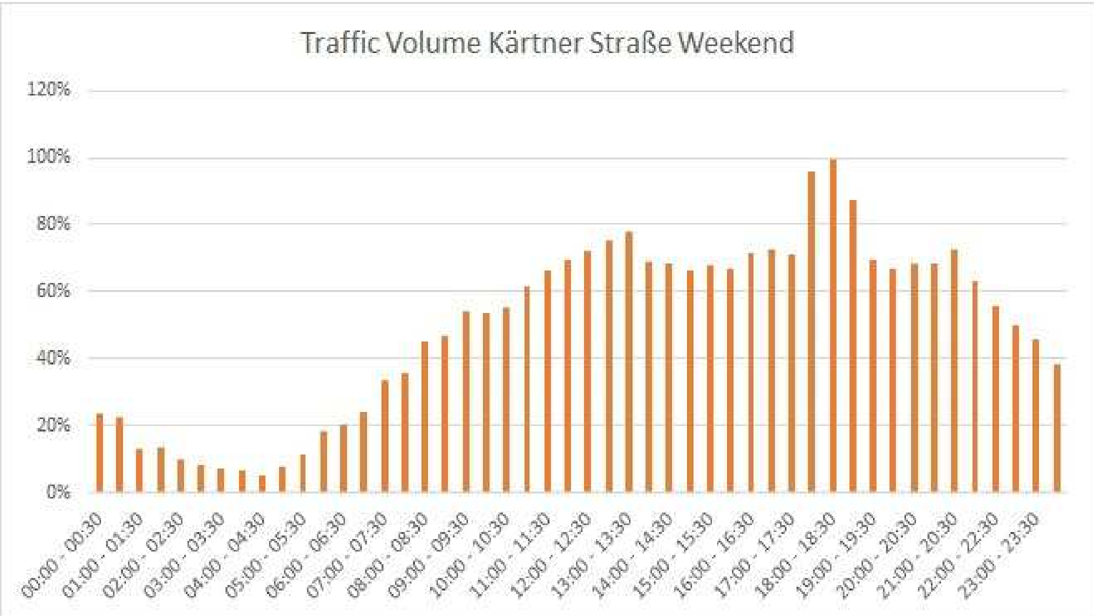


Chart 2: Traffic Volume Kärtner Straße Weekend (Source)

Apparent is the difference in profiles between weekdays and weekend. Peak periods (rush hours) are evident on weekend chart. The morning peak is milder, because people do not commute to work at the same time, but rather during the period stretched over several hours. The afternoon peak is sharper. More pronounced, because commuters are leaving the work during the narrower time period. During the weekend, the values – busy Saturday and slower Sunday averaged values – show slower buildup of traffic volumes in the morning, followed by the sharp increase in the afternoon, once department stores and other business close at EOB.

Chart 3: Traffic Volume Kärtner Straße Weekday (Source)

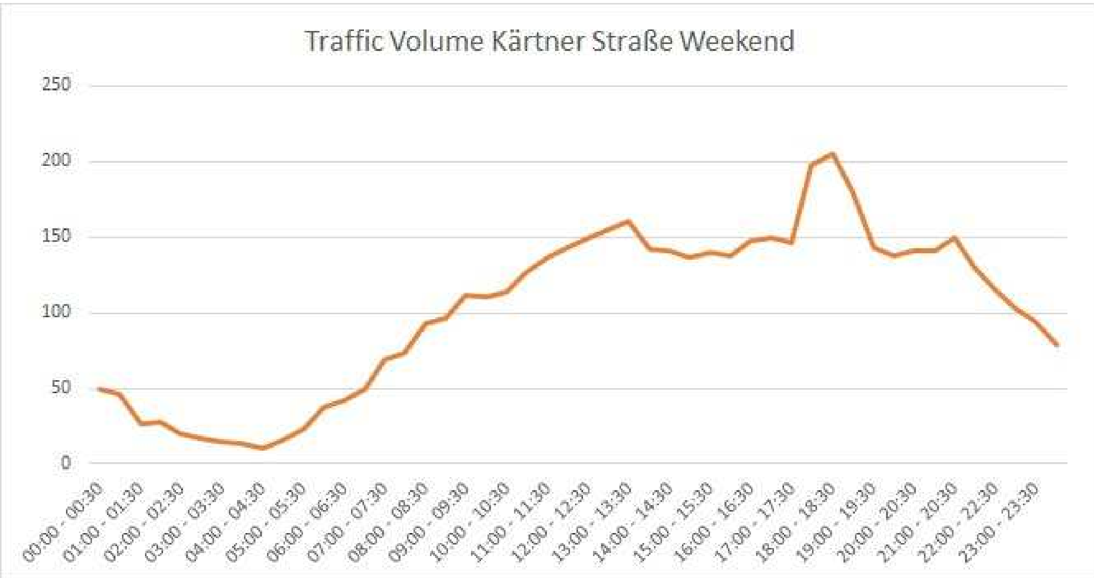
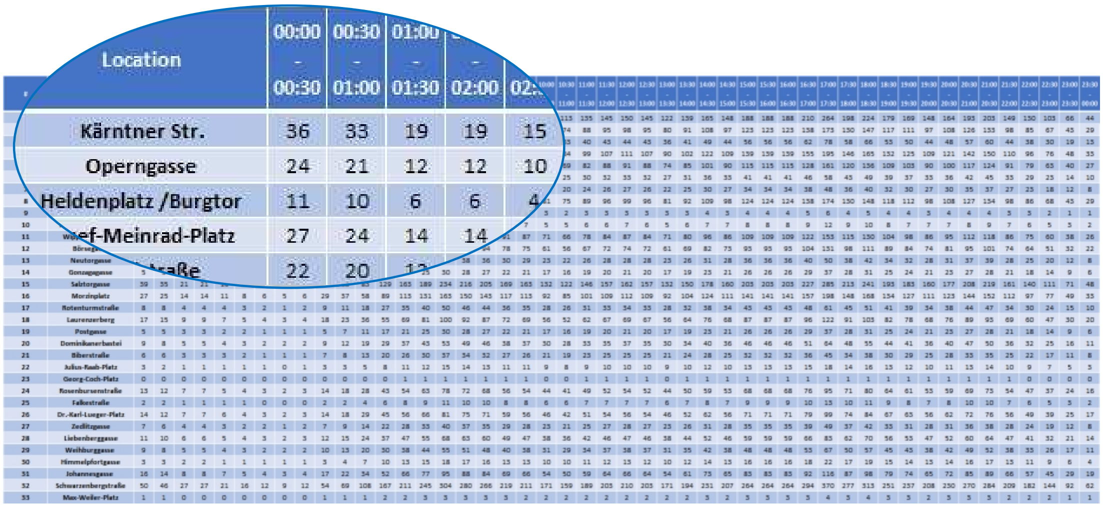


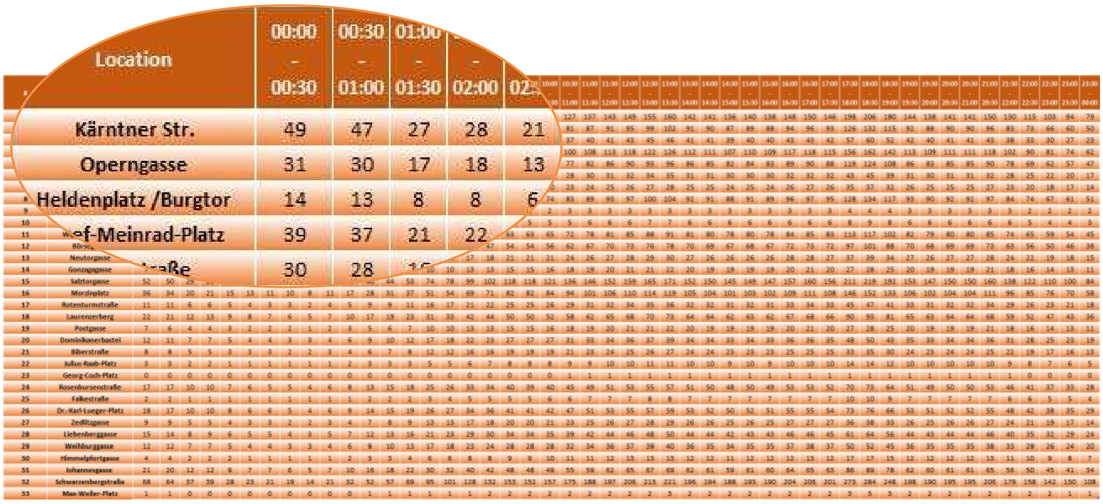
Chart 4:Chart 3: Traffic Volume Kärtner Straße Weekend (Source)

Both weekdays and weekend derived traffic profile curves, as seen above, were then applied to remaining 32 metering points around the first district. The derived tables contain 30-minutes counts for each one metering point, and added up they amount to full daily count, for both weekdays and weekends.



Location	00:00 - 00:30	00:30 - 01:00	01:00 - 01:30	- 02:00	02:
Kärntner Str.	36	33	19	19	15
Operngasse	24	21	12	12	10
Heldenplatz /Burgtor	11	10	6	6	4
...ef-Meinrad-Platz	27	24	14	14	
...raße	22	20	12		

Table 7: Total daily count for weekdays *(Source)*



Location	00:00 - 00:30	00:30 - 01:00	01:00 - 01:30	- 02:00	02:
Kärntner Str.	49	47	27	28	21
Operngasse	31	30	17	18	13
Heldenplatz /Burgtor	14	13	8	8	6
...ef-Meinrad-Platz	39	37	21	22	
...raße	30	28			

Table 8: Total daily count for weekends *(Source)*

The number of MIT movements in a single day is surprisingly high: **75633** MIT movements on average weekday, and **60364** MIT movements on average weekend day (averaged Saturday and Sunday). There are 260 weekdays and 105 weekend days in an average year. So, the total number of MIT movement in a calendar year in Vienna's first district, and without holiday corrections, is 75633 * 260 + 60364 * 105 = 26,002,800. Assume that traffic volume drops 20% during three holiday months - January, July, and August (December drop in business-related commute is compensated by shopping and festivity commute). In that case we need to reduce the total annual traffic volume by 5% (3/12 * 20). This brings us to adjusted and final figure of **24,702,660** (26,002,800 * 0.95) MIT movements per year in Vienna's first district.

But what is the average distance those MITs are covering daily? The longest trip that can be taken from the periphery of first district terminates somewhere at or in vicinity of Stephansplatz, the geographical center of Vienna and Vienna's first district. The table below shows distances between 33 entry/exit points and the Stephansplatz.

#	Location	Distance to Stephansplatz (km)
1	Kärntner Str.	0.75
2	Operngasse	0.95
3	Heldenplatz /Burgtor	0.25
4	Josef-Meinrad-Platz	2.40
5	Löwelstraße	1.80
6	Schreyvogelgasse	1.70
7	Mölker Bastei	2.10
8	Schottengasse	2.10
9	Heßgasse	1.60
10	Hohenstaufengasse	1.40
11	Wipplingerstraße	1.40
12	Börsegasse	1.40
13	Neutorgasse	1.40
14	Gonzagagasse	1.60
15	Salztorgasse	0.95
16	Morzinplatz	0.90
17	Rotenturmstraße	0.45
18	Laurenzerberg	0.60
19	Postgasse	0.70
20	Dominikanerbastei	0.75
21	Biberstraße	1.40
22	Julius-Raab-Platz	1.00
23	Georg-Coch-Platz	1.20
24	Rosenbursenstraße	1.10
25	Falkestraße	1.00
26	Dr.-Karl-Lueger-Platz	0.65
27	Zedlitzgasse	0.75
28	Liebenberggasse	0.60
29	Weihburggasse	0.80
30	Himmelpfortgasse	0.70
31	Johannesgasse	0.75
32	Schwarzenbergstraße	1.30
33	Max-Weiler-Platz	0.85
	Average:	1.13

Table 9: Distance to Stephansplatz ***(Source)***

All 33 distances were measured using google maps directions tool with selected "car" option. Distances ranged from 250 to 2400 meters, with average value of 1130 meters. Most trips do not extend all the way to Stephansplatz, so the half-way value of 565 meters is taken as length of an average trip. Knowing the number of vehicle movements in one year - 24,702,660 – we can come up with the estimation of total number of kilometers driven by MITs within the first district: 24,702,660 * 565 meters = 13,957,003 kilometers. If we know that the distance to Moon is 363,104 kilometers[55], then is easy to calculate that - if they were to combine their trips - vehicles driving annually through the first district could reach the Moon and return back to Earth 19 times.

2.1.3. Likelihood of MIT to E-Scooter Shift

2.1.3.1. Survey and Questionnaire

In order to determine the share of current MIT users likely to switch to E-Scooter for their daily work commute, a standard paper printed survey forms (questionnaires) were employed. 300 forms were prepared, together with 300 self-addressed stamped envelopes.

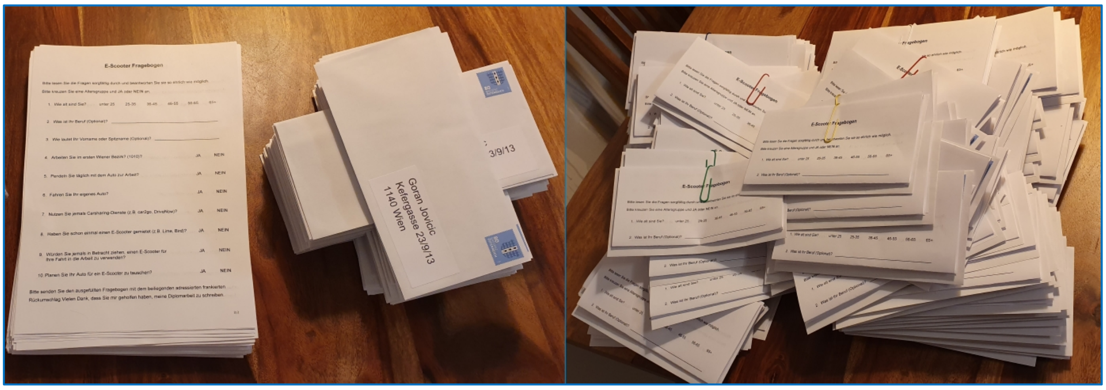


Figure 28: Questionnaire in preparation (Source)

The questionnaire listed following questions:

1) What is your age?

2) What is your occupation (Optional)?

3) What is your first name or nickname (Optional)?

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[55] (Sharp, 2017)

4) Do you work in Vienna’s first district (1010)?

5) Are you commuting daily to work by car?

6) Are you driving your own car?

7) Do you ever use car-sharing services (e.g. car2go, DriveNow)?

8) Have you ever rented an electric scooter (E-Scooter, e.g. Lime, Bird)?

9) Would you ever consider using an E-Scooter for your travel to work?

10) Are you planning to swap your car for an E-Scooter?

Respondents were thanked and kindly invited to mail the completed questionnaire using the included self-addressed stamped envelope.

Questionnaire forms were distributed throughout the first district, handed out to individuals resembling daily (both residents and visitors) commuters, for instance drivers of vehicles entering and exiting public garages (e.g. BOE and WIPARK), inserted into mailboxes of companies, placed on windshield of cars parked on reserved parking places in front of businesses (e.g. Helvetia insurance, Hofburg library). Out of 300 questionnaires distributed, a total of 36 questionnaires was completed and returned, amounting to a response rate of **12%**

#	Question	Response					
1	What is your age?	under 25	25 -35	36- 45	46 - 55	56 - 65	65+
		1	4	6	12	8	5
2	What is your occupation?	No Response	White-Collar	Street Sweeper	Self-Employed	Physician	Technician
		8	7	1	3	1	1
		Lawyer	Clerk, Self-Em.	Secretary	Contractor	Diplomat	Librarian
		2	1	1	1	1	1
		Teacher	Student	Artists	Enterprenuer	Clerk	Unemployed
		2	1	1	2	1	1
3	What is your first name or a nickname?	GIVEN			NOT GIVEN		
		17			19		
4	Do you work in Vienna’s first district?	YES			NO		
		27			9		
5	Are you commuting daily to work by car?	YES			NO		
		13			23		
6	Are you driving your own car?	YES			NO		
		33			3		
7	Do you ever use car-sharing services (e.g. car2go, DriveNow)?	YES			NO		
		6			30		
8	Have you ever rented an electric scooter (E-Scooter, e.g. Lime, Bird)?	YES			NO		
		7			29		
9	Would you ever consider using an E-Scooter for your travel to work?	YES			NO		
		8			28		
10	Are you planning to swap your car for an E-Scooter?	YES			NO		
		1			35		

Figure 29: Survey results (Source)

The age of respondents was diverse, covering all age groups. Most represented were middle aged respondents, age group 46-55:

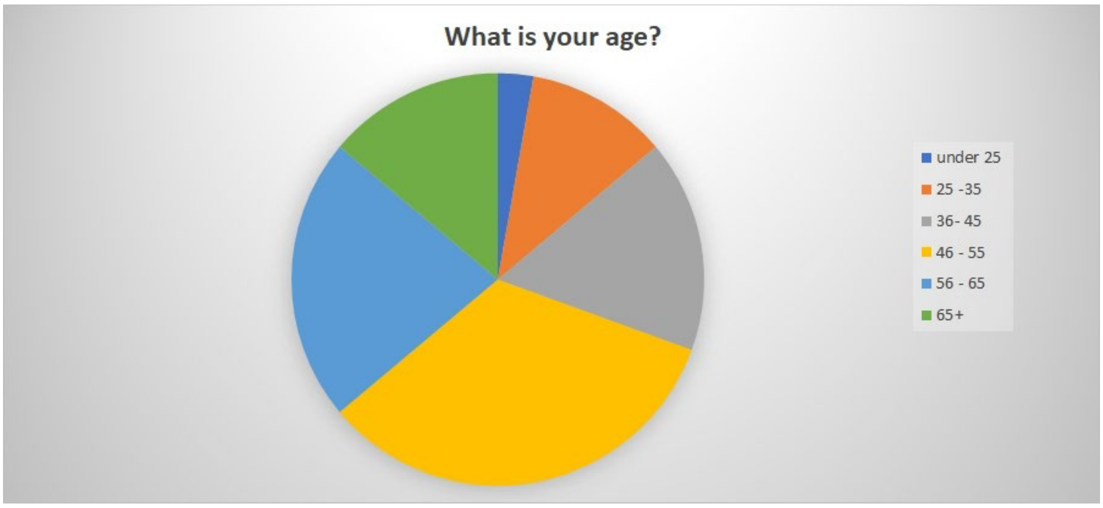

Chart 5: Age of respondents (Source)

Two thirds of respondents revealed their occupation. Sixteen different professions were represented, ranging from artist to entrepreneur. White-collar (Angestellte) was the most accounted for profession, the fact consistent with the geographical location:

Chart 6: Occupation structure (Source)

The questionnaire was formulated in such way to respect and preserve identity and privacy of respondents. Besides occupation question, the name or nickname question was left optional. Almost half of respondents chose to disclose their names and nicknames. Two respondents wrote their full names and return address on envelopes.

From names origin it can be concluded that most, if not all respondents belong to demographic category of natives.

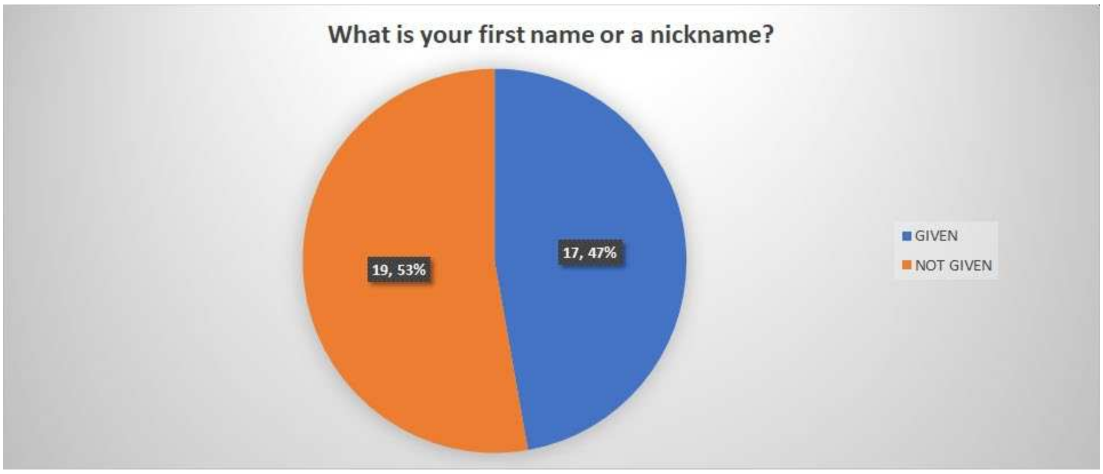

Chart 7: Names of respondents (Source)

Large majority of respondents, three quarters, work in first district of Vienna:

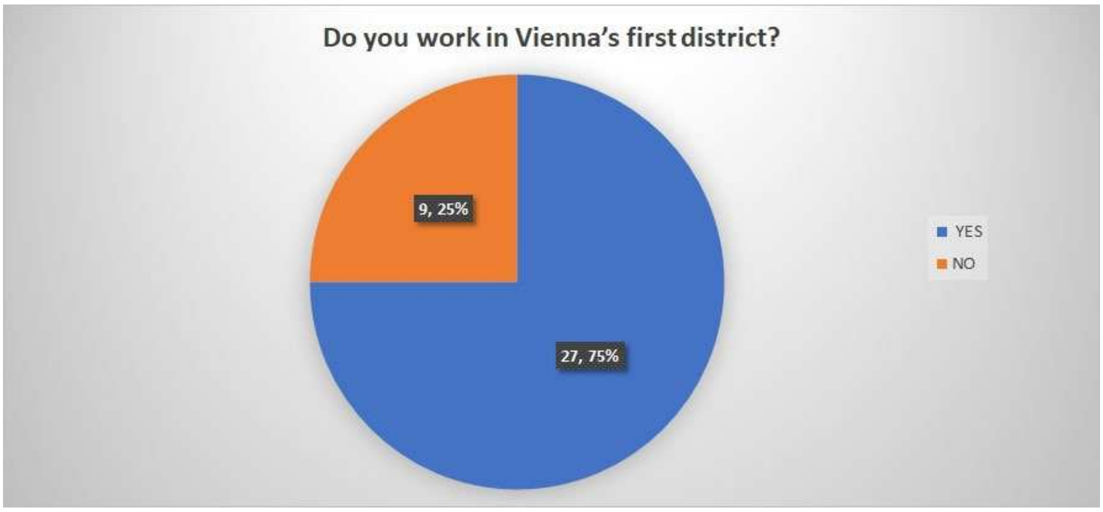

Chart 8: Location of workplace (Source)

While majority of respondents work in first district, less than half of them (36%) commute by car to work. Since the survey shows that a great majority of respondents own their own car, it is likely that low availability of parking spots plays a decisive role. Most old and historical buildings in Vienna's first district do not have underground garages, and the parking capacity of relatively narrow old town streets is very limited. One respondent added in writing that while he possesses a personal vehicle, he prefers to use public transportation for daily commute to work. The bottom line is that only nine out of six respondents commute daily using their own car:

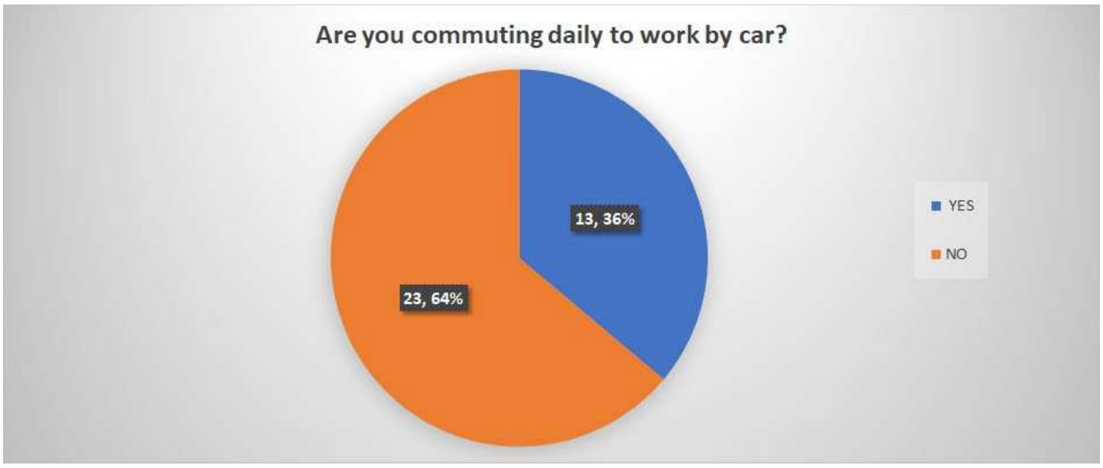

Chart 9: Commuting by car (Source)

Concerning the car ownership, almost all respondents (92%) own a car:

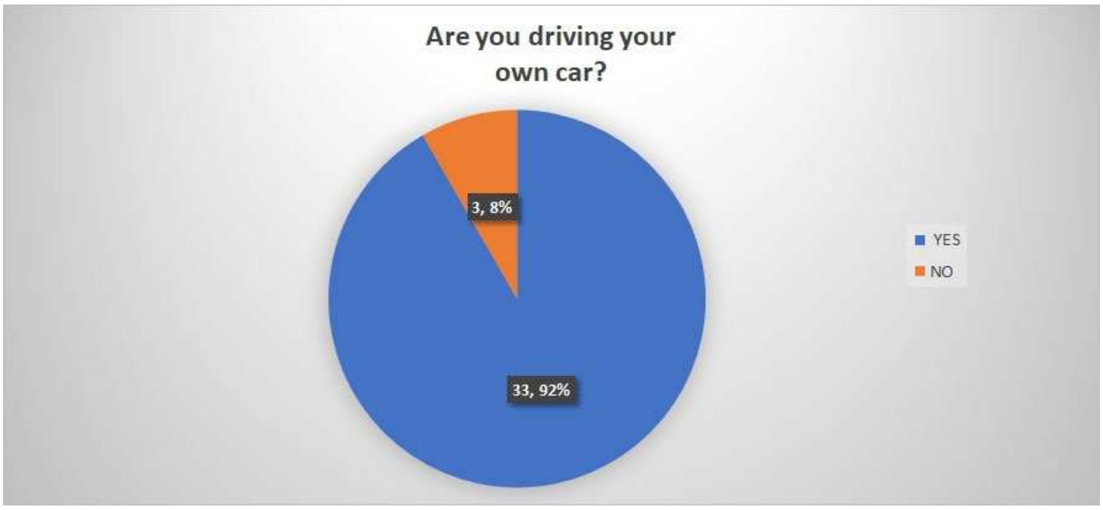

Chart 10: Car Ownership (Source)

Relatively high percentage of respondents reported having used car-sharing services, especially considering that most of them own a car. Five out of six respondents report owning their own vehicle. It could that they periodically resort to car-sharing service because of difficulties with parking. Contrary to popular belief, renters of shared cars are not always young people. Our six responders fall on average into middle aged category 45-55, with outliers being 25-35 and 65+. The correlation between affinity for hiring cars and hiring E-Scooters is not apparent.

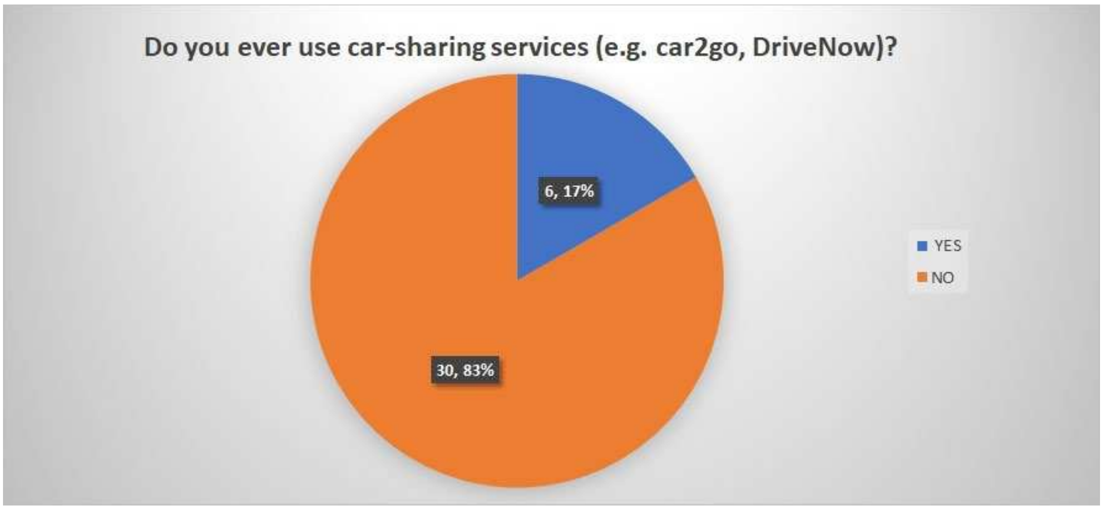

Chart 11: Car-sharing use history (Source)

About same percentage of respondents have first-hand experience with renting E-Scooters. Six out of seven respondents who have used E-Scooter have their own car. The age of those user ranges from 25 to 65+ (two respondents) and between, so there appear to be no age factor. Interestingly, all seven of E-Scooter enthusiasts gave their names, indicating their extrovert nature. They have also revealed their occupations, which include a street-sweeper, teacher, technician, and lawyer. Most, five out of seven, do not use their car for daily commute. It is interesting fact that only three out of seven are working in first district.

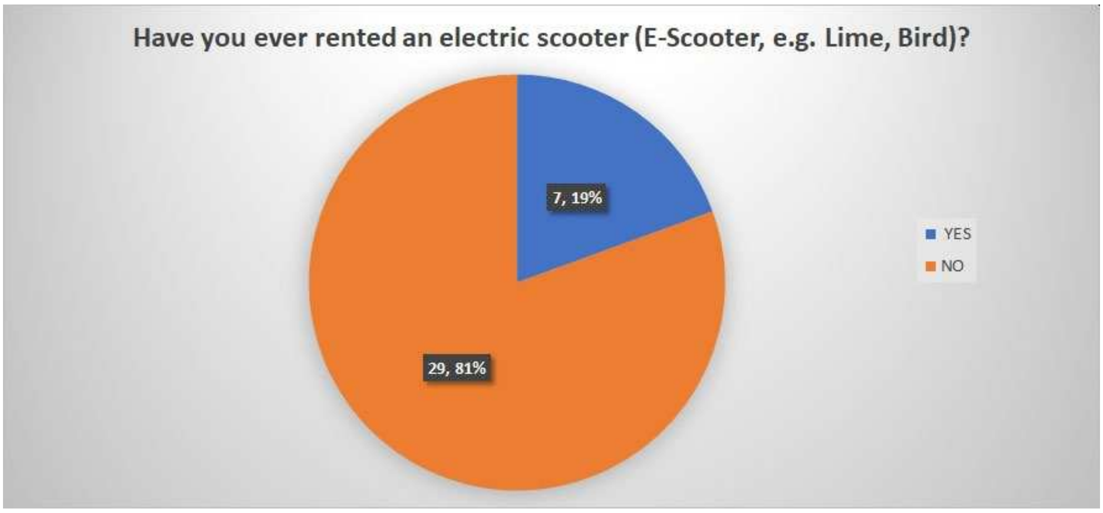

Chart 12: E-Scooter use history (Source)

One person made an additional remark of having a residence in the first district. The remaining three might be either residing (and working elsewhere) or visiting 1st district.

Concerning share of respondents willing to consider using E-Scooter for daily commute to work, it stands at relatively high 22% (eight out of 36).

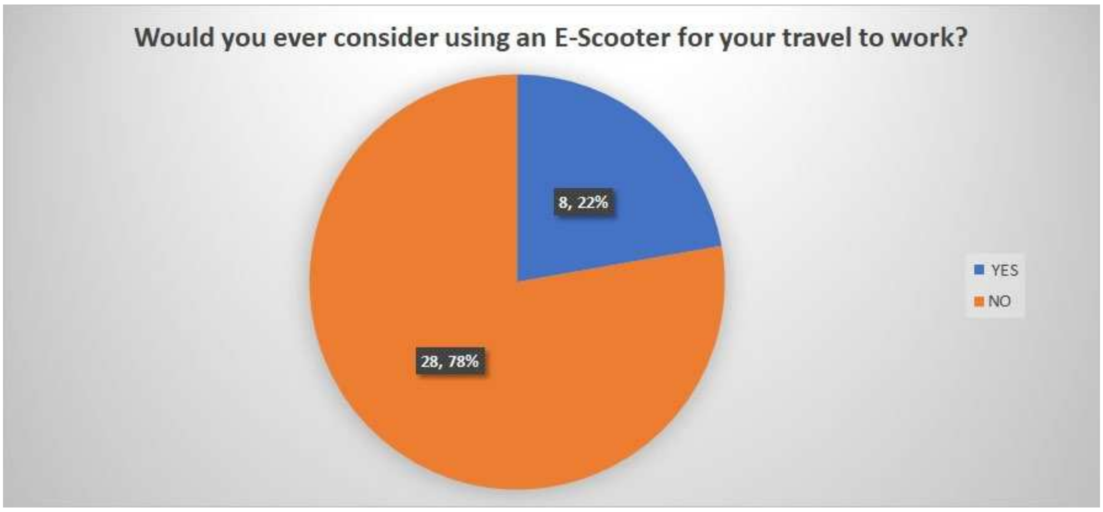

Chart 13: Willingness to commute using E-Scooter (Source)

Again, there is no strict rule regarding age of respondents. All age groups are presented almost uniformly, from under 25 to 65+, and all in between. The interesting fact is that there are two age 65+ enthusiast, a lawyer and a self-employed. It may be environmental conscience behind their willingness to give E-Scooter a try. Half respondents from this group have never hired nor tried an E-Scooter. Seven of them own a car, 25 years old student as well, but none is willing to surrender it to a scooter.

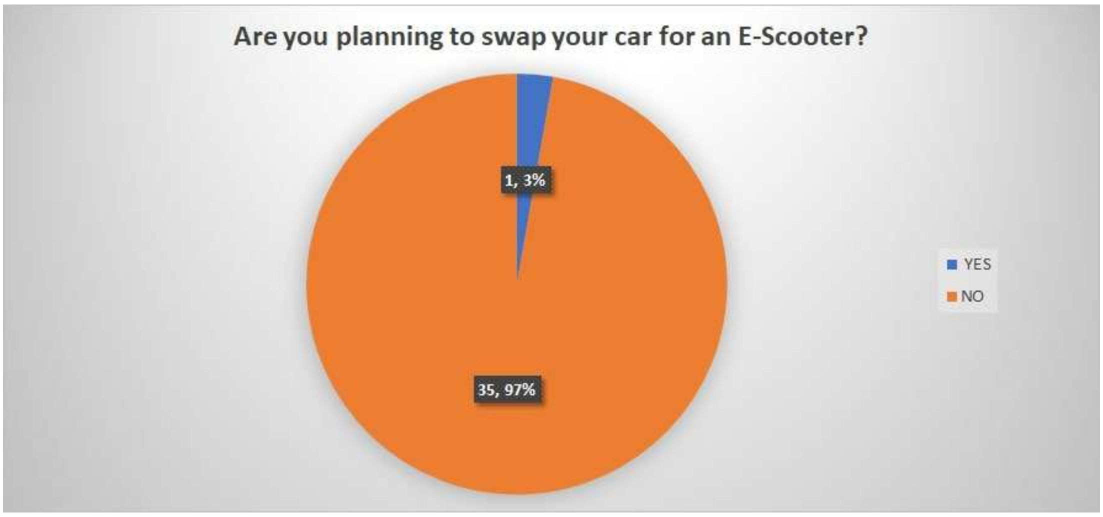

Chart 14: Likelihood of replacing a car with an E-Scooter (Source)

In the end, it comes down to a likelihood of replacing a car with an E-Scooter. Only one of correspondents signaled his (it's him) willingness to substitute his car with an E-Scooter. This person is between 25 and 35 years old, has his own car, with which he commutes daily to his workplace in first district. He has never used a car-sharing service but has experience with renting E-Scooters. He is considering an E-Scooter for his travel to work, and again, he is willing to try something different, dropping his car for an E-Scooter. This super enthusiast is employed by MA 48, municipal department in charge of waste management, street cleaning and vehicle fleet (Abfallwirtschaft, Straßenreinigung und Fuhrpark). This person spends most of his work hours outside, maintaining streets infrastructure, and using an E-Scooter for daily transportation might feel natural to this person.

There are a few strong opponents to E-Scooter mobility concept. Three respondents wrote additional notes on their survey forms, in sections pertaining to willingness to use E-Scooters for commute and readiness to surrender cars. There were multiple exclamation signs behind "NO" selection, written word "never", and one elaboration on respondent's resolve never to use E-Scooters, which reads: waste of clean energy, yes to scooters, no to E-Scooters, no to E-Bikes, get moving.

Two figures derived from this survey are important for answering research questions and closing this thesis. Let's recall those research questions:

- What share of current MIT users will switch to E-Scooter?
- What practical impact, in terms of reduction of harmful emission, will this shift have?

To help answer those questions, following conclusions of this survey are needed:

- What is percentage of commuters willing to use an E-Scooter for daily commute?
- What is the percentage of commuters willing to permanently swap their car for an E-Scooter?

To derive those two figures, we need to adjust survey responses a bit, we must consider the car ownership factor. There are total of 33 car owners. Out of those 33, seven is willing to consider using an E-Scooter for commute, for a total of **21.2%** (7/33). Out of 33 respondents that own a car, only one is willing to surrender that car in favor of an E-Scooter, for a total of **3%** (1/33). These two figures will be used later for originating MIT and emission reduction figures.

2.1.4. A Real-Life Insight

In order to obtain missing information (from sub-chapter 1.2.10.6) about E-Scooters' role in Vienna's urban development, urban mobility, and smart city strategies, the author reached to several key city officials, which were or still are in charge of creating policies and long-term strategies. Important answers were obtained thanks to kindness and generosity of following city champions:

- Ms. Maria Vassilakou, Vienna deputy major, who in period between 2010 and 2019 served as an Executive City Councillor for Urban Planning, Traffic and Transport, Climate Protection, and Energy and Public Participation. Nowadays Ms. Vassilakou serves as a member of the Smart Cities board of Horizon Europe, the most important and prolific research and innovation framework program up to date.
- Mr. Gregor Stratil-Sauer, an expert from Mobility Strategies division of Vienna's Urban Development and Planning municipal department (MA 18 - Stadtentwicklung und Stadtplanung).
- Mr. Martin Blum, head of Vienna's Mobility Agency (Mobilitätsagentur) and agency's delegate responsible for development of bicycle traffic system.
- Mr. Thomas Vith, an expert from Mobility Strategies division of Vienna's Urban Development and Planning municipal department (MA 18 - Stadtentwicklung und Stadtplanung).

2.1.4.1. Interview with Vienna Deputy Mayor Ms. Vassilakou

The interview took place on February 18, 2020, in Vienna. Following is the transcript of discussion between the author and Ms. Vassilakou.

Beginning of transcript

Q: Arrival of commercial E-Scooters to Vienna in 2018 was quick and apparently spontaneous. It appears that permits were granted before a regulatory framework was laid down. Was that the case?

A: It is the true that E-Scooter introduction was for the most part spontaneous, at least from the city perspective. The implementation was initiated by E-Scooter vendors. City officials were comprehended by two E-Scooter pioneer operators, Lime and Bird, with offer for establishment of services and networks. They offered no business nor feasibility plan at that time. A long internal discussion ensued – some, if not majority of city officials – were skeptical, having learned of trouble-plagued E-Scooter launch in Paris and other cities. Some major stakeholders, such as MA 65, municipal traffic affairs department, were opposed. Others, such as mobility agency, were supportive. The fact that E-Scooter operators offered to establish and enforce and monitor voluntary rules helped sway the decision in favor of moving forward and granting the operation permits to Lime and Bird.

Q: What was the intention behind E-Scooter launch?

A: City wanted to keep up with latest trends and offer this novelty to its residents and visitors. E-Scooter service was also perceived as an additional convenience for tourists, a good selling point for attracting in more tourists. Finally, the decision to allow E-Scooters was driven by good intentions; city wanted to provide its residents, and especially its young people, with additional options.

Q. Were the environmental impact and potential fully understood at that time?

A: No. At that time not much information regarding environmental performance was available. There was no reliable internal info in carbon footprint, for instance. E-Scooters were generally perceived as environmentally friendly means of transport.

Q: Which groups were identified and target users – tourists, visitors, commuters?

A: It was expected that young people, such as students and fun-seekers, will emerge as major E-Scooter users.

Q: Were self-imposed rules and regulations effective?

A: No. soon after introduction a chaos ensued. There were a lot of complaints from residents, mostly about sidewalk congestion. By end of 2018, no stakeholder at city council was optimistic about E-Scooters. For instance, E-Scooter was no longer in favor of SPÖ officials and district administrations (Bezirksvorstehunge). This universal displeasure led to tightening of rules and introduction of Amendment 31, a set of rules mirroring existing bike traffic rules. This approach was favored by then-minister of Ministry of Transport, Innovation and Technology Norbert Hofer.

Q: As of today, is there a full understanding of E-Scooter's purpose and usefulness in Vienna's transportation system? Volumes, share in the modal split?

A: According to my knowledge, no. However, this should be confirmed by a city official that currently holds the post. E-Scooter is relatively new concept, and previous administration had neither the opportunity nor basis for conducting in-depth study of E-Scooter's role.

Q: Are commercial aspects known, who benefits, who profits monetary?

A: it was never cities intention to profit from E-Scooters (permits were not generating much revenue) but to offer choice to its residents and visitors. The operators were of course in for profit, but there is still a doubt whether they managed to turn profit.

Q: Are E-Scooters perceived as a welcome addition to the current transportation structure, or an uninvited competition (mainly to Vienna's highly developed public transportation network)?

A: Wiener Linien does not perceive E-Scooters as a threat. The welcome any mode of transport that is compatible with theirs. They consider E-Scooter compatible, even for sharing infrastructure (portable and collapsible E-Scooters are welcome in underground stations and trains). The only exception is tram network which suffers from congestions. Furthermore, Wiener Linien especially welcomes combining E-Scooter mode with their modes during summertime, when E-Scooters help decongest lines of already paying customers (holding annual passes). It is a sort of welcome cannibalization, from the holistic perspective.

Q: Vienna legislators and officials are set to further regulate the E-Scooter sector in near future (6/2020), by imposing more restrictions – among others limiting the size of vendors' fleets down to one quarter. What is the motivation behind this drastic move?

A: The determined tightening of rules is due to persistent inflow of complains. This made city official were critical; by end if 2019 no city official was in favor of E-Scooters.

Q: Is there a place for E-Scooters in Vienna's urban mobility strategy?

A: During my tenure in the office E-Scooter have not been made a part of any long-term urban development strategy. The policies that are currently in force were created long before E-Scooter proliferation. You should reach to my successors for more current information, if available.

Thank you very much for your time and assistance.

End of transcript

2.1.4.2. Summary of Email correspondence with Mr. Gregor Stratil-Sauer

February 19, 2020

"E-scooter-sharing is one of the most discussed topics in the current (shared-) mobility discussion. Our strategy paper STEP 2025 was published in 2014, for apparent reason without mentioning of E-scooters.

The Vienna approach is that we are open for new developments. We try to see the positive aspects of innovative ideas. Regulation and prohibition are the second step if this is really necessary. The current policy of the city of Vienna was spoken out by our Vice Mayor Mrs. Hebein in a Press statement in December 2019. There will be 9 ad-hoc measures that will be implemented this spring. We will watch the development of the market in 2020 and then we plan to make a public tendering in 2021 to regulate the market if necessary.

E-scooter-sharing was not an idea of cities or research institutes to save mobility problems. It is a commercial business model. And the commercial operators try to make money with this new idea. From our point of view, we are sure that this exploding market will go on changing very fast. In Vienna we have 8 operators with quite the same product.

To examine longterm effects of new mobility services it takes at least some years of operation. As the services all around the world are only existing for some month, there cannot be any reliable study now.

If E-scooters will be a sustainable and useful part of our mobility strategy I could answer you maybe in two or three years".

2.1.4.3. Summary of Email correspondence with Mr. Martin Blum

February 21, 2020

"The city's strategic transportation plan was created when e-scooters still didn't play a role in traffic. A sharing strategy is currently under development. This will also include the topic of e-scooters. In principle, it is not yet clear how many of the current

providers of e-scooter sharing will remain. A lot of money has been invested by risk investors. The business models are not yet profitable.

Compared to bicycles, the e-scooter is less environmentally friendly and health-promoting. The city is challenged to expand and modernize the aging bike system."

2.1.4.4. Summary of Telephone Interview with Mr. Thomas Vith

March 5, 2020

E-Scooter received a lukewarm reception from city of Vienna due to prior negative experience with dockless bicycles. The bicycle-sharing vendors failed to comply with rules, and traffic issues and public complains ensued as a result. Therefore, it seems that some of city officials met the E-Scooter introduction with skepticism, which turned out to be justified. The E-Scooter operators exhibited the same behavior as their bike predecessors, cementing the skepticism. Simply said, from the perspective of city managers, the E-Scooter was and continues to be perceived as a nuisance. The city officials appear to be unconvinced about and therefore troubled with subjects such as battery lifespan and recycling, E-Scooter sustainability in general, parking and (pedestrian) traffic congestion issues, etc. Still, Vienna city officials are hopeful that at least some of these issues will be resolved with introduction of upcoming 9-points regulations plan.

During the first two years of E-Scooter service in Vienna no study concerning their environmental effect has been ordered or sponsored by the city government.

Concerning the Vienna's urban mobility strategy, it is worth noting that at this time the city is neither accepting nor rejecting the E-Scooter concept. It is still a relatively new concept, and the facts surrounding it are still being collected. The city favors a holistic approach when it comes to mobility in Vienna in near future. The main goal is to reduce the share of motorized individual traffic to 20 percent, as prescribed in STEP 2025 urban development plan. In order to get there, every possible mean and mode of transport, collective and individual, will be considered and given fair chance, and that includes E-Scooters as well. Any solution to the problem is welcome.

It is already clear that E-Scooters could facilitate the transition to 80/20 modal split, and that it can play a role in future mobility scheme. Nevertheless, its potential is already regarded as rather limited, in other words the E-Scooter alone is not expected to solve the problem. Only time will tell how truly beneficial E-Scooters are.

3. Results, Data Analysis and Discussions

Let's once more recall the main research questions:

1. What share of current MIT users could switch to E-Scooter?
2. What practical impact, in terms of reduction of harmful emission, could this shift have? Can this reduction be quantified and expressed in simple terms?

Now let's list the key data obtained through theoretical research and empirical studies:

1. The average carbon emission of a ICE-powered car in Austria is 194 g/pkm (average gross carbon footprint for both gasoline and diesel passenger cars).
2. The average carbon emission of 123 g/pkm for an electric scooter ridden in Austria (with electric energy generated in Austria).
3. Average annual number of vehicle movements in Vienna's first district is 24,702,660, an equivalent to 13,957,003 kilometers driven.
4. 21.2% of MIT daily commuters in first district Vienna is willing to consider using an E-Scooter for daily commute. 3% of them is willing surrender that car in favor of an E-Scooter, eliminating the possibility of reverting back to ICE MIT.

The first research question is already answered: 21.2% of current MIT users might switch to an E-Scooter.

Let's focus on quantifying the maximum theoretical reduction of harmful emission, in this case the CO_2 emission.

If 21.2% of commuters quit cars and switch to E-Scooter, MIT fleet servicing the first district will cover 21.2% less distance. 13,957,003 * 0.212 = **2,958,885** kilometers less driven.

The difference in carbon emission per kilometer covered between an average MIT and an average E-Scooter is 194 g/km – 123 g/km = **71** g/km.

Finally, let's calculate the theoretical maximum CO_2 emission reduction if all above conditions are met. 2,958,885 km * 71 g/km = 210,080,835 grams, or 210 thousand kilograms, or 210 tons of carbon dioxide.

To summarize, optimal promotion and implementation of E-Scooters, in their current state of technological development, and within geographical realm of Vienna's first district, could reduce the emission of CO_2 by a bit more than **210 metric tons** per year.

This is of course only theoretical maximum. How large share of this maximum capacity can be realized depends of several factors, such as local government's willingness and capability to popularize, regulate, encourage and sustain E-Scooters.

These estimates are no expected to remain valid for a long time. E-Scooter concept is evolving quickly. Even slight changes in E-Scooter construction, reliability, and lifespan will increase their environmental performance significantly. That, in turn, will alter E-Scooters environmental effect, in a positive sense. The above value of 123 g/km in indirect/direct carbon emission will become irrelevant, perhaps even absurd. The time will quickly and irreversibly affect the E-Scooter acceptance rate. Today's setting is still dominated by matured car owners not willing to sacrifice old days comfort. Members of so-called New Generation are unable to identify themselves with those old ways and behaviors. Owning a car means to them nothing other than having a ballast, a financial drain. Once they get in position to voice their opinion, and exercise their behavior, our 21.2% acceptance rate will skyrocket, perhaps triple itself. The young generations are the future of E-Scooter.

4. Summary and Conclusions

The E-Scooter concept and existence turn out to be far more complex than most of us assume. Apparently, it is a perfect answer for first and last mile connection, as well as convenient solution for any other urban transportation need. It is cheap, light, compact, economical, swift, and entertaining. It brings 21st century vision to our streets, it makes its riders hover around at surprising speeds. No wonder E-Scooter arrival has been met with great enthusiasm everywhere it appeared. To some, for a moment it seemed like E-Scooter will replace walking, and as the result the urban transportation will get more efficient and less time consuming.

But many unforeseen issues developed quickly. Some perhaps believed that E-Scooter concept, being so logical, honest, and welcomed, will regulate itself, start as a self-regulated industry. The responsibility and accountability for E-Scooter launch and operation was entrusted to operators, whose main goal and focus were the shortest possible TTM and ROI. Orderly introduction seemed to be of secondary importance. As a result, the E-Scooter initiation backfired in most locations, including Vienna. Overdeployment and resulting congestion - coupled with safety issues - quickly turned the tide against E-Scooters.

E-Scooters were given benefit of the doubt – they were perceived as being extremely environmentally friendly, without having much (known) merit. From the very start E-Scooters were “greenwashed” – labeled green by its owners before proving its advances in efficiency.[56] Not many individuals, including officials, knew that E-Scooters are not more environmentally friendly than a diesel engine-powered bus, for instance, despite being electrically powered.[57] Most markets failed to conduct a due diligence before approving E-Scooter services in its jurisdictions, and had no understanding of short or long-term effects of scooters on environment.

The situation is somewhat clearer now, there is a consensus that E-Scooter didn’t live up to expectations. There are some obvious advantages, but they do not seem to be able to outweigh the flaws. The major hindrance is the fact that the whole E-Scooter concept is based on a short-lived hardware. The true benefits and potentials are still not fully understood and are currently being investigated. Outcomes of those investigations will decide the future fate of E-Scooter, whether they will play a significant role in future urban mobility models.

[56] (Motavalli, 2011)
[57] (Shipman, 2019)

The same is valid for city of Vienna: The future of E-Scooters in Vienna is at this time hard to predict. Some modest benefits were overshadowed by myriad of persistent issues, such as safety hazards and incompatibility with current modal mix and infrastructure. These issues resulted in repeated and ever lauder complaints, which in turn killed the last traces of enthusiasm. Furthermore, so far E-Scooter concept doesn't seem capable of achieving profits, and it is hard to tell when investors' patience might run out. There are even more arguments against E-Scooters in Vienna: Their practicality seems limited in a city having a very advanced public transportation system. The health benefits of riding an E-Scooter are non-existent, in contrary, they are certain to deprive people of even minimum physical activity and contribute to sedentary lifestyle diseases. Vienna city officials know all this, and as a result they are reluctant to long-term commit to E-Scooter growth and involvement in city urban and mobility development plans.

Even the theoretical annual CO_2 emission reduction for the 1st district, as calculated by author of this thesis, is not particularly promising. 210 tons might sound huge, but it is not that much when put into a perspective: for instance one fully occupied (306 passengers) Austrian Airlines Boeing 777-200ER[58] will release at least 500 tons of CO_2 on its single flight to Chicago,[59] and that is the best-case scenario, where all passengers on board are classified as economy-class carbon dioxide emitters (the business class is nearly double). Or let's take for an example cement producing industry: for each kilogram of Portland cement produced 0.93 kg of CO_2 is released.[60] Cement is produced in huge quantities, globally over 4 billion tons per year,[60] and even the smallest possible rotary kiln for producing cement releases daily a lot more CO_2 than our annual E-Scooter save. Needless to say, that doesn't mean that we should give up on E-Scooters and other means of environmentally friendly and sustainable modes of transportation, it just means that we need to be realistic with our expectations.

E-Scooter is still under scrutiny in Vienna, and it will stay so for another couple of years. One thing for sure, E-Scooters must evolve and mature in many different aspects (safety, reliability, ecology) before it's able to assume the role it aspires to fulfil.

The author's personal belief is that there is a rough road in front of E-Scooters, in Vienna and in general. The economics behind dockless E-Scooters is not viable, the

58 (Austrian Airlines, 2019)
59 (atmosfair, 2020)
60 (Lehne, Preston, 2018)

concept presently depends on conscience of users, and that is fundamentally flawed concept. Some users will follow the rules, and continue to follow the rules forever, and some won't. As a result, we will always have issues and complains. Unless some sort of punitive system (mandatory collateral, strict monetary penalties) is introduces, troubles are bound to persist.

The author is foreseeing another development: the society is rapidly moving move towards healthy lifestyle related modes of transportation, such as traditional biking and walking. We are witnessing the revolution in healthy nutrition, and physical activity. People are starting to move more and more on their own. And E-Scooter unfortunately does not potential to contribute to development and sustainment of physical fitness and overall health. It will likely maintain its presence, not on a large scale, but for sakes of convenience and amusement.

5. Recommendations for Actions

One recommendation for Vienna city officials is not to routinely accept ready-made solutions from E-Scooter manufacturers and operators. E-Scooter specifications are often designed to maximize cost-effectiveness, at the expense of users' convenience, comfort, and safety.

If Vienna decides to get serious about E-Scooters, its city officials should regularly and generously contribute to development of new generations of E-Scooters, by defining minimum technical requirements, for instance. This cooperation between manufacturer, renting operator, and end customer should commence as soon as possible, the best during the early phase of product development.

Such approach will likely yield an easy to implement product with superb characteristics - near perfect E-Scooter.

Finally, knowledge base about E-Scooters is already huge, and ever-growing. Collect the best practice cases from all over the World and implement them home.

6. Appendices

1. Survey form – English version

E-Scooter Questionnaire

Please read the questions carefully and answer each one as honestly as you can.

Please circle appropriately an age group and YES or NO.

1) What is your age? under 25 25-35 36-45 46-55 56-65 65+

2) What is your occupation (Optional)? ____

3) What is your first name or nickname (Optional)? _______________________________

3) Do you work in Vienna's first district (1010)?	YES	NO
5) Are you commuting daily to work by car?	YES	NO
6) Are you driving your own car?	YES	NO
7) Do you ever use car-sharing services (e.g. car2go, DriveNow)?	YES	NO
8) Have you ever rented an electric scooter (E-Scooter, e.g. Lime, Bird)?	YES	NO
9) Would you ever consider using an E-Scooter for your travel to work?	YES	NO
10) Are you planning to swap your car for an E-Scooter?	YES	NO

Please mail the completed questionnaire using the included self-addressed stamped envelope.
Thank you very much for helping me complete my thesis research.

2. Survey form – German version

E-Scooter Fragebogen

Bitte lesen Sie die Fragen sorgfältig durch und beantworten Sie sie so ehrlich wie möglich.

Bitte kreuzen Sie eine Altersgruppe und JA oder NEIN an.

1) Wie alt sind Sie? unter 25 25-35 36-45 46-55 56-65 65+

2) Was ist Ihr Beruf (Optional)? ____

3) Wie lautet Ihr Vorname oder Spitzname (Optional)? __________________________

4) Arbeiten Sie im ersten Wiener Bezirk? (1010)? YES NO

5) Pendeln Sie täglich mit dem Auto zur Arbeit? YES NO

6) Fahren Sie Ihr eigenes Auto? YES NO

7) Nutzen Sie jemals Carsharing-Dienste (z.B. car2go, DriveNow)? YES NO

8) Haben Sie schon einmal einen E-Scooter gemietet (z.B. Lime, Bird)? YES NO

9) Würden Sie jemals in Betracht ziehen, einen E-Scooter für Ihre Fahrt in die Arbeit zu verwenden? YES NO

10) Planen Sie Ihr Auto für ein E-Scooter zu tauschen? YES NO

Bitte senden Sie den ausgefüllten Fragebogen mit dem beiliegenden adressierten frankierten Rückumschlag. Vielen Dank, dass Sie mir geholfen haben, meine Diplomarbeit zu schreiben.

7. List of Figures

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10. Bibliography

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