Activity Deliverable

Living lab e-micromobility - MOBY Guideline of best practices, and results of e-micromobile integration potentials

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Authors

Name	Organisation	Contribution
Greger Henriksson	KTH Royal Institute of Technology	1; 2; 2.3; 2.4; 3.3; 3.4; 4; 4.5
Domokos Esztergár-Kiss & Attila Aba	Budapest University of Technology and Economics (BME)	2.1
Nicola Fricke & Fabian Kanisius	Fraunhofer IML Society for the Advancement of Applied Research	2.2; 3.1; 3.5; 4.6
Clement Lemardelé	CARNET - UPC Technology Center	The subsection *'Freight Micromobility',* in section 2.1 ; 3.7; 4.4; A1
Ismini Stroumpou & Joan Moreno*	UPC - Universitat Politècnica de Catalunya	3.6; 4.1*; 4.3
Gabriel Trachtenberg & Fabio Scheinkman Shachar	Municipality of Tel Aviv - Yafo	The subsection *'Tel Aviv - short facts of current micromobility and regulations',* in section 3.1
Aaron Nichols	TUM - Technical University of Munich	3.2; 4.2

Contents

1. Executive Summary

In this report we review research and statistics that illustrate how e-micromobility has become an integral part of urban mobility systems. E-micromobility should be seen as a new mode of transportation, that responds to a widespread demand for multimodal urban transport. This conclusion points to a need for conceptualizing perspectives and possible regulative frameworks, which could enable micromobility to become a significant part of an open-to-public multimodal system. In this way micromobility could constitute an important part of an attractive alternative to private motoring and fossil-fuelled vehicles.

In line with the above this study provides examples of current best-practices of e-micromobility in European cities (including Tel Aviv), as well as examples of the problems and complaints that the introduction of e-micromobility has been met with. At the end we present a toolkit for regulations, policies etc. that we believe could help release the potential of micromobility as a vital part of sustainable, intermodal urban transport.

2. Introduction

This report is part of the EU-funded (EIT Urban Mobility) project Living lab e-micromobility - MOBY.

During the years around 2016-2019, so-called e-scooters have been one of the new ways of traveling that have attracted the most attention in larger cities in Europe and around the world. In addition to electric scooters, there are also other new types of small vehicles, and the word micromobility has begun to be used to designate them.

One aspect that is of particular interest to this paper is what is usually referred to as the first and last mile of a journey, which concerns so-called intermodality with other modes of transport, often public transport, see, for example, Shaheen & Nelson (2016). Relevant in this context is also a relatively long-standing debate about the need to reduce the generalized costs of transfers in public transport (Hine & Scott 2000). The authors note that so-called seamless public transport journeys (from the traveller's point of view) has become an important political goal, already since the turn of the 2000s. To what extent travellers perceive a journey as seamless depends on changes, waiting times for these, etc. These perceptions and factual conditions may limit the use of public transport among ordinary car users, as well as among habitual users of public transport (ibid).

Attention has been given to the fact that the electric scooters are a partly controversial feature of the cityscape and traffic. One study used news media to evaluate and interpret significant sources of concern or irritation, before and after the introduction of e-scooters in ten cities in Europe, the United States, Australia and New Zealand (Gössling 2020).

Another aspect that has received a great deal of attention is the environmental impact of the traffic type and the potential to contribute to sustainable development. In research on this, aspects relating to environmental impact from manufacturing as well as collection / charging / deployment have been analysed, and compared with the environmental impact from electricity use for vehicle operation (Hollingsworth, Copeland et al. 2019). Since it has emerged that today's use has a significant environmental impact for manufacturing and collection / battery charging, the potential has also been assessed for, with changing future usage patterns, reaching low environmental impact, relative to today's dominant motorized means of transport (Gössling 2020).

In this report we highlight issues regarding first and last mile intermodality between e-micromobility and public transport. To do this we also present a broader picture of current e-micromobility in Tel Aviv and a handful of European cities. Also issues of acceptance and governance will be discussed. To do this, we argue that we need reasonably clear starting points regarding how e-micromobility, and its different aspects can be defined, and these aspects and definitions will be presented below.

2.1. Aspects and definitions of e-micromobility

We see a need for clarifying the concept e-micromobility, in terms of its scope and possible definition. In this section we therefore tentatively define, the following aspects of micromobility: electric vs man-powered; passenger vs. freight transport; private vs commercial/rented vehicles; intermodality with other means of urban transport.

E-micromobility – requirements of a definition

Based on user surveys, stakeholder interviews and workshops, typically two main considerations or aspects appear for what should be defined as micromobility: (a) micromobility is a device or (b) micromobility is a mode of transport. Another consideration is that (c) micromobility is a service, this mainly appears in the media, for example shared e-scooter services are considered as "micromobility". In this section, the difference between e-micromobility and micromobility is not discussed, but rather a priori-defined as:

- With the prefix "e-", e-micromobility is defined as powered (at least auxiliary) by electricity.
- Without the prefix "e-", micromobility is defined as man-powered (or in some case combustion engine powered), but not electrically powered.

In order to have a clear and useable definition of micromobility as a whole (incl. it's electric and non-electric varieties), the aim of the definition should be clarified. There are two different concerns:

- Legislation, regulations, and commercial perspective:

  When considering micromobility from the regulatory perspective, it must be clear, measurable, and enforceable. The framework should cover most of the devices and services, which are available in the market. A commercial perspective is quite the same as the regulatory perspective, since manufacturers and service providers (ideally) would like to produce and operate legally. Two concerns should be considered.

- Devices: a legislative definition should and must describe what is a micromobile with given range of size, weight, driving force, etc.
- Services: a legislative definition should describe, who is a micromobility service provider.

- Urban planning perspective:

  During the expert survey done in WP1, an interesting aspect appeared related to definitions: for urban planners micromobility definition should be rather fuzzy or intangible and must be inclusive for unknown future solutions. In this way, visions and strategies can play their part.

Survey on what should be a part of the definition

A non-representative expert survey was carried out amongst MOBY project partners in order to see, what are the necessary and unnecessary parts of a definition. The expert pool contained 20 participants representing industry, urban planners, municipality representatives and industrial partners. The experiment consisted of two parts. In the first part the experts could evaluate some parameters based on their necessity to include in the definition. In the second part the experts had to decide, whether a specific transportation tool is a micromobile based on their judgement or not.

In the first part the following parameters were assessed: size, weight, capacity, maximum speed, range, number of wheels. The parameters were defined based on previous expert interviews and describes physical features of micromobiles. Participants could assign each parameter with one of the following statements: very necessary, necessary, unnecessary, very unnecessary. The questionnaire did not give a hint, what should be the definition itself (e.g. “maximum 500 kg”), just what kind of parameters are defining a micromobile. For each answer a simple weight was associated (very necessary: 4, necessary: 3, unnecessary: 2, very unnecessary: 1), and based on the answers and weights from the experts, an order of the parameters was created. The results are shown below:

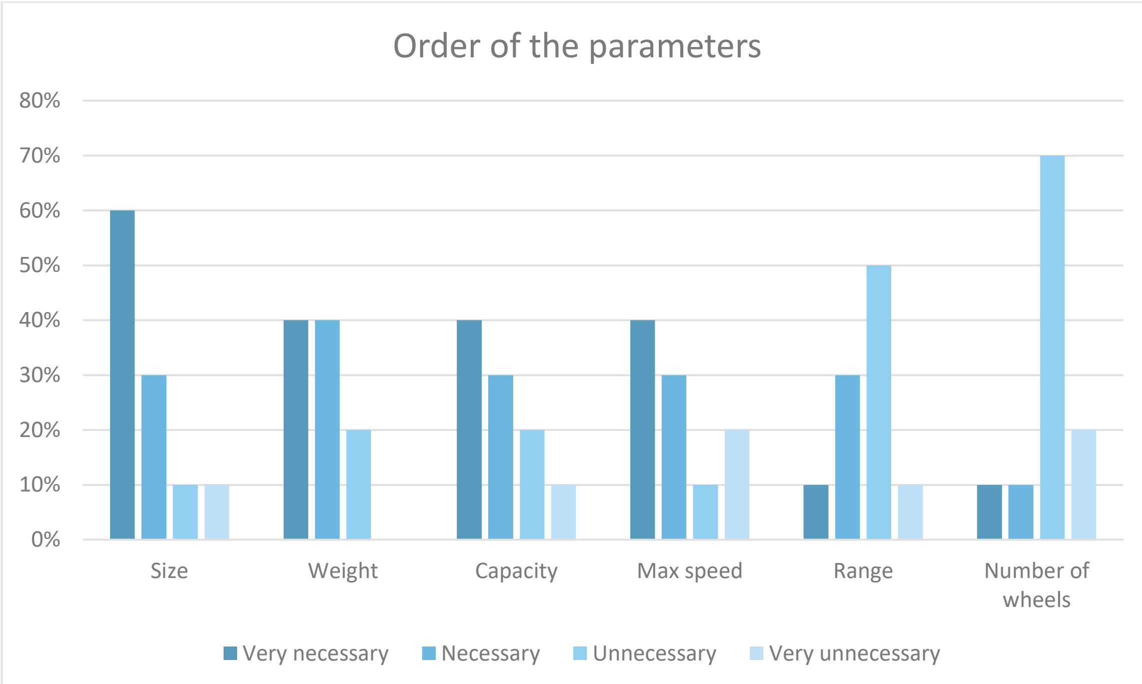


Figure 1. Order of parameters based on expert experiment

The number of responses was 20. The following parameters were analysed when defining micromobiles. In all cases, a maximum value should be a part of a definition.

- Size was ranked as the most important parameter to be included in the definition. 60% of the experts considered this parameter as very necessary. It affects the required area during use and for storage. In general, defining width should be enough, hight and length are consequences of the width and the manoeuvrability of the device. The width is important in order to examine on what infrastructure are micromobiles being allowed to use. This parameter is easily measurable for legislation purposes.
- Weight was ranked as second important. In this case, 40%-40% choose very necessary and necessary option, which is still quite convincing. Although, in some regulations/legislations a precise maximum value is declared (e.g. 500 kg), a more flexible approach (appeared during an expert workshop) sets the maximum weight to be comparable to a normal body weight. This parameter is easily measurable for legislation purposes.
- Capacity was ranked almost as important as weight, however here more experts considered it as very unnecessary. Measuring capacity is on the one hand a question of design and scaling, on the other hand a practical usage issue, as classic bicycles or kick-scooters are typically designed for one user, but occasionally used by two people. This improper use can be a safety issue. This parameter is easily measurable for legislation purposes.
- Speed is ranked almost the same as capacity or weight, however with even more experts on the side of very unnecessary. There could be several types of speed defined: design speed, maximum allowed speed, maximum speed reached by power assistance. However, it can differ a

lot in regard to allowed speed, as for example in case of a micromobility service, speed can be controlled remotely via IT solutions. Some means of speed can be measured by an authority in advance, but generally this parameter is more a law-enforcement issue.

- **Range** was considered debatable, where 60% of the experts choose unfavourable options. It has two different aspects. One aspect is the range of an e-micromobile without recharging the batteries. The other aspect is the allowed range, what is more applicable for a micromobility service than the device itself. It can be defined as a service area, or length of a specific trip. In the last case, measuring range of private micromobiles is hard to implement, and it is only suitable for services as a legislative/regulation parameter. However, effective range is a crucial standpoint from the urban planning perspective, since this defines the competition between micromobility with either public transport or private cars.
- **Number of wheels** was clearly unnecessary based on the opinion of the experts. Although vast majority of micromobiles are two-wheeled (bicycles, e-kickscooters), restricting this parameter brings no benefits.

Passenger micromobility vehicles

In the second part of the experiment, the experts were asked to identify micromobiles by photos. The following photos were the options in the experiment.

Picture 1. Option 1 - Scooter / moped

Picture 2. Option 2 – (E-) Bike

Picture 3. Option 3 – Mobility scooter

Picture 4. Option 4 –Kick scooter

Picture 5. Option 5 – Cargo bike

Picture 6. Option 6 – Cruiser moped

Picture 7. Option 7 – One-seated car

Picture 8. Option 8 –Two seated car

Picture 9. Option 9 – One-wheeler

Picture 10. Option 10 – Segway

Picture 11. Option 11 – Seated kick-scooter

Picture 12. Option 12 – Gyropod

Picture 13. Option 13 –Tricycle moped

Picture 14. Option 14 –Skateboard

Picture 15. Option 15 – Electric roller skate

Picture 16. Option 16 – Roller skate

Picture 17. Option 17 – Golf car

Picture 18. Option 18 – Cargo golf car

The results of experiment are shown in Table 1. The maximum number of responses was 20. By this experiment, it can be stated that micromobility is not yet a well-defined topic, e.g. bike did get only 85% of the answers, although it is clearly a micromobile. Based on the scores, three categories were defined. With a k-means cluster analysis, we divided the results into three categories (high score, mid score, low score). We considered a transportation tool definitely a micromobile, if at least 75% of the experts agreed. If this value was between 25% and 75%, then the transportation tool is debatably a micromobile.

While if less than 25% of the experts choose a transportation tool, then it is not considered as a micromobile. Another aspect can be established: based on this expert experiment micromobiles has no, or minimal cockpits.

Table 1. Results of the experiment

Option	Name	Score	Share	Category
4	Kick scooter	20	100%	Definitely a micromobile (75% - 100%)
10	Segway	20	100%	
11	Seated kick-scooter	20	100%	
12	Gyropod	20	100%	
9	One-wheeler	19	95%	
2	Bike	17	85%	
14	Skateboard	17	85%	
5	Cargo bike	15	75%	
15	Electric roller skate	13	65%	Debatably a micromobile (25% - 75%)
3	Mobility scooter	11	55%	
6	Cruiser moped	10	50%	
13	Tricycle moped	10	50%	
1	Scooter / moped	9	45%	
16	Roller skate	8	40%	
7	One-seated car	4	20%	Not a micromobile (5% - 25%)
17	Golf car	2	10%	
18	Cargo golf car	1	5%	
8	Two seated car	1	5%	

Recommendation for a definition

Comparing the two parts of this experiment, if we would use the parameters (size, weight, capacity, speed) from the first part to define micromobiles, just a couple of transportation tools (mostly car types) would not fit into the concept. However, in the second part, where experts had to decide on actual transportation tools, the results were not so straightforward anymore. But, still, if we consider both categories in the second part as part of the definition of a micromobile, then the answers of the experts were consistent.

As a final concern, the following fuzzy definition is suggested for micromobility:

- Size: can be a bit wider than a width of a grown-up person, the other two dimensions (length and height) are not determinative, but the whole tool should be handled by a person.
- Weight: can be lifted by one or two grown-up people.
- Capacity: design capacity is one or two grown-up people.
- Speed: design speed of regular use is 10 to 30 km/h.

Freight micromobility

The need for transporting small amounts, and single purchases, of goods to private households is related to the growth of e-commerce. During a survey conducted by Eurostat (2018), European citizens were asked about their use of the Internet. Considering the results of this survey, "almost 7 out of 10 internet users in the 12 months prior to the survey made online purchases in the same period. Overall, the share of e-shoppers in internet users is growing, with the highest proportions being found in the 16-24 and 25-54 age groups (73 % each)". More and more citizens are buying online and the e-commerce is booming. The current coronavirus sanitary crisis will enhance this long-term trend because e-commerce is promoted as a very efficient way to increase the social distancing between individuals.

The consequence of this increase in the number of online orders is the very fast development of the parcel delivery market. Still owing to the Eurostat survey (2018), "most purchases, by a third or more of e-shoppers, involved clothes and sports goods (64%), travel and holiday accommodation (53 %), household goods (45 %), tickets for events (39 %) and books magazines and newspapers (32 %). Less than one in five e-shoppers bought telecommunication services (20%), computer hardware (17 %), medicines (14 %) and e-learning material (7 %)". The "physical goods" that require a final delivery to the client - clothes and sports goods, household goods, books, computer hardware – are among the products that are most ordered online. The others, such as the travels and holidays, are not considered in this study about freight e-micromobile devices because they fully rely on ICTs and do not require a "physical" distribution network. As a conclusion, the number of parcels that need to travel from the carriers' Distribution Centers (DC) to the final clients' houses will greatly increase in future years.

Unfortunately, last mile operations (the last twenty kilometers of the supply chain) are less and less efficient. They currently represent 29% of the total good transportation costs approximately (Lopez, 2017) and urban environments are becoming more and more complex. Little by little, municipalities tend to reduce the importance of private vehicles in cities to move towards a more sustainable model. Two very representative measures (among many others) are the reduction in the number of parking spots and the creation of new pedestrian areas. These urban modifications greatly affect the carriers' operative protocols and the economic viability of their business models as well. If the number of parking spots is reduced, the drivers cannot park their vans easily, or they do it inadequately, which bothers the other road users. If the space dedicated to pedestrians increases, it is more and more difficult to access the final customer. The situation is even more challenging in the historic centers of European cities. A few years ago, the access to the Barcelona Gothic Quarter for delivery vans was restrained from 9:30 am to 12:30 am (Guerrero, 2018). The carriers only have very little time in the morning to distribute all the goods in the historical center of Barcelona where the density of small retail shops is very high.

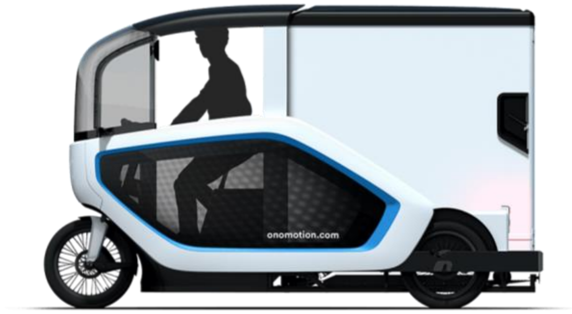
In a nutshell, two main factors are to be considered. On the one hand, the current last mile operations in urban environments are less and less efficient because of external actions that affect the carriers. If they do not change the configuration of their current distribution network, their business models will be economically unviable. On the other hand, the parcel delivery market is skyrocketing, it generates a huge amount of money, which increases the competition between the different stakeholders. This is the perfect cocktail to see innovative last mile delivery solutions emerge.

From starting points such as the above, result regarding freight e-micromobility are presented further below in the results section of this report. In this section freight is concluded with the following subsection regarding freight vehicles.

Freight micromobile vehicles

In the context of MOBY, we will focus on the emergence of these new freight e-micromobile devices and the change of business models they induce. Figure 2 presents a non-exhaustive state-of-the art of what can be found in the market at the moment of the final editing of this report.

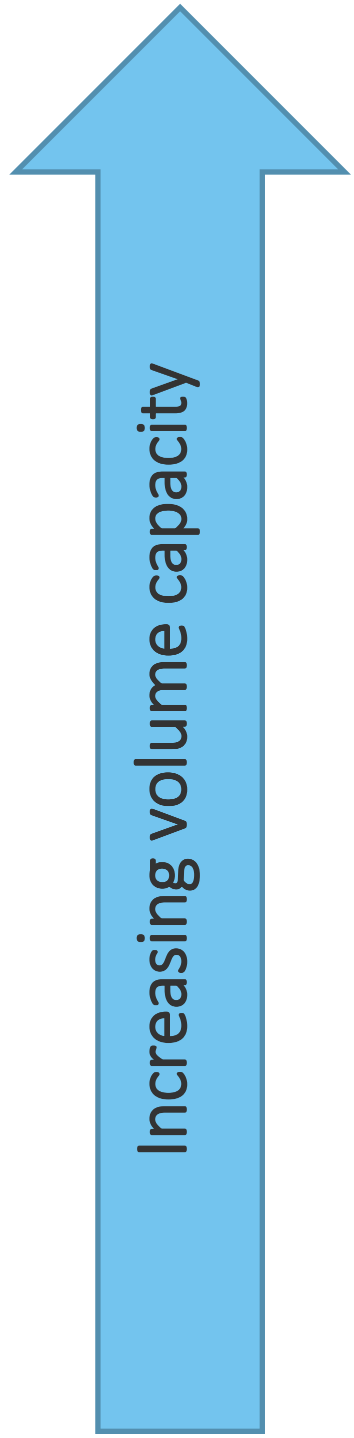
Picture 19 (velove, 2019)

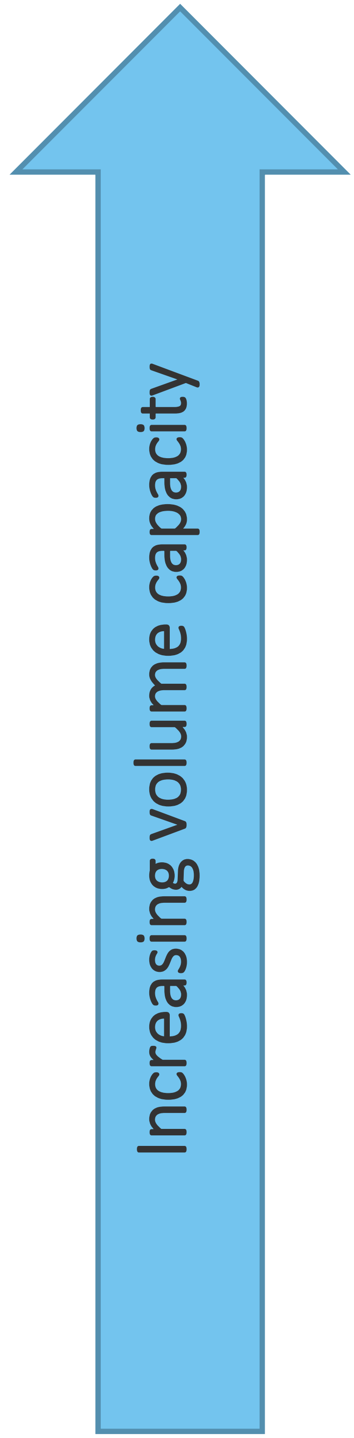


Picture 20 (ONO, 2019)

Picture 21 (RYTLE, s.f.)

Picture 22 (STRAIGHTSOL, 2015)





Picture 23 (CENTAUR CARGO, s.f.)

Picture 24 (URBAN ARROW, s.f.)

Picture 25 (Volkswagen, 2020)

Pictures 19 - 25. Emerging freight micro-mobile vehicle concepts

Even if the external design changes, the main idea of these new freight e-micromobile devices is to associate an e-bike with a box to carry the parcels. In pictures 19-25 above these new devices are ordered owing to their volume capacity. The e-cargobike from Volkswagen seems to have the smallest useful volume (to carry the parcels) and the Velove model the biggest one. These are approximate deductions only considering the available pictures. For the scope adopted in MOBY, it is not necessary to have much more precise technical characteristics. We chose to classify the different devices this way because we will see later on in the study that the volume capacity is one of the most important decision variable that affects the economic competitiveness of the carriers.

Stakeholders of micromobility

The current micromobility system is connected to a large number of stakeholder groups. Amongst them, the following partners are the most relevant: manufacturers, service providers, users, authorities, cooperation partners. The following discussion analyses the requirements and added value to an integrated and sustainable urban mobility of each stakeholders. Without further description, the following partners are somewhat involved in micromobility, but do not play a central role: road infrastructure management, local citizens, mobility data providers, law enforcement bodies.

Manufacturers

Considering the stakeholders on the market, the first group is manufacturers, who are producing the micromobiles. Manufacturers can be connected to specific service providers or can be independent actors.

- Innovation, product development, design and production are long processes, and are strongly connected to the legislation and standards of a specific market. Also end users may determine development directions. By these two aspects, manufacturers requirements can be deducted: stable and unified legislation, same standards on different regions and markets, and growing markets on the long run.
- Manufacturers can contribute to sustainable urban mobility with their devices. When observing the sustainability of e-micromobility, one of the key questions is the life cycle or life span of the e-micromobiles, with special attention to the batteries.

Service Providers

Service providers are those who provide their own micromobiles for public use for a fee or for free. It can be a station based, free floating or a hybrid service.

- Service providers requires stable legislation and competition neutrality (e.g. access to public spaces), standardized solutions on different markets can help to lower their costs.
- Service providers can contribute to the urban mobility with lowering travel time in their service area in comparison with walking or giving missing connections in comparison with public transport. When observing the sustainability of e-micromobility, a key topic is the waste treatment of either the batteries or the whole e-micromobiles, which is a responsibility of the service provider.

Users

Various subcategorization can be done for end users, but we consider two aspects. The first category is whether the end-user of micromobility is a for-profit user (e.g. cargo bikes, food delivery), who earns money from using micromobiles or non-profit user. The second is whether their micromobiles are shared ones (direct connection to a service provider) or private (direct connection to manufacturer).

- Users requires clear and easy-to-follow regulation, safe and efficient service and infrastructures for micromobility and rational integration between different modes. Also requires a good selection of mobility opportunities, so they can choose the best.
- Users contributes to sustainability by choosing sustainable modes, including micromobility instead of their own private cars.

Authorities

Every market has its own legislations at national, regional, and city level, or even district level legislation can be occurred. All these levels of governance have various decision-making processes and level of authority. In developing markets, no specific rules apply to micromobiles. In these cases, general legislations have been or should be applied. These rules or legislations affect road use (moving with micromobiles), public space use (storing micromobiles) or general legislation on providing service.

- They require complaint service providers and users, and an evidence that the city's micromobility fulfil its role in the (sustainable) urban transport system.
- Authorities are responsible for sustainability goals of the city and (at a given level) for the legislation. Authorities can directly contribute can control service providers operations.

Competition partners

The micromobility can be a single mode of transport (mainly with private tools) or can be a complementary mode in a travel chain (mainly with shared tools). In the latter case, public transport and car-sharing are the main coopetitors. Coopetition means that stakeholders from these sectors are in competition for end-users, but in given circumstances they can cooperate to support the experience of end-users, e.g. with harmonized services (e.g. multimodal mobility points, mobility packages, e.g.). Coopetition is part of the integration process, which is discussed in more details in this document.

Relationship between partners

The relationship between partners were observed considering three categories, such as a mutual agreement, a one-way directive, or a non-formal interaction. Users of micromobility are accepting general terms and conditions of the micromobility service provider or the instruction manual of the manufacturers, this is considered as a mutual agreement between them, since users are not forced to obey these regulations. At the same time users must accept rules of usage described in the local legislations or regulations, so this is a one-way directive, even if the users sometimes are not aware of the actual regulations. As an opposition, users can have the public voice, public involvement processes and other communication channels, where they can express their opinion on the legislation and regulation, but it still remains not a mutual connection, since the responsibility is always at the authorities and governance bodies.

The micromobility service providers are in service contract with users and manufacturers, based on mutual agreement, without this the service cannot be implemented. They can also set up mutual agreements with coopetition partners to fulfil their common business interests. Towards authorities, service providers can also the public voice or other non-formal interaction to reach their interest with regard the regulations.

Intermodality between micromobility and other modes of urban transport

Intermodality in passenger transport is when a door-to-door trip contains more than one mode of transport. Generally saying, walking is considered to be one mode of a trip, so every public transport trip contains intermodality. Developing intermodality is key towards sustainable mobility, as the sustainable modes do not provide door-to-door access (e.g. public transport is rarely door-to-door) or it works just for a given distance (e.g. biking performs poor in intercity trips).

However, in urban and mobility planning practice intermodality is mainly considered to be realized between trip legs (e.g. between bus and rail services at a station, but also a bike shelter in a bus stop), therefore topics of intermobility are typically focusing on nodes.

Micromobility's intermodality has two approaches. First is the conventional approach, where a mobility node can be a place of transferring from a micromobile to a public transport vehicle (or any other mode). Reshaping mobility nodes by giving accessibility to micromobility can help the integration of this new paradigm into urban mobility systems. For shared services, this can be a dedicated place included into passenger information systems. For private micromobiles, this can be lockers or shelters, where passengers can leave their vehicles.

The other approach that serves intermodality between micromobility and other modes, is travelling with micromobiles on other modes, mainly on public transport. In this case, intermodality requires the allowance of the micromobiles on public transport vehicles and in the meantime respecting other passengers' safety. It can be improved with dedicated places on rolling stock or providing charging facility during the trip (where applicable, e.g. in trains).

The first approach is supporting shared and private micromobiles equally, the second is supporting more the private ones. The two approaches do not exclude each other, and the main development directions should be focusing on a system and strategic level considering the constraints of intermodality (limited space on mobility nodes and limited space on vehicles as well).

2.2. The role of e-kick scooters in new urban mobility – review of research and official reports

In order to evaluate the role of electric kick scooters in urban agglomerations and their transport systems, various indicators need to be identified and analysed. Which trips are being replaced so that statements can be made about the influence on the modal mix? What factors determine the decision for or against the use of e-kick scooters and which potentials are inherent in these new means of transportation? Finally, the question needs to be asked what role electric kick scooters can play in a low-emission transport system that wants to meet the demands of the climate crisis. These questions will be examined in the results and discussion chapters.

Modal Shift?

In many European cities, the usage of bicycles is traditional for many short local trips of up to 7-10 km, accounting for 15-45% of the trips, depending on the individual countries (Zagorskas & Burinskienė, 2019). Powered light electrical vehicles are becoming more attractive as they are able to cover greater distances, run at higher speeds and overcome natural obstacles such as steep inclines, hills and wind. Even users with limited mobility can benefit from micro-electric vehicles such as e-kick scooters due to their physical condition, as a French study suggested (6t-bureau de recherche, 2019), according to which a proportion of shared e-kick scooter users reported that they did not walk (8%) or cycle (7%) the last ride they took, particularly because of their physical condition. E-kick scooters therefore offer a generally attractive alternative to private vehicles powered by fossil fuels and actively promote local mobility.

A study (Greater London Authority, 2015) stated, that two-thirds of car trips made by London residents could be cycled in under 20 minutes, underlining the potential for innovative short-range mobility solutions. Therefore, it seems necessary to assess the extent to which e-kick scooter in free-floating services substitute trips conducted by other modes of transport, and thus contribute in achieving this goal.

A French survey (6t-bureau de recherche, 2019) conducted in spring 2019 asked local users in different cities in France, what kind of vehicles they would have chosen if e-kick scooters had not existed. The results stated that 23 % of the free-floating e-kick scooter trips are intermodal and are likely combined with public transportation (66%) and walking (19%). Another survey conducted in San Francisco by the operator Lime (2018) even indicated that 39% of the 600 respondents had used the vehicles for intermodal links with public transport in their last trip. Following the French study, 44% of the local citizens, which were using a free-floating e-kick scooter on their last trip, would have walked instead, if the e-kick scooters had not existed and another 30% would have relied on public transportation instead. Only 9% of local respondents would have used a shared bike and 3% would have ridden their own bike to take their last trip instead, if the free-floating e-kick scooter had not existed. Therefore, replacements mainly happen to affect the trips conducted by public transportation and walking. However, extrapolating the results the study induced, that an impact of shared e-kick scooters on the modal shares of walking and public transportation is expected to be extremely marginal, reducing the proportions of public transportation by 0.3% up to 0.6% from 26.4% and affecting the share of bicycles of 60.3% with reductions by estimated 0.3% up to 0.8%.

Regarding the replacements of trips relying on the usage of cars, several studies conducted in different nations, mostly the U.S. due to the early integration of e-kick scooter in urban traffic, promote different outcomes. A study conducted by the International Transport Forum (2020) gathered detailed information on existing research, on which mode of transportation would have been chosen for the most recent ride, had an e-kick scooter not existed. The results vary from 8% replaced car or taxi trips in Paris (France), followed by 21% of the latter in Lisbon (Portugal) up to 50% in Santa Monica (U.S.A.) (for results figure see Appendix 1). This appears to be most likely the effect of the varying intensities of car usage in the individual countries, characterized by their individual mobility habit, which also can be read in the individual countries modal split. To illustrate this point, car ownership serves as indicator, according to which in Europe 602 out of 1000 inhabitants have a private car (European Automobile Manufacturers' Association, 2017), whilst in the USA about 831 vehicles are owned per 1000 citizens as of 2017 (Oak Ridge National Laboratory, 2020). While public transportation in most parts of Europe is substantial, well organised and works mostly reliably and effectively, U.S. city planning paradigms mainly focus on the encouragement of the car usage, whereas the public transportation systems and short-range mobility, especially outside of urban agglomerations, play a more subordinate role.

The following figure illustrates the estimated effects on shifting the modal mix according to three comparable studies, conducted in the years 2018 and 2019.

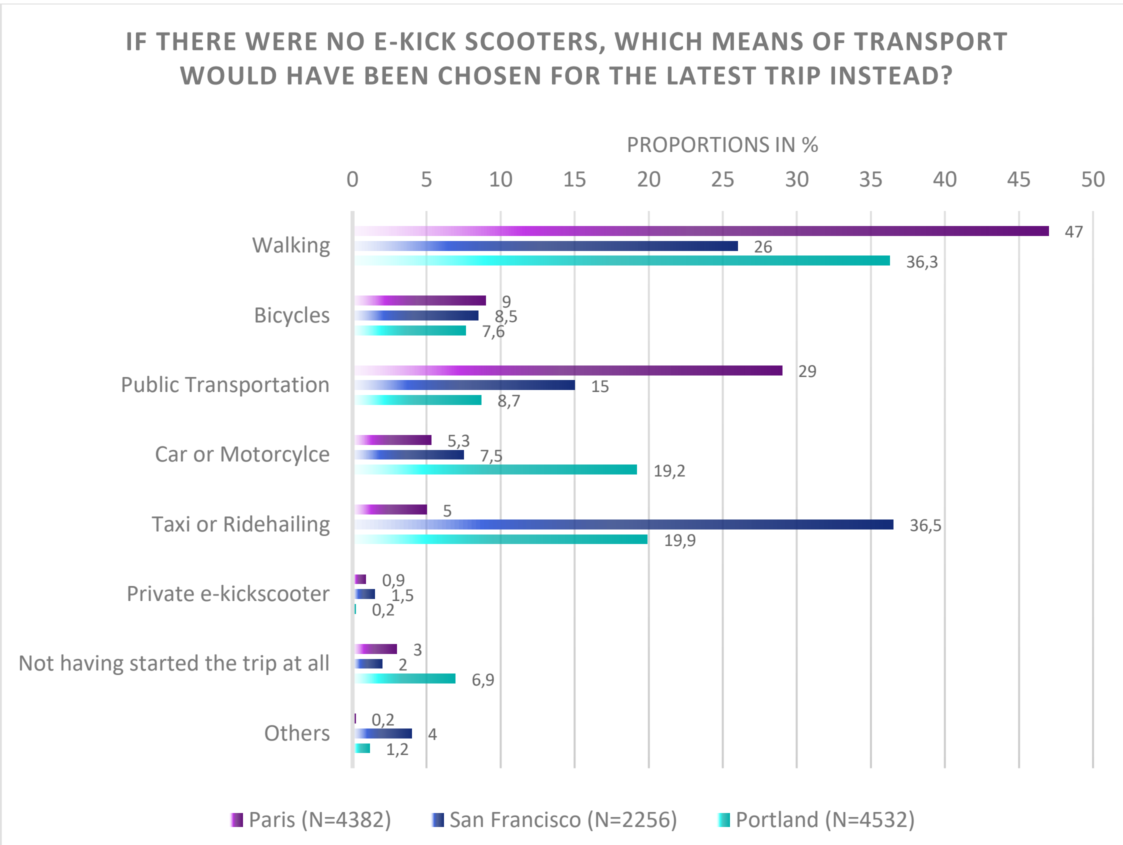


Figure 2: E-kick scooters and their impact on the modal mix (adapted from 6t-bureau de recherche (2019), Portland Bureau of Transportation (2018), San Francisco Municipal Transportation Agency (2019))

The impact on modal shift, depending on car ownership or use of mobility services, was also examined in a study (Moreau, et al., 2020) in Brussels. The survey examined in 2019 the timeframe from June to August and questioned participants who either owned an e-kick scooter privately or used free-floating e-kick scooters as a service. The study investigated which means of transport were replaced by the respective form of use of the e-kick scooters. The results show that trips made with a privately owned e-kick-scooter replace more trips that depend on the use of a car (+1.7%), compared to the numbers of replaced trips that e-kick scooters appear to have in a free-floating system. In addition, private vehicles replace more trips made by public transport (+1.0%) and by bicycle (+1.3%). This indicates that privatly owned vehicles tend to replace trips conducted with other vehicles that are also used for short distances, while e-kick scooters in the free-floating system have an increased number of replaced trips that could be covered on foot (5.0%), probably due to their leisure use and the ubiquity of supply in city centres.

Table 2: Modes of transportation replaced by the use of free-floating and personal e-kick scooters (adapted from Moreau, et al., 2020)

Replaced Modes of Transportation	Free-floating e-kick scooter sharing (n = 757)	Privately owned e-kick scooters (n = 329)
Public transportation	29.2%	30.2%
Car	26.7%	28.4%
Walking	26.1%	21.1%
Bicycle	14.2%	15.5%
Electric bicycle	1.5%	1.6%
Additional trips	1.8%	1.5%
Other	0.1%	1.1%
Motorcycle	0.4%	0.6%

E-kick scooters as an environmentally friendly mode of transport?

There were several debates on whether e-kick scooters could be of use as a mode of transport, contributing to a substantial reduction of the emissions generated in the transport sector. Yet, only a few detailed studies of their environmental impacts have been published so far. In order to assess the greenhouse gas emissions of a means of transport, a life cycle analysis can be of help, in the course of which the emission values for all stages of a product's life cycle are determined, from production to use and recycling.

North American researchers carried out a standardized life cycle assessment like this in 2019, analysing a free-floating rental system in Raleigh, North Carolina (Hollingsworth, Copeland, & Johnson, 2019). It showed that the greenhouse gas emissions per person-kilometre were significantly higher than a bus with a high load factor, but only about half as high as a car trip. To point out some values: If the journey is covered by car, the average emissions are about 404 grams of CO_2 per mile (United States Environmental Protection Agency, 2018). If the ride is done with an e-kick scooter, according to the North Carolina survey, the average emissions are estimated at 202 grams of CO_2 per mile. The most significant emissions were thereby generated during production and hold a share of about 50%. This, on the one hand, was due to the high energy input required to produce aluminium in the country of origin, and on the other hand to the very short service life of the vehicles of mostly less than two years. Daily trips to collect and recharge the e-kick scooters continued to account for another large proportion of about 43%, as the vehicles were spatially dispersed, so that irregular and long distance traffic occurs due to the collection of vehicles and, at the time the survey was conducted, mainly diesel-powered vans were used to provide the vehicles. Apart from those parameters, transportation from the production site to the USA, where the survey was conducted, and the energy required to charge the batteries had a rather minor impact on the emissions balance of the electric kick scooters.

In 2020, to supplement these results for the US market, the sharing provider Voi commissioned a recent study for its operations in Paris from the consulting firm Ernst & Young (2020). The study concludes that the CO2 equivalent emissions per passenger kilometre are with only 28% (about 56 grams of CO2 per mile) of the emission values estimated in the survey conducted in North Carolina significantly lower. These improvements are attributed, among other things, to the effect of replaceable batteries and the associated possibilities of battery logistics as well as the significantly increased durability of new e-kick scooter models. Moreover, the use of cargo bikes or electric vans to collect the vehicles and the resource-saving operator policy contribute to the significant reduction in the average life cycle emissions.

Another recent study (Moreau, et al., 2020) has carried out a life cycle assessment for shared, free-floating e-kick scooters in Brussels in comparison with privately owned e-kick scooters as well other means of transportation. The results show that the use of the shared e-kick scooters in the free-floating system would have emitted 131 g CO2 eq. per passenger kilometre (81,4 g CO2 per mile), whereas the means of transport they replaced would have generated an average of 110 g CO2 eq. passenger kilometre (68,4 g CO2 per mile). Consequently, free-floating e-kick scooters have an estimated higher environmental impact than the modes of transport they are replacing. According to the study, this is mainly due to the short life expectancy of the shared electric kick scooters, as the most impacting phase is by far the materials phase, contributing to between 68% and 90% of the total impacts. However, as the market becomes more developed, the lifespan of the vehicles and their battery systems could increase in the future, resulting in a corresponding decrease in the impact per kilometre driven. Considering the use of personal e-kick scooters, the results show an impact of about 67 g CO2-eq per kilometre (41,6 g CO2 per mile), as the distribution phase by the providers is not required here, since charging is mostly done at home in the private household.

Another often discussed topic concerns the recycling process of electric kick scooters and their components, since the necessary disposal of the built-in lithium battery in particular is a challenge for the waste management companies, as those can cause fires or leak harmful substances that risk damages in the millions of Euros (Porsche Consulting, 2019). Moreover, as the amount of lithium-batteries rises, e.g. in Germany starting from 3.000 tons of lithium batteries in 2009 in circulation to more than 10.000 in 2017, the waste disposal companies fear a capacity overload, since the sector only processes products at the end of their life cycle, making acute effects difficult to predict today (RecyclingPortal, 2019).

To put it in a nutshell, environment and health effects of micro mobile modes of transport are determined by how they are used and what kinds of means of transportation they replace. A short trip using an e-kick scooter can hold positive effects on health and environment, if it replaces a conventional motorcycle or a car trip, but if a trip by foot or by bike is replaced, more energy is consumed and more emissions are produced. Future developments, for example in the field of waste management and battery technology, can also help to reduce the environmental footprint and thus strengthen the transport mode as an alternative for sustainable urban transport.

Eco-social qualities of electric kick scooters

The social and health aspects of micro mobility are discussed controversially, as numerous factors play a role in their evaluation process. As electrically powered vehicles, e-kick scooters can on the one hand contribute to a reduction of noise generated by road traffic and congestion in metropolitan areas, provided that trips conducted by fossil-fuelled cars can actually be replaced. Electric kick scooters, run by a battery powered electric propulsion system, do not emit any direct greenhouse gases within the urban agglomerations, which seems increasingly important as larger agglomerations like Paris and London suffer from air pollution dramatically. Additionally, due to their light, small and two-wheeled design, the amount of particulate matter emitted by tyre abrasion can be estimated considerably lower than compared to a significantly heavier, four-wheeled vehicle with wider tyres. This is all the more important as recent studies (EmissionsAnalytics, 2020; Fraunhofer für Umwelt-, Sicherheit- und Energietechnik, 2018) have found that tyre abrasion from heavy vehicles, especially electrically powered cars, appears to be the main contributor to micro plastic pollution in oceanic waters and is extremely harmful to human health in air-polluted cities. Even if recent methods of collecting, recharging and reinstalling vehicles do not rely on diesel-powered vans and use electric vehicles instead, additional traffic will be generated that did not exist before, causing noise and air pollution. However, the contribution of these methods to air and noise pollution in cities cannot yet be estimated by reliable studies.

Apart from that, electric kick scooters in free-floating sharing operation have the possibility to ensure a significant improvement in the field of local transport. This requires that operating the e-kick scooters is based on non-discriminatory principles, which take into account socio-economic differences and guarantee a fair geographical coverage that is not purely profit-oriented. In other words, even outside the city centres, in areas that seem less profitable for providers, a guaranteed supply must be provided in order to create a real, resilient complement to public transport. Especially in the suburban and rural areas, where a less well-developed public transport chain seems to be characteristic, electric kick scooters can generate a substantial improvement and provide multimodal access to mobility hubs. In order to ensure this, the cities must hold the providers accountable with regard to the individual legal regulations to which the municipalities are bound, or consider offering e-kick scooter sharing services on their own initiative, so that the operations run as desired.

In addition to non-discriminatory spatial distribution, financial aspects are also important for all socio-economic layers of the population. The enforcement of affordable prices is of course essential, especially for the accessibility of the economically weaker parts of the population. Only when the costs of mobility services are affordable for all income groups, a shift in modal split become apparent, especially in the particularly relevant area of commuter traffic. However, if the integration of micro-mobility services is structured on an equal basis, local jobs and new service solutions could open up new perspectives, even for socio-economically weaker groups. Above all the municipalities are challenged to develop methods for structuring public-private partnerships in such a way that arrangements are agreed and the operators take responsibility for operation in accordance with the contract.

Aspects of safety regarding the usage of e-kick scooters

As already mentioned, in most European countries electric kick scooters are subject to road traffic regulations that are similar to those for cyclists, so that they usually share the conventional bicycle traffic facilities. Therefore, assuming that trips made by means of transport that do not use cycle paths are substituted, there will be an increasing pressure put on the cycling infrastructure, due to the enhanced traffic volumes. Moreover, as tourists in the city centres frequently use electric kick scooters also, as a German report published in 2019 stated (Civity, 2019), additional traffic is estimated to be created especially at points of interests, replacing journeys that are normally covered by foot or public transport, putting even more stress to already stressed bicycle infrastructures in the city centre. A recent study (Conference of European Directors of Roads, 2019) has shown that road safety is one of the biggest obstacles for non-cyclists to use bicycles more often. The same can be assumed for the use of electric kick scooters, especially since these are relatively fast and equipped with smaller wheels, reacting sensitively to occurring obstacles (European Environment Agency, 2020). Due to their two-wheeled design with small tyres, they are highly dependent on road conditions for user safety, as several studies suggest. About half of the accidents reported by emergency patients were, according to the patients, direct consequences of inadequate road conditions (International Transport Forum, 2020). Therefore, future developments require appropriate infrastructure established in the cities, for example, protected bike lanes which allow overtaking without danger, avoiding danger zones at crossroads and with separated traffic light systems.

As a survey conducted by the International Transport Forum (2020) states, the safety of electric kick scooters is likely to improve as users learn to move safely and cautiously in urban traffic and car drivers become accustomed to this new form of mobility as an integral part of traffic. According to the study, mandatory training of motor vehicle drivers could contribute to road safety, as fatal micro mobility accidents usually involve cars or trucks, which cause four to seven times more deaths among vulnerable road users than among vehicle occupants and therefore pose a greater risk to other road users than to themselves as a group. When comparing the total number of third parties killed in collisions with electric kick scooters or bicycles with the total number of fatalities in collisions with electric kick scooters or bicycles, it is found that less than 10% of those who died were third parties. Therefore, the dangers for other road users posed by e-kick scooters and bicycles can be considered significantly lower than those posed by the use of cars. On the other hand, a distance travelled using a light electric vehicle presumably appears to have higher fatality rates than a distance covered by foot. However, comparing the accident risk for cyclists and e-kick scooter users is not showing significantly different results yet, although the risk of hospitalisation is considered higher for electric kick scooters. In any case, public transport can still be regarded as by far the safest mode of transport, so promoting the integration of micro-mobility alongside public transport services could avoid road fatalities, provided that journeys would replace those by car, taxi, moped or motorcycle (International Transport Forum, 2020).

Therefore, from a general perspective, predictions suggest that if car traffic in cities is reduced, inner-city traffic flows are estimated to become less dangerous, reducing the fatalities in urban traffic. This is the outcome stated by the report published by the International Transport Forum. As shown above, a distance travelled by car or motorcycle seems much more likely to lead to the death of a road user than a distance travelled by bicycle or e-kick scooter and can thus contribute to a safer urban transport system. Moreover, micro mobility can provide access to railway links that are more distant or not easily accessible without motorised vehicles. This potential to choose entering stations on a broader scale allows fast and direct transportation to destinations desired, increasing the capacity of the overall public transport system, which is often facing capacity constraints at interchange nodes. This can provide a convenient transport solution that facilitates door-to-door mobility with electric kick scooters and, as a result, minimize car traffic in future urban traffic (International Transport Forum, 2020).

The more modes of public urban transport are available and the simpler and more convenient they get, the more people could renounce car rides and become attracted to use e-kick scooters, which could put an additional pressure on the utilisation of the infrastructure for bicycles, as in most European countries the same traffic rules apply to e-kick scooters as to bicycles. In many cities, bike lanes are already under enormous tension, e.g. in Amsterdam (TheGuardian, 2016), due to the rising numbers of cyclists especially in the metropolitan areas (Bundesministerium für Verkehr und digitale Infrastruktur, 2019) and the occurrence of new types of vehicles like cargo bikes and micro mobiles (Abend, 2019). Adjustments on infrastructure for bicycles are therefore highly recommendable in order to prevent congestion and to create a safe environment for these vulnerable road users. Although the proportion of shared free floating e-kick scooter trips in the modal split is relatively low yet – the modal split in Paris is estimated to be between 0.8% and 1.9% (6t-bureau de recherche, 2019) and individuals in Spain using shared e-kick scooters more than twice per week account for only 3.5% of the total population (Aguilera-García, Gomez, & Sobrino, 2020) – there are tendencies in rising numbers, as the offer gets more and more attractive and reliable. As this new mode of transportation responds to an effective demand and has rapidly become an integral part of many mobility systems around the globe, it is necessary to conceptualize perspectives and regulative frameworks, which enable their usage to be part of an open to public multimodal system, which provides an attractive alternative to fossil-fuelled vehicles.

2.3. Aim

The research and statistics, reviewed above, illustrate how e-micromobility has become an integral part of urban mobility systems around the globe. E-micromobility could be seen as a new mode of transportation, that responds to a widespread demand for multimodal urban transport. This conclusion points to a need for conceptualizing perspectives and possible regulative frameworks, which could enable micromobility to become a significant part of an open-to-public multimodal system, resulting in an attractive alternative to private motoring and fossil-fuelled vehicles.

The aim of this study is to provide examples of current best-practices of e-micromobility in European cities (including Tel Aviv), as well as examples of the problems and complaints that the introduction of e-micromobility has been met with. Finally, the aim is to conceptualize possible future developments, regulations, policies etc., that we see as possibilities for sustainable, intermodal urban transport.

2.4. Method

The methods used for data collection are document studies (of research reports, public and media documents), and a few additional methods. The results in the following section include:

- An overview of current situation, and near-future plans for intermodal and sustainable micromobility, especially in the project's partner cities.
- Thematic overviews of residents and authority’s relation to new e-micro mobility. Two themes that are covered are:
- Near-future potential for enhanced accessibility for residents’, through intermodal (combined) micromobility and public transport
- General public understandings of prominent issues related to the introduction of new e-miromobility.

3. Results

In the below results chapter, each partner in work package two (WP2) of the project, has reported on at least one city, covering aspects of its own choice. Therefore, the heading of each main subsections includes the name of the city and the covered aspects. The subtitle for each section includes the name of the reporting partner and author(s).

3.1. Tel Aviv – best practice and integration

The city of Tel Aviv encourages bicycle and e-kick scooter riding across the city due to its ecological benefits and its potential to reduce parking issues, decreases traffic congestion and emissions. Therefore, the city restructured the urban road space to engage the construction of bicycle lanes, increasing the attractiveness of bicycling and the usage of e-kick scooters. Depending on the moderate to subtropical Mediterranean climate, the city is predestined for the integration of personal light electric vehicles (PLEV) into the urban transport system as an integral part. To ensure a smooth integration of PLEV into road transport, detailed road traffic regulations have been established. According to these regulations, cyclists and users of electric kick scooters riding on roads without defined cycling facilities must ride on the road near the right-hand curb, not on the curb itself. On roads where integrated cycling and e-kick scooter traffic is combined with regular road traffic, as well as in traffic-calmed areas, users must ride on the right-hand side of the road. However, if a bicycle lane is installed in the road space, it must always be used by cyclists and e-kick scooters. These could be either bicycle lanes on the road space, exclusive bicycle lanes on the curbside or joint lanes for bicyclers and pedestrians, in which pedestrians are entitled to the right of passage. To ensure the compliance with those regulations the city government is intensifying the enforcement of according laws to protect pedestrians from injuries caused by bicycles and electric kick scooters. Each violation of law will entail a fine of 250 up to 1000 NIS, which corresponds to an amount of more than €60 up to €250 (Tel Aviv-Yafo Municipality, kein Datum).

According to Israeli regulations, effective from January 2019, citizens who do not have a driver's license and have not yet passed the written exam required for issuing a driver's license must complete a short course, which ends with the successful completion of a test consisting 30 questions on traffic laws, bicycle safety, and pedestrian rights. The license will be available to Israelis from age 15.5 and can be acquired in the Israeli driving test centres (The Times of Isreal, 2018). To improve enforcement of the existing rules, drivers under the age of 16 are sanctioned with a one-year postponement of their regular driving licence entitlement if they are caught driving an e-kick scooter. In order to reduce the number of fatal accidents and make the use of e-kick scooters safer, the city council also introduced the obligation to wear a helmet and the obligatory reflective vest, which must be worn at nighttime. To reduce the number of fatal accidents and make the use of e-kick scooters safer, the city council also introduced the obligation to wear a helmet and the obligatory reflective vest, which must be worn at night. Additionally, the transport of another driver, cycling under the influence of alcohol, the use of a mobile phone while driving and the crossing of a red traffic light are sanctioned according to the imposed regulations in order to reduce the numerous avoidable accidents (The Times of Isreal, 2018). Violations are punishable by severe fines of 1000 NIS, which equals a monetary value of €250 (CTech, 2018).

In August 2019, the municipality imposed a set of restrictions concerning designated parking areas, operator responsibility in terms of infringement and fine payments, as well as the limitation of the fleet size to a maximum of 2500 per operator. Since then, Vehicles must be parked in special spaces designated by the city, each of which can house an amount of eight vehicles at a time. In case no such parking zone is located near the user, the vehicle can also be parked outside these areas, provided that an interference with pedestrian traffic or block access to shops, buildings or bus stations can be prevented. Furthermore, an amount of more than three vehicles at the same spot is prohibited, unless the vehicles are parked in the designated parking zones (CTech, 2019).

Tel Aviv police has started to systematically check the users of electric kick scooters for compliance with the relevant regulations. Therefore, breathalyzer tests have been implemented, obstructively parked shared e-kick scooters were confiscated and illegal driving and infringements were severely punished due to police controls. Also, the municipality announced an official mobile application, using which residents can report illegally parked e-kick scooters immediately, to have it confiscated right away. In addition, service operators are now also required to maintain a customer call centre where violations and complaints can be raised directly (CTech, 2019).

Since January 2020, the currently operating shared mobility providers Lime, Bird and Wind are obliged to attach license plates to all their e-kick scooters in the city due to newly imposed regulations. Additionally, the city administration has introduced a new official application that enables citizens who encounter accidents and incidents, including e-kick scooters illegally driven on sidewalks, to report violations to city authorities and operating companies based on photographs taken, so that direct action can be taken against the offenders. The first offence will result in warning, the second leads to a two-month lasting prohibition to use the vehicles and with the third offense, a permanent ban will be sentenced. To ensure the adequate compliance with these regulations, the city introduced a unit of 22 inspectors, whose main task is the prevention of e-kick scooters riding on sidewalks by issuing tickets if violations occur. In February 2020, the city issued further regulations, introducing bans on certain high traffic areas such as the port of Tel Aviv and lowering the speed limit in some areas to 15 kilometres per hour, using geofencing technology to secure the compliance of regulations. From 15th June 2020 on, the shared mobility operators will be required to provide their users with helmets attached to the e-kick scooters (Globes, 2020).

Tel Aviv - short facts of current micromobility and regulations

Modal share

Eleven percent of Tel Aviv-Yafo residents' trips are with micromobility devices (Transportation, Traffic and Parking Authority, 2019).

Bike sharing

- City operated "Tel Ofan"; 1600 bikes total; over 650 trips per month
- One licensed bike company; 2500 bikes total; over 20,000 trips per month; avg distance per trip: 1.8 km; Median distance per trip: 1.1 km

(Transportation, Traffic and Parking Authority, 2019)

E-scooters

Three licensed companies

- 6000 scooters total
- over 1 million trips per month
- average distance per trip: 2km
- median distance per trip: 1.6km

(Transportation Traffic and Parking Authority, 2019)

Who uses e- scooters?

- Over 70% Residents
- Over 70% Men
- Over 60% aged 25-39

(Transportation Traffic and Parking Authority, 2019)

Local opportunities for e-micromobility and its intermodality

- Among factors behind e-micromobility popularity can be found “hot climate, congestion and dissatisfaction with public transport” (Transportation Traffic and Parking Authority, 2019)
- When asked in official survey, “why did you choose to take a shared e-scooter?”, 15% chose the alternative “lack of public transport” (Transportation Traffic and Parking Authority, 2019)
- When asked “what form of transportation does it replace?”, 23% chose (it replaces) ‘Public Transport’; 23% chose (it replaces) ‘walking” and 18% (it replaces) ‘taxi’. (Transportation Traffic and Parking Authority, 2019)

Current regulations of e-micromobility

- Operators must prove compliance to apply for permit
- 2,500 vehicles cap per operator
- Insurance requirements for all operators
- Required to operate dedicated call centers for customers and to receive information from the municipality
- Must operate in the entire city of Tel Aviv
- Must deploy at least 12% of vehicles in underserved areas of the city
- Geo-fenced restrictive parking in city center- 450+ dedicated spaces in district 3,5,6,8 (district 4 underway)
- Must not obstruct public right of way
- 50 meter no parking zone around schools
- Strict enforcement – over 20,000 vehicles confiscated by the city
- Operators most transmit live data via API
- Operators most provide anonymized demographical data one a month
- Operators are required to implement a safety program to minimize traffic violations
- Must require valid ID proving legal age
- Must limit users to 1 account per ID card
- License plates required for all e-devices
- Must provide helmet (from a specific date in year 2020)

(Transportation Traffic and Parking Authority, 2019)

Based on all the above the current municipal strategy for e-micromobility includes achieving a balance between micromobilty users and pedestrians, and to curb sidewalk use by micromobility users. It also includes so called ‘data-based cycle lane planning’.

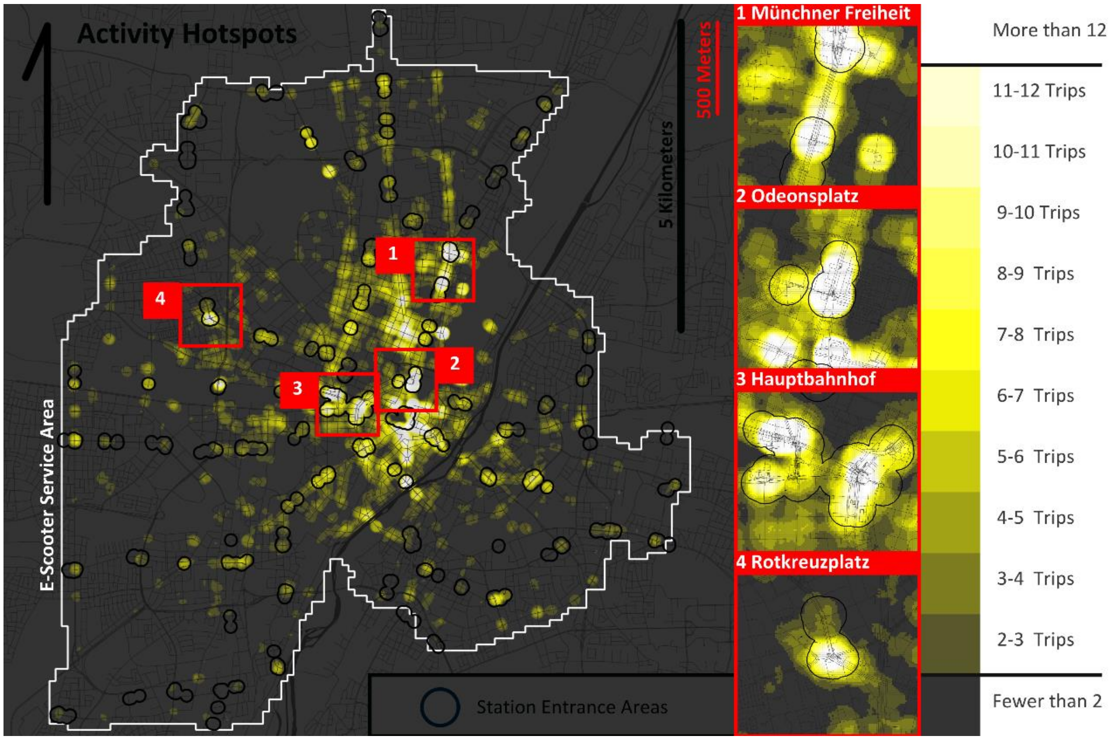
3.2. Munich – accessibility and intermodality

Current intermodal integration

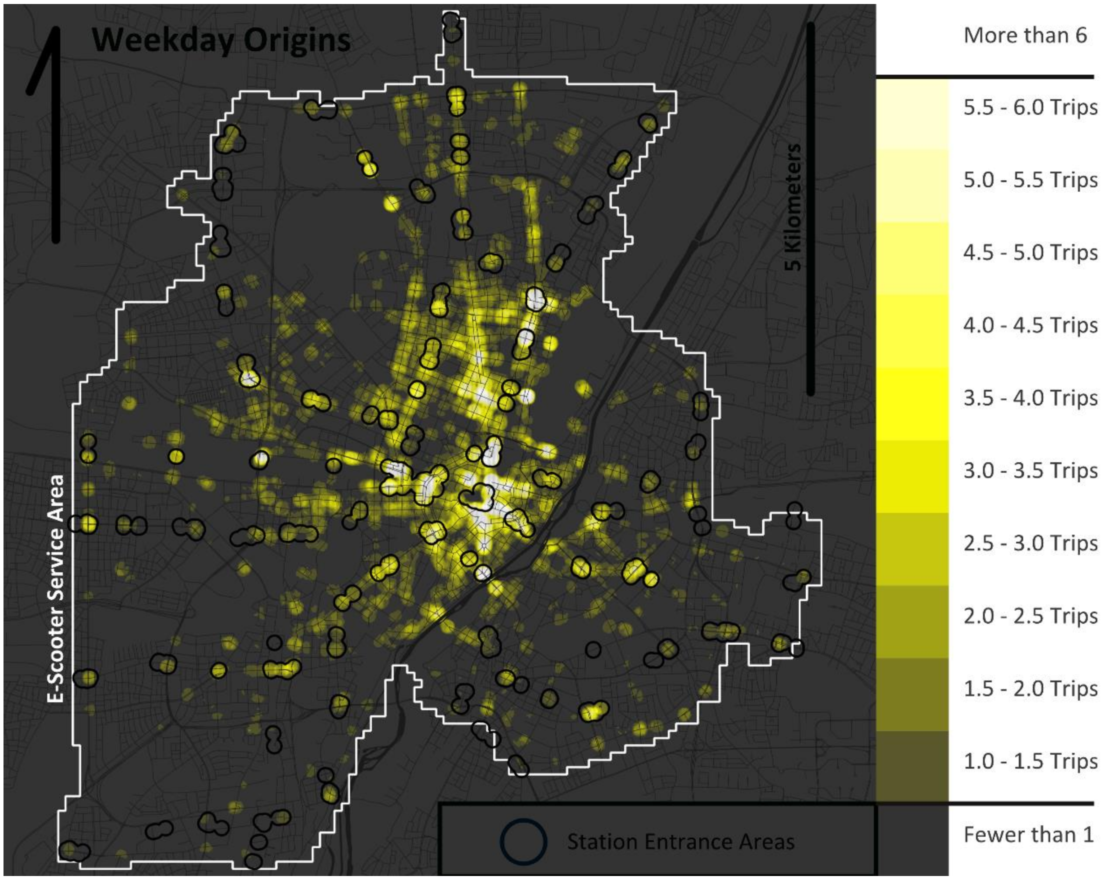
When studying e-micromobility, it is important to get a clear view of actual travel behaviour so that e-micromobility can be effectively incorporated into existing transportation systems. An analysis of actual e-scooter trips in Munich was done in order to understand the current link between e-scooter trips and public transport. This was done by mapping scooter activity (trip origins and destinations) in relation to public transport entrances. The areas around public transport entrances were compared to the other areas where there was e-scooter activity in order to see if a greater proportion of trips were starting or ending near public transport stations compared to other areas. For the purpose of this analysis, only the areas surrounding subway stations (U-Bahn) and commuter rail stations (S-Bahn) are used. The following map shows the results of this analysis in Munich.

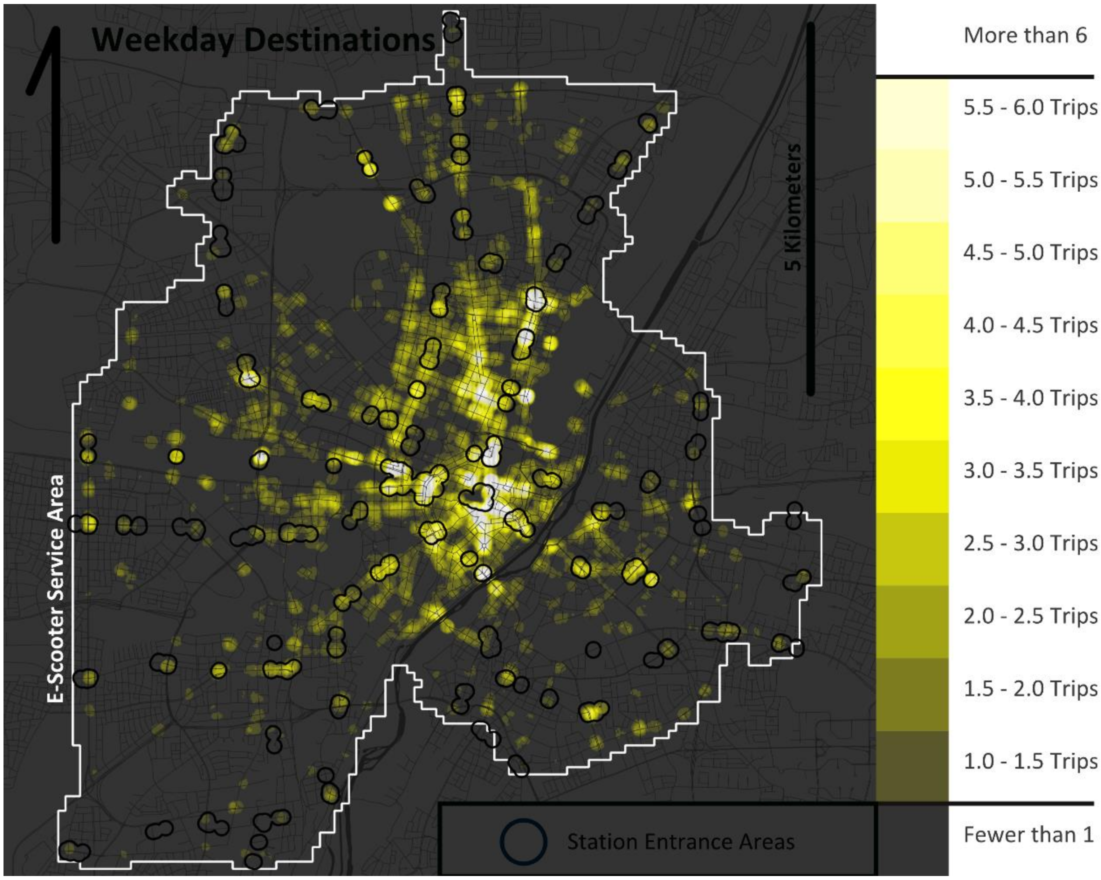
This map shows general e-scooter activity for one of Munich's e-scooter providers. In this case, general activity is defined as the beginning or ending of a trip. The trip values reflect the average daily number of trips. The average is based on a data collected between May 4th and June 28th 2020. A trip value of 1 means that, on average, there was at least one trip starting or ending in an area for every single day that data was collected. The map shows data in 10-meter by 10-meter grid cells and the value within each grid cell represents the number of trips within a 100-meter radius of that grid cell.

Many areas with high e-scooter activity overlap with public transport station entrances (U-Bahn, S-Bahn). The four callout maps highlight some of the more noteworthy areas where e-scooter activity is concentrated near transit stations. While the exact purposes of these e-scooter trips are not known, the concentrations of activity close to public transport station entrances gives the impression that people are using the e-scooters as a means of access or egress for public transport stations.

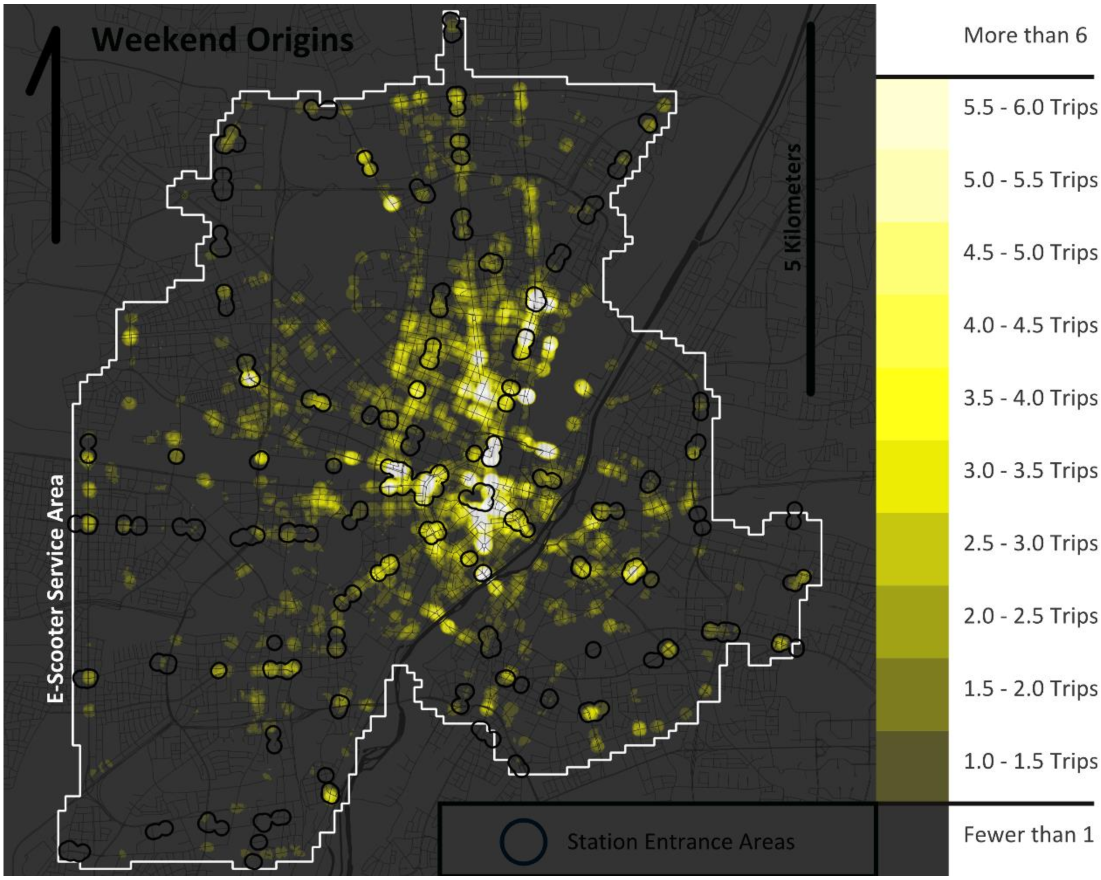


The following four maps also show average daily e-scooter activity in Munich. However, they separate trip origins and destinations for average weekday and average weekend trips. The weekday maps show origins and destinations for a typical weekday during the time period when data was collected and the weekend maps show origins and destinations for a typical weekend day during the time period when data was collected. A quick visual inspection of these maps reveals that there is not a huge difference between the origin and destination activity areas. Trips seem to start and end at about the same rates in the same places. Visually comparing the weekend and weekday maps also shows that there is not a huge difference between weekend and weekday activity. However, the actual numbers reveal slight differences.


Weekday Origins
5 Kilometers
E-Scooter Service Area
Station Entrance Areas
More than 6
5.5 - 6.0 Trips
5.0 - 5.5 Trips
4.5 - 5.0 Trips
4.0 - 4.5 Trips
3.5 - 4.0 Trips
3.0 - 3.5 Trips
2.5 - 3.0 Trips
2.0 - 2.5 Trips
1.5 - 2.0 Trips
1.0 - 1.5 Trips
Fewer than 1



Weekday Destinations
5 Kilometers
E-Scooter Service Area
Station Entrance Areas
More than 6
5.5 - 6.0 Trips
5.0 - 5.5 Trips
4.5 - 5.0 Trips
4.0 - 4.5 Trips
3.5 - 4.0 Trips
3.0 - 3.5 Trips
2.5 - 3.0 Trips
2.0 - 2.5 Trips
1.5 - 2.0 Trips
1.0 - 1.5 Trips
Fewer than 1


Weekend Origins
5 Kilometers
E-Scooter Service Area
Station Entrance Areas
More than 6
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5.0 - 5.5 Trips
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4.0 - 4.5 Trips
3.5 - 4.0 Trips
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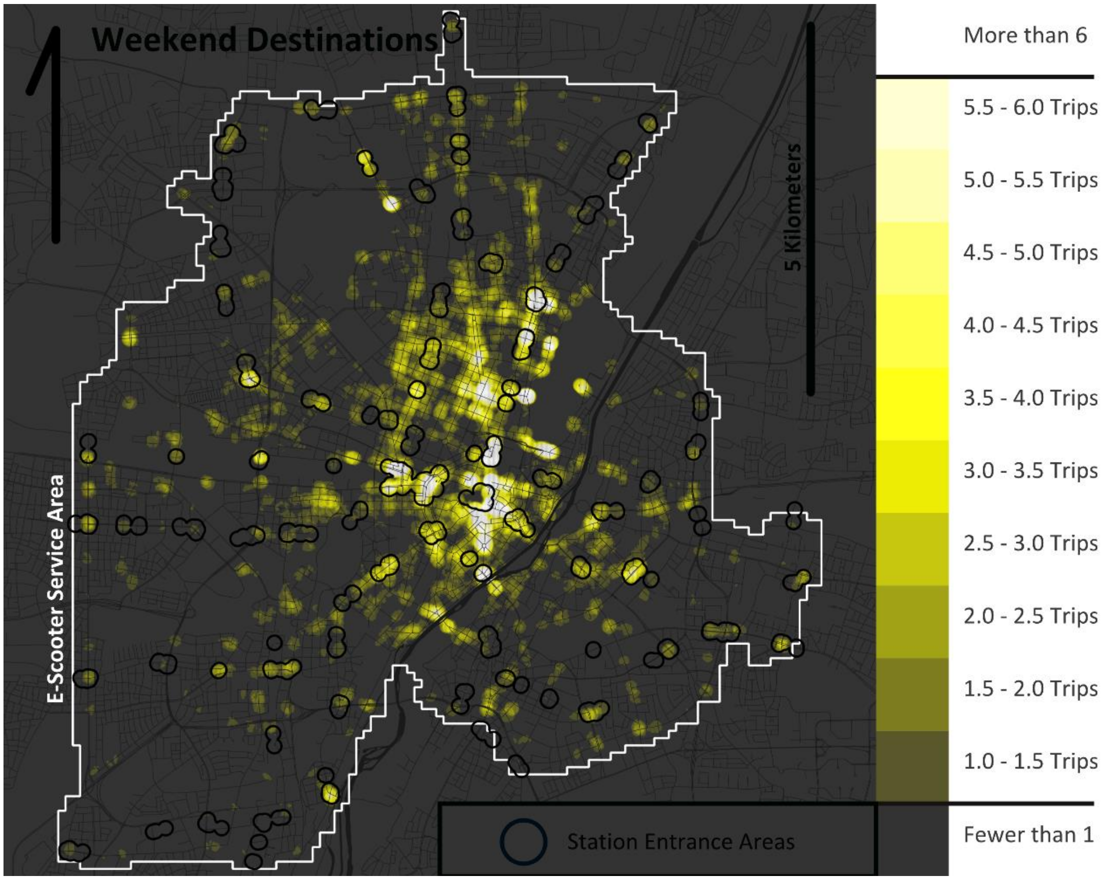
1.5 - 2.0 Trips
1.0 - 1.5 Trips
Fewer than 1



The following table highlights the differences in e-scooter activity between areas near transit station entrances and other areas in Munich. The percentages represent the percentage of the land area where a certain number of trips can be expected. For example, under the section called "weekday origins" there is a column for "other areas" and a column for "station areas". In the row corresponding with 1 trip, 23% of the land area outside of station areas can expect on average at least one trip per day, while 65% of the land area within the station areas can expect on average at least one trip per day. As the trip numbers increase, the share of the land area where this density of trips is likely to occur decreases, but it is always higher in the areas surrounding transit station entrances. This indicates that hotspots of activity are more likely to occur near transit stations than in other areas. The numbers support this when looking origins and destinations for both average days during the week and average days during the weekend.

It should be noted that the weekday and weekend maps look almost indistinguishable, but the numbers indicate that larger areas with high densities of trips are slightly less likely to occur in station areas during the weekend than during the week. This could be explained by more leisure trips on weekends and fewer people commuting to work.

Coverage of Different Areas by Average Daily Trips

	Weekday Origins		Weekday Destinations		Weekend Origins		Weekend Destinations	
Trips	Other Areas	Station Areas	Other Areas	Station Areas	Other Areas	Station Areas	Other Areas	Station Areas
1	23%	65%	23%	64%	23%	58%	24%	58%
2	7%	35%	7%	34%	7%	29%	7%	29%
3	2%	19%	2%	19%	3%	16%	3%	16%
4	1%	11%	1%	10%	1%	9%	1%	9%
5	1%	7%	1%	6%	1%	6%	1%	6%
6	0%	4%	0%	4%	1%	5%	1%	4%
7	0%	3%	0%	3%	0%	3%	0%	3%
8	0%	2%	0%	2%	0%	2%	0%	2%
9	0%	1%	0%	1%	0%	2%	0%	2%
10	0%	1%	0%	1%	0%	1%	0%	1%

The hotspot analysis is important because it establishes a connection between e-scooter trips and public transport station areas. This supports the idea that people are already using e-scooters to make multi-modal trips and establishes a baseline measurement for future analyses.

Potential impacts of e-micromobility on accessibility

Since the current intermodal integration analysis established that there is a relationship between e-scooter use and public transport stations, it is important to dive deeper into the potential implications this could have on public transport accessibility in Munich.

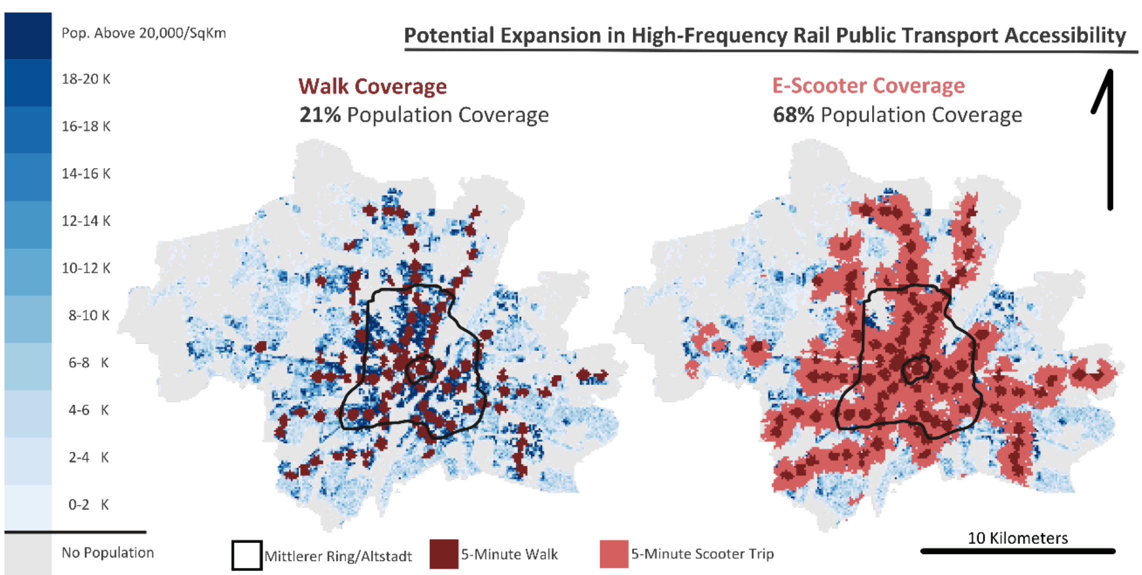
The following maps visualize these potential effects of e-scooters on public transport accessibility. This analysis was done by first measuring a base public transport accessibility scenario for Munich, then comparing that base scenario to a scenario where everyone can access public transport using an e-scooter. Five-minute travel times are used for both scenarios, except the base scenario assumes that public transport is only accessed by five minutes of walking while the other scenario assumes everyone can access public transport with five minutes of e-scooter travel. Coverage areas were overlaid with population data in order to get an estimate of exactly how many people could benefit from better e-scooter connections to public transport.

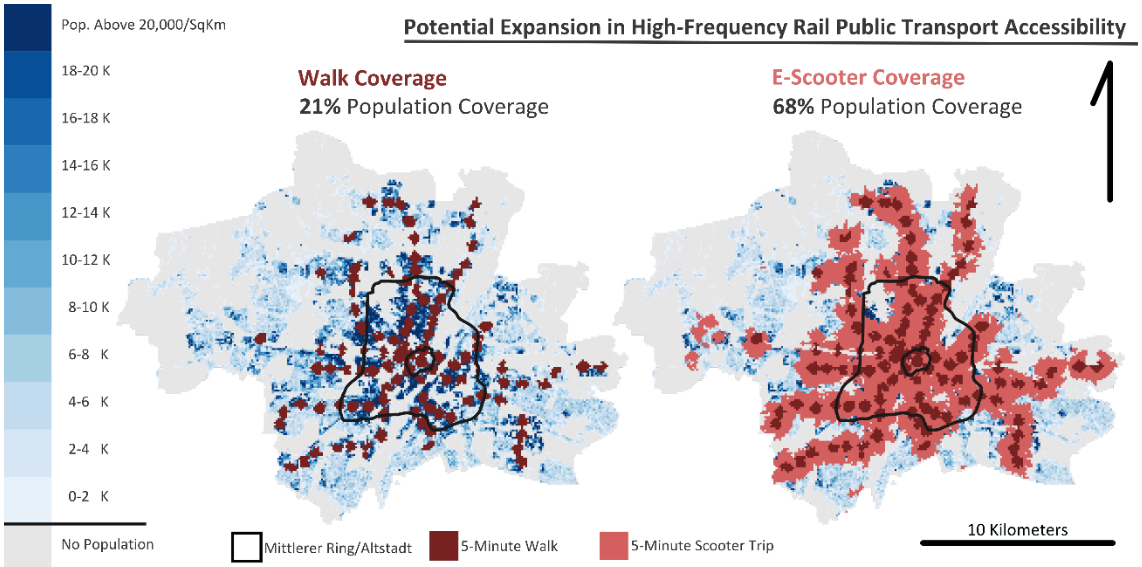
This analysis was done twice, once looking at all high frequency public transport stations, regardless of mode, and once looking at high frequency rail stations, which means U-Bahn and S-Bahn stations in the case of Munich. For this analysis, "high-frequency" public transport services were defined as stations where there were at least 288 transit departures in a typical weekday. This comes out to one departure every five minutes. This may seem quite a high threshold, but it takes into account departures traveling in multiple directions.

In the analysis that looked at all high-frequency public transport, it was found that 80% of Munich's population lives in an area with a five-minute walk of high frequency public transport services. When e-scooter trips are considered, 99% of Munich's population lives in an area that is within a five-minute e-scooter trip of high-frequency public transport services.

In the analysis that only looked at high-frequency rail transport services (U-Bahn and S-Bahn), it was found that only 21% of Munich's population lives in an area within a five-minute walk of high-frequency rail services. When e-scooter accessibility is considered, that percentage of the population jumps up to 68%. This means 68% of Munich's population lives in an area that is within a five-minute e-scooter trip of a high-frequency rail service.

The following maps reflect the results of this analysis. Different transit service areas have been overlaid with population density to give an idea as to how much of the population is covered by these service areas. Populated areas are shown in varying shades of blue and can be seen when they are not covered by service areas. This should visually show the highly-populated areas that are not covered by the different service areas.





While the maps only show the relationship between public transport accessibility and the distribution of the general population, more information can be learned by looking at the breakdown of different population groups. Specifically, extra attention was paid to the young population (18-29) and the older population (65 and over). People in the younger population may be less likely to own a car and people in the older population group may be less likely to drive a car. In theory, these two groups could benefit from improved accessibility to public transport. The population under the age of 18 would normally also be worth looking at since effectively nobody in this age group can use a car. However, most people in this age group also cannot use an e-scooter since one has to be at least 14 to use an e-scooter in Germany. Therefore, this age group was not examined.

The following table shows what proportions of these different population groups live within a five-minute travel distance of high-frequency transit using different transportation modes (walking, e-scooter). This is broken down by all high-frequency transit and high-frequency rail transit. When looking at all high-frequency transit trips, most of the population already lives within a five-minute walk of these transit services. However, assuming e-scooter as the access mode increases this value to essentially accommodate the entire population. When looking solely at high-frequency rail transit, a relatively small proportion of the population lives within a five-minute walk of these services, but the proportion of the population within the five-minute service areas increases dramatically when e-scooters are assumed as the access mode. This is most notable when looking at the young population (18-29). If e-scooters are used to access high-frequency rail transport, then the percentage of the young population that lives within a five-minute trip of these services increases from 24% to 74%.

Potential PT Accessibility Expansion

	High Frequency Transit (All)		High Frequency Transit (Rail)	
	Walk	E-Scooter	Walk	E-Scooter
General Population	80%	99%	21%	68%
Population 18-29	84%	100%	24%	74%
Population over 65	78%	99%	19%	65%

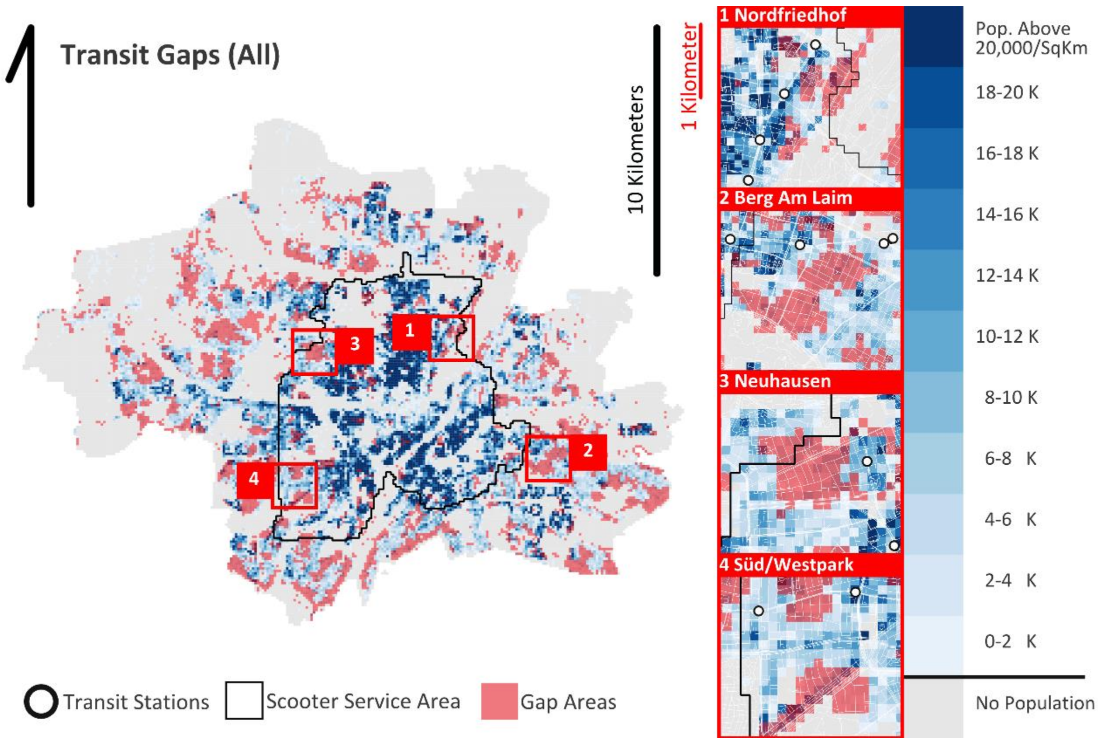
It should be noted that the five-minute e-scooter travel area was based on an assumed average travel speed of 14 km/h. This figure came from looking at the origin and destination points for 1000 e-scooter trips in Munich, routing them on a street network (assuming shortest route is used) to get an estimate of the trip distance, comparing the estimated trip distance to the known trip duration in order to get a travel speed, then identifying the modal, or most common, travel speed for the 1000 trips. This value turned out to be 14 km/h.

Accessibility gap analysis

While the previous analysis focuses on the areas that are within a five-minute travel distance of high-frequency public transport stations, the gap analysis looks at the areas that are not within a five-minute travel distance of high-frequency public transport stations.

Like the potential accessibility analysis, the gap analysis was also done twice, once looking at all high-frequency public transport services, and once looking only at high-frequency rail services. The main function of this analysis is to identify the specific areas that could benefit the most from improved connections to public transport services with e-scooters. These areas could be the focus of future parking interventions near public transport stations that facilitate better connections between public transport and e-scooters.

The following map shows transit gap areas (in pink) for all high-frequency transit overlaid with population distribution. The gap areas are areas that are outside of the five-minute walking service area, but within the five-minute e-scooter service area. Four areas of interest are shown in more detail within the call-out boxes. These areas were chosen because of their relative size and location either within or near the current e-scooter service area.

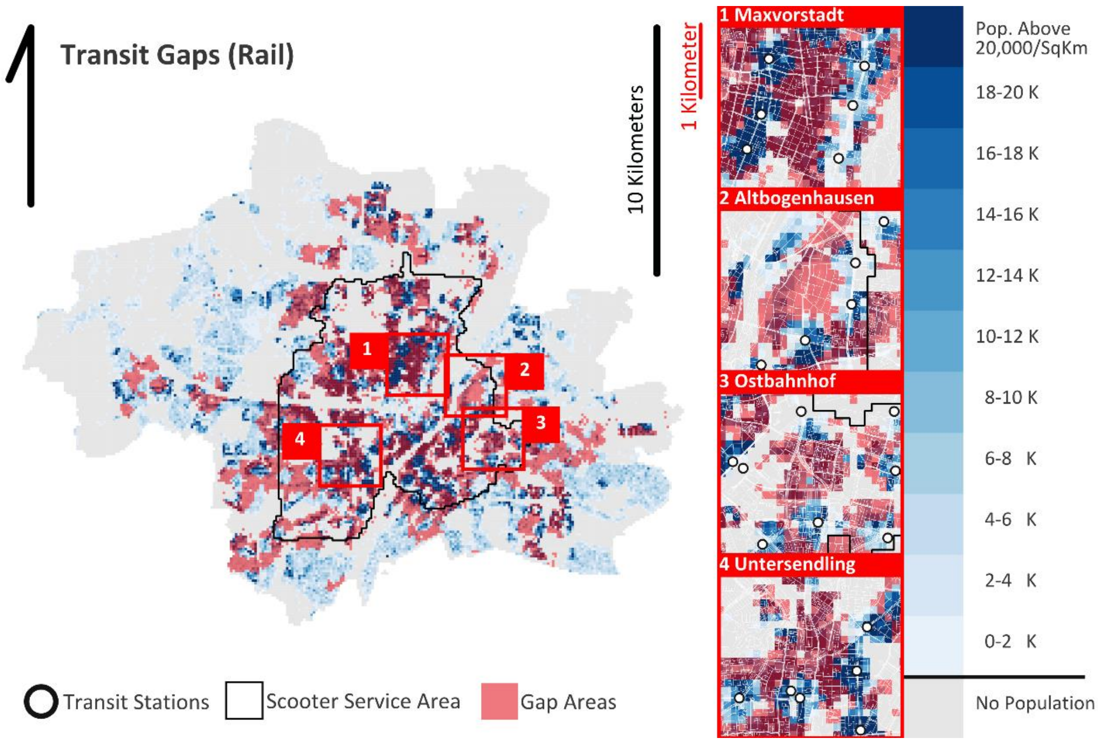


The following table shows population estimations for the four areas in the call-out boxes. The populations are estimated by summing the populations within the affected grid cells.

Transit Gap Areas (All Transit)

Area	Population
Nordfriedhof	3,600
Berg Am Laim	5,500
Neuhausen/Nymphenburg	4,000
Südpark/Westpark	5,700

The following map shows the transit gap areas (in pink) for all high-frequency rail transit overlaid with population distribution. Four areas of interest are shown in more detail in the call-out boxes. These areas were chosen because of their relatively central locations and sizes. Most notably, a large part of Maxvorstadt is between two subway lines, but more than a five-minute walk away from any of the stations. This area is also very densely populated, meaning that improvements that facilitate intermodal connections between transit and e-scooters could potentially affect a lot of people in this area.



The following table shows population estimates for the four areas within the call-out boxes. Some of these areas have very large populations that reside just outside of the five-minute pedestrian service areas.

Transit Gap Areas (Rail Transit)

Area	Population
Maxvorstadt	31,400
Altbogenhausen	8,700
Ostbahnhof	10,800
Untersendling	24,900

The accessibility gap analysis is significant because it highlights specific areas that could potentially benefit the most from interventions that improve intermodal connectivity between e-scooters and public transportation. The analysis also provides population estimates for these areas.

3.3. Copenhagen – current status quo of e-micromobility

E-scooters

There seems to have been a good level of willingness from the e-kickscooter service providers to cooperate with e.g. the publicly owned transport operator companies and the municipality regarding placement of vehicles.

There is an official website for national legislation regarding “motorized kickscooters”, where it says that "the Municipality decides on permits for placement of e-micromobility vehicles, while the National Government issues the rules for traffic.” There hasn’t yet been issued permits for e-kickscooters in Copenhagen. The city was awaiting the Danish government’s legislation regarding micromobility. Now this legislation has been introduced, and one main outcome for providers of shared e-scooters in Copenhagen is that from the autumn of 2020 they can not be placed in public spaces at all. Rentals of e-scooters can only be done in shops, and after each rental the e-scooter has to be returned to the shop again.

Bike sharing

"Bycyklen” (The City Bike) has placed bicycles and docking stations in relation to most train stations in Copenhagen."

Travellers can use “Rejsekortet” (which is a public transport debit card in Denmark) to register when they want to use “Bycyklen”.

Intermodality between micromobility and public transport

"Rejseplanen” (Journey Planner) and google maps travel planner have incorporated bike sharing and e-scooters as travel options in route planning.

On the so called S-trains it has been facilitated for ”commuters to bring their own bicycle with them and utilize their bicycles as a means of first/last-mile transport …”

- In the S-trains it is allowed to bring e-scooters (and e-bikes for that matter) for free if they are parked properly the same way as the regular bicycles.
- In the intercity trains you can also bring e-kickscooters, but whether or not you have to pay for it depends on the size and ability to fold. If the e-kickscooter meassures more than 100x60x30 cm, it is regarded as a bicycle, and to bring it you would therefore have to buy a bicycle ticket (same ticket you would buy in order to bring your regular bicycle or e-bicycle on the train). If the e-kickscooter can be folded together, you can bring it for free as hand luggage, as long as it does not meassure more than 115x60x30 cm.

- In the metro you can also bring e-kickscooters, if you buy a bicycle ticket. During rush hour (on work days 7:00-9:00 and 15:30-17:30) you cannot bring bicycles or e-kickscooters. If the kickscooter folds to max. 110x60x30 you can bring it for free as hand luggage.
- Whether or not you can bring bicycles and e-kickscooters on busses depends on what bus it is. Generally speaking you cannot bring them on the busses in Copenhagen, but as soon as you get out of the city and into the suburbs and areas surrounding Copenhagen it is possible to bring bicycles, if there is room enough in the bus (that's up to the driver to decide). In that case you have to buy a bicycle ticket. E-kickscooters can be brought on for free as hand lugage on all busses (as long as they are smaller than 110x60x30 cm).
- On the harbour busses you can bring e-kickscooters and bicycles for free regardless of their size.

3.4. Stockholm, Göteborg and Malmö – e-sooters in Swedish city district press

This section is based on a media study, carried out in order to explore general understandings and views that e-scooters have become associated with during recent years. Articles about e-scooters in the three largest cities' local, weekly newspapers (city district press) during the years 2018-2020, were reviewed. The choice of city district press was based on two assumptions. The first was that in this press, articles, opinion pieces and letters to the editor have a focus on local events and opinions, i.e. what should be on top of the local residents' minds. If this assumption is correct, city district press can provide concrete input into general understandings and views that e-scooters became associated with during their introductory years. The second assumption is that the district press is comparatively rich in information on the reactions and actions of residents, authorities and companies. The aim of the media study was to identify and categorize noticeable, much reported on issues regarding e-scooters. Related research questions for the analysis could also be:

- What does the media discourse reflect in terms of reactions and everyday practices of the residents and municipal authorities?
- What does the reception of e-scooters show about issues that need to be addressed in governance processes, by those who have interests in new means of transport and traffic behaviour, in order for these to be integrated in a sustainable way in urban planning and traffic systems?

The study's analytical framework consists mainly of cultural and social practice theory. Within this broad direction, I want to place the concept of cultural breakpoints (see for example Löfgren, 2007). This is because the e-scooter system could represent a breakpoint for the experience and use of urban space and traffic environment, among the city's residents and visitors. The term breakpoint can also signify circumstances in which every day routines are "broken or problematized" (Ehn & Löfgren, 2006).

In the review I found that the reactions and debates that e-scooters brought during the introductory years (2018-2019), were mainly related to

- Facts about the introduction of e-scooters
- Traffic safety and regulations
- Working conditions for collection / charging
- Environmental aspects of operation, discarding and production of e-scooters

Therefore, I have chosen to present the press material below under these four aspects / headings. For each category or aspect, criticism has been raised and problems have been highlighted, but also suggestions for improvement and development have been reported.

Facts about the introduction of e-scooters

The activity of e-scooter companies draws considerable attention. Local newspapers in the three largest Swedish cities report information about their arrival and statistics about usage.

> Since Voi Scooters was founded in August 2018, over 14 million people in Europe have used their electric scooters. The company's launch has also become popular in Gothenburg and in 2019 over 500,000 trips were made in Gothenburg.
>
> At present, there are four different electric scooter companies represented on the streets of Gothenburg. Voi, Tier, Lime and the newcomer Wind who arrived in November 2019. Tier and Lime was launched in Gothenburg in the spring of 2019 while Voi was first released when they arrived in August 2018. E-scooters have become popular among Gothenburg citizens in a short time and a city guide made by the company Voi shows that over 500,000 trips were made in Sweden's second largest city in 2019. Which can be compared to Stockholm where over 2.5 million trips have been made and Malmös over 300,000 trips. (…). - Electric scooters have started to find a natural place in society as an alternative to short car trips in the inner city and a complement to bus, train and metro. (GöteborgDirekt Hisingen, 2020-01-18, Sektion: NYHETER ■ HISINGEN, Page 12, part 1)

Comparisons to usage in other cities are interesting, so exact information is asked for.

> Voi, Tier, Lime and Wind have already become part of the Gothenburg urban space. Now Wheels is also rolling in from California - an electric powered mini bike with a saddle. - (…) No one knows exactly how many electric scooters are there in Gothenburg. (GöteborgDirekt Centrum - Majorna/Linné, 2020-02-29, Section: Nyheter, Page 12, part 1)

The phenomenon is analysed under all weather conditions.

Voi and Circ do not completely remove their electric scooters from the streets, but equip them for the winter.

> The electric scooter companies have found different solutions to make it safer to drive during the winter months. The German company Circ reduces the number of vehicles, and equips those that remain with winter tires. They have also developed a stop button that disables all vehicles

at the same time when the weather poses too great risks. (HässelbyDirekt, 2019-11-02. Section: Nyheter, Page 10, part 1)

Traffic safety and regulations

Risks ensuing from e-scooter users' reckless driving and conduct is one of the topics that is most often found among the approximately four hundred articles in the district press that have been part of my selection. One way to write about this is from the perspective of what problems it can bring among groups that do not use e-scooters.

> - He [the dog Emil] was walking in front of me and then he banged his head on the mudflap. / - - - / It turned out that the dog's eye had burst, and that the wound had become infected and that they had to have the eye removed. In addition, the operation cost Kristina SEK 29,000. / - - - / - I have had a dog for 50 years and have never experienced anything similar. (Vasastan Direkt, 2020-02-08, Section: Nyheter, Page 10, part 1)

> "Caption: ALARMED. Next time, it might be a disabled person who gets into trouble. Kristina thinks that people need to learn to take responsibility and have compassion for each other. Emil is lively again but his eyesight is half as good after the accident." (Vasastan Direkt, 2020-02-08, Nyheter, Page 10, part 1)

> "Birgitta Blom, 80, has lived in the same house on Folkskolegatan all her life. / --- / But she thinks the traffic has gotten worse and you now have to watch out for both electric bikes and electric scooters." (Mitt i Södermalm, 2020, page 5, part 1)

The users' driving is also addressed in letters to the editor.

> "/ - - - / In addition to the darkness and the rain, they bring some hell for the motorists, among others. Yes, even for pedestrians, of course! They show up on the right side of the motorist or on the sidewalk at full speed, it rains and visibility decreases significantly. Should one make a right turn, it is basically impossible to spot these LIGHTLY egoists who refuse to take into account everything else that is moving in their vicinity !!!! / - - - / Caption: NOT APPLICABLE. The submission writer believes that light is needed on electric scooters. (ÖstermalmDirekt, 2019-12-28, Section: Tyck Om, Page 23, Part 1)

If e-scooters can evoke this kind of feelings, then it is also no surprise that many wanted to read about the cyclist who hit a police officer in the face after being told to drive more carefully.

> "This is what you wanted to read about the most on Mitt in Södermalm's website in 2019. On / --- /the 3rd [place] 'Electric scooter user in Hornstull hit police in the face." (Mitt i Södermalm, 2020-01- 07, Page 8, Part 1)

The involvement of the authorities in regulating how e-scooters should be used appears often as a reaction to situations that have already raised discontent.

> Now there will be parking zones for e-scooters in Gothenburg. It is not a requirement to place the electric scooter on the newly established positions, but some e-scooter lending companies reward users who do. / - - - / Electric scooters that lie around higgledy-piggledy have annoyed Gothenburg citizens since the new mode of transport has made entry into the city. For visually impaired people and people with motor aids, carelessly parked electric scooters have also become dangerous. In October, the rules were tightened, among other things it was decided that electric scooter bikes can no longer be parked on several places. Now comes another solution to improve the situation: Excellent parking spaces for electric scooters. (Göteborg Direkt, Angered - Östra Göteborg, 2020-02-29, Section: NEWS, page 12, part 1)

New regulations are presented in a positive light as a natural response to repeated indications of something going wrong.

> Permits may be required to put up electric scooters in Stockholm, according to a new legal investigation in progress from the police. The explosive entrance of electric scooters into Stockholm and elsewhere in the country has led the Swedish Transport Agency to now investigate and review the regulations for the hype vehicles. But at the same time, a legal investigation is underway within the police regarding the applicable rules, after the traffic office wanted to get a straight message about whether or not permission is required to put up electric scooters. (Hammarby Direkt, 2020-02-22, Section: Nyheter, page 8, part 1)

A thoroughly considered reaction seems to be supported. Even when presented with possibly dangerous mishaps that tend to generalize the authorities do not rush to step in.

From the point of view of traffic security e-scooters involve some risks for both users and other traffic participants, risks that are linked to the speed they can run at - comparable to bicycles as well as motorized vehicles, and to the obligations of the users in terms of education and traffic rules.

> To ride a bike, I have to wear a helmet and I have to ride on the bike lanes that have been made for this purpose. Electric scooters in our city are allowed to drive on the road, sidewalks and also on tram tracks. (…) Why don't those who drive electric scooters need helmets and training? I want to know how politicians or those who decide have thought about this. What does it cost the City of Gothenburg or if there is a profitable aim in these electric scooters? (GöteborgDirekt Askim - Norra Halland, 2019-12-07. Section: TYCK OM ■ ÅSIKT ■ DEBATT, Page 22, part 1)

As accidents have affected e-scooter users as well as other traffic participants, hypotheses about what might help to avoid them have arised. They hint to forbidding alcohol consumption, prohibit using pedestrian lanes, and regulating the parking of micromobiles (see quote above, GöteborgDirekt Angered - Östra Göteborg, 2020-02-29, Section: NYHETER ■ GÖTEBORG, Page 12, del 1).

> In Finland, where the electric scooter bicycles first arrived in May, several accidents have been registered. Among other things, Yle has reported that a man was fined in Helsinki after driving on a red light on an electric scooter. Several others have been fined after driving on the sidewalk, which has also been common in Stockholm.

> In Sweden, the first fatal accident occurred with an electric scooter bike at the end of May, after a cyclist in Helsingborg crashed into a car. Serious accidents have also occurred in Södertälje, Stockholm and Gothenburg. (Metro, 2019-08-05, Published on the web)

> Between January and August this year, 150 e-scooter accidents were reported in Stockholm (...). Most accidents occur between 11 pm and 1 am, mainly during the nights towards Saturday. It is also at this time that the three accidents that led to the most serious personal injury have occurred. - These are figures that indicate that people are inebriated and should not drive, says Daniel Helldén (MP), Traffic Citizens' Council, to SvD. Victor Lindberg, co-owner of the company Ezride, which sells electric scooters, is not surprised by the statistics. - People use the electric scooter to get between bars. Some give others a lift. It is easier to think about safety if you, for example, use electric scooters in commuting to work, he tells SvD. (...) Most accidents occur on Södermalm and Norrmalm. (ÖstermalmDirekt, 2019-11-02, Section: Nyheter, Page 22, part 1)

> Birgitta was out on a walk at Norra Bantorget with her sister when her foot got stuck in an electric scooter dumped on the walkway.

> The accident resulted in three bone fractures, nine days on the hospital with severe pain, six weeks in plaster and a risk of permanent injury.

> - My summer was ruined and I don't even know if I will get recovered. I am far from being the only one, electric scooters lie about and make trouble everywhere. And nobody wants to take responsibility! says Birgitta. (Mitt is Stockholm, 2019-08-20, Published on the web)

Traffic security for e-scooters is also influenced by weather conditions, so some companies took additional measures to be able to put the vehicles on pause in the case of severe weather.

> They have also developed a stop button that disables all vehicles at the same time when the weather poses too great risks. - In this case, ongoing trips can be completed safely. (...) App notifications inform users about how the weather affects the trip and the company will collaborate with snow removal companies to adapt the working method during the winter. (HässelbyDirekt, 2019-11-02. Section: Nyheter Page 10, del 1)¨

Due to their design e-scooters are not steady by themselves and this makes them less secure in traffic than electric bicycles for example.

> Safer than electric scooters since the wide wheels of the bikes are only 14 inches, just like regular children's bikes. At the same time the bikes have a built-in speaker that you can play your own music on. The maximum speed is 20 kilometers per hour. According to the company, they will also try to prevent the vehicles from being parked incorrectly by having the users take a picture of the parking place when they are to end the ride. (ÖstermalmDirekt, 2019-11-16, Section: NEWS ■ STOCKHOLM Page 20, part 1)

Working conditions

Working conditions for those who collect or charge the e-scooters raise questions about equity and impact on the environment. With no trade union rights and no base salary the “juicers” and “hunters” that collect and charge e-scooters sometimes do not earn enough to cover their expenses and use their personal cars to reach the areas where the e-scooters are.

> But those who take care of the services and ensure that the market’s wheels roll on are often people who are far from the regular labor market and take on gigs because they simply do not get any other work.
>
> (…) The price of the services is kept low due to the fact that the person performing the gig job only gets paid during the time the assignment is performed, i.e., as long as you have a customer in the car (Uber), as long as you have food boxes to deliver (Foodora), or as long as you have an electric scooter to charge (Lime). Trade union rights, such as a fixed base salary or earned vacation, are only to be forgotten, since you, as involved in the gig economy, are not seen as employees, but as self-employed. Sydsvenskan's undercover reporter Elina Pahnke recently managed to earn SEK 80 on a whole evening's work searching for discharged electric scooters and recharging them, and then put them up again at their specified positions. (ETC Göteborg, 2019-08-19, Section: Ekonomi, Sida 19 Page 19, part 1, Published in print.)
>
> It is also necessary to review the model for the collection and charging of the electric scooters. It is now often done through "juicers" or "hunters", private individuals who use their own cars to find the bikes, drive them home, load them and then place them back in town. There are reports of very low remuneration that barely covers expenses, such as gasoline costs. This model also creates a major climate impact. It is gratifying that a couple of players have introduced more socially and environmentally sustainable ways of collecting and charging their bikes, but it is important that the city demands that all companies do so. (StockholmDirekt, 2019-08-22, Published on the web)

Environmental aspects

The aspects taken into account when it comes to the environmental impact of the production and use of e-scooters are the materials they are made of, their lifespan, emissions, and scrapping.

> Part of signing a contract is about having communication about the whole phenomenon. It is in everyone's interest that not only is the traffic environment good, but also that e-scooters will not be an environmental problem. If they have to be discarded as quickly as today, there will be no environmental gain. There was some rumour that they only lasted a month, but today they last for over six months. Of course, we want to continue that trend so that they become sustainable products. (Göteborgs-Posten, 2019-06-13, Published on the web)

E-scooters can be counted among the dangerous waste material that has been found on the bottom of the sea/lakes as they contain batteries.

On the surface it looks calm and peaceful - but just a few meters down the depth a whole other world lurks. Here, along the inner quay and beach edges, are the hidden garbage tips, with everything from tons of boat batteries to electric scooters, shopping carts, car decks, bikes and televisions. The diver Fredrik Johansson is stunned by the large amounts of debris and therefore took the initiative for the project “Rena Mälaren (Clean Mälaren)”. Here, divers and volunteers work to fish up objects from the seabed - which can often be environmentally hazardous. “- Most people have no idea how bad it looks. There are huge amounts of garbage. That's scary,” says Fredrik Johansson. Worst, he thinks it is with the boat batteries. - They contain very toxic substances such as lead and sulfuric acid, which dissolve in the water we drink. The goal of “Rena Mälaren” is to fish up as much toxic substances as possible and contribute to a better environment. But also influence people to stop debris. The project has been underway for about a year and a half and divers dive several times a week at various locations in the city. (Mitt i Kungsholmen, 2020-02-11, Section: GENERAL, Page 4-5, part 1. Published in print.)

The electric scooters are not environmentally sustainable in the absolute sense. They consume non-renewable resources such as metals and oil and generate emissions both during manufacture and operation. But on the other hand, it is difficult to find any phenomenon that can be regarded as absolutely environmentally sustainable. Walking can also be considered unsustainable in this context, it wears shoes that are manufactured and distributed using non-renewable resources. Sustainability should reasonably be understood in practical application as a balance between various aspects, environmental, financial and social. (Sydsvenskan, 2020-02-28, Published on the web)

Electric scooters have become extremely popular. Many see them as a climate-smart alternative for short trips. But, digging a bit in articles and surveys, it appears that the electric scooter has a relatively large climate impact: 125 grams of carbon dioxide per person kilometre. The relatively high climatic load is explained by a short lifespan, rare minerals in the production and extensive management (collection, loading, deployment and more). The corresponding climate footprint for a petrol car in city traffic is 250 grams of carbon dioxide per passenger per kilometre. Replacing a car journey with the electric scooter is thus a smart decision. Unfortunately, studies show that this choice is quite rare. Only two percent of trips with an electric scooter replace a car ride. In 98 percent of cases, the electric scooter replaces climate-smart alternatives such as walking, cycling or public transport. The e-scooter thus turns into a climate culprit! (…) According to an article in Svenska Dagbladet, 4 million trips by electric scooter were made in the first eight months last year. This corresponds to 2 million car trips or 3,000 car return trips Stockholm - Gothenburg! Many times the trips are completely unnecessary. (Mitt i, 2020-02-19, Published on the web)

Another problem concerns the sustainability of electric scooters. The industry markets them as climate smart, but the climate benefit is questionable. According to a survey from North Carolina State University, most of the environmental impact comes not from the trips themselves, but from the manufacture and collection of the bikes. The survey shows that a trip with an electric scooter is only climate-positive if it replaces a car trip, but it accounts for only 34 percent of trips in American cities (probably replacing even fewer car trips in Stockholm). (StockholmDirekt, 2019-08-22, Published on the web)

The impact of traveling by e-scooter is also appreciated by comparison to other modes of transport.

> Charging the electric scooter itself is a very small part of the environmental impact, below 5 percent, even with American electricity generation. Handling and especially manufacturing is significantly worse. Hired electric scooters are parked around the city and are collected daily by vans, which then reposition them after charging. This management accounts for 43 percent of the environmental impact. The greatest environmental impact, about 50 percent, occurs in the production of the electric scooter. Most rented electric scooters live a really hard life and usually get a short life before being discarded. Therefore, much would be gained, the American researchers argue, if the electric scooters were maintained and repaired instead of scrapped. If their lifespan could be extended from a few months to two years, the total environmental impact would be reduced by 30 percent. In terms of transported passenger distance, the electric scooter bikes therefore do not give impressive figures in terms of environmental impact. By comparison, the environmental impact is significantly less if the person jumps on a city bus instead (which is relatively crowded), even if it is powered by a conventional diesel engine. (Recharge, 2019-08-06, Published on the web)

Interpretation of the media discourse on e-scooters

Cultural breakpoints are a term used for "situations where a new medium is introduced" (Löfgren, 2007). In my interpretation, the e-scooter system could be seen as a medium for experience and use of urban space and traffic environment. The term breaking point can also be used for circumstances under which everyday routines are "broken or problematized" (Ehn & Löfgren, 2006). I believe that the introduction of e-scooters can be considered a cultural breakpoint, as these are new in cityscape and traffic, create new routines, and problematize established routines and habits. I also make the assumption that the media discourse may reflect the reactions of residents as well as authorities and other stakeholders. The influence between common perceptions and media discourses is, of course, two-way. The media discourses that are established early in relation to a new phenomenon, influence, and are influenced by the early, widespread understandings of the phenomenon.

The concept of breakpoint also opens up for at least two additional dimensions, the first of which is that other current issues and problems in society affect what is first thought and written about the completely new phenomenon. In this case, for example, environmental aspects and working conditions came up early in the debate. I think this may be due to the fact that already several years before the advent of e-scooters, for example, the working conditions in the so-called gig economy attracted attention and criticism. And similarly, the climate debate has meant that, for everything from food to renewable energy facilities, the life cycle perspective has become an increasingly widespread framework for discussing environmental aspects. In the case of e-scooters, for example, the short actual life of the batteries (and of the entire scooters) became something that was highlighted as counterproductive in relation to the obviously energy-efficient propulsion.

The second dimension can simply be said to be the connection between words and deeds. The question of how, and to what extent discourses are connected with prevalent patterns of action in society. A connection between knowledge and action patterns that I imagine is interesting in the long run is how the knowledge that the debate creates can in itself stimulate or slow down the use of micromobility.

There is probably no theoretical basis for claiming that a 'negative' discourse slows down, and a positive one accelerates, the spread and increased use of micromobility, or vice versa. Rather, sociological studies (a proper reference to such a study will be provided here shortly) indicate that both critical and clearly positive public debate is knowledge-raising in a way that can stimulate the spread of the pattern of action, while a slow spread may be associated with the absence of debate and attention.

3.5. Best-practices of e-micromobility integration in some European cities

As the analysis has shown so far, the legal landscape in Europe is very heterogeneous and inconsistent. For this reason, individual measures are presented in the following, which were successfully implemented and solved a concrete conflict considering the respective national basis. From this compendium, a tabular summary of the most important measures has been compiled below, which as potential templates can provide answers to concrete problem situations.

The City of Madrid

In Madrid, an ad hoc city ordinance was drawn up at the end of 2018, requiring the newly established shared mobility providers to stop operating in the Spanish capital. After the swift introduction, municipal stakeholders were forced to issue new regulations, after several severe accidents involving electric kick scooters occurred and the citizens’ complaints started growing. Shortly afterwards the city revoked the operators' licenses and a ban from pedestrian areas and the carriageway was imposed on the fly (Neue Züricher Zeitung, 2018).

The city consequently conceptualized an Urban Mobility Ordinance (Eltis, 2018) in October 2018, which empowered new rules, governing the occupation of public space for all electric kick scooters in parking and circulation, so that companies planning to operate the city were forced to comply with the regulations and develop monitorable measures for compliance. The regulation has since prohibited e-kick scooters from riding on pavements, bus lanes, roads with more than one lane in each direction, and from most orbital motorways, whereas they were allowed to use cycle lanes, as they were treated the same as bicycles. Moreover, the ordinance introduced a minimum age for users of 15 years and the mandatory wearing of safety helmets, in order to avoid accidents. Concerning the parking of electric kick scooters the new regulation stated that only designated parking areas for motorcycles and bicycles could be used. If none of those was in reach, the users were allowed to leave the device parked on the pavement, provided that a three metre gap could be obtained for pedestrians passing by (Smart Transport, 2020). Apart from that, several particular streets were prohibited for e-kick scooter drivers and the operating areas were regulated carefully by the city.

In February 2019, the City Council of Madrid authorized 18 shared mobility providers to operate in the city, provided that the obligations imposed by the Sustainable Mobility Ordinance are fulfilled. The city set a maximum amount of vehicles in each district to avoid extraordinary allocations in certain areas of the city. Furthermore, the providing operators were obliged to have their vehicles insured, to offer geolocation and to design apps in a way that enables the users only to start or stop the vehicles in well-defined areas of the city. As Spain's city councils have financial autonomy and self-sufficiency, also regarding their urban passenger transport, the municipalities can have major impact on how to integrate innovative mobility solutions properly as well on the imposition of specific regulations (Smart Transport, 2020).

Despite that, on a national level the Spanish Directorate-General for Traffic (DGT) published a Provisional Directive (Dirección General de Tráfico, 2019) taking effect in January 2020, which affects the set of regulations imposed by the municipality of Madrid directly. The defined minimum age set by the municipality was supplemented by regulations about liability questions, in case minors under the age of 18 committed offences. If an infringement is sanctioned, parents, guardians or persons legally or actually responsible are to be held jointly and severally liable for the offence committed. Moreover, supplementary regulations were set up, prohibiting any vehicle from circulating on footpaths except for skateboards, rollerblades and similar, not faster than walking pace. If infringements are observed, the fine is set to €200, although this may also vary depending on local regulations (Emesa, 2020).

Concerning the traffic regulations imposed by the DGT, the e-kick scooters within 30 km/h zones are permitted the ride on the road. Elsewise, the bicycle lane and bicycle boulevards are to be used by e-kick scooter riders. Despite that, precise regulations on how to behave whilst driving were imposed, so that a person is prohibited to wear headphones, use the phone, drive under the influence of alcohol or carry another person on one device. Each of those violations is bound to a specified fine. In particular, drivers who exceed the alcohol limit of 0.25 per mille can face severe penalties of up to €1.000. Additionally, the national law defines requirements for obligatory equipment. Wearing a helmet is mandatory, as for all cyclists, and at night-time it is required to wear lighting, reflective clothing and reflective elements. Violation of these regulations may issue a €200 fine or even lead to the vehicle to being confiscated. In addition, e-kick scooters with a professional purpose must take out liability insurance similar to cars and other vehicles (Emesa, 2020).

The City of Zaragoza

In order to reduce the enormous number of providers of shared mobility, as was the case in Madrid or Paris after the implementation in road traffic, the city of Zaragoza set a number of drastic requirements that must be met, in order to obtain an operating licence, which already expired after two years of time. This comparatively short duration had put a lot of pressure on the operating companies, but allowed the city to regulate the use of e-kickers more flexibly and to impose iterative amendments (Wired, 2020). The requirements issued for shared mobility operators included a direct and permanent employment of their employees, who at the time were hired as freelancers. The regulations also required the operators to create responsibilities to ensure, that monitoring can be guaranteed, so that all vehicles offered by the company are parked correctly (Inline Policy, 2019). Only two companies were granted an authorisation in 2019. Zaragoza was therefore one of the first municipalities to limit the number of operators and provide their licensing with specific provisions.

The City of Paris

More than 20.000 vehicles, operated by 12 different shared mobility providers, flooded the City of Paris back in 2018. Paris in some ways has become one of the most important open living labs for shared micro-mobility services. The city, with more than 16 million tourists a year and its enormous size and importance for its surroundings, harbours a complex transport system with many tensions, conflicts and traffic jams.

On 25 October 2019, on national level France announced the legalisation of the use of electric kick scooters and similar devices. Before there was no law regulating the use of this new type of vehicle. According to these new regulations, the e-kick scooters are bound to a speed limit of 25km/h and are obliged to use bicycle lanes or roads with speed limitations prohibiting more than 50km/h (The Straits Times, 2019). Contraventions are punished with fines up to €135 (The Local, 2019). Moreover, due to the new regulations riding the electric kick scooter requires a minimum age of 12 years, wearing headphones is prohibited as well as transporting other passengers. According to the introduced set of regulations, e-kick scooters must be equipped with front and rear lights, a horn and a retro-reflective system (The Mayor, 2019).

For the city of Paris, a speed limit of 20km/h was set up on municipal level, answering the enormous numbers of accidents in the town centre (Channel New Asia, 2019). In June 2019, additionally the local authorities issued a series of regulations, prohibiting the use of e-kick scooters in parks and gardens. Moreover, according to these since then the vehicles had to be parked in parking spaces designated for cars and motorised two-wheel vehicles (France24, 2019) or on one of 2.500 dedicated parking spaces provided for e-kick scooters, which were installed by the year 2019 (The Guardian, 2019). Parking on the sidewalks, pedestrian areas and on the road is prohibited, resulting in a fine of €35 if infringed and eventually having the inadequately parked vehicles removed. To survey the compliance of the regulations a new taskforce was put into place, given the large number of sanctions imposed in the past. Nevertheless, the enforcement of fines and the consequent punishment of perpetrators are huge issues, which in future need addressing in a properly manner. Finally, in order to regulate the number of e-kick scooters an annual fee of €50 each vehicle for the first 499 units has been imposed by the city council, which rises up to €65 for companies operating more than 3.000 vehicles (Channel New Asia, 2019).

Moreover, operating companies were committed to sign a Charta of good conduct, which encouraged the providers to comply with the Accessibility plan for streets and public spaces, the Hygiene regulations and Road traffic regulations, anyhow without imposing any sanctions to infringements. In respect to this lack of municipal monitoring powers and possibilities to ensure compliance, the city introduced a call for tenders in order to supervise and control the operators (Shared-Micromobility.com, 2020).

Finally, on 19 December the City of Paris published a call for proposals, of which only the three applicants with the highest number of points will be awarded the right to operate only 5000 vehicles in the city. The evaluation criteria implicated in the catalogue contains three main categories:

- User safety
- Operations
- Environmental responsibility

The first criterion - user security - counts for 30 % and focuses on the strategies presented by the operating companies to ensure compulsory insurance and to provide data privacy. The second criterion is also weighted with 30% and addresses the operating conditions, which consist of management, maintenance and charging. It focuses on equitable geographical distribution in a citywide service area, to avoid concentrations and as well insufficient supply in less profitable areas. Moreover, solutions in parking management are taken into account, so that positioning accuracy, implementations of parking zones in apps and distribution patrols enter the focus of ratings. The third criterion – environmental responsibility – count for the most with 40% and deals with proposals concerning energy consumption, gas emission, hardware durability, maintainability, recycling and multimodal integration. The last aspect focuses on an integration of the offered services into a future public MaaS platform, mainly dealing with the adoption of standards and business development strategies (City of Paris , 2019).

The City of Berlin

After the use of electric kick scooters on German roads was permitted by the enactment of the Ordinance on Small Electric Vehicles, a chaotic start took place in Berlin, with almost no municipal measures regulating the e-kick scooters and accident rates, violations of road traffic laws (Tagesspiegel, 2019) and numbers of acts of vandalism (B.Z. Berlin, 2020) underlining the situation in the best possible way. The need for municipal regulations and measures became apparent. Consequently, the municipality established no-parking zones at the most congested sites and locations, so that important point of interest in the city could remain their functionality, regarding their touristic and civil value as well. For this reason, bilateral agreements were concluded between the operating companies and the municipality, which are not legally binding on the partners. In these agreements, restricted areas were defined where users could not log out, which could be achieved by using geofencing technologies (Berliner Zeitung, 2020). As a further measure, the municipal administration planned to transform 500 parking lots for cars in dedicated parking zones for rental bikes and e-kick scooters (Redaktionsnetzwerk Deutschland, 2020). Moreover, in consultation with the existing operators of shared mobility fleets, the municipal authorities initiated a revision of the design of the sharing-provider apps, so that the safety-relevant information on how to use the vehicles as well as the legal requirements are outlined more clearly (TAZ, 2019).

Interestingly, the city of Berlin has opened several mobility hubs in an iterative process, where e-kick scooters can be rented since June 2019 using the "Jelbi" app, which enables users to search, book and pay for a bunch of different mobility services. These mobility hubs are located at important public transportation nodes, where shared vehicles from different providers can be rented locally to cover the last mile. The local authorities planned to create a Berlin-wide network of mobility stations, where mobility services are offered and can be used easily and conveniently via the Jelbi platform. The idea is to make multimodal services more attractive and thus promote environmentally friendly local mobility. For this purpose, the Jelbi app was designed in such a way that local transport and various sharing services, but also digital ridesharing systems or taxis are integrated in one app. In addition, users can do everything from route planning and booking to payment and billing with just one registration (Morgenpost, 2020).

According to current legislation, cities have little opportunity to impose mandatory rules for the services offered by operators, as the e-kick scooters supplied by private companies are considered as vehicles for traffic purposes only, so that only bilateral agreements without legal binding force can be imposed. Berlin was the first German municipality to question the treatment of e-kick scooters in road traffic law, which considers them as vehicles for the sole purpose of locomotion and therefore does not require them to obtain a special permit. Instead, the city administration argued, e-kick scooters should be regarded as a special commercial use of street space, such as events and gastronomy, so that municipal actors could influence the operating companies through stricter, legally binding regulations. For example, precise fleet caps and distribution keys could be introduced, charges could be applied or the provision of the vehicles could be completely prohibited altogether. To address this discrepancy, the city of Berlin submitted a draft bill to the Bundesrat, a constitutional body of the Federal Republic of Germany, in order to revise the road traffic regulations. The bills aims at the concretion of the jurisdiction in such a way, that the classification of e-kick scooters of the providers of shared mobility is clearly determined and thus guarantees planning security for the municipality. However, the motion to revise the corresponding article of the Road Traffic Act did not receive a majority in the Bundestag, so that no changes will be made to the legal status of shared kick scooters for the time being (Morgenpost, 2020).

The German think-tank Agora recognises the need to reform the legal framework in Germany and suggests an adaptation of the federal law on road traffic regulations to deal with excessive road use under Article 29. A revision of the content written in this article could give municipalities more room for acting with regard to dealing with parked e-kick scooters. In addition, regulations on the parking of rental bicycles in public spaces are also put up for discussion and amendments are proposed. Until a national law is passed, however, the federal state road laws can also be amended in way that enables municipal authorities to implement local regulations through special usage statutes (Agora Verkehrswende, 2019).

The City of Bremen

The Federal State of Bremen, which only consists of the city of Bremen and the city of Bremerhaven, has limited the provision of e-kick scooters by shared mobility providers to those who have a special use permit, which underlines the diversity of possible ways in dealing with national law at a local level. In this case, only those companies that accepted the strict regulations that came with the permit were allowed to offer their services in the city. Interestingly, in the City of Hamburg, directly located next to the City of Bremen, the Higher Administrative Court decided in 2009, that the parked rental bikes of a commercial supplier also belong to common use and due to this do not need a permission to operate. If the same will apply to the e-kick scooters offered by shard mobility providers in Bremen has to be decided in court, provided an operating company wishes to take legal action against it. However, there have been no attempts yet (Sueddeutsche Zeitung, 2019).

The city prepared an eight-page special use permit, which needed fulfilment in all points in order to grant the permit, which was only met by the providers Voi and Tier. These obligations included a limit of 500 e-kick scooters per provider, a limitation of the operating area, a ban on the use of green areas, certain regulations for dedicated parking zones and the removal of disruptive vehicles within 24 hours by a local partner, who could intervene at short notice in the event of infringements. An additional fee of 0.50 euros per week per e-kick scooter is also charged. Furthermore, the permits issued are limited in time and the city obtains the right of terminating the contract if compliance cannot be guaranteed. Due to the legal binding force, the municipality is able to take actual measures and can withdraw the permission if conflicts occur. According to the municipal authorities, the currently imposed regulations are an expedient way to acquire practical information on the necessity of further measure, as well as the effectiveness of e-kick scooters as means of a sustainable transport for the future (Senatspressestelle Bremen, 2019).

So far, the operators fulfilled the strict requirements to the satisfaction of the community and the employees of the public order department have been spared the burden of disposing of badly parked e-kick scooters due to the disposal measures organised by the operators. In addition, the city is planning an iterative expansion of the special use permit issuance, so that further operators will be active in the city in the future (Buten Un Binnen, 2019).

3.6. Multimodal travel companions

Trend analysis

The following section aims to present existing travel companions applications, their functionalities and their main target user (e.g. car driver, tourist, commuter etc). This analysis indicates the level penetration and of micromobility or the information which can be used to promote micromobility in different urban settings as well as aspects that can improve the coexistence and integration of different transport modes. Information provided by a travel companion app can vary depending on its objective e.g. planning, navigation, hailing etc. When we discuss about deeply integrated of micromobility, we mean supporting micromobility discovery, intermodal routing to incorporate bikes, e-scooters etc as part of a first/last mile solution in an intra or intercity journey, unlock, lock and pay for the use of the scooter inside a 3rd party Mobility as a Service (MaaS) application also known as travel companion.

The following four topics are the most common topics regarding micromobility integration in multimodal travel companions.

A. Light vs. Deep Integration

Although, the latest years there is a lot of fuzz around micromobility, we were surprised by how few were either technically or commercial ready to support deep integration but the scene is changing rapidly.

B. Dock less vs. Station-based Micromobility Sharing Systems

Another important factor for micromobility in MaaS platforms and hence in travel companions is the system choice of the operator, dock less vs. station-based. For example, in Barcelona the City outlawed fully dock less deployments so several operators existed in a grey area by supporting locking functionality and requiring users to at least lock the shared vehicles to public bike racks (which are rarely available with open APIs.

C. Booking vs. On-Demand Only

The predictability issue (booking vs on demand only) is a big issue as intermodal algorithms and deep integrations seeking to support modal shift by providing users the confidence they can get out of their cars with the knowledge their whole journey is accessible in an affordable, timely and enjoyable way.

D. Commoditized vs. Self-sustained services

Micromobility providers are afraid that will lose their "ownership" of the user and become commoditized so they prefer to offer their services separately especially those that are owned by global ridehailing behemoths who have massive installed user bases such as Uber. While many others struggle to obtain and maintain high vehicle utilization rates in the face of significant competition in many cities especially in Europe and cities such as Barcelona and Amsterdam. Also, a significant role plays the user who has confirmed that hates to download a new app when he/she is visiting a city only for a few days.

The aforementioned aspects are reflected in the analysis that follows concerning travel companions' functionalities but before that we will provide some information for the main actors of the system and also present the functionalities that we examined.

Main actors that influence developments of travel companions' developments are transports service providers (A Transport Service Provider (TSP) is any party, person, agent or carrier that provides freight or passenger transportation and related services to an agency), transport users and transport authorities. These actors have different expectations which are based on their interests as well as the relevant technological developments.

Transport service providers' expectations

Transport service providers' expectations are led by market and business rules as there are companies, environmental legislation and policies such as minimization of CO_2 emissions and carbon footprint and also by societal factors. The latter factors are interrelated with the community mindset, the infrastructures as well as the government decision and pricing schemes. The main expectations of transport service providers are the following:

- manage the fleet efficiently;
- increase customers and market share by providing an improved travel experience;
- increasing customer satisfaction;
- internal increase of efficiency;

Transport users' expectations

Different transport users have different expectations in this deliverables we aim to present

- reach their destination safely, on time and in comfort.
- receive real-time information.
- receive personalized journey solutions through the specification of personal criteria and preferences.
- have access to integrated booking, ticketing, and payment which provide convenience through the one-stop-shop travel experience.
- be assisted during the trip also through location-based services and recommendations.

- Discover new itineraries and destinations

Transport users also seem to expect overviews of transport systems and travel options, for PT e g in terms of maps and timetables showing intermediate stops etc. So that they can also plan 'out of the box' and find new destinations and time slots, linked trips (with errands on the way) etc, since the user doesn't always have a set destination and point in time, that s/he needs the travel companion to present travel options for. This suggested need or expectation, on the part of the potential user, might to some extent be fulfilled by e g Citymapper, the way that it is described on the next page.

Transport authorities' expectations

- Improve mobility of their responsibility areas
- Promote safety and security in transport systems and take measures whenever is necessary
- Draft and implement policy strategies to improve sustainable transport and mobility services

We analysed more than 70 travel companion (TC) apps and our focus was to identify functionalities and information provided which could influence and promote the usage of soft modes (e.g. bikes, e-scooters etc.) and therefore e-micro mobility for the first or last mile as well as the main transport mode for a small number of commuters. Table X presents the most popular or relevant TCs used in EU and internationally.

Functionalities and relevance with micromobility:

- Journey planning: Calculates multimodal routes from the point A to point B, shows alternative itineraries to the user. A micromobility user can utilize this functionality to identify his/her itinerary and plan a multimodal trip.
- Offer building: Calculates multimodal routes from the point A to point B including offers (e.g. provision of cost estimation in different modes). A micromobility user can utilize this functionality to check different offers and decide which is the most cost effective.
- Booking: Booking of all online payable parts of an offer, such as reserve a seat or a vehicle
- Issuing and payment: Issuing Entitlement/Token/Embodiment and pay with different methods (e.g. credit card, subscription) and provision of different rules of payments (e.g. pre-payment for the service, after finalizing the trip, hourly cost etc.)

Table 1: Travel companions and functionalities related to micromobility

App Name	Main Customer	Modes	Journey Planning	Offer building	Booking	Issuing and Payment
Citymapper	commuter	Bus, subway, train, ferry, car sharing, bike sharing, e-scooter	Yes	Yes	No	No

Moovit	commuter	train, subway, bus, light rail, ferry or metro, use dock less scooters, bikes, ride-sharing like Uber	Yes	No	No	No
Waze	Road drivers	Ride sharing	Yes	Yes	Yes	Yes
Free2move	car, scooter, escooter, bike sharing	Ride sharing	Yes	Yes	Yes	Yes
Urbi	car, scooter, escooter, bike sharing + public transport and taxi!	commuters	Yes	Yes	Yes	Yes
Uber	Ride sharing users	Ride sharing, logistics (Uber-eats, Uber ice)	Yes	Yes	Yes	Yes
AMB Mobilitat	Commuters	Train, subway, Bus, tram, bikes	Yes	No	No	No
ScootRoute	Micromobility users	Micromobility vehicles	Yes	No	No	No
Mapy.cz Cycling & Hiking offline maps	Bikers and hiking tourists	Public transport, Bikes	Yes	No	No	No

Citymapper

Citymapper allows the users to compare all travel options in real-time across all transport modes. The web app and the app works in different EU cities, however it does not provide to all the cities the same level of information. The information provided in each city depends on the local TSPs agreement with

Citymapper as well as with the city's transport system (e.g.in Monaco helicopter is also an option). Citymapper's journey planning functionality feautures multimodal combinations as the ones presented in Figure 21. Citymapper app is also connected with 3rd parties services called floating transport (it has no set stops or infrastructure, and it's filling a mobility gap in our cities) which complement fixed transport (i.e train) (Figure 23) to generate new A to B options across cities, improving travel times and increasing access to mobility .Hence, Citymapper is providing information on different bike sharing (e.g. in Vienna-Figure 24 and Milan-Figure 25), e-scooter sharing companies, Figure 26 and e-kick scooter. In the majority of the cities information is availiable concerning bikes. However the infomation on routing is not customized always towards micromobility e.g.in Rome the itineraries generated for bikes are the same generated for cars.

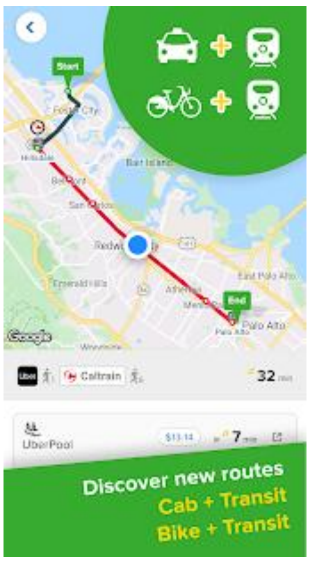


Figure 21: Citymapper multimodal journey planning options

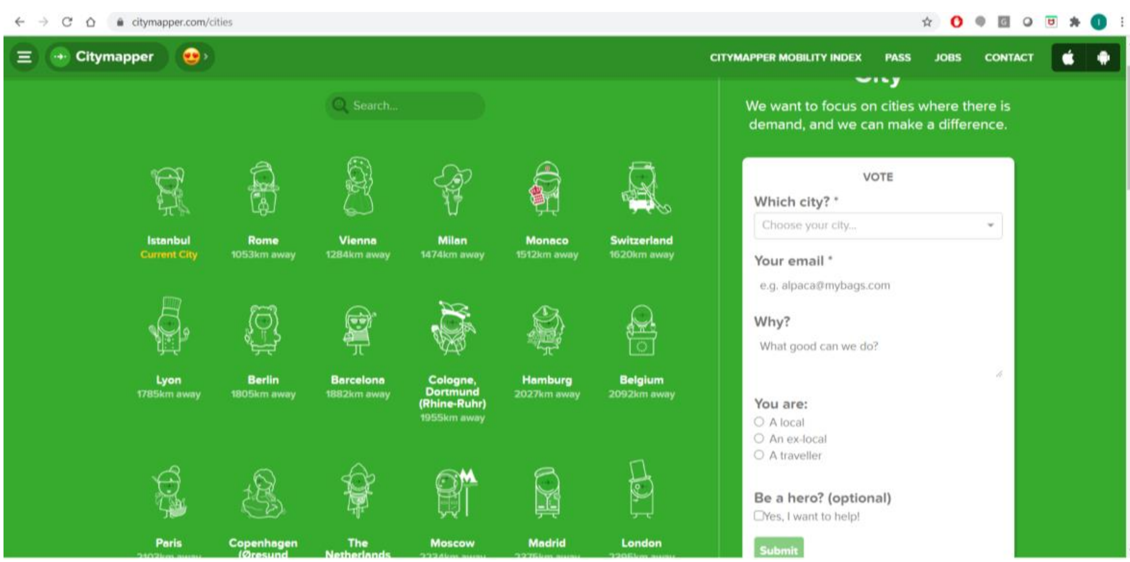


Figure 22: Citymapper coverage

Figure 23: Floating vs Fixed transport

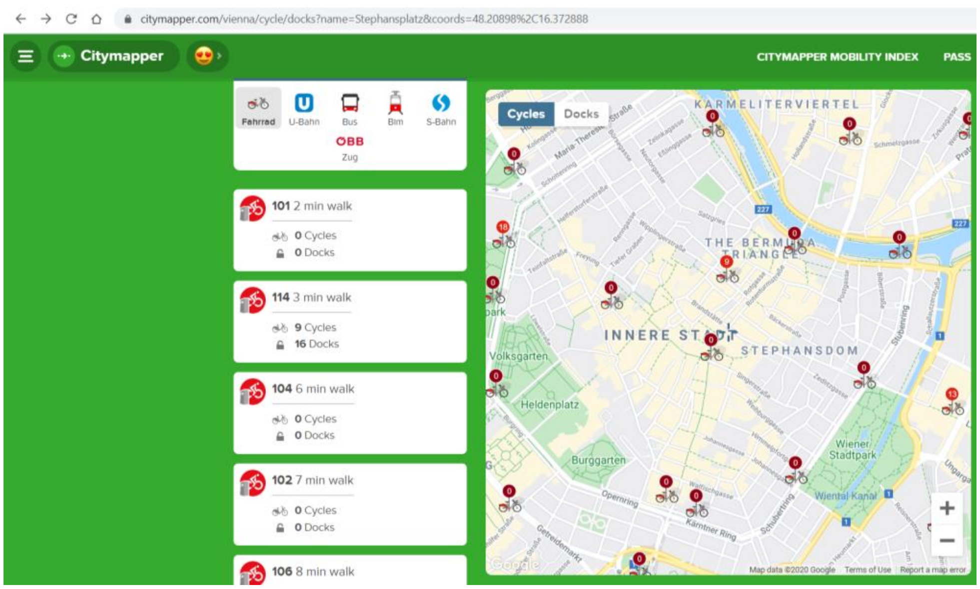


Figure 24: Citymapper bike sharing information in Vienna

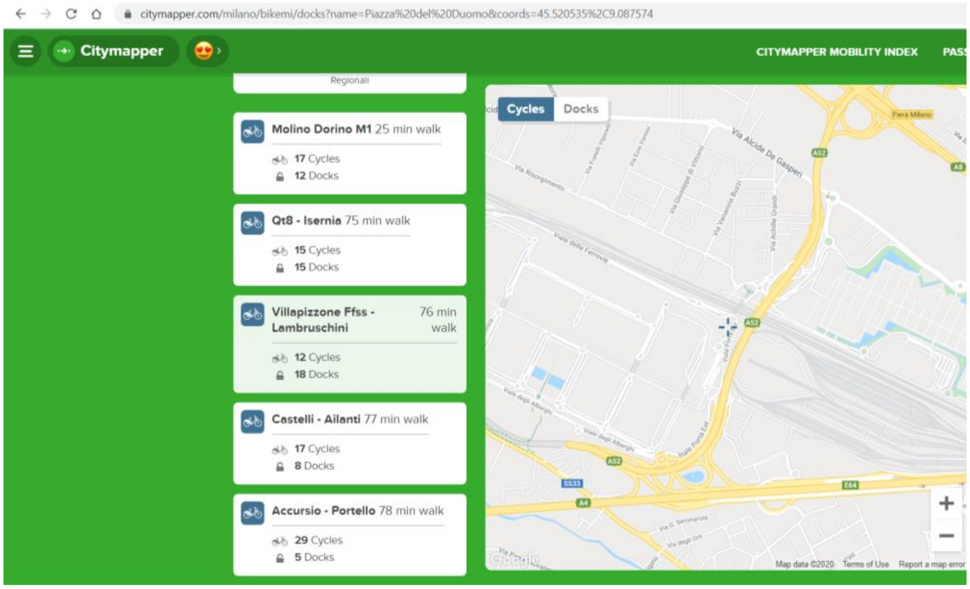
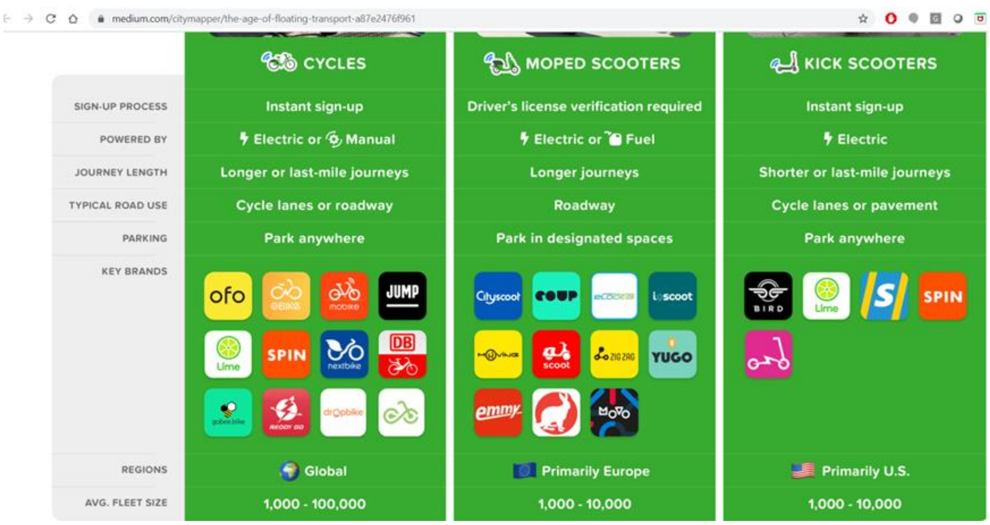


Figure 25: Citymapper bike sharing infomation in Milan



	CYCLES	MOPED SCOOTERS	KICK SCOOTERS
SIGN-UP PROCESS	Instant sign-up	Driver's license verification required	Instant sign-up
POWERED BY	Electric or Manual	Electric or Fuel	Electric
JOURNEY LENGTH	Longer or last-mile journeys	Longer journeys	Shorter or last-mile journeys
TYPICAL ROAD USE	Cycle lanes or roadway	Roadway	Cycle lanes or pavement
PARKING	Park anywhere	Park in designated spaces	Park anywhere
KEY BRANDS	ofo, JUMP, Lime, SPIN, nextbike, DB, dropbike	Cityscoot, COUP, YUGO, scoot, emmy	BIRD, Lime, SPIN
REGIONS	Global	Primarily Europe	Primarily U.S.
AVG. FLEET SIZE	1,000 - 100,000	1,000 - 10,000	1,000 - 10,000

Figure 26: Micromobility companies connected with Citymapper

Citymapper provides information concerning bike sharing, e-scooter sharing and e-kick scooter sharing in various cities around the world, The information provided is depended on the micro mobility provider, so the micro mobility provider need to add information for its dockers and fleet. Also, the cost for the transport different transport means is provided hence the user can be tempted to use a cheaper option for his/her last mile.

Moovit

Moovit is one app for all your urban mobility rides. It has integrated some micromobility aspects such as up-to-date bike route info or use shared bike systems with our real-time docking station info. As a multimodal app Moovit presents good quality information on public transport (Figure 27) but the information offered towards micro mobility is limited.

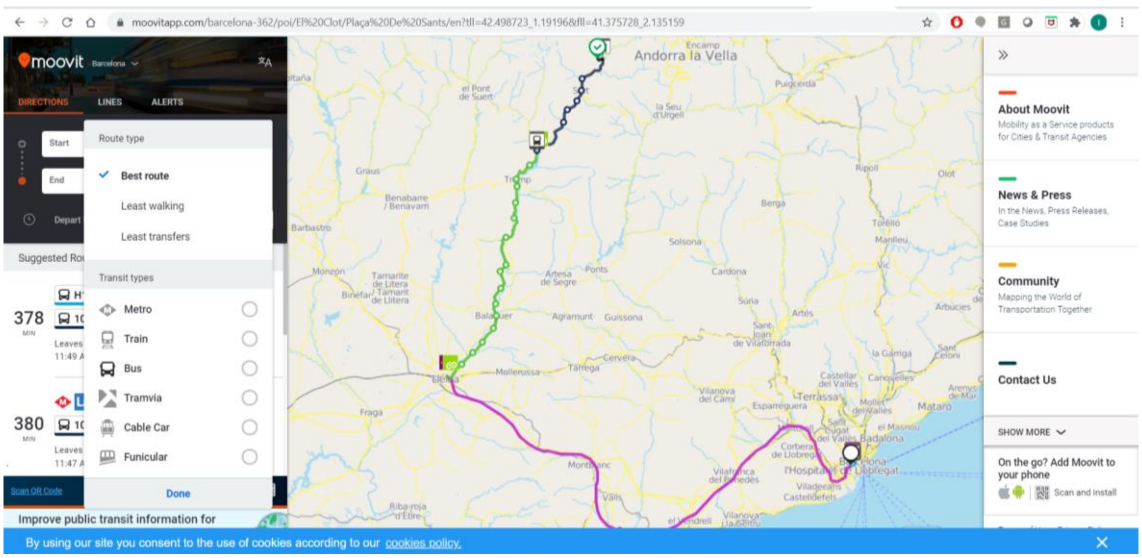


Figure 27: Moovit example

Waze

WAZE (formerly FreeMap Israel) is a community-driven GPS navigation software app owned by Google since 2013, its headquarters are in California, USA. Waze users are able to report a multitude of traffic-related incidents from accidents to police traps. This data is used by Waze to help other users either by alerting them of the condition ahead or rerouting the user to avoid the area entirely. So, Waze has the ability to direct users based on crowdsourced information therefore the accuracy and quality of information depends a lot on users (i.e. critical mass and number of users) as it is a crowdsourcing app. The idea behind this is that the more people that provide data the more accurate it will be the information presented in the app. In addition to user input, Waze relies on information from state agencies for traffic events such as road construction. Although, waze is a multimodal travel app. Waze provides indirectly information concerning micromobility but can be a good community creation example for future integrations of micromobility.

Free2Move

Free2Move is an app that allow you to search and book vehicles that best fit your needs. It has integrated different micromobility TSPs such as Lime, Bird, Skip.

Urbi - urban mobility aggregator

URBI is available in several cities in Italy, Germany, Spain, Austria, Portugal, France, Sweden, Denmark, Finland, Belgium, The Netherlands, Poland, USA and allows the user to rent different kind of transport modes such as car, scooter, escooter, bike sharing and taxi (Figure 28).

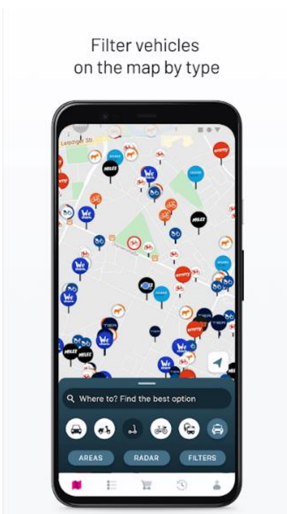


Figure 28: Urbi example of micromobility vehicles on the map

Urbi like Free2Move provides information for micromobility vehicle sharing.

Uber

Uber is a well-known car sharing app with a bike and e-kick scooter sharing app option (Jump e-scooters). But also, it has a nice feature related to micro mobility and safety (further analysis on safety aspects is conducted in D4). Uber is relatively currently (May 2019) piloting the Bike Lane Alert feature in San Francisco, New York, Washington, D.C. and Toronto to alert their passengers to the presence of bike lanes. When a trip's arrival point is located close to a bike lane (or to a bus lane where bikes can ride), the passenger receives a notification on their phone 500 metres before the arrival point. These bike lane alerts are intended to promote awareness among passengers of the surrounding micro vehicle traffic, and avoid collisions. These safety-relevant messages can enhance the usage of micromobility and by preventing accidents, to reduce the risk of "dooring" someone riding a bike or scooter (Figure 29).

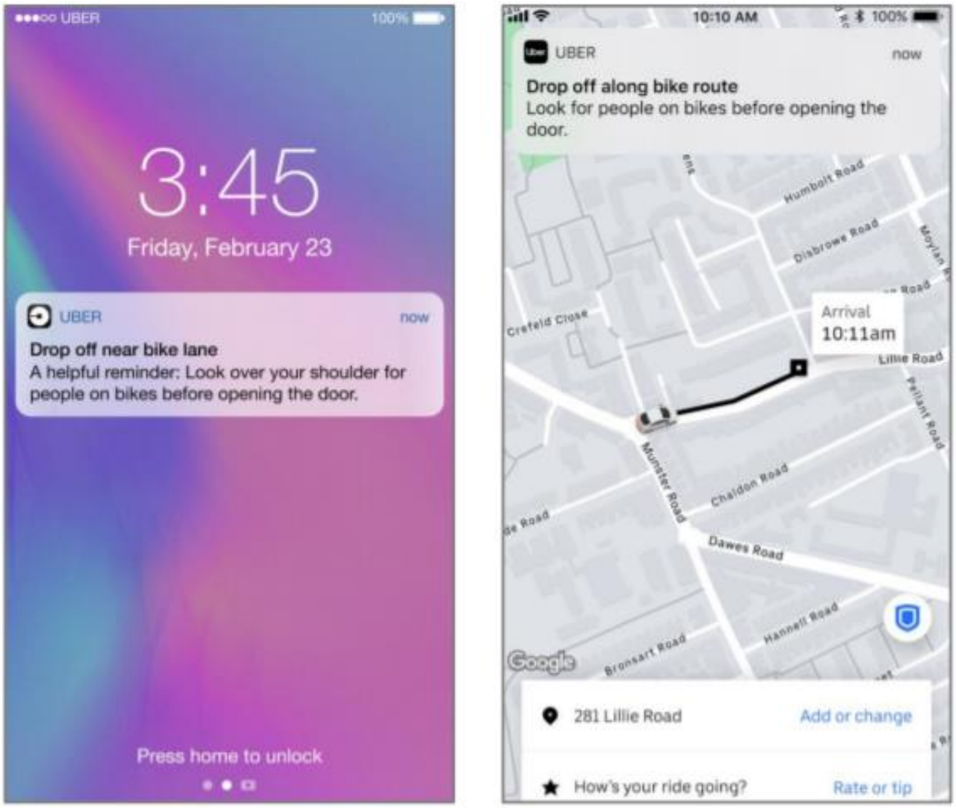


Figure 21: Uber feature that alerts car drivers to avoid dooring

The aforementioned feature can be extended and provide huge benefits to the integration of e-micromobility in the urban transport systems by promoting awareness to the car drivers towards the more vulnerable users of micromobility modes.

AMB Mobilitat

AMB Mobilitat is a free app that allows travellers in Barcelona metropolitan area to plan their journey by public transport and cycling routes. It has an integrated router (Figure 10) to present the best possible combination: public transport, bicycle or on foot. It has the feature of presenting itineraries in bike routes, traffic calm streets and green paths allowing in that way the information flow and the decision to the micromobility user (Figure 11).

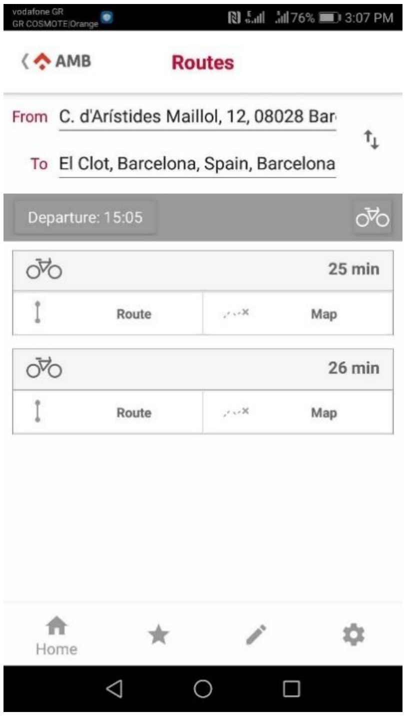


Figure 2: AMB travel companion presentation of different itineraries for micromobility vehicles

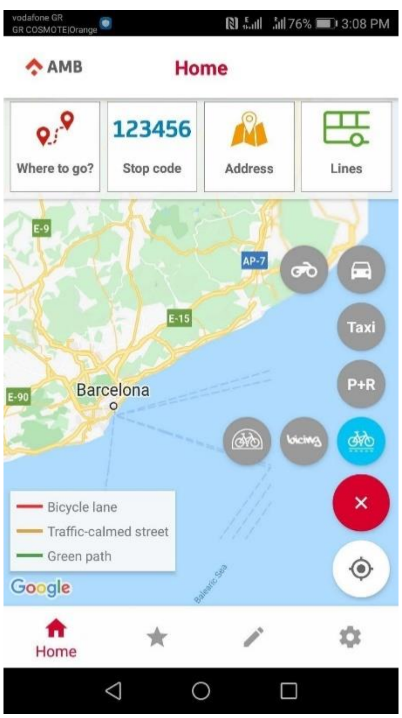


Figure 11: AMB travel companion different options for micromobility users

ScootRoute

ScootRoute is a travel companion develped in August 2020 as an effect of COVID-19 for assisting micromobility commuters in Boston city therefore is dedicated to micromobility and especially to two-wheeled electric vehicles, it works in cities and suburbs, letting riders select specific perimeters to receive customized turn-by-turn GPS directions. The specific parameters are for example hill-climbing tolerance, traffic, bike lane availability, road type, and speed limits can be adjusted by the user, according to travellers' preferences.

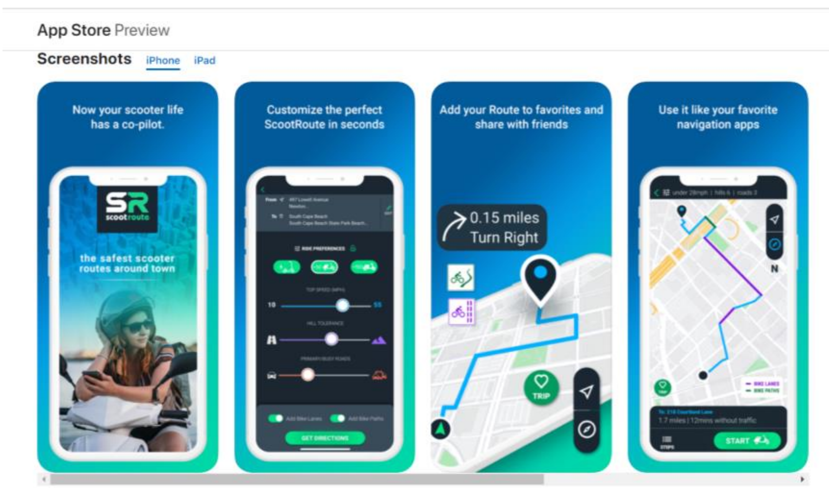


Figure 12: ScootRoute screenshots of functionalities

SccotRoute is an example of integration of micromobility to transport system but unfortunately its functionalities could not be tested for this deliverable as it is not available in Europe for the time being.

Geovelo - bike GPS

Geovelo is dedicated to cyclist chooses, first and foremost, cycleways, bike lanes and low traffic streets to ensure comfort, safety and serenity. The application includes many features such as the display of bicycle facilities, local weather, Points of interest etc. It also has a crowed sourcing feature where its users can report missing bike parking, cartographic issues or road works, dangerous roads for cyclists and much more in order to help the cycling community. For shared bikes system, we use data provided by JCDecaux, ClearChannel, Keolis, and others. Geovelo works mainly in France and although that is dedicated to bike its features are interesting for micromobility in general and can be upgraded to serve multimodality.

Mapy.cz - Cycling & Hiking offline maps

Mapy.cz differs from the usual travel companions as it is dedicated to cycling and hiking and its main customers/end users are not commuters but tourists, although it offers also multimodal information in Czech cities. It has interesting functionalities that can contribute to the integration of micromobility even at an urban setting which are the following

- Offline tourist map of the world with marked tourist trails and bikeways. (Figure 14)
- Cycling and hiking navigation. (Figure 13)
- Weather forecast for any place on world. Temperature, wind, and precipitation for the next 5 days.

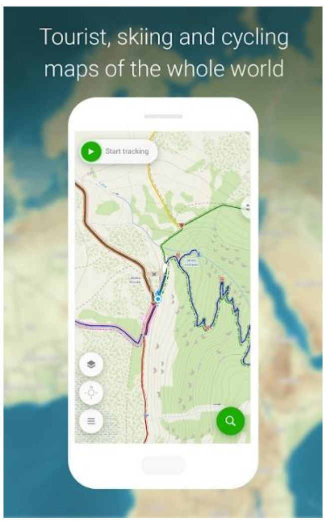


Figure 13: Mapy.cz Cycling and skiing maps

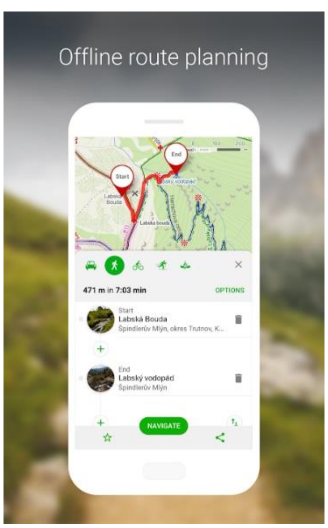


Figure 14: Mapy.cz offline route planning

Other apps

Customers of shared micromobility companies all rely on smartphones to locate and unlock vehicles e.g.Lime. Therefore, smartphones could become an effective solution for providing rider training to that end e-scooter sharing companies can and should provide substantial help to people who are not familiar with the vehicles or the rules of the road. Already some standing e-scooter companies are investing significantly in user training. An example is E-scooter company Voi developed an online training platform “RideLikeVoila” (https://vimeo.com/355518662) (Figure 15). Lime organised several free training events called “First Ride Academy” upon completing the 30-minute training course, all riders were given a free helmet (Figure 16) along with a voucher for a free coffee and pastry in many cities of USA in 2019. Also, Bird hosted more than one hundred educational events called “s.h.a.r.e. Safe Streets” in 2019.

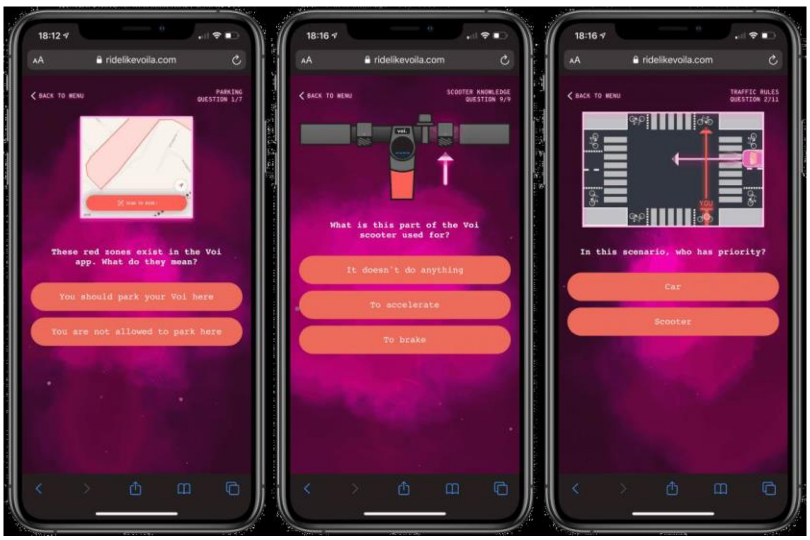


Figure 15: Screen captures from online traffic school RideLikeVoila

Figure 16: Lime first ride academy

3.7. Intermodal integration of freight e-micromobility

As previously presented in subsection 2.1, the current business model of the last mile distribution is expected to evolve in future years because 1. The total numbers of parcels that will need to be delivered in the inner parts of the cities will skyrocket because of the boom of e-commerce, and 2. Cities are more and more willing to impose some restrictions on these operations to limit the externalities they generate.

The objective of this Subsection is to present how the implementation of freight micro-hubs could impact the carriers' operations costs using a simplified logistics model. The idea is not to precisely quantify the carrier's operations costs but to get a first idea about how a change in the supply chain can affect the economic competitiveness of this sector. The "freight micro-hubs" strategies will be compared with the current "business as usual" situation.

Business-as-usual vs freight e-micromobility

Business-as-Usual strategy. In this strategy, which we assume to be the current one, Light Commercial Vehicles (LCV) go from the carrier's Distribution Center (DC), usually in the suburbs, directly to the final customers in the inner part of the city (see Figure 37). The objective of the carrier is to visit all the final customers' locations rapidly, limiting the total distance travelled by the vehicle fleet, to minimize its operations costs (if the drivers work longer and travel more kilometers, it then will cost lots of money to the carrier). This is the most straightforward delivery pattern, directly from the carrier's DC to the final customer. Let us recall that both the B2C (citizens) and B2B (retail shops) markets are addressed in this study.

Freight e-micromobility strategy. To make the last-mile operations more sustainable, more and more cities experiment the usage of freight micro-hubs. A freight micro-hub is, most of the time, a facility through which the carriers can make their freight transit, splitting the last mile into two distinct legs: the first one from the carrier's DC to the micro-hub and then from the micro-hub to the final customer. All the parcels are taken from the carrier's DC to the center of the service region (using bigger trucks to maximize the economies of scale and optimize the operations costs) and the last leg of this intermodal trip to serve the final customers is done using freight e-micromobile devices, mostly e-cargobikes. This two-echelon problem can be assimilated to the public transportation concepts of "shuttle" and "feeder". To sum up, the parcel travels first from the DC to the logistic micro-hub, which can be the truck itself (see Figure 38) or a built city infrastructure. Then a freight e-micromobile device takes the parcel from the logistic micro-hub to the final client.

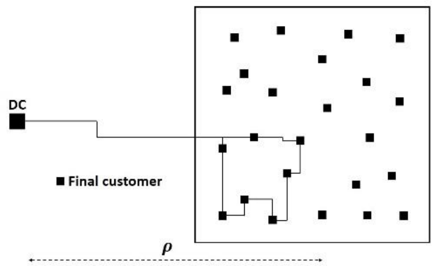


Figure 37. Business-as-usual strategy. Direct distribution from the DC to the final client with regular vans (Estrada & Roca-Riu, 2017)

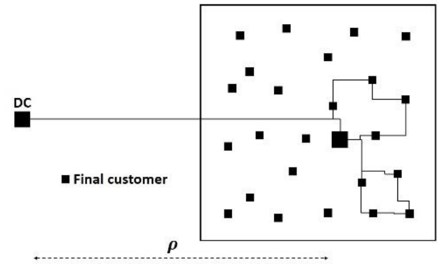


Figure 38. Freight e-micromobility strategy. Distribution using a logistic micro-hub and e-micromobile freight devices (Estrada & Roca-Riu, 2017)

Figure 39. Business-as-usual strategy. Example of a regular van (FedEx, 2013)

Figure 40. Freight e-micromobility strategy. Example of a logistic micro- hub in Brussels (TNT, s.f.)

Our objective in this part of MOBY is to present a simple model using Continuous Approximation (CA) equations, as described by Daganzo (2005), to estimate some of the carrier's Key Performance Indicators (KPI) and assess its economic profitability in Business-as-usual strategy and Freight e-micromobility strategy. Continuous Approximation is a widespread technique to model transportation systems. The resulting models are very useful in a first approach because they provide an overall vision of the concepts at stake behind each one of the considered supply chains. They will enable us to easily identify the most relevant decision variables in each framework. However, our calculations are of a quite technical nature, and therefore we have chosen to put them in the 'Appendix 1 – Continuous approximations regarding Freight e-micromobility", at the end of this report.

Numerical Results

Figures 41 and 42 present the outputs of the developed model. In Figure 14 is represented the average operation cost per parcel delivery as a function of the demand density (δ) for the Business-as-usual (Strategy A), and Freight e-micromobility (Strategy B) strategies. The total operation costs of the carrier includes the vehicles depreciation, the drivers' salaries, the insurance costs, the gasoline expenses and the maintenance costs. To have a representative metrics, these total costs are divided by the total number of delivered parcels to obtain an average cost per parcel delivery (that would be charged to the final customer).

As explained in the previous sections, many e-cargobikes technologies with different designs are emerging. As a consequence, we chose to consider the useful volume of the freight e-micromobile devices as an unknown of the model (see Table 1 in App. n, and Fig. 8 and 9). Through the assumptions and calculation we have made there, we have a useful vision of these new technologies, from the smallest to the biggest ones. As it can be observed in Figure 14, the average operation cost per parcel delivery strongly depends on the volume of the e-cargobike (see the red band).

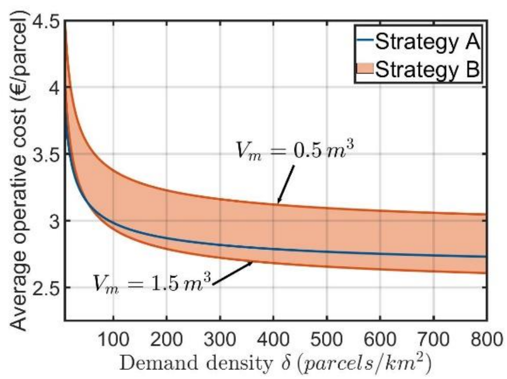


Figure 41. Average operative cost per parcel delivery

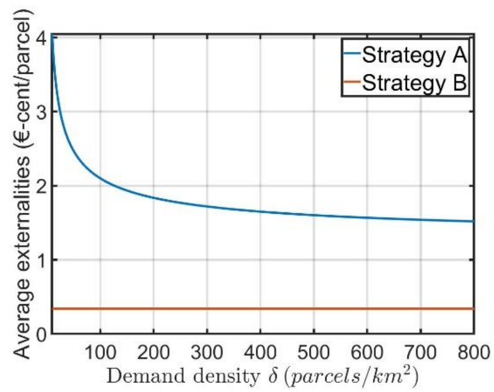


Figure 42. Average externalities emission per parcel delivery

In Figure 42 is plotted the average externalities emitted per parcel delivery in the Business-as-Usual (Strategy A) and Freight e-micromobile (Strategy B) strategies as a function of the total demand density δ. The concept of externalities quantifies (in term of monetary unit) the impact that the distribution strategy has in the city. An externality can be the greenhouse gases (carbon dioxide, methane…) and exhaust fumes (nitrogen dioxide, particles of matter…) emitted by the delivery trucks, the congestion (induced by the delivery trucks) or the noise generated during the delivery. Within the scope of MOBY, only the emissions of greenhouse gases and exhaust fumes were considered, in a Well-to-Wheel perspective. Because we assumed the e-cargobikes did not emit any externalities (strong assumption but not so far from reality), the induced externalities per parcel delivery in Freight e-micromobility strategy (Strategy B) do not depend on the e-cargobikes volume (V_m).

Table 4 provides some numerical insight about the carriers' relevant Key Performance Indicators (KPIs) in the Business-as-usual strategy A, as well as in the Freight e-micromobility strategy B, with a total demand density equal to 300 parcels/km^2.

Table 4. Carriers' relevant KPIs in Business-as-usual strategy A and Freight e-micromobility strategy B with δ = 300 parcels/km^2 and a service region of area 7.5 km^2

KPIs	Business-as-usual strategy	Freight e-micromobility strategy (V_m = 1 m3)
Total number of delivered parcels	2 250	2 250

Total distance travelled by Light Commercial Vehicles (veh-km)	690	-
Total distance travelled by High-Duty Vehicles (veh-km)	-	122
Total distance travelled by the e-cargobikes (veh-km)	-	317
Total working time of Light Commercial Vehicles (veh-h)	129	-
Total working time of High-Duty Vehicles (veh-h)	-	1.9
Total working time of e-cargobikes (veh-h)	-	144
Total operation costs (€)	6 342	6 372
Total operation externalities (€)	39	7.7

To have a better representation of this demand density of 300 parcels/km2, let us consider a very dense urban environment of 20 000 inhabitants per square kilometer. If we assume that there are 3 main carriers operating in the city, the total demand density is 3 x 300 = 900 parcels/km2/day. Let us consider 250 working days in a year, i.e. the yearly total demand density is 900 x 250 = 225 000 parcels/km2/year. We assumed a population density of 20 000 inhabitants per square kilometer, which means that, under these assumptions, a person receives on average 11 parcels per year. This value can appear at first sight quite high. However, here we only considered the B2C market. To be fully representative, we should take into account the B2B one too. In some neighbourhoods, the density of small retail shops is very high and they receive much more parcels (in some cases 2 or 3 parcels per week) than citizens do. As a consequence, this total demand density per carrier of 300 parcels/km2 may not be so far from reality (in dense urban environments).

Conclusion, challenges and opportunities for freight transport

The main conclusions we can draw from Figure 41, Figure 42 and Table 4 are that:

1. **The number of parcels delivered per e-cargobike route strongly affects the carrier's operative costs**. This number of delivered parcels per route greatly depends on the design of the freight e-micromobile vehicle and the types of parcels (size, format…). To maximize its profit and improve its economic profitability, the carrier should use big freight e-micromobile devices, which may be in contradiction with the usage that is done of the urban space; the citizens may not be willing to accept such big devices in the streets.

2. **For most demand densities, it is not economically profitable for the carriers to pass from Business-as-usual strategy to Freight e-micromobility strategy (freight e-micromobile vehicles in association with a logistic micro-hub).** In less dense environments, ICE vans even seem more economically profitable.
3. **In dense urban environments** (demand density of approximately 300 parcels/km2/carrier), **passing from Business-as-usual strategy to Freight e-micromobility strategy could help reduce the induced externalities up to 80%.** This result is based on the assumption that an e-cargobike does not induce any externality. This figure should be confirmed with a more precise and detailed simulation.

Some comments on these results have to be done. First, Continuous Approximations equations (on which is bases the model) are not 100% representative of the reality. It is widely assumed in literature that the error induced by Continuous Approximation models (when compared to the current on-field operations) can reach 10%. To have a more accurate value of the carrier's Key Performance Indicators, numerical simulations considering the actual street grid of the service region should be performed and some hypotheses relaxed. In other words, we can consider in our study that the operation costs in Business-as-usual strategy and Freight e-micromobility strategy are equivalent because the differences, in relative values, are not significant enough.

Secondly, these results are quite in accordance with the conclusions of the Straightsol project (Macharis et al., 2012). During this project, TNT (a carrier with a worldwide network) implemented a logistic micro-hub pilot in the city of Brussels. An increase in their operative costs was detected during the pilot. The necessity to find a parking facility within the city center for the micro-hub truck and the parcels transfer operations from the truck to the e-cargobikes affect the economic competitiveness of the carrier. These aspects have not been considered in our study, which means that the operative costs are slightly under evaluated in the model we presented in the previous section.

To conclude, we argue that without any incentive from the city, the carriers will not by themselves change their business models to adopt these freight e-micromobile devices in association with a logistic micro-hub because 1. The money savings are not guaranteed at all. Implementing an intermodal transfer of the parcels from the micro-hub to the freight e-micromobile devices is operationally complicated and some cooperation with the city is greatly needed.

4. Discussion

Below we discuss the findings regarding potentials for integration and intermodality. A special focus is put on the relation between, on the one hand, the authorities and providers plans for micromobility, and on the other, the potential for sustainable development of residents', visitors' and freight transport in larger cities.

4.1. Intermodality in urban planning and design

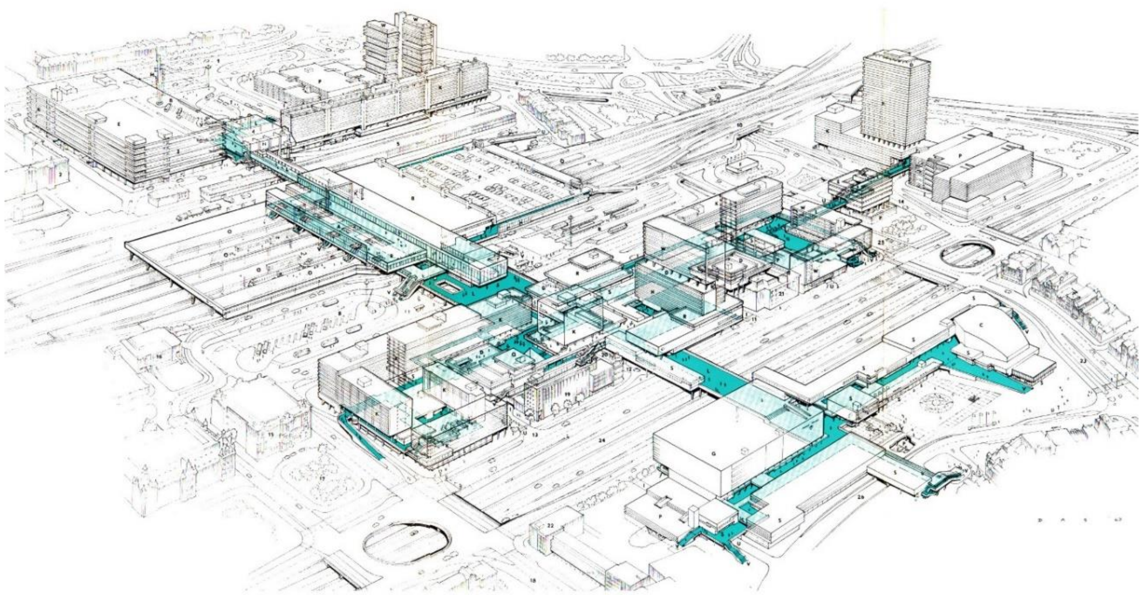
In accordance with the Sustainable Development Goals on urban transport (SDG 11, Sustainable cities and communities), the United Nations recommends the implementation of accessible and sustainable transport systems in conditions of safety and comfort, with special attention to the transport network public and the most vulnerable social groups. In this sense, the coordinated and integrated management of transport networks is one of the key aspects in creating a model of sustainable urban development, especially in promoting the use of collective transport and in favoring modal exchange between different systems. In the European context, many initiatives have favored modal integration, especially between means of active or non-motorized mobility and the mass public transport network. This integration takes place at three different levels: spatial integration, operational integration and finally, tariff integration.

The fare integration allows the user to pay for the entire trip and not for each of the journeys made in each of the systems they use. This type of initiative makes the use of public transport more comfortable and attractive, thus increasing the influx of public transport. On the other hand, spatial integration. It has to do with the design of the exchange spaces in such a way that a comfortable transfer between different modes such as the bicycle or the scooter is possible. These types of systems are especially useful in the urban periphery for capillary or last-mile distribution. Bu, in addition to nodes in the transport network, modal interchanges are also spaces with urban centrality. In other words, intermodal stations concentrate a certain intensity of activity due to permanent exposure to the flow of travelers. Therefore, the modal exchanger meets the condition of a transport node and an urban place.

The node is a basic element of the communication network in which a significant accumulation of transport infrastructure, of access, or both takes place simultaneously. Formal and dependent urban networks develop around these communication nodes. In this way, the concept of node can be linked to an intersection / access of the transport network or as urban centrality. In the first case, the node is valued as a space of confluence of flows and its importance will depend, from a quantitative point of view, on factors such as the intensity of traffic or the capacity of the infrastructure. The greater the traffic intensity, the greater the opportunity for the development of urban activity in its surroundings and the greater the viability of public transport systems. On the other hand, the quality of the node will depend on the ability to link transport flows of a diverse nature, in short, to promote modal exchange.

According to the node-place model (Luca Bertolini, 1999) applied to the environment of rail transport interchanges, the node index depends on the combination of quantitative parameters related to the intensity of traffic, and qualitative, related to the diversity of forms of displacement. On the other hand, the place index, defined as the physical space with morphological and functional characteristics that distinguish it from the urban context in which it is located, is, therefore, a fragment of the city with its own identity. In the surroundings of the railway station, but in general of the modal interchange node, and specifically, in a pedestrian radius of 10-15 minutes are the set of open and built spaces that confer the condition of place and whose development depends on physical, functional, but also psychological factors.

The place index of the modal exchange nodes, according to the node-place model, allows evaluating both quantitative parameters such as population density, as well as qualitative parameters, such as diversity or functional mix, in a service radius of the exchange node 700m, comparable to the distance traveled in 10-15 minutes by a user in an urban environment. Beyond the safety and comfort conditions in which the transport takes place and the nature of the flows that coincide in the node, the indicators of the place are related to the physical characteristics of the urban environment in which the modal exchange takes place.

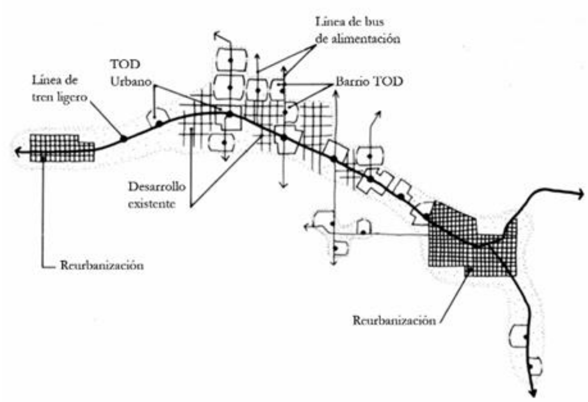


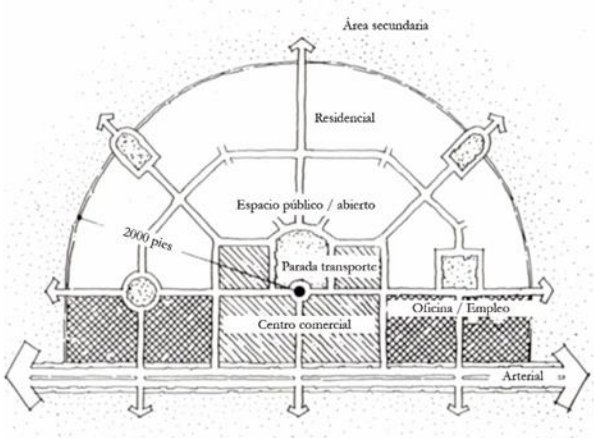
Hoog Catharijne (Utrecht), general view of the plan with the level of pedestrian circulation highlighted. Source: Hoog Catharijune plan: bijdrage tot Utrechts centrumfunctie [The Hoog Catharijne plan: contribution for a functional center in Utrecht]. Utrecht: N.V. Maatschappij voor rojekoontwikkeling "EMPEO", 1962. (p, 46-47)

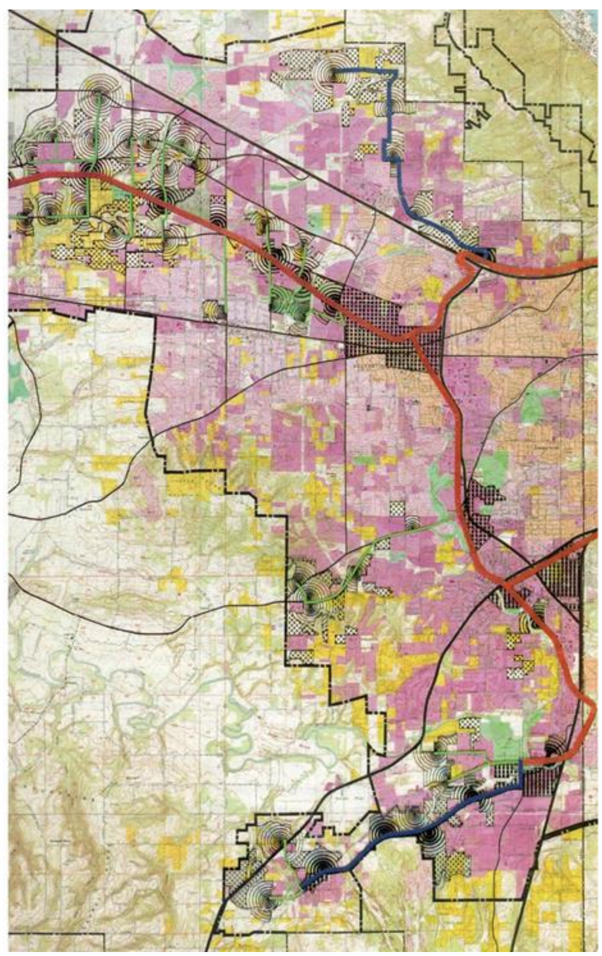
Modal interchanges are urban spaces whose design can favor the efficiency of the transport network. An urban-scale approach requires defining two types of exchange spaces. On the one hand, the transport nodes that allow immediate modal exchange without oversized spatial needs or long waiting times, such as bus or taxi stops. In this case, the exchange time will depend both on the frequency of the services passing through, and on the ability to coordinate the schedules of the different transport services. The second of the types of modal exchangers is the one that favors deferred exchange, that is, the change of mode is prolonged in time so that the user has to move between platforms, for example, from the railway platform to the bicycle parking.

The comfort in the exchange will depend on the time invested in the transfer, but from a spatial point of view of the distance, the legibility of the route and the architectural barriers that may hinder the free movement of users. In this sense, adequate signage allows the orientation of commuters and the incorporation of complementary services on the journey such as cafeterias, break rooms, etc. improve the comfort of the itinerary.

From the point of view of the metropolitan network, a modal interchange is the node of the transport network where different mobility systems converge and the passage from one system to another is allowed, producing a break in the continuity of the route, especially in inter-municipal routes. The value of the exchanger in the urban system depends on the hierarchy of the lines that converge and the territorial scope it serves. In this way, a structure of urban transport centralities is placed that complements the activities. In this way, spatial planning of land uses is integrated with the structure of the transport network. This type of transport-oriented urban planning integration models are called Transit Oriented Developments (TOD) and consist of the formation of urban centralities near the transport nodes. This type of urban development around a modal interchange station (600m) also promotes active or civic mobility, and allows reaching an optimal degree of efficiency between mobility and land uses, with the aim of avoiding processes of urban dispersion. The consolidation of a TOD model in a territory depends on the existence of a legible urban pattern and on policies to promote public transport. The strategies are based on the densification of accesses to transport networks through mixed functional patterns and the control of urban growth, thus preserving land for future needs.







Transit Oriented Development (TOD). A TOD is a functionally mixed community in a walkable distance of 2000 (609 meters) to a public transport stop and commercial center. Source: CALTHORPE, Peter. The next American metropolis: ecology, community, and the American dream. New York: Princeton Architectural Press, 1993. (p. 56)

4.2. Accessibility

The analyses that took place in this work package set out to investigate several distinct questions. First, in the hotspot analysis, the relationship between e-scooter activity and areas immediately surrounding public transport station entrances was established. This showed that there does seem to be a link between e-scooter use and public transport and suggests that people are using e-scooter trips to make multi-modal trips. Next, the accessibility analysis highlights the potential benefits of integrating shared e-scooter services into the public transport system. This demonstrated not only the accessibility implications for large shares of Munich's population, but also showed how different age groups, especially those that are less inclined to drive or own a car, could potentially benefit from improved integration of e-scooters into the public transport system. Finally, the gap analysis expanded on the accessibility analysis and showed specific areas in Munich where people live within a five-minute e-scooter service area, but outside of a five-minute walking service area for high-quality public transportation services. These gap areas, and the public transport stations that are near them, are the ideal locations for interventions that might facilitate the integration of shared e-scooter services into the existing public transportation system.

Future analyses like the ones that have been conducted in this work package could focus on measuring the effects and accessibility implications of interventions in the built environment that are intended to facilitate multi-modal integration between e-scooters and public transport. The analyses that have already been conducted serve as an excellent baseline to compare against, but they are only the first steps in understanding what sorts of interventions can be used as effective tools for encouraging multi-modal integration.

In the future, once cities have made more concrete efforts to integrate e-micromobility into their existing transportation systems, similar analyses could provide useful insights regarding the effects of these efforts. However, integration could take many shapes. This could be something like a physical intervention in the built environment or some sort of policy change. This could also be a change in the pricing structure. In the case of Munich, all of the shared e-scooter services have essentially the same pricing structure. They charge 1€ to unlock an e-scooter and a certain amount per minute of use, which is usually around 0.20€ per minute. Different pricing structures that are more integrated into existing public transport pricing schemes could be a mechanism for facilitating multi-modal trips. With the current system, someone might have to buy a transit ticket, then essentially pay the same value again to complete the last leg of a journey with an e-scooter. It is possible that a more integrated pricing structure could facilitate multi-modal trips, but the exact effects of a change in pricing will have to be evaluated using similar methods to the ones used in these analyses.

4.3. Data sharing and possibilities for multimodal travel companions

With the introduction of new micromobility services such as bike sharing, electric scooter sharing, kick scooters sharing, self-balancing boards, one wheels and skates in the past few years in many cities of Europe, micromobility options have rapidly grown to become firmly entrenched in our cities as viable transportation options. As these services continue to evolve, mature and transform the mobility landscape of our communities, it's increasingly important to better understand how they are reshaping our communities Hence, data sharing can contribute at a great extent to integration of micromobility and e-micro mobility to public transport and multimodality. For facilitating the data sharing also an Alliance was created. NUMO's (the New Urban Mobility alliance) New Mobility Atlas, is a free-floating shared micromobility services alliance (hosted by WRI Ross Center for Sustainable Cities) already operating in 630 cities in 55 countries around the world in order to provide data on shared micromobility services about safety, access to platforms, environment etc.

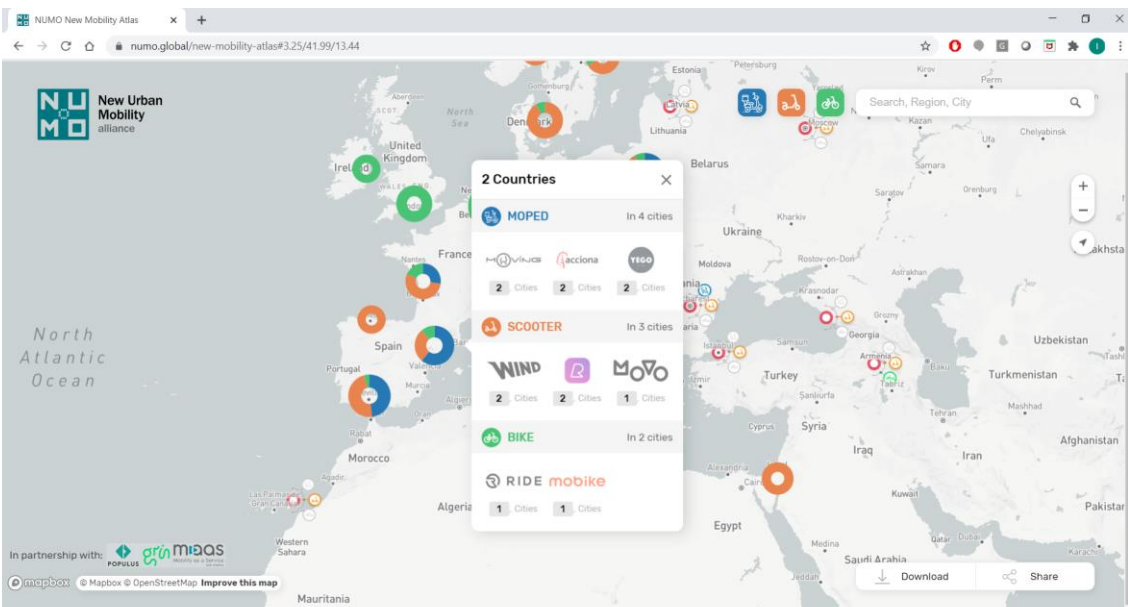


Figure 17: NUMO interactive atlas on shared micromobility

On the one hand shared micro mobility data could support policy making in several ways: (i.e. e-scooters, e-kick scooters, bikes) such as:

- Trip data can reveal potential demand for new public transport routes.
- Manage of parking and on street spaces
- Indication of the level of interchange with public transport
- Support the planning and maintenance of a cycling network

On the other hand, public transport, traffic data and data on the infrastructure conditions could support a smooth uptake of micro mobility

- Manage of crowdedness and alerts of systems discontinuity
- Indication of safe itineraries
- Transit data can reveal potential demand for soft mode usage for the first and last mile
- Transit data can reveal routes that are not covered by public transport (e.g. due to maintenance works)

4.4. Possibilities for freight/delivery e-micromobiles

As shown in the results section 'E-micromobility in urban freight distribution', there is a basis for arguing that without any incentive from the city, the carriers will not by themselves change their business models to adopt a strategy of freight e-micromobiles in association with a logistic micro-hub because, 1. The money savings are not guaranteed at all (see Figure 48 in Appendix 1). Implementing an intermodal transfer of the parcels from the micro-hub to the freight e-micromobile devices is operationally complicated and cooperation with the city would be needed. One solution could be to propose an economic incentive to the carrier, based on the externalities savings, to make the freight e-micromobile devices more attractive economically speaking. The use of e-vans (instead of Internal Combustion Engine vehicles) in Business-as-usual strategy appears as an interesting solution too because it would decrease the externalities without affecting too much the carriers' business models (there is no fundamental differences from an operational point of view between an e-van and a conventional ICE vehicle). Nevertheless, these e-vans would still be greatly penalized by congestion, a lack of flexibility in dense urban environments, a decreasing number of parking facilities and an increase in the space dedicated to pedestrian areas.

Integrating the urban last-mile logistics in the "15-minute city" concept

Many cities, such as Paris (Kane, 2020) are implementing the concept of the "15-minute city". In this model, every citizen lives at less than 15 minutes (including different means of transport) from all the main urban facilities (supermarkets, restaurants, sports centers…) and services (public administrations, hospitals…) he/she needs. The objective is to make the cities more liveable and more inclusive because the citizens would essentially live in their neighbourhood, fostering the local economic and social activity. This concept has different translations depending on the studied city. In Barcelona, it is expressed through the new urban plan based on the superblock concept (Roberts, 2019). Some superblock projects have already been piloted and it is foreseen that all the city will be covered by this urban structure in future years.

In this model of the "15-minute city", much more attention is dedicated to the citizens, the design of the public space being much more user-centric, kicking private cars and motorbikes out of the city. Citizens will be the great beneficiary from this new urban design. Nevertheless, in this type of model the last-mile logistics will get an increased importance. If the customer does not come to the good (because he/she should not travel more than 15 minutes to go shopping), the good needs to come to the customer directly in the local shops.

It is widely accepted that the urban logistics sector has to make its operations more sustainable because this is an important economic activity that has a huge impact in the cities (in terms of congestion and greenhouse gas emissions). However, carriers are caught between two contradictory trends:

- Increasingly-complicated operations due for instance to this “15-minute city” concept as described previously. Cities want to kick private vehicles out from the public space by increasing the number of pedestrian areas, charging congestion tolls to the vehicles or limiting the number of parking spots (these are examples of measures among many others). All this makes the last mile operations more and more inefficient because the drivers have to make large detours to access the final customer’s location, finding a parking place is really hard and the driver has to walk a lot to hand over the parcel to the final client (because the vehicle cannot park within a pedestrian area).
- The very fast surge of e-commerce that will produce much more important fluxes between the different distribution centers (usually in the outskirts of the city) and the inner neighbourhoods of the service region.

These two phenomena will considerably strain a market that is already suffering a great pressure. On the one hand, more fluxes. On the other hand, an increasing operative complexity.

A few weeks ago, a representative from the city of Barcelona suggested that a new tax on these last mile operations would be created to eliminate the “unnecessary trips” (Gónzalez, 2020). This created a great opposition within the logistics sector (Gónzalez, 2020b) (Hernández, 2020). Beyond the fact that the opposition to the implementation of a new tax (when you are the person that will be charged with it) is natural, this reaction is understandable. This very imprecise declaration (what is exactly an “unnecessary trips”?) highlights that the challenges at stake behind the urban last-mile logistics operations are not fully understood. The city cannot pretend make the urban logistics more sustainable by creating a new tax without proposing new solutions and a closer dialogue directly with the professionals, above all in a market that is very competitive and constrained. Carriers, in a sense, are asked too much in a too little time. In addition, the carriers cannot be accused to be the generators of these “unnecessary trips” whose final destinations are the houses of the people that ordered a good online.

More convincingly, the representatives of the Barcelona metropolitan area proposed a White Book about the urban distribution of freight (Metropolitan Transport Authority, 2019). This is a much more interesting approach because a close collaboration between the transport authorities and the carriers is promoted. In addition, different innovative solutions, integrated in the superblock scheme previously presented, are proposed:

- The creation of various urban logistic micro-hubs. The parcels would transit through these facilities and delivered in the neighbourhood with low-impact vehicles such as e-cargobikes. This is exactly what has been described in the previous sections of this study. Some very important details about the governance of these infrastructures (would they be run by the city? By the carriers themselves?) and the pricing strategies still need to be clarified.
- The promotion of night deliveries with silent vehicles to avoid noise externalities. This measure seems to be directly focused on the particular challenges of the supermarkets that can be hardly replenished by e-cargobikes or other kinds of freight e-micromobile devices.

- The implementation of shared lockers to limit the inefficiency created by the delivery failures, basically because the final customer is not at home when the carrier delivers the parcel. In this configuration, the driver drops the parcel in the locker and the final client gets it whenever it bests suits him/her.

All these solutions, to be successfully implemented need a close collaboration between all the stakeholders involved in the urban last-mile logistics operations: the transport and mobility public authorities, the carriers, and the final customers (either B2B or B2C). Creating more liveable and more citizen-oriented urban spaces is a great objective and the quality of life will greatly benefit from this shift in the planning processes. However, urban logistics will be a key activity to make these "15-minute cities" work properly and this sector should not be left behind by public authorities as it may have been the case in the past decades (Hernández, 2020).

Autonomous Delivery Devices

The major changes in the field of the urban last-mile distribution are expected to be induced by the emergence of Autonomous Delivery Devices (ADD). Figure 10 gives a first overview of the competitive landscape right now. Many multinational companies such as Amazon, FedEx or UPS are currently prototyping their vehicles, that strongly differ in the size and design.

(Francis, 2019)

(REUTERS, 2019)

(Robotics Business Review, 2019)

(Web 24 News, 2020)

Picures 26-29. Some ADD technologies

These technologies seem very interesting because they will help reduce the carriers' operation costs and limit the externalities at the same time. They are mid-size autonomous e-vehicles (less noise, no exhaust fumes) able to travel on bike lanes in most cases (little impact on congestion). To understand the economic potentialities of these ADDs. Let us try to estimate the unit time and distance operative costs of an ADD and compare them to an e-cargobike (see Table 5).

The unit time operation cost of a vehicle is the amount of money that the operator (in our case the carrier) has to pay to run the vehicle during one unit time. It is generally expressed in € per working hour. Similarly, the unit distance operation cost of a vehicle represents the amount of money that the operator has to pay to run the vehicle for one unit distance. It is generally expressed in € per travelled kilometer.

Table 5. Comparison between e-cargobikes and ADD unit temporal costs

	E-cargobike		ADD	
	Yearly cost (€/veh-year)	Unit temporal cost (€/veh-h)	Yearly cost (€/veh-year)	Unit temporal cost (€/veh-h)
Vehicle depreciation	1,667	1.3	4,000	3.2
Insurance	500	0.4	2,000	1.6
Carrier structural cost	2,000	1.6	3,000	2.4
Personal cost	50,000	40	-	-
Total	54,167	43	9,000	7.2

Table 5 presents some estimations of the unit operations costs based on some data the MOBY partners had access to. In any case they can be considered as completely representative figures. Because the last-mile distribution market is very competitive and this data is strategic, very few open sources exist, which complicates the study of the different supply chains.

The major improvement lies in the null personal costs of ADDs because they are autonomous technologies. With an e-cargobike, the personal costs are estimated to represent 90% of the total costs. This is the main reason why ADDs are so economically profitable. We assumed null personal costs for the ADDs. This may be a too strong assumption depending on the regulatory framework one is working in. It is possible to imagine a regulation in which a driver has to supervise a certain number of ADDs. In this case, the ADD personal cost would not be null.

Table 6 presents an estimation of the ADD unit distance operative cost.

Table 6. Comparison between e-cargobikes and ADD unit distance costs

	Unit distance cost (€/veh-km)	
	E-cargobike	ADD
Vehicle maintenance	0.13	0.26
Energy (electricity)	0.00125	0.00125
Total	0.13	0.26

We assume that the ADD maintenance costs twice more money because the technology within the ADD is much more exposed to failure. The electric energy consumption is assumed to remain constant.

Figure 11 presents the output of the model described in the previous sections considering ADDs instead of freight e-cargobikes. The average cost per parcel delivery is shown as a function of the total demand density per carrier δ. We assumed that the ADD commercial speed was equal to 5 km/h for safety reasons (this will greatly depend on future regulation). Freight e-micromobility strategy (Strategy B) is now a combination of ADDs and a logistic micro-hub in the center of the service region.

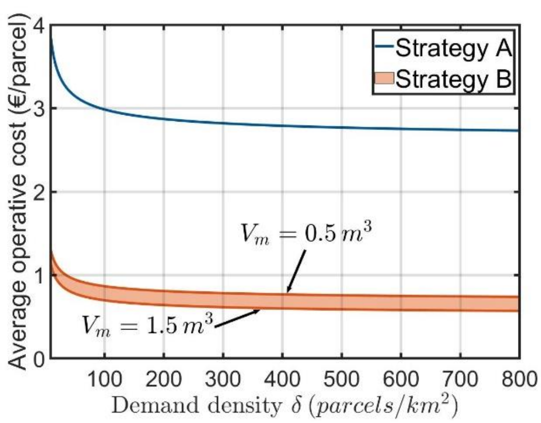


Figure 11. Average operative cost per parcel delivery with ADDs

The economic competitiveness of ADDs is much higher than the conventional vans. The average operative costs per parcel delivery is cut by 2/3, which tends to justify even more the emergence of these technologies. This is a first very raw estimation of the ADD operation cost. Nevertheless, one can perfectly see that, even if ADDs' costs are under evaluated in our study, the margin remains important. Conceptually, it appears quite clearly that ADDs will have lower operation costs.

As compared to autonomous cars, the strategic advantage of ADD may lie in their better user acceptance. It seems relatively reasonable to think that the citizens are ready to get a parcel from an autonomous robot that travels on bike lanes at a very low speed. This is very different from travelling in an autonomous car which goes at 90 km/h on a road.

4.5. Guidelines and recommendations for governing and piloting e-micromobility integration

Concerning safety for pedestrians and micromobility users there is nothing to suggest that the regulation of these vehicles in traffic, and the behaviour of the drivers in traffic, could not be satisfactorily resolved within existing frameworks of legal preconditions and legal practice. This has been possible for other relatively recently introduced vehicles (for example, for jet skis and quad bikes/ATVs).

When it comes to the behaviour of e-scooter companies, though, there seems to be a lack of experience in handling it in legal practice. This, we argue, can be because this kind of companies are part of the "international e-economy", which in its entirety is still relatively problematic to deal with for national and local authorities. This is a question that largely falls outside the scope of this study. However, we believe that the conditions for regulating "e-economy" companies in the traffic sector seem more favourable than in other sectors. Also, we like to argue that issues like road safety, the users' carefulness and the setup of the vehicles, can be regarded as typical "childhood diseases" that come with all novel modes of transport, and can be resolved relatively soon. On the other hand, I believe that the issues regarding working conditions and the organization of e-scooter businesses' activity within current financial legislation will take longer to resolve. However, one possible direction towards a solution that we have already begun to explore within MOBY is the procurement of e-scooter systems by the authorities, such as the regional public transport agencies or by municipalities, which could also affect the fact that current micro-mobility services provided on the free market operate only in the central parts of major cities.

With regard to the third and final point, the environmental impact, we believe that it depends (in a corresponding way) on globalized production and European / national trade legislation, the overall organisation of recycling and other established systems and practices. Regarding the local dumping of e-scooters on land and in water, by contrast, the issue most frequently raised in the district press is already in place - because that is how I think the indignation towards dumping should be interpreted. And here there are already legal means available to use (although city environment offices, county administrative boards, etc., do not seem to have been updated yet regarding resources for controlling/sanctioning compliance). Finally, the press material contains questions about the impact on the life cycle. My interpretation is that the social debate about this is still unmature, mainly because it has not been an issue at all until very recently. For many other types of products, EU directives for 'eco-efficiency' have been able to contribute to improving technical and actual service life, as well as reducing the environmental consequences of global production and European trade. But this, too, will be outside the scope of the study. However, what will lie within the scope is the very last aspect, namely how intermodal urban travel, especially public transport in combination with micro-mobility, could help to improve the environmental impact of city traffic, from a life cycle perspective (including land use and use of materials and energy. And that question can be divided into at least two, namely how residents' practices and usage patterns can be developed to integrate e-micro mobility with active modes of transport and public transport, and how the impact can be estimated in scenarios that include the life-cycle perspective. For the first question, it is mainly studies of current mobility practice and historical shifts in the use of (new) modes of transport and mixed-mode commuting that need to be studied, and for the second part scenarios with environmental assessments. This means that there is a need for illustrating the connection between e-micro mobility and public transport for the MOBY European pilot cities, including Tel Aviv. There should be provided a basis for discussing whether acceptance can be affected by how the connection to public transport looks in the cities in question. What would be a desirable outcome from the pilots in terms of sustainable integration of e-micro mobility with public transport, and in the city's traffic environment? What recommendations can we then make for e-micro mobility to become a part of sustainable city traffic? One way to go is to provide illustrations of consequences and risks with different choices, that should be interesting for so-called decision-makers. And that a risk from a decision-maker's perspective is that groups that can look like losers in a short-term perspective (e.g. 'motorists') also do not perceive any benefits of the long-term choices and that their passive acceptance may fail, or perhaps become active resistance, for example when voting in political elections.

5. Concluding lesson

5.1. Compendium for a customized toolset

The European regulatory landscape is still very inhomogeneous and inconsistent, which needs to be addressed in an adequate manner in the future by the European legislative. Still municipalities can cope with the problems arousing on a local or regional scale. As the emerging conflicts regarding the use of e-kick scooters seem to be similar in different cities around the world, there are several exemplary measures that are already in use in municipalities to solve specific conflicts. The following is an overview of the different municipal approaches already established in European cities and attempts to summarise the conclusions that can be drawn so far.

Approaches	Measures
Permissions	• **Limited duration of permissions** By limiting the duration of the licence issued, pressure on operators can be built up and additional room for manoeuvre can be granted to the local authority, as undesirable developments can be addressed and corrected in the next issuing period (e.g. Zaragoza, Bremen) • **Limited permissions and public tenders** If the approval is linked to strictly formulated conditions and the number

	of operators is reduced, the effects of the free floating e-kick scooter operations on the local area can be analysed, communicated and monitored more precisely. Therefore, sustainability, safety and operational knowledge can be fostered and operating companies have more investment security, allowing them to make more sustainable investments (e.g. Paris, Bremen) • Operational fees The operating licence for free-floating fleets can also be linked to operating fees, thus reducing the financial burden on local authorities, as the operations of commercial mobility services arises significant cost to the municipality (e.g. Paris)
Compliance	• Geofencing Those technologies can be used to define specific no-driving zones or implement regulations on parking restrictions and speed limits (e.g. Berlin, Tel Aviv) • Penalties The introduction of penalty payments and their consistent monitoring can contribute to compliance with legal requirements. To this end, the necessary framework conditions must be created (e.g. Madrid, Paris, Tel Aviv) • Compliance-Taskforce In order to enforce compliance with agreed regulations, a task force run by the operating companies can be a helpful instrument to relieve existing municipal authorities and to provide for fast interventions (e.g. Paris) • Establish complaint services In order to punish infringements of regulations as promptly as possible, public complaints offices or digital applications with comparable functions can be of great use, where citizens' complaints can be sent to and be processed directly (e.g. Tel Aviv)
Accidents and Safety	• Mandatory helmets The use of mandatory helmets can significantly contribute to the safety of e-kick scooter riders. The operator's obligation to make helmets available to service users can also be negotiated and stipulated (e.g. Tel Aviv) • No-driving zones and slow-zones The declaration of no-driving zones in neuralgic areas can significantly reduce safety for the users of electric kick scooters as well as for other (vulnerable) road users. For free-floating providers, compliance with such restrictions can be ensured among others by using geofencing technologies (e.g. Berlin, Tel Aviv)

	• **Information on road traffic regulations** Road traffic regulations regarding the use of e-kick scooters ought to be formulated comprehensible. User-friendly information should be communicated to those using the vehicles very clearly. Information on where and where not to drive and park is of fundamental importance, as regulations vary around cities and nations and thus may even lead to involuntary infringements • **Mobility-app-design** An intelligent app design on the part of providers can clarify traffic rules and motivate users to comply with them (e.g. Voi-Credits-System). On the one hand, information can be passed on or infringements of rules can be traced or prevented by suitable technology solutions
Sustainability	• **Electric vehicles for collection and distribution** In order to strengthen the sustainability of the vehicles, the e-kick scooters are not to be collected and distributed with diesel-powered vehicles, but with vehicles that are based on sustainable energy sources like electric vans or e-cargo bikes, as this accounts for a substantial share of emissions produced in the life cycle of e-kick scooters • **Renewable energies for recharging** To ensure that the charging processes of the batteries are also based on sustainable energy sources, respective determinations are to be considered and promoted in bilateral agreements, calls for tenders or in municipal regulations • **Foster the life cycle duration** As the environmental performance of vehicles is highly dependent on their service lifespan, preference should be given to suppliers whose vehicles have an increased durability and are based on sustainable operating concepts, such as replaceable batteries or reuse- and recycling-concepts
Parking regulation	• **Designated Parking Zones** The provision of designated parking areas reduces the number of vehicles parked on footpaths and public spaces. The designation of parking areas on existing parking spaces for stationary car traffic can also provide incentives for the usage of short-distance mobility modes (e.g. Berlin, Bremen) • **Photographic monitoring of parking regulations** Providers of free-floating fleets can ensure compliance with the regulations by means of obligatory photos showing the parked vehicle after use in accordance with the stipulated regulations (e.g. Voi, Lime)

Integration in urban mobility systems	• **Integration into mobility hubs** Through integration into mobility hubs, e-kick scooters as a new mode of mobility can be a useful addition to existing local mobility systems. For this purpose, designated parking spaces are to be located near intermodal nodes, as this strengthens short-distance mobility and may lead to a reduction of car traffic and therefore even enhance safety of VRU (e.g. Berlin) • **Provision in peripheral areas** In order for the e-kick scooters to be a substantial enrichment for short-range transportation, particularly non-central, less profitable urban areas require the provision of services. To this end, the operators are to be made accountable for an extension of the service area. A distribution key can be stipulated to secure this on a legally binding basis (e.g. Paris) • **Municipal use of mobility data** The data collected by the mobility providers on the vehicles can be used in particular for infrastructure planning and enable municipal authorities to enhance the adjustment of the infrastructure and to the location of deployment areas in accordance to the mobility patterns of road users, enhancing also the convenience for users
Education	• **Driver's license** The obligation to hold a driving licence or, if not available, the obligation to attend preparatory courses can be a way to positively influence the traffic behaviour of e-kick scooter drivers (e.g. Tel Aviv) • **Driving schools for users of e-kick scooters** In driving schools first experiences with e-kick scooters can be gained and user learn how to use the vehicle in traffic. This increases driving safety and allows training of rule-compliant behaviour (e.g. Voi, Lime)

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Annex

A1. Continuous approximations regarding Freight e-micromobility

Our objective in this part of MOBY was to present a simple model using Continuous Approximation (CA) equations, as described by Daganzo (2005), to estimate some of the carrier's Key Performance Indicators (KPI) and assess its economic profitability in Business-as-usual strategy A and Freight e-micromobility strategy B. CA is a widespread technique to model transportation systems. The resulting models are very useful in a first approach because they provide an overall vision of the concepts at stake behind each one of the considered supply chains. They will enable us to easily identify the most relevant decision variables in each framework.

Input Parameters

Table 1 presents the different input parameters that will be needed to build the CA models. We are considering a rectangular service region whose dimensions are l_x and l_y. We assume that the parcels that are to be delivered have an average size $E(u)$ of 0.027 m^3, which corresponds to a typical parcel of dimensions 30 cm x 30 cm x 30 cm. The useful volume V_{LCV}, V_{HDV} and V_m of each vehicle type refers to the volume that is used to carry the parcels. We assume that the useful volume of a LCV is around 4.5 m^3 (which is consistent with the technical characteristics given by the different constructors) and 20 m^3 for a Heavy-Duty Vehicle (HDV). The HDV is used to carry the parcels from the DC to the center of the service region in Freight e-micromobility strategy, the so-called mobile depot. Then, the commercial velocities of each vehicle type are defined. We assume that on the first leg (between the DC and the center of the service region) the vehicles travel on metropolitan highways, which means that the line-haul velocity v^{LH} is much higher than the inner city one v^L; the vehicles are less affected by traffic and congestion in the suburban area than in the inner part of the city. The handover time τ refers to the actual delivery of the parcel to the final client; the driver needs to park, access the final customer's location, hand-over the parcel, and come back to the vehicle.

Inputs	Value	Unit
Distance between the DC and the center of the service region ρ	20	km
Dimensions of the service region l_x, l_y	3 – 2.5	km
Demand density δ	-	parcels/km^2
Average size of parcels $E(u)$	0.027	m^3
Useful volume of LCVs V_{LCV}	4.5	m^3

Useful volume of HDVs V_{HDV}	20	m^3
Useful volume of freight e-micromobile devices V_m	-	m^3
Inner city velocity of LCVs v_{LCV}^{L}	15	km/h
Inner city velocity of freight e-micromobile devices v_m	10	km/h
Line-haul velocity of LCVs v_{LCV}^{LH}	80	km/h
Line-haul velocity of HDVs v_{HDV}^{LH}	65	km/h
LCV handover time τ_{LCV}	3	min
Freight e-micromobile device handover time τ_m	3	min
Unit distance cost of LCVs c_{LCV}^{d}	0.2	€/veh-km
Unit temporal cost of LCVs c_{LCV}^{t}	48	€/veh-h
Unit distance cost of HDVs c_{HDV}^{d}	0.29	€/veh-km
Unit temporal cost of HDVs c_{HDV}^{t}	51	€/veh-h
Unit distance cost of freight e-micromobile device c_m^d	0.13	€/veh-km
Unit temporal cost of freight e-micromobile device c_m^t	43	€/veh-h
Line-haul unit distance externalities emission rate of LCVs $\$_{LCV}^{LH}$	5.0	€-cent/veh-km
Inner city unit distance externalities emission rate of LCVs $\$_{LCV}^{L}$	7.8	€-cent/veh-km
Line-haul unit distance externalities emission rate of HDVs $\$_{HDV}^{LH}$	6.3	€-cent/veh-km
Inner city unit distance externalities emission rate of freight micromobile devices $\$_m^L$	0	€-cent/veh-km

Table 5. Model input parameters

Table 1 details the different unit operative costs of the carriers. We assume that the carriers' operative costs structure can be divided as follow:

- On the one hand, some unit temporal operative costs to describe the carrier's expenses that do not depend on the distance travelled by its vehicle fleet. The main expenses that enter in this category are the vehicle depreciation (generally linearly depreciated over a certain number of years), the insurance paid for the vehicles, and the costs of personal. The drivers' salaries, in most cases, only depend on the working time, not on the distance travelled by the drivers to deliver the parcels.
- On the other hand, some unit distance costs. In this category are gathered the expenses that almost exclusively depends on the distance travelled by the vehicle fleet. The main components of this unit distance cost are basically the energy (gasoline, petrol, even electricity for e-vehicle) used to move the vehicle and the maintenance operations that have to be done regularly on the vehicle. These maintenance operations usually depend on the total travelled kilometers (even if the total working time may be considered as well in some cases).

As for HDVs and LCVs, the numerical value of these different unit time and distance operative costs are quite well-known because this is the current business-as-usual, and some statistics are produced. We chose to use the data provided by the Observatory of road freight transports costs in Catalonia (2019).

As for the freight e-micromobile devices, it is much more complicated to have representative numerical values because no large-scale on-field data is available. There are mainly two reasons for this. First, as far as the knowledge of the MOBY partners extents, the use of these freight e-micromobile devices is at the moment essentially reduced to pilots, in limited areas of some cities, which limits the scale of the different projects. Secondly, as previously explained, there is lots of competition between the different stakeholders of the market. Because these unit time and distance operative costs are very important from a strategic perspective (because they condition the viability of the carriers' business models), very few data are made public, which complicates the work of the researchers.

As a consequence, we will have to limit ourselves to some approximations. Table 2 proposes an estimation of the unit temporal cost of a freight e-micromobile vehicle. As previously explained, we consider here the vehicle depreciation, the insurance cost, the carrier's structural costs and the personal costs. We assume that a freight e-micromobile vehicle costs around € 5,000 and is linearly depreciated over 3 years, which means a depreciation of € 1,667 on a yearly basis. We consider that the yearly costs for insurance are the half of a LCV insurance expenses stated by the Observatory of road freight transports costs in Catalonia (2019). The carrier's structural costs is given by the Observatory of road freight transports costs in Catalonia (2019) as well. Finally, the personal costs are the same as for a fleet of LCV drivers; we assume there would not be any fundamental difference between the salary of a conventional LCV driver and a freight e-micromobile device rider. To pass from a yearly to an hourly basis, we considered 1250 working hours per year (250 working days each year and 5 working hours per day).

	Yearly cost (€/veh-year)	Unit temporal cost (€/veh-h)
Vehicle depreciation	1,667	1.3
Insurance	500	0.4
Carrier structural cost	2,000	1.6
Personal cost	50,000	40
Total	54,167	43

Table 6. Unit temporal cost of a freight e-micromobile vehicle

Table 3 presents an estimation of the unit distance operative cost of a freight e-micromobile vehicle. It includes the vehicle maintenance and the energy consumption, in our case the electricity needed to refill the batteries of the e-cargobikes. As stated by the Observatory of road freight transports costs in Catalonia (2019), the maintenance costs of a LCV are 0.098 €/veh-km. We assume an increase of 50% in these maintenance costs because the freight e-micromobile devices are expected to be less robust than regular delivery vans. The freight e-micromobile maintenance costs are thus 0.13 €/veh-km. Finally, we assume an energy consumption of 5 Wh/km, which approximately corresponds to the energy consumption of a regular e-bike in normal conditions. Taking into account a price of the electricity of € 0.25 per kWh, the unit distance cost of the energy consumption is around 0.00125 €/veh-km. In this estimation, the costs of energy can be neglected because they are much smaller than the maintenance ones.

	Unit distance cost (€/veh-km)
Vehicle maintenance	0.13
Energy (electricity)	0.00125
Total	0.13

Table 7. Unit distance operative cost of a freight e-micromobile vehicle

The last point that needs to be addressed in this section (and maybe the one that would require a deeper discussion but this is not the object of this study) are the externalities induced by each type of vehicle. Table 1 presents the line-haul (between the carriers' DC and the service region) and local (within the inner part of the city) externalities emission rates for each type of vehicle. The objective of these figures is to quantify in terms of monetary units the social cost of each kilometer travelled by each type of vehicle, mainly focusing on ICE vehicles. Without entering too much in the details of the methodology (because it is currently an active field of research and the methodology is constantly improved), the main types of considered externalities are:

- The Tank-to-Wheel (TTW) externalities that correspond to the actual emissions of pollutants from the combustion fumes. It includes Greenhouse Gas (GHG) (carbon dioxide $\mathrm{CO_2}$, methane $\mathrm{CH_4}$…), the oxides of azote NOx, the fine particle matters (PM2.5, PM10…), and all the other substances emitted during the combustion of the fuel to move the vehicle. E-vehicles cannot be charged with these types of externalities because they do not emit any exhaust fumes.
- The Well-to-Tank (WTT) externalities that correspond to the production of the energy. These externalities are much higher for e-vehicles because the electricity production process (with carbon, gas, nuclear or renewable energies) emit more pollutants (depending on the energetic mix of the studied area) than the production of gasoline or diesel, even if the energy consumption to refine the crude oil has to be considered.
- Other externalities induced by the vehicle production and the impact on road infrastructure, particularly high for HDVs because of their huge weight.

Other externalities, such as noise or congestion for instance, could be considered but it is much more difficult to, first, quantify them and then assign them a social cost (in € per vehicle-km). This is why we chose not to include them.

This methodology is gaining more and more momentum at the moment and it still needs to be refined because the computation methods may differ from the different agencies (United States, Europe…) in charge of this work. The vast majority of the data used in this section was taken from the Observatory of road freight transports costs in Catalonia (2018), considering a social cost of € 90 per ton of emitted $\mathrm{CO_2}$. These numerical figures are of course questionable. Our objective here is to propose a first quantification of the induced externalities.

Carriers KIPs Modelling

The objective of this section is to propose some equations using the previously defined input parameters to estimate some relevant KPIs – total distance travelled by the fleet, total working time… - and evaluate the total operative costs of the last-mile distribution. These equations are essentially based on the work done by Estrada & Roca-Riu (2017).

The final objective of the modelling process is to compute, in both Business-as-usual strategy and Freight e-micromobility strategy, an operative cost per parcel delivery z as well as an induced externality per parcel delivery e. In all the equations, δ stands for the demand density (either B2B or B2C) in the service region, expressed in parcels per square kilometer.

Business-as-usual strategy

Let us begin with Business-as-usual strategy. First of all, we are to compute the total distance travelled by the carrier's fleet. It can be divided into two components. On the one hand, the line-haul distance D_A^{LH} between the DC and the service region. On the other hand, the total distance travelled in the urban road grid D_A^L. $\delta l_x l_y$ is the total number of parcels that has to be distributed in the service region (whose area is $l_x l_y$). The total volume of the parcels is thus $\delta l_x l_y E(u)$, where $E(u)$ is the mean size of the parcels. However, the volume capacity of the LCVs is limited to V_{LCV} (it is impossible to carry an infinite number of parcels in a LCV). As a consequence, the number of LCV routes is $\frac{\delta l_x l_y E(u)}{V_{LCV}}$. In each route, the vehicles have to travel a line-haul distance of 2ρ to go from the DC to the service region and come back. The expression of D_A^{LH} is given in Equation (1).

$$D_A^{LH} = 2\rho \frac{l_x l_y E(u)}{V_{LCV}} \delta \quad (1)$$

To compute the total distance travelled in the urban road grid D_A^L, we directly use the expression given by Daganzo (2005), as expressed in Equation (2).

$$D_A^L = \frac{2}{\sqrt{3}} l_x l_y \sqrt{\delta} \quad (2)$$

Where $\frac{2}{\sqrt{3}} l_x l_y \sqrt{\delta}$ is an approximation of the Travelling Salesman Problem (TSP) optimal solution considering a L1-metrics. This expression is very well documented in the literature and we will not enter more in the details of its demonstration.

As presented previously, some operative costs of the carrier depends on the total working time of the vehicle fleet. To compute it, we first define an operative time per parcel delivery t_A^d, as defined in Equation (3).

$$t_A^d = \frac{2}{\sqrt{3}} \frac{1}{v_{LCV}^L} \sqrt{\frac{1}{\delta}} + \tau_{LCV} \quad (3)$$

Where $\frac{2}{\sqrt{3}}\sqrt{\frac{1}{\delta}}$ is the average distance between two consecutive clients (in the configuration of the TSP optimal solution), v_{LCV}^{L} the speed of LCVs in the local urban grid (inner city) and τ_{LCV} the parcel hand-over time.

As a consequence, the total working time of the vehicle fleet in Business-as-usual strategy T^{A} is given by Equation (4).

$$T^{A} = \frac{D_A^{LH}}{v_{LCV}^{LH}} + t_A^d l_x l_y \delta \tag{4}$$

It is the sum of two components. First, the time spent by the drivers to travel from the carrier's DC to access the service region. This is the ratio $\frac{D_A^{LH}}{v_{LCV}^{LH}}$. Then, the time spent to actually deliver all the parcels $t_A^d \delta l_x l_y$ using the unitary time per parcel delivery t_A^d previously defined and estimated.

The total operative costs of the carrier in Business-as-usual strategy Z_{op}^{A} can now be computed using the LCV unit time and distance operative costs c_{LCV}^{t} and c_{LCV}^{d}. This modelling of the cost is quite simple but it is represents well the reality.

$$Z_{op}^{A} = c_{LCV}^{d}(D_A^{LH} + D_A^{L}) + c_{LCV}^{t} T^{A} \tag{5}$$

After performing some operations, we get the expression of Equation (6).

$$Z_{op}^{A} = 2\rho \frac{l_x l_y E(u)}{V_{LCV}} \left(c_{LCV}^{d} + \frac{c_{LCV}^{t}}{v_{LCV}^{LH}} \right) \delta + \frac{2}{\sqrt{3}} \left(c_{LCV}^{d} + \frac{c_{LCV}^{t}}{v_{LCV}^{L}} \right) l_x l_y \sqrt{\delta} + c_{LCV}^{t} \tau_{LCV} l_x l_y \delta \tag{6}$$

To obtain the unit operative cost per parcel delivery z_{op}^{A}, the total operative cost Z_{op}^{A} is divided by the total demand $\delta l_x l_y$.

$$z_{op}^{A} = \frac{Z_{op}^{A}}{\delta l_x l_y} \tag{7}$$

Finally, the total externalities induced by the last-mile delivery operations in Business-as-usual strategy E^{A} are estimated the unit externalities emission rate of each vehicle type, as defined in Table 1. A distinction has to be done between the line-haul distance (on "metropolitan highways") and the distance travelled in the local urban grid. The externalities emission rates are not equivalent in these two configurations.

As before, the unit induced externalities per parcel delivery e^{A} is computed dividing E^{A} by the total demand $\delta l_x l_y$.

$$E^{A} = \$_{LCV}^{LH} D_A^{LH} + \frac{2}{\sqrt{3}} l_x l_y \$_{LCV}^{L} \sqrt{\delta} \tag{8}$$

$$e^A = \frac{E^A}{\delta l_x l_y} \quad (9)$$

Freight e-micromobility strategy

Let us now go through Freight e-micromobility strategy. The same concept are to be applied as in Business-as-usual strategy. First of all, the total line-haul distance travelled by the HDVs D_B^{LH} (the mobile depot in this model) is computed.

$$D_B^{LH} = 2\rho \frac{l_x l_y E(u)}{V_{HDV}} \delta \quad (10)$$

Then, the expression of the total distance travelled in the local urban grid D_B^L is modelled. The expression is different than in Business-as-usual freight e-micromobility strategy because the volume of the freight e-micromobile device is much lower than the LCV one. This means that in one round route, the freight e-micromobile devices will be able to distribute less parcels than what the LCV would do.

$$D_B^L = \frac{2}{\sqrt{3}} l_x l_y \sqrt{\delta} + \frac{l_x + l_y}{2} \frac{l_x l_y E(u)}{V_m} \delta \quad (11)$$

Where $\frac{2}{\sqrt{3}} l_x l_y \sqrt{\delta}$ is still an approximation of the TSP optimal solution. A new term has to be added to take into account the quite limited useful volume of the freight e-micromobile devices V_m. Because the freight e-micromobile devices have a smaller useful volume, they can deliver less parcels in one round route (see Figure 6). As a consequence, before actually delivering the parcels they carry, they have to travel from the logistic micro- hub to the "delivery zone" where they can start distributing. This total access distance is the second term in Equation (11).

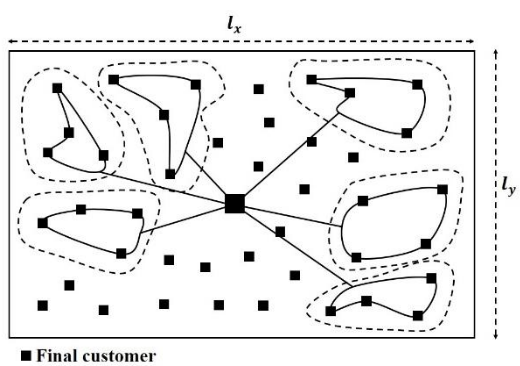

Figure 48. Parcel deliveries with low volume capacity vehicles.

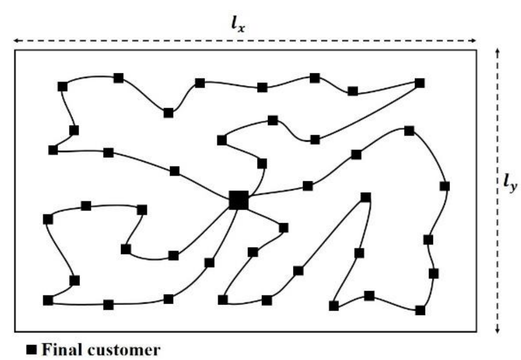

Figure 49. Parcel deliveries with high volume capacity vehicles

As before, the working time per parcel delivery in Freight e-micromobility strategy t_B^d is computed.

$$t_B^d = \frac{2}{\sqrt{3}}\frac{1}{v_m}\sqrt{\frac{1}{\delta}} + \tau_m \tag{12}$$

The total working time in Freight e-micromobility strategy T^B is the sum of the HDV fleet total working time and e-cargobikes total working time.

$$T^B = \frac{D_B^{LH}}{v_{HDV}^{LH}} + \frac{1}{v_m}\frac{l_x + l_y}{2}\frac{l_x l_y E(u)}{V_m}\delta + t_B^d l_x l_y \delta \tag{13}$$

Finally, the total operative costs in Freight e-micromobility strategy Z_{op}^B, the unit operative cost per parcel delivery z_B^{op}, the total induced externalities E^B and the unit externalities emissions per parcel delivery e^B are estimated. Let us recall that we assumed that the e-cargobikes did not emit any externalities (see Table 1). As a consequence, the total externalities emissions only depend on the distance travelled by the HDVs in this Freight e-micromobility strategy.

$$Z_{op}^B = 2\rho\frac{l_x l_y E(u)}{V_{HDV}}\left(c_{HDV}^d + \frac{c_{HDV}^t}{v_{HDV}^{LH}}\right)\delta + \left(c_m^d + \frac{c_m^t}{v_m}\right)\left(\frac{2}{\sqrt{3}}l_x l_y\sqrt{\delta} + \frac{l_x + l_y}{2}\frac{l_x l_y E(u)}{V_m}\delta\right) + c_m^t \tau_m l_x l_y \delta \tag{14}$$

$$z_{op}^B = \frac{Z_{op}^B}{\delta l_x l_y} \tag{15}$$

$$E^B = 2\rho\frac{l_x l_y E(u)}{V_{HDV}}\$_{HDV}^{LH}\delta \tag{16}$$

$$e^B = \frac{E^B}{\delta l_x l_y} = 2\rho\frac{E(u)}{V_{HDV}}\$_{HDV}^{LH} \tag{17}$$