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DEPARTMENT OF CIVIL, GEO AND ENVIRONMENTAL
ENGINEERING

Master's Thesis in Environmental Planning and
Engineer Ecology

Design of a sustainability-oriented Mobility-as-a-Service framework for the City of Munich

Julian Zöschinger

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Entwicklung eines nachhaltigkeitsorientierten Mobility-as-a-Service Frameworks für die Stadt München

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I hereby confirm that the presented thesis work has been done independently and using only the sources and resources as are listed. This thesis has not previously been submitted elsewhere for purposes of assessment.

Munich, 14.01.2019 Julian Zöschinger

"*An advanced city is not one where even the poor use cars, but rather one where even the rich use public transport*" – Enrique Peñalosa, ex-mayor of Bogotá

Abstract

Ranging from substantial CO_2-emissions and harmful air pollutants to extensively congested cities, urban transportation is encountering multi-layered challenges all around the globe. Looking at the city of Munich the same problems become apparent: serious congestion, deficient air quality as well as a comprehensive demographic and economic growth.

The recently emerged approach of Mobility-as-a-Service (MaaS) claims to be a game-changer in pushing the transition towards sustainable mobility. Through user-centrism, digital access and service bundling it promises to disrupt the paradigm of car-ownership. Even though MaaS' impact is widely vague, by gaining momentum it could play a role in Munich to cope with transport-related issues.

In order to properly drive and frame a MaaS scheme in Munich, the thesis provides a preliminary evaluation and presents an outlining concept. For this purpose, previously carried out qualitative research is adopted into a conceptual design process. Initially, a fundamental knowledge base on inherent characteristics is gained by guided interviews with international experts. Complemented by literature review as well as case studies, scheme requirements, promoting drivers as well as sustainability criteria are elaborated. Combined with local stakeholder insights and desk research, those MaaS attributes serve as a basis for a design proposal as well as recommended fields of action in Munich.

Among others, the most crucial schematic elements for a sustainability-oriented MaaS implementation are an outstanding role of public transport, adequate regulation and high user acceptability. The thesis suggests twelve actions to pave the way for a desirable local development, wherein extending urban transportation services, a participative vision and open data efforts are of prime importance.

Concluding, MaaS does have the potential to positively contribute to a sustainable urban transportation system. The decisive factor is how it unfolds and by whom it is driven. Hence, a design-oriented and strategic framing process for Munich is proposed.

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Glossary

A

AI Artificial Intelligence
API Application Programming Interface
AV Autonomous Vehicle

B

B2B Business-to-Business

C

CCTV Closed-circuit Television
CSR Corporate Social Responsibility

D

DB Deutsche Bahn
DoS Denial-of-Service
DRT Demand-responsive Transit

E

EMM Europäische Metropolregion München
EV Electric Vehicle

F

FCEV Fuel Cell Electric Vehicle

G

GDP Gross Domestic Product
GDPR General Data Protection Regulation
GHG Greenhouse Gas

I

ICT Information and Communication Technology
ITS Intelligent Transport System

K

KPI Key Performance Indicator

L

LLCM Living Lab Connected Mobility

M

MaaS Mobility-as-a-Service
MSP Mobility Service Provider
MVG Münchner Verkehrsgesellschaft
MVV Münchner Verkehrs- und Tarifverbund

N

NDA Non-disclosure Agreements
NGO Non-governmental Organization

P

PT Public Transport

R

RQ Research Question

S

SLA Service Level Agreement
SP Stated Preference
SSO Single Sign-On

U

UN United Nations

W

WLAN Wireless Local Area Network

()

1. Introduction

The first chapter addresses the thesis' intention, which contains the problem statement and its briefly depicted background. Moreover, it defines the object of research and presents the general study structure.

1.1. Global challenges in transportation

Currently, about half of the worldwide population is accommodated within urban areas. According to the 'Revision of World Urbanization Prospects' by United Nations (UN), this number is going to rise up to 68% by 2050. Although enormous urbanization processes mainly take place in developing countries and emerging economies, this general phenomenon applies globally. It is further expected that the number of so called mega-cities (more than 10 million inhabitants) will significantly increase. It is one of the most impact-related and decisive anthropogenic interventions of the 21th century. (Reller et al., 2013; United Nations, 2018). Ongoing urbanization processes are a pervasive and tough challenge for transportation systems. Especially, concerning the fact that societies tend to raise their mobility demand by gaining societal prosperity. A high degree of mobility refers to freedom, self-determination, independence and assures economic competitiveness as well as social integration, which is highly appreciated. Nevertheless, meeting those objectives often comes along with fatal, negative externalities.

Inherently connected to these overloaded urban transportation systems, worldwide cities are facing air quality and congestion issues. The European Environment Agency (2018a) considers air pollution in urban areas as a serious threat to human health and biosphere. Distinct deficits in its prevention are explicitly expressed – even in highly developed European countries. Certainly, poor conditions have differing and complex causes, but transport is grasped as main emitting source of nitrogen dioxide and PM_{10} within the European Union.

Due to limited urban space, ongoing urbanization, and high private car use, cities are increasingly congested. It is a key challenge for nearly all densely populated areas around the globe (Ramos et al., 2017). Beside environmental problems and reduced urban livability, it affects economic productivity. Christidis and Ibáñez Rivas (2012) estimated a reduced Gross Domestic Product (GDP) by 1% in Europe due to urban road congestion.

Since the abovementioned problems are largely linked to motorized individual mobility, car-restrictive measures emerged in the last two decades and are increasingly applied. By now, various European municipalities charge to enter their city center by car (EPOMM, 2015). In Latin-America, it is common that private car use is restricted to daily alternating number plates – in some cities during rush hour, in others full-time (Ramos et al., 2017). In Singapore and several Chinese cities (Beijing, Shanghai, Guangzhou, etc.), citizens who want to purchase private vehicles need to participate in a registration lottery. In the year after the implementation in Beijing 2011, car purchase dropped by 57% percent (Yang et al., 2014).

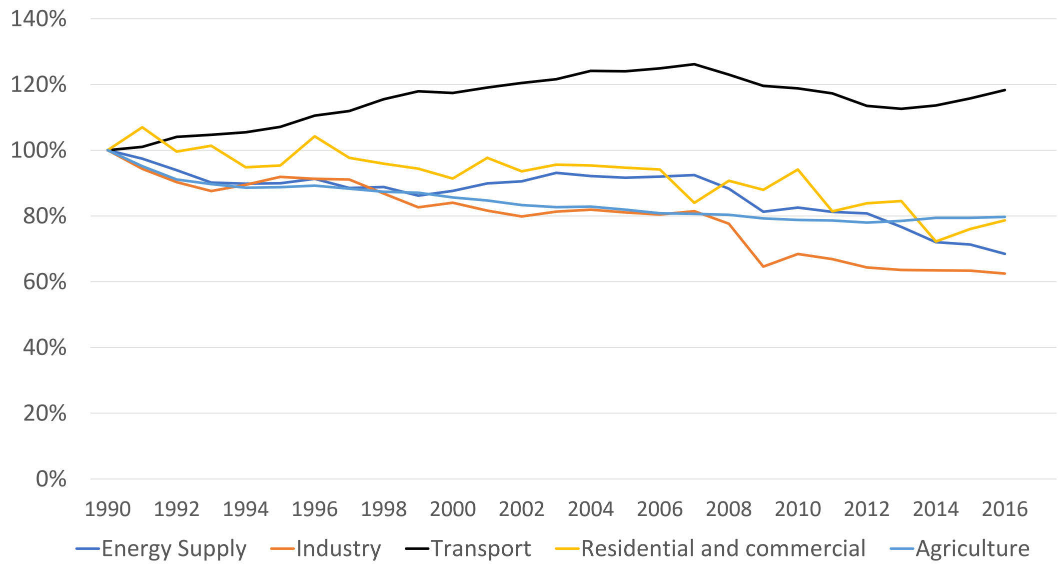

Figure 1.1.: Development of GHG-emissions by sector in EU-28 (own elaboration based on data by European Environment Agency (2018b))

Mitigating climate change and adopting to its impact is considered as a crucial and global challenge of the 21th century. Worldwide transportation is responsible for a quarter of emitted Greenhouse Gas (GHG)-emissions and depends to over 90% on fossil fuels. Significant growth in global car fleet turns it in the fastest growing CO_2-emitter.

Therein, road transport accounts for over 80% of its climate-damaging output. Even in Europe, where in all sectors substantial reductions could be achieved, transport-related GHG-emissions increased in reference to 1990, which is clearly illustrated by figure 1.1 (Canzler and Knie, 2017; European Environment Agency, 2018b).

Apart from coping with those negative externalities, the transportation system itself is facing certain disruptive developments. From a technology point of view, new propulsion options are gaining importance and offer alternatives to fossil-based transport. Enormous progress in Information and Communication Technology (ICT) pushed vehicle automation, which resulted in first operational test pilots with Autonomous Vehicles (AVs) and their commercial appearance in near future (Audouin and Finger, 2018b; Docherty, Marsden and Anable, 2018).

Ubiquitous internet availability and smart-phone usage turned shared mobility services from a niche phenomenon into mass adoption. By now, travel planning applications are installed on nearly every hand-held device. E-ticketing and smart-phone based payment solutions became wide-spread – especially amongst young people. This new era changes the way we perceive and access transport. Multi- and inter-modal mobility gains importance and becomes service-oriented (Audouin and Finger, 2018b; Canzler and Knie, 2017).

All those tendencies affect the involved actors. While traditionally car manufacturers and PT mainly shaped the system, more and more mobility-related operators (e.g. bike sharing, ride hailing, ICT-related booking and routing services, etc.) play a role within in the urban transportation system (Audouin and Finger, 2018b). Those companies are considered as Mobility Service Providers (MSPs) in this thesis. Those incorporate all stakeholders offering passenger transport – apart from PT. Progressively, service and product landscape within transportation is becoming diverse, disruptive and influenced by multiple stakeholders. Hence, Docherty, Marsden and Anable (2018) emphasized the need for adequate governance accompanying this process.

1.2. Challenges in the city of Munich

To a large extent, globally existing transport-related issues affect also Munich on a local level – most of them with reduced intensity. Nevertheless, even in context of highly developed countries Munich is dealing with serious challenges.

According to INRIX (2018), Munich is the most road congested city in Germany. In 2017, average car commuters stuck 51 hours per year in traffic – increasingly by trend. Hamburg, Berlin and Stuttgart share second place, all with 44 hours. In the international context, Munich ranks at place 35. Furthermore, it is stated that outside of rush-hours Munich's traffic situation is relatively good, which suggests a high share of in-commuters.

Also in terms of air quality Munich leads the negative ranking in Germany – at least its measuring station in Landshuter Allee. There, a mean value of 78 $\mu g/m^3$ nitrogen dioxide was detected in 2017, which is the worst value on the national stage. Two out of five measuring stations for nitrogen dioxide in Munich overshot the limiting value (40 $\mu g/m^3$ in average) by the European Union (Umweltbundesamt, 2018b). Since 66 German cities do not comply with the preset limiting value and Germany's tackling efforts are insufficient, the European Union filed already an action against Germany (Bauchmüller and Kirchner, 2018). Even the City of Munich itself is confronted with court proceedings due to bad air quality (Hutter, 2018a).

In terms of PM_{10}, Munich's situation is significantly better. The emission of both pollutants is downward by trend. Even though Munich's poor air quality does not only result from transportation, it constitutes major shares (Local stakeholder #2, 2018; Umweltbundesamt, 2018a).

On strategic level Munich acts quite ambitious in terms of climate protection and reduced per capita GHG-emissions already by 33% in reference to 1990 (Kenkmann et al., 2017, p. 34). However, especially transportation still accounts for a very high share of Munich's climate-damaging impact (Stadtrat der Landeshauptstadt München, 2018).

Looking into Munich's future, a significant population growth is predicted concerning the city and its surroundings. In 2035, Munich will compromise 1,85 million inhabitants, which is almost 400 000 more than nowadays. Decisively regarding this development, is that from now on Munich's surroundings grow even faster. In terms of transportation it requires demanding capacities and enhanced system performance. In a business-as-usual scenario, Munich will face full use of road capacity between 6 am and 9 pm by 2030. It would enlarge the traffic situation of peak hours to the entire course of a day (Local stakeholder #2, 2018; Kinigadner et al., 2016).

On a national level Munich's PT system is considered as relatively good. In terms of waiting time and changing trains it performs significantly better than Berlin or Hamburg. With 92% barrier-free PT stations it ranks on top. High ticket pricing and accessibility are perceived as drawbacks (Greenpeace, 2017; Moovit, 2018).

Facing distinct economic and demographic growth, Munich missed to prepare its PT system for such a progression in the last decades. Local stakeholder #2 (2018) stated that its stellar pattern sets certain limitations in the system capacity. Furthermore, initiated major projects (e.g. reconstruction of Munich's central station), which are currently in preparation, have long planning and realization horizons. The second trunk road for suburban trains is expected to be finalized by 2026 and the planned subway line (U9) for enhanced inner-city connectivity and load removal could be operational by 2037 (Local stakeholder #2, 2018; Hutter, 2018b).

1.3. Problem statement and research questions

Coping with manifold challenges transportation is facing, the paradigm of sustainable mobility was postulated and gained popularity in recent years. Principal characteristics of sustainable mobility within this thesis refer to Banister (2008), Gerlach et al. (2015, pp. 14) as well as Götz (2011) and can be described with the following attributes: environmental and climate friendliness, energy efficiency, public accessibility, social integration, health and safety consideration as well as economic viability. PT consolidation, active and shared modes of transport, low-emission propulsion or comprehensive services for the public are commonly proposed fields of action towards a paradigm shift (Canzler and Knie, 2017; Gerlach et al., 2015).

Not only academia recognizes the need for an inevitable system change, also on governmental level, within society and private sector an increasing rethinking is perceivable in the last years. Municipal strategies and planning activities continuously adopt such principles, general public gets more conscious – especially among responsive societal milieus – and project and innovation funding put relevant issues on the agenda. Picking up the transformation urgency, the European Commission (2018b) spent 6,3 € billion for activities promoting sustainable mobility with its Research and Innovation (R&I) program 'Horizon 2020'. Canzler and Knie (2017) emphatically claimed the need for not only replacing propulsion technology, but also establishing new service offers and overcoming private car-dependency.

Among many others, one proposed solution is MaaS, which is an transport-related approach emerging lately. It combines increasingly popular transport-access through smart-phones, novel offerings containing subscriptions and service bundling as well as shared mobility. Its intention consists in serving as all-in-one mobility solution for everyday life and reducing private car-dependency. Promises by front-runners point to its pervasive potential in order to promote sustainability and act as disruptive game-changer within transportation.

Assuming MaaS continues in gaining momentum and enlarging its diffusion, it might play a future role in the city of Munich. Particularly, in the context of Munich's profound transport-related challenges, which are described in the previous section. Therefore, this thesis aims to address essential uncertainties and core issues in advance to pave the way for an adequate and desirable local evolvement. To evaluate Munich's potential for a MaaS system, its requirements and possible threats, the following Research Questions (RQs) are defined, to whose this thesis replies:

RQ 1: What are inherent requirements of municipal MaaS schemes? What are drivers and barriers of implementations?

RQ 2: What are MaaS criteria and design features contributing towards sustainable urban mobility? What possible negative threats are conceivable?

RQ 3: How should a local MaaS scheme be designed and deployed in order to address transport-related and environmental challenges in Munich?

Although the thesis intends to provide valuable information regarding a possibly Munich-based implementation, it fills the needed scientific knowledge gap through RQs 1 and 2, and hence contributes explicitly to the research-related MaaS progress.

1.4. Thesis structure

Chapter two conveys a knowledge base on MaaS and its state-of-the-art containing preceding developments and its conceptual approach. Furthermore, an illustration is provided by four depicted case studies.

In the chapter three thesis procedure and research design are stated. This segment presents applied methods, their realization and analysis as well as considered sources.

The main study segment constitutes chapter four entailing the scientific outcome and its consequences. It responds two the RQs 1 and 2. Its direct application to the case of Munich is provided by the fifth chapter, wherein a guiding MaaS framework is proposed. Thereby, it replies to the third RQ incorporating design principles and recommended actions.

Methodical benefits and limitations are discussed in chapter six. In addition, it deals with criticism – in general as well as in terms of MaaS in Munich. The thesis is concluded by chapter seven, which provides a short summary and a brief outlook.

2. The paradigm of Mobility-as-a-Service (MaaS)

This chapter introduces the MaaS concept and presents the state-of-the-art, starting with socio-technical developments and preconditions, which enabled new and disruptive mobility approaches. Followed by the corresponding theoretical framework and key characteristics regarding MaaS, as well as potential market evolvements.

The second part of this chapter briefly illustrates four case studies of MaaS implementations within the European context, to which the subsequent study assessment frequently refers. By describing historical developments as well as related political background information, those MaaS cases can be assessed within a broader picture.

Furthermore, it provides a brief overview of conducted studies and assessments related to a potential MaaS impact on transportation system and mobility behavior.

2.1. MaaS enabling preconditions

Even though transported-related sharing schemes gained popularity and are fast spreading through ICT, their emergence happened much earlier. Referred to DeMaio (2009), Amsterdam provided white-painted bikes for public use in the 1965. Due to abuse and vandalism, the program stopped operation after short time. In the 1990s bike sharing schemes appeared that required user registration and validation before access.

Also car sharing was established before smart-phone usage was widespread. In 1970s and 1980s, first projects with shared cars evolved. In 1988, StattAuto Berlin was founded and started its operation as first car sharing provider in Germany. Of course, early shared modes were limited to station-based approaches (Breitinger, 2014).

Due to ICT enhancements and its diffusion, the number of shared modes and provided schemes raised exponentially within the last decade. This also paved the way for transport approaches beyond shared mobility like MaaS. Shared modes are an inherent component, but its integration approach goes even further. Since MaaS schemes are considered as a specific component within the smart city paradigm, relation between data and urbanism is illustrated before focusing on mobility and transportation aspects.

One of the essential changes of the last two decades is the enormous progress in ICT – in terms of software and hardware. It came along with several societal developments and technological enhancements, which strongly affected our everyday life and interrupted traditional patterns of interpersonal communication as well as the access to information and services. The exponential increase of information storing and processing as well as the dissemination of the internet enabled the era of big data. This new digital age is characterized by data-related capabilities huge in volume, high in velocity, fine-grained in resolution and divers in variety (Kitchin, 2014). In addition, more and more devices are interconnected and equipped with computational features. The so called phenomenon of 'ubiquitous computing' allows us to access, handle and analyze data in real-time.

Relating the abovementioned characteristics to an urban context allows new ways of analyzing, assessing and managing the complex multi-layer system of a city. The datafication of urban infrastructure, traffic flow and energy consumption gains new insights and reveals potential improvements of efficiency. Especially by geo-referencing and merging the information of different urban layers and subsystems, shortcomings and opportunities can be identified easily. The up coming applications are wide-ranging: from Closed-circuit Television (CCTV)-cameras with face recognition, electronic payment systems for roads to smart buildings that regulate their energy consumption automatically. All these approaches and technologies can be subsumed under the term 'smart city', which was proclaimed a couple of years ago. Mostly private actors drove this narrative and shaped the smart city paradigm, because they saw a market opportunity for their products and services. Due to the promise of more sustainable and efficient cities, which is inherently linked to this concept, also political and administrative actors perceived smart city as a way to a more holistic, integrated and controllable urban management approach (Kitchin, 2018; Waal, 2018).

At all times in history municipalities were interested in collecting and analyzing information as a base for planning, regulating and managing activities. After information was continuously digitized in the last decades, it now plays an increasing role on operational level of city management enabled by real-time data processing. Kitchin (2018) stated that currently the former data-informed urbanism is shifting towards a data-driven approach, because more and more processes in urban life are executed by algorithms and big data systems.

Without doubt data-driven systems that have been applied to cities improved the efficiency and performance in many cases. Nevertheless, the emerging smart city paradigm raised also a lot of criticism and fears referring to the approach itself and to the way it unfolded in many cases. Chapter 6.3 presents the corresponding discourse more detailed and in the context of MaaS.

Since smart mobility declares the same objectives and applies equal tools in terms of transportation, Flügge (2013) as well as Andreas Meier and Edy Portmann (2016) identified smart mobility as one of several fields of action embedded in the smart city paradigm. Within this study Intelligent Transport System (ITS) is used exchangeably with smart transportation systems, even if some authors address rather telematic aspects with this term. In the context of ITS Audouin and Finger (2018b) introduced four relevant pillars that unfold a disruptive character: sharing, automation, electrification and integration.

The first pillar refers to the sharing economy in general and to shared mobility in particular. The socio-economic shift from ownership to an access of services is also disrupting the transportation system – especially in urban areas. The emergence of those offers is also deeply linked to ICT-facilitation of providing shared assets. Thus, especially so called 'digital natives' are open-minded towards a service-oriented lifestyle (Godelnik, 2017).

In developed countries, bike and car sharing schemes are nowadays available in almost every large city. Within less than 10 years, ride-hailing services like UBER, Lyft and DiDi are operating globally and created a billion dollar market. The most recent approach is called Demand-responsive Transit (DRT), which do not have defined routes and fixed departure times. Algorithms translate passenger requests and their indicated destinations into a demand-driven routing. DRT usually operates with vans and minibuses, and attempts to establish a flexible PT-complementing system (Audouin and Finger, 2018b). Among others Kamargianni et al. (2015, pp.9) stated that users of shared mobility are in particular younger societal groups, which are already familiar in accessing digital services in other areas of daily life.

Improving ICT-based assistance systems towards fully-automated AVs correspond to the automation pillar, while electrification describes the transition towards electric propulsion technologies instead of fossil fuels. Besides the conventional car, the phenomenon of electrification applies to different modes and vehicles. Nowadays more and more mobility devices are electrified: smaller cars designed for urban purposes, pedelecs, segways, skateboards and kick-scooters.

The last dimension of smart transportation systems mentioned by Audouin and Finger (2018b) is integrated mobility. Due to real-time data, smart-phone dissemination and new transport services multi-modal trips are enabled. Hence, mobility is decreasingly limited to one specific mode of transport. Travel planning and information applications as well as digital payment solutions promote combined and user-tailored mobility services.

Driven by the sharing economy, bundling of services and products occurs in several sectors. According to Matyas and Kamargianni (2018), it is a common marketing strategy to scale a product with complementary added-values and wide-ranging alternatives sold as one single package. Netflix represents a prime example within media consumption. The company Urban Sports Club sells access to various sport facilities and offerings in bundled packages. Depending on the option, customers can use fitness centers, swimming pools and tennis courts or attend yoga classes and dancing lessons - offered by monthly subscriptions (Urban Sports GmbH, 2018). This bundling of products and services attempts to cope with diverging user requirements and individual lifestyles in a highly globalized 21th century.

2.2. The conceptual approach

The following section presents the underlying concept, introduces relevant MaaS features and deals with possible definitions. Moreover, the intended objectives that come along with this emerging approach are being described. In order to address colloquial used labels and differences in applied schemes, the last segment provides options for differentiation and categorization of MaaS systems.

2.2.1. Definition and scope

Due to recent advent and short period of scientific research on this topic, there is so far no universal consensus of what MaaS is (Pangbourne et al., 2018). Corresponding to the previous section, MaaS inherently links to shared and integrated mobility as well as to bundled offerings. In addition, the two mentioned pillars of electrification and automation are more and more considered within MaaS approaches. Generally speaking, MaaS is an innovative, disruptive and ICT-facilitated approach that seeks a highly integrated mobility, fostering shared assets and provides a bundled access.

MaaS was developed and refined over years by various actors and socio-technical tendencies. However, a few authors indicated that the term ’Mobility-as-a-Service’ was first introduced by a master’s thesis in 2014, which was procured by the city planning department of Helsinki (Heikkilä, 2014). Some sources use the interchangeable term ’combined mobility services’ for MaaS (Holmberg et al., 2016), which is relinquished in the thesis.

A widely-used definition was proposed by the MaaS Alliance (2017, p.2) in a white paper promoting an international MaaS ecosystem:

> "For the user, MaaS offers added value through the use of a single application to provide access to mobility, with a single payment channel instead of multiple ticketing and payment operations. To meet a customer's request, a MaaS operator facilitates a diverse menu of transport options, be they public transport, ride-, car- or bike-sharing, taxi, car rental or lease, or a combination thereof. A successful MaaS service also brings new business models and ways to organize and operate the various transport options, with advantages including access to improved user and demand information and new opportunities to serve unmet demand for transport operators. The aim of MaaS is to be the best value proposition for its users, providing an alternative to the private use of the car that may be as convenient, more sustainable, and even cheaper."

The MaaS Alliance is an international consortium of private and public players involving industry and consulting partners, transport companies as well as city administrations. Their fore-cited MaaS description is possibly relative industry-driven and market-oriented and takes up a user-centric perspective, which is also emphasized by Giesecke, Surakka and Hakonen (2016). Dotter (2016) complemented multi-modal, seamless door-to-door mobility aspects and elements of demand-driven transportation. Beside the involvement of both, public as well as private actors within a MaaS scheme, Li (2018) noted the emergence of a new aggregating layer between transportation service operators and users.

By reviewing literature, González et al. (2017) identified and summarized certain core elements to facilitate a holistic view on MaaS. Based on this paper, key characteristics of MaaS schemes are presented instead of a generally valid definition:

Integrated mobility: MaaS includes several transport modes in one system and promotes a multi-modal mobility behavior. Usually PT, taxi and sharing schemes are incumbent elements of this bundled offering. In addition, DRT and other assets are possibly considered in future systems.

Platform-based: There are various IT-architectures possible, but especially larger scaled systems generally require a digital platform. It serves for data exchange, user requests and integrated features like routing, payment and ticketing. In addition, the platform approach enables the inclusion of non transport-related services.

Multiple stakeholders: MaaS is often been described as an ecosystem, which relies on a constellation of heterogeneous actors: various transport operators from the private and public sector, third party service providers and end-users (private customer or business customer). However, local authorities, telecommunication and data management companies as well as payment clearing providers are not intrinsically connected to MaaS, they play an important role in facilitating and improving its performance.

ICT use: Advanced ICTs ensure real-time characteristics and facilitate information exchange and integrated services within a complex, multi-stakeholder system. This includes hand-held devices, telecommunication networks, GPS, databases, interfaces, etc.

Demand-responsive: MaaS schemes seek to improve the transportation system in terms of demand orientation. It comes along with a transition to more flexible and user-centric mobility offerings as well as data-driven adjustments on the supply-side in order to enhance the systemic efficiency.

User orientation: Catering individual lifestyles and flexible working conditions, MaaS places the service in the center point instead of the different transport modes. It offers user-tailored mobility options, while trying to ensure convenience and economic issues. Customizing and addressing user needs for a high value proposition are identified as core elements of the proposed paradigm shift.

Approaches in defining MaaS presumably vary a lot depending on actors, area of expertise, branches and cultural aspects, but the above-quoted feature set provides a universal overview. Due to its space for interpretation, this study gets along without an own MaaS definition and refers to the assembled feature set. Section 2.2.3 attempts to differentiate MaaS systems by applying certain key criteria.

Even though Whim is presented more detailed in section 2.4.3, it serves as a good practice illustration of MaaS. Whim is a smart-phone app that bundles PT, bike sharing, taxi and car rental in Helsinki, Finland. The included multi-modal travel planner suggests the best route and provides ticket options. Beside pay-as-you-go, it offers two monthly subscription models, which contain unlimited access to PT and bike sharing. While the basic package allows to purchase other transport modes to special fares, 'unlimited' subscription extends the flat-rate also to car sharing, car rental and taxi rides (MaaS Global Oy, 2018a).

Transferring the MaaS depiction to a user point of view, figure 2.1 shows the schematic customer journey following Ratilainen (2017). When accessing the service through a hand-held device, firstly the user indicates the desired destination. In a second step, multi-modal travel suggestions are provided and the user chooses the option, which fits best. After the booking process, the preferred modes of transport could be ideally accessed (e.g. e-ticketing for PT, unlocking sharing bikes, etc.) through the same app (Ratilainen, 2017).

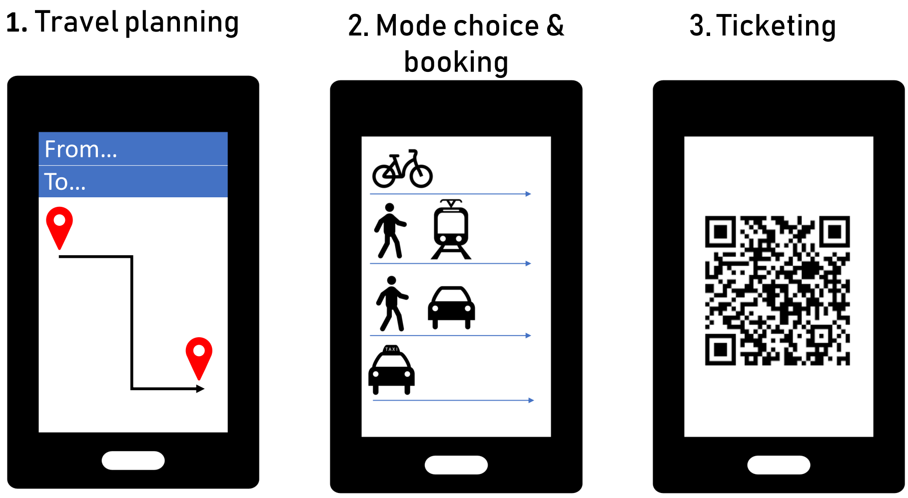

Figure 2.1.: MaaS from a user's perspective according to Ratilainen (2017)

2.2.2. Objectives

MaaS promises improvements on both, user level as well as transportation system in its entirety. Smith et al. (2018) saw the overall societal goal in tackling negative externalities by reducing private car-ownership. Such an effect could be expressed by less congestion, reduced transport-related injuries and mitigated local emissions like noise and pollutants. In the long run MaaS intends to contribute to sustainable, livable and less vehicle-centric cities (Sochor et al., 2017a).

Referring to urban planning and transport-related issues, MaaS wants to reclaim public space for people and enhance urban attractiveness. Firstly, it might increase the efficiency of the whole transportation system by harmonizing supply and demand - in terms of performance and public spending. This also includes complementary services by the private sector, which can address specific user needs appropriately. Additionally, through ICT-enabled sharing concepts and DRT an increase of vehicle-related occupancy rates is expected. The promise of more efficient car-based mobility could address the urgent problem of road congestion and parking issues in cities (Smith et al., 2018).

Derived from the aspiration of an efficient and car-reduced transportation system, certain environmental advantages come along. On a local level pollutants and noise could be reduced through less and different vehicles. Since MaaS intends to shift travel behavior towards DRT, sharing schemes and PT, which are considered to be relatively CO_2-friendly, it might unfold also a positive impact in terms of climate protection (Holmberg et al., 2016; Sarasini, Sochor and Arby, 2017). Moreover, Smith et al. (2018) added that MaaS implementations are likely to improve accessibility to personal transport services, because it is less depended from a specific transport mode and service requests are ubiquitously available. However, this aspect is controversially discussed.

Furthermore, MaaS claims to guarantee a high level of comfort and flexibility for the end user without owning a private car. By full-filling all tailored user demands to competitive fares, a decoupling of transport mode and mobility need is claimed. Exemplified, the Finish Start-Up MaaS Global promotes its service with the slogan 'Freedom of Mobility' (MaaS Global Oy, 2018a).

Finally, there is another dimension related to MaaS objectives. Often and specifically in the Finnish context, it is deeply linked to an innovation agenda and to economic growth in general. By disrupting the whole transportation market, it is proposed to generate new business opportunities and create innovative cooperation models for traditional transport actors. Such a transition also affects and blurs the classic pattern between private and public stakeholders (Dotter, 2016; MaaS Alliance, 2017; Holmberg et al., 2016).

2.2.3. Integration level

In recent years various MaaS and MaaS-like systems occurred in Europe and North America, which all unfolded the in section 2.2.1 presented feature set. In order to distinguish and compare such schemes, it is common to assess MaaS in terms of integration. Sochor et al. (2017a) suggested a basic topology, which is cited frequently in MaaS literature. Nevertheless, it does not allow a differentiation in the number of included modes. Therefore, Kamargianni et al. (2016) presented a more quantitative index approach of describing MaaS. Both are introduced in this section.

Figure 2.2 presents the proposed classification ranging from level 0 (no integration) to level 4 (integration of societal goals). Sochor et al. (2017a) noted that levels do not inevitably depend on each other. Applied to real services, it offers certain scope of interpretation. For instance, the case of UBiGo, which is illustrated in section 2.4.1, can be categorized as level 3 without full-filling all level 1 characteristics.

Figure 2.2.: MaaS topology adapted from Sochor et al. (2017a)

Level 0 – No integration: It represents separate services for separate modes of transport. Actually, it is another expression of the problem statement MaaS intends to solve.

Level 1 – Integration of information: In general, level 1 consists of a multi-modal routing service, which supports mobility decision-making. Additionally, price information, reservations and notifications regarding interruptions are conceivable. There are already numerous services on the market: from globally operating Google Maps to local ones. Level 1 services are usually provided for free and do not offer business opportunities. Thus, multi-modal travel planners are either provided by global players and private-public transport operators or financed through advertising.

Level 2 – Integration of booking and payment: Adding payment and ticketing features to multi-modal travel planners would lead to a level 2 service. It addresses mainly single trips. Due to high cost and complexity, but low margins, developing and running such a service is rather considered as an early stage for level 3 than a long-term business model. Level 2 service operator act as mobility brokers and aggregators. The SMILE project that is presented in section 2.4.2 is associated with MaaS level 2. Many partial level 2 integration schemes are on the market, which complement the core service by information and booking options of MSPs.

Level 3 – Integration of the service offer: By introducing the service offer, level 3 shifts from a user perspective towards a customer approach. Level 3 MaaS operators are in charge and accountable for the provided service. Furthermore, by addressing all costumers' mobility needs, it focuses on subscriptions and flat-rates. From an end-user perspective level 3 blurs the link between a certain transportation service and the allocated cost. Thus, it is less transparent and offers more business opportunities and space for contractual arrangements between aggregators and MSPs. The MaaS operator could sell some trips with low margins or even deficit, while compensating through high margins in other modes. In terms of ICT complexity, level 3 could result in a simpler platform architecture in comparison to level 2 due to less interaction.

Level 4 – Integration of societal goals: Added socio-environmental value through MaaS represents level 4. Such a service would extend its positive impact from the transportation system to other related fields like air quality, climate protection or accessibility. It is stated that such a service requires a balance between economical profitability and societal, impact-related measures. Furthermore, level 4 links to public sector assignments like urban planning and regional development as well as to policy activities.

As already mentioned, the presented topology looks at the range of integrated functions, but does not consider modes of transport. A subscription-based service incorporating only two transport modes is hardly comparable with a less integrated MaaS scheme that includes a wide range of inter-modal transport. Addressing this issue, Kamargianni et al. (2016) suggested a MaaS integration index, whose pattern is presented in table 2.1.

Table 2.1.: Grading scheme of MaaS integration index (Kamargianni et al., 2016)

Score	Category	Description
6	Ticketing	*One point for each mode of transport*
1	Payment	*Existence of payment functionality*
2	ICT	*One point for routing and booking*
1	Monthly package	*Existence of subscription options*
10	**Total**	***Added score of MaaS integration index***

Firstly, four different integration categories are proposed: ticketing, payment, ICT and mobility package. Considering the six most common MaaS modes (bike sharing, car sharing, car rental, rail, urban public transport and taxi), a total score of 6 is possible in the ticketing class. Another point is added, if the payment function is integrated into the service. In terms of ICT, the score ranges from 0 - 2: one point for multi-modal travel planning and booking. Lastly, a point is given for contractual elements like a subscription option. Adding it together, this grading scheme allows a total score of 10.

Although, the MaaS integration index intends to cope with the lack of comparability between various schemes, there is still a lot of space for interpretation and vagueness. For instance, it does not indicate any information regarding spatial expansion and accessibility. It can be assumed that the provided approaches are capable to provide a first informative basis, but for a comprehensive comparison further analysis is necessary. Moreover, Kamargianni et al. (2016) added that more sophisticated schemes and rankings are expected in the future.

2.3. Vision, narrative and market evolvement

Currently, the phenomenon of MaaS is limited to just a few cities incorporating some providers and MSPs. It also implies primarily pilot projects, conceptual initiatives and early stage commercial operators. In comparison to the whole transportation market and the number of users, MaaS presents a not observable fraction. Though, this new disruptive mobility approach possibly will unfold its area-wide dissemination in the future. This section aims to address long-term MaaS visions and discuss possible market developments.

Due to the inherent link to PT operators and very operational scope for design, first MaaS implementations are primarily applied on a local level – apart from certain company-driven tendencies. This is not a mandatory model. Maybe a regional, national or international MaaS scheme would make even more sense. Presuming an ongoing progress, MaaS will be available in more and more cities. Furthermore, to cope with competition issues providers will expand their services to other cities and will cooperate with other MaaS operators (Karlsson et al., 2017; Holmberg et al., 2016; Interviewee - IT-Consulting, 2018).

Adopting the global evolvement of telecommunication networks, the concept of roaming was introduced to get along with an area-wide MaaS phenomenon. Similar to the mobile networks, users would be able to access MSPs abroad with the same application as in their home town. The MaaS operator abroad would then clear the purchased tickets through underlying agreements and contracts with the local provider, where the user account is managed. Even though it is still far from reality, in this way MaaS operators would be able to extend their coverage and enable international service provision (Karlsson et al., 2017).

Figure 2.3 illustrates, how a MaaS roaming service could work. MaaS operators provide their service locally or regionally. In addition, they have contractual arrangements with corresponding providers abroad. As a result, users of all MaaS providers within the roaming network are able to access services abroad. Depending on the negotiated arrangement, services might be more expensive or contain special charges, but further registrations and additional applications might be avoided (Karlsson et al., 2017).

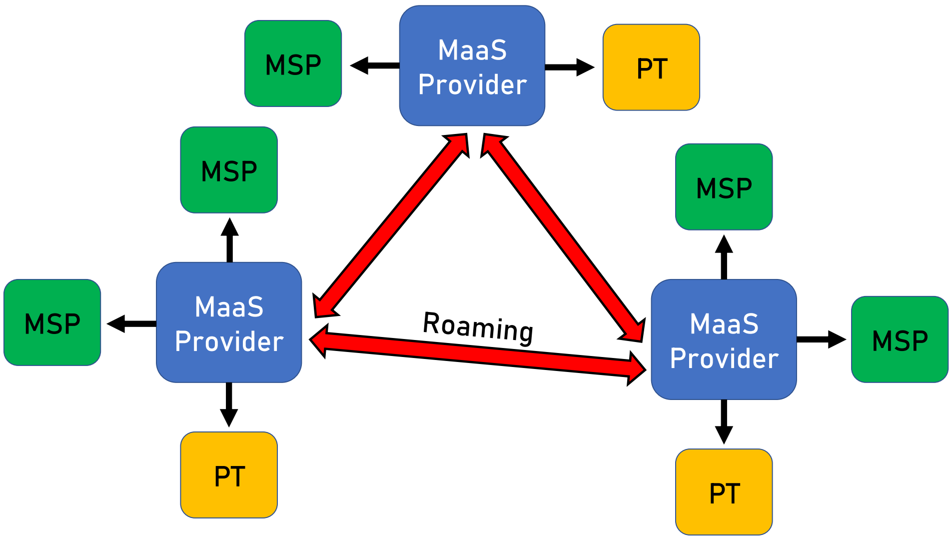

Figure 2.3.: MaaS roaming concept according to Karlsson et al. (2017)

Beside the roaming concept, also the way MaaS is offered and consumed might change over time. According to Interviewee - MaaS operator (2018), subscription-based offerings are not the end-goal. It might advance towards an approach, which is basically known in the IT-sector as Service Level Agreement (SLA). It can be understood as a commitment between service provider and user addressing certain qualitative and quantitative statements. Usually, it defines responsibilities and periods of time to full-fill certain statements without determining how this should be achieved.

Transferred to mobility, it could be kind of a promise to be carried from A to B within a specific time – independent from the mode of transport. The MaaS operator would be in charge to guarantee an appropriate transport in order to comply its promise. Referring to Sampo Heitanan, MaaS pioneer and CEO of MaaS Global, noted that in future MaaS schemes it is all about the service promise (Moreno, 2017).

This would lead to a couple of new challenges as well as potential improvements. An efficient, flexible and demand-responsive transportation system would not only contribute to societal goals, but also makes economic sense for MaaS operators. Becoming mobility brokers and service providers, MaaS operators would appreciate high occupancy rates and sustainable modes of transport due to economic reasons. By combining individual mobility interests and managing transport supply, they might approximate to an efficiency optimum (Interviewee - MaaS operator, 2018; Kamau, Ahmed and Rebeiro-h, 2016).

As MaaS is already blurring the distinction between route and mode of transport, an SLA approach would lead to a further decoupling. It would come along with highly attractive characteristics for the end user, likewise SLA requires a well established, reliable and advanced MaaS scheme.

Regarding the narrative MaaS front-runners are using, a distinct similarity to the general smart city discourse can be observed, which emphasizes to classify MaaS as a corresponding sub-component. The key message of MaaS advocates incorporates efficiency improvements within the transportation system through private stakeholders as well as a data-driven approach in order to access, manage and enhance this city layer.

Although public authorities are traditionally in charge of transport issues, MaaS appears quite interesting for city administrations, because it may help to reach societal goals without any additional public spending. Contrariwise, they fear the reversal of regulation control and the dependency on private actors. In summary, the discourse of smart city and MaaS in particular is also linked to a general debate of neo-liberalism. The question which responsibilities and competences should remain in the public sector and which can be taken over by private actors, strongly influences the current narrative and decisively drives future developments.

Picking up the neo-liberal discussion, there are three main scenarios how the MaaS market could evolve in the future. First option is that one big player establishes a MaaS monopoly due to its economic strength and ubiquitous availability. May it be UBER, a MaaS start-up or a less transport-related company like Amazon or Google. It would require a lot of resources and power, but the global players already proved to be capable of taking over new sectors. It would undermine a fair competition and limit costumer options. Of course, this winner takes it all scenario does not win a lot approval among MaaS front-runners and political actors (Interviewee - IT-Consulting, 2018; MaaS Alliance, 2017; Interviewee - MaaS operator, 2018).

By continuing with the traditional division between public and private actors in terms of transportation, PT operators could win the race on MaaS. Outside of central Europe it is already way more common to incorporate private stakeholders in mobility services. Apart from taxi companies, emerging sharing schemes are already disrupting this pattern. Nevertheless, PT as regime actor of the transportation system is in a favored and powerful position (Kamargianni et al., 2015; Interviewee - City administration, 2018).

The last scenario is often named 'open ecosystem' and it is described as a fair level playing field for mobility services. Taking the analogy of the telecommunication sector, advocates are emphasizing the necessity of customer choice and promoting a competition of various MaaS actors dealing with the same assets. In order to be competitive, MaaS operators would be forced to offer the best user value proposition. The market would be also capable to serve niches and cover different target groups. It is definitely the most desired market development of all actors shaping this concept (MaaS Alliance, 2017; Interviewee - Academia, 2018; Moreno, 2017)

Of course, presented scenarios constitute idealistic cases. Certain nuances and hybrid options as well as differences between regions are probable. In addition, another factor was ignored in this brief market analysis. It is assumed that on the long run a growing MaaS market might lead to a shrinking sales output in the automotive industry. Hence, start-ups emphatically remark that by growing MaaS and its ecosystem, also new market shares will arise and people will shift their spending from private car ownership to mobility services (Interviewee - MaaS operator, 2018).

2.4. European MaaS cases

This section aims to illustrate MaaS implementations in practice. The four case studies presented in subsection 2.4.1 - 2.4.4 focus on the municipal level.

However, MaaS approaches and efforts can be also observed on larger scale. In the same way, various MSPs and transport operators are focusing more and more on multi-modal door-to-door offerings which can be also classified as MaaS (Interviewee - IT-Consulting, 2018).

Before describing the city cases, two company-driven MaaS implementations are mentioned. The first one is the front-end of German's railway company Deutsche Bahn (DB), which is called 'DB Navigator'. The application that provides travel planning, booking and payment of inter-regional railway connections is fostering a door-to-door service. Even though travel planning for local PT was always included, they recently added the ticketing option for many cities. The app further provides information concerning the company-owned bike sharing scheme 'Call A Bike'.

In addition, DB became the major shareholder of the start-up Clever Shuttle, which is a ride pooling company operating in seven German major cities. Thereby, its service will also be included in the 'DB Navigator' in 2019. By integrating more and more services, DB aspires to become an area-wide all-in-one solution – especially in terms of inter-city trips (Local stakeholder #3, 2018; DB Vetrieb GmbH, 2018).

Although it is not a European example, it illustrates perfectly the ongoing developments to multi-modal integration. Lyft, main competitor of UBER within the US ride hailing market, recently acquired the largest US bike sharing company. It was an essential asset to expand their ride hailing to a multi-modal service offering. Beside additional real-time information on PT, bike and e-kick-scooter sharing systems were continuously integrated in the app (Davies, 2018).

Furthermore, it is reported that Lyft is considering a subscription-based package proofing clearly that big players in transportation foster to bundle different modes of transport in order to enhance their mobility service as well as refine the way transport is purchased (Davies, 2018).

Table 2.2 gives an overview of European MaaS implementations and the corresponding integration level. Due to fast-moving developments, it is difficult to define a status quo. Gathered information could be outdated within a couple of weeks or months.

Thus, the presented overview should be rather considered as a snap-shop of the rapidly evolving market. During this study work, Whim launched its service in Antwerp and announced Singapore for 2019. In October 2018, involved actors declared the temporary end of Hannovermobil by end of the year. Moreover, Tuup, Switchh and WienMobil Lab announced new features, services and modifications for 2019 (Interviewee - MaaS operator, 2018; Haase, 2018; Durand et al., 2018; Li, 2018).

Beside Whim and UbiGo, there is so far no other case with integration level 3. Most of the initiatives stuck in level 2 and do not full-fill payment and ticketing for all services and included MSPs. Especially, if the MaaS service is mainly PT-driven, services of third-parties are mostly limited to information and booking functions.

Table 2.2.: Overview and characteristics of European MaaS initiatives (Sochor et al., 2017a; Durand et al., 2018; Kamargianni et al., 2016; Li and Voege, 2017; Goodall et al., 2017; Eckhardt, Aapaoja and Sochor, 2017)

Initiative	Run by	Place	Status
UbiGo	R&I project	Gothenburg, Sweden	Field trial with level 3 integration in 2013-2014. Relaunch planned in Stockholm, Sweden
SMILE / WienMobil Lab	R&I project; since 2017 Upstream Mobility	Vienna, Austria (partially also Linz & Graz)	Field trial with level 2 integration in 2014-2015; Followed by WienMobil Lab since 2017; Currently partial level 2 integration
Whim	MaaS Global	Helsinki, Finland; Birmingham, UK; Antwerp, Belgium	Level 3 integration; since 2016 operational in Helsinki; since 2018 service expansion in other cities
Moovel	Daimler	Stuttgart & Hamburg, Germany	Since 2015 operational; partial level 2 integration
Tuup	Kyyti	Turku, Finland	Since 2015 operational; partial level 2 integration
Hannovermobil	GVH & ÜSTRA	Hannover, Germany	2014-2018 operational; level 2 integration
Switchh	Hamburger Hochbahn	Hamburg, Germany	Since 2018 operational; partial level 2 integration

2.4.1. Gothenburg, Sweden

The first highly integrated MaaS services was launched in Gothenburg (Sweden) as a field trial within the research and development project GO:Smart. 195 persons of 83 households became test costumers of MaaS in 2013-2014 accompanied by questionnaires and interviews. The pilot named UbiGo included PT, car rental, car sharing, bike sharing and taxi, all managed and purchased through a web-interface, which was adapted to smart-phone use. In addition, a 24 hours service hot-line was installed to be engaged in customer needs and problems (Karlsson, Sochor and Strömberg, 2016).

For the project purpose a company was founded, the UbiGo AB, which served as a mobility broker between the participants and all MSPs, and further managed bureaucratic issues. During the trial, households were able to adjust their purchased subscription level every month in order to address their mobility needs accurately and unused credit was refunded. The minimum household package was set to approximately 135€ per month. Moreover, there was the possibility to give up the private car during the project period in return for economical compensation. The field trial explicitly catered young urban households (Karlsson, Sochor and Strömberg, 2016; Smith, Sochor and Sarasini, 2017).

Sochor et al. (2017a) identified UbiGo as level 3 integration due to its subscription option. Concerning the wide-range of integrated modes, Kamargianni et al. (2016) awarded 9 out of 10 points in the MaaS integration index to this field trial.

The scientific results on this field trial published by Karlsson, Sochor and Strömberg (2016) were quite promising in terms of sustainable mobility and acceptance of MaaS. After the six months, 93% of the participants reported to be satisfied with UbiGo and 97% would keep using the MaaS service. In total, 64% indicated changes in their travel behavior, which is split up regarding transport mode in table 2.3. Especially car sharing and PT like bus and tram were significantly used more often, and almost half of all participants reported less private car use. Furthermore, 20 households took the opportunity to resign their private cars.

Table 2.3.: Conducted changes in mobility behavior within the field trial UbiGo according to Karlsson, Sochor and Strömberg (2016)

Mode of Transport	More seldom	As before	More often
Private car	48%	48%	4%
Bike sharing	16%	61%	23%
Bus & tram	4%	46%	50%
Local train	7%	75%	18%
Car Sharing	6%	37%	57%
Taxi	12%	68%	20%
Walk	6%	73%	21%

In addition to changes regarding the chosen transport mode, Karlsson, Sochor and Strömberg (2016) detected an increase of active travel planning among participants.

This entails shifting attitudes regarding several modes of transport. Like in terms of travel behavior, PT and car sharing were perceived more attractive and in contrast private car use less appealing after the trial. The anticipated need for certain modes was generally overestimated by households – in terms of car sharing about 30%. Concerning economic issues, UbiGo was rated as at least equal to previous expenditures and many reported reduced costs. Moreover, many households appreciated higher transparency on travel spending due to MaaS. Nevertheless, it should be stated that the addressed target group can be considered notably open-minded regarding MaaS.

Although UbiGo wanted to continue and expand its service, the company was shut down due to a lack of financial support and several regulatory issues. During the field trial UbiGo acted as a non-profit organization for research purposes. Under normal conditions their mobility brokerage would have become a regular business. Since PT is subsidized by taxes, the UbiGo service would have been subsidized too, what was incompatible with current Swedish law (Smith, Sochor and Sarasini, 2017; Karlsson, Sochor and Strömberg, 2016).

Apart from regulatory aspects, Smith et al. (2018) noted that a lack of commonly shared vision on MaaS among the stakeholders and missing leadership led to the end of MaaS in Sweden. In contrast to the Finish case in section 2.4.3, there were insufficient political activities on national level.

In 2016, two years after the UbiGo trial, MaaS was kind of rediscovered in Sweden. The Ministry of Enterprises and Innovation initiated an expert group in order to develop and prepare further MaaS implementations. Subsequently, the government launched a program called KOMPIS to promote the diffusion of ICT-driven mobility financed with around two million Euros. It also announced that by 2030 the framing conditions in terms of regulation and policy will favor MaaS and shared mobility (Smith et al., 2018; Smith, Sochor and Sarasini, 2017).

KOMPIS was already integrated in the action plan for the national transportation system by the Swedish Transport Administration. Furthermore, various PT operators, which initially were quite skeptical in terms of MaaS, together created the Swedish Mobility Program. Its principal goal is to develop a national platform for integrated transport services. In 2017, the follow-up company of the field trial named UbiGo Innovation AB teamed up with the Austrian start-up Fluidtime. Together, they are currently working on a MaaS relaunch in Stockholm, Sweden. This project is part of the European research and innovation project CIVITAS ECCENTRIC. (Smith et al., 2018; Smith, Sochor and Sarasini, 2017).

2.4.2. Vienna, Austria

Simultaneously to UBiGo, another MaaS field trial was launched in Vienna, Austria called SMILE (Simply MobILE). It was realized by a consortium of various private and public actors and led by the Austrian railway company Österreichischen Bundesbahnen (ÖBB) and Vienna's PT company Wiener Linien. After two years of preparation, the pilot started in 2014 with over 1 000 participants including PT, rail, car sharing, taxi and bike sharing. Additionally, parking services and charging points for Electric Vehicles (EVs) could be accessed through the app.

Due to a lack of subscriptions and flat-rate options, Sochor et al. (2017a) assessed SMILE as a level 2 integration. Though, spatial scope and range of included MSPs was more comprehensive than in UbiGO. ÖBB routing and ticketing addressed all national rail connections, PT was accessible in Vienna and Linz, three different bike sharing companies and four different car sharing schemes based in Vienna, Graz and Linz participated within SMILE. However, for various MSPs an additional registration process was required. A special focus entails the front-end routing feature. It provided different travel options, which could be ranked regarding price, travel time or CO_2-emissions. Even though there was only pay-as-you-go, participants were billed only once at the end of each month for all they had purchased (Smile Mobility, 2015; Audouin and Finger, 2018a).

According to Smile Mobility (2015), the participants of the trial were not representative for the Austrian society. Testers were in large majority male (79%), relatively young, highly educated (51% with university degree), with high income and 84% already owned a season pass for PT in Vienna. Hence, attended pilot users can be considered as early adopters in terms of ICT-issues in general and MaaS in particular (Durand et al., 2018).

Within subsequent surveys 21% indicated reduced private car travel, 48% reported increased PT utilization and 10% accessed bike sharing more often after six months of MaaS trial. In particular for occasional transport demands apart from routine mobility, SMILE was used. In addition, a more inter-modal mobility behavior was observed among the participants. The overall satisfaction of the MaaS service was stated to be quite good (Smile Mobility, 2015).

After the project, there was no consensus concerning a further collaboration among leading stakeholders and financial support by the Climate and Energy Fund discontinued. Thus, ÖBB founded its own start-up called iMobility and the Viennese utility company Wiener Stadtwerke created a private-public IT-company named Upstream Mobility. The involved technical platform provider Fluidtime operated after SMILE by themselves focusing on the market outside of Vienna. iMobility and Upstream Mobility launched their own multi-modal travel planner (Audouin and Finger, 2018a).

According to Audouin and Finger (2018a), failed continuation of SMILE also originated in a lack of municipal intervention and engagement. The project was driven by ÖBB and Wiener Linien, but the City of Vienna was merely involved. There was no visible political support for SMILE, neither was MaaS addressed in any strategic work or municipal vision. Viennese vision on smart city mentioned SMILE, but hardly derived any measures or future proposals from this MaaS initiative (City of Vienna, 2014).

Furthermore, it is stated that maybe heavy funding into one single project was not beneficial for the long-term success. At least in transition and change management, financial support of various smaller initiatives and companies is considered to be more effective instead of funding one big consortium. It would rather lead to competition and promote transition progression (Audouin and Finger, 2018a).

Both routing front-ends, Wegfinder by iMobility and WienMobil by Upstream Mobility provide multi-modal travel planning as well as booking options for MSPs. While Wegfinder enables ticketing for ÖBB, WienMobil includes this functionality for Viennese PT. Beside front-end applications, the two companies established their own back-end structure (Audouin and Finger, 2018a).

In 2018, WienMobil entered the next phase and relaunched its design. Beside multi-modal information on PT and MSPs, the app offers travel planning for private bikes and cars. As within SMILE, additional services like available parking spots and charging points are included. Addressing user customization, WienMobil incorporates individual settings for travel planning. Users can choose which MSPs are displayed and are able to indicate the existence of privately owned bikes and cars. Furthermore, the routing service is able to explicitly address persons with limited accessibility (Upstream Mobility, 2018).

On back-end side, Upstream mobility as a publicly owned MaaS platform, is now focusing on big data analytics and transportation insights in order to improve Viennese mobility issues. Such revealed information could also be used for data-driven transportation management like dynamic pricing and enhancements in traffic control. Furthermore, they work on a blockchain-based service, which should enable secure back-office payments. This so called 'Mobility Identify Wallet' would serve as single-point validation in order to facilitate and simplify further MaaS integration. As reported, legal and technical issues are currently in research and innovation process (Li, 2018).

The Viennese MaaS platform is kind of a PT service extension with plug-in option for various private front-ends. According to Li (2018), resale for third parties of tickets and services is considered in the future. Instead of acting as full-stack MaaS provider Wiener Linien is shifting its focus on the back-end part to enable MaaS without losing regulation options and striving for viable business models.

2.4.3. Helsinki, Finland

Already in 2009, the Finnish Ministry of Transportation and Communications released a strategy on ITS. Announcing that ICT will help to tackle private car use in favor of PT, walking and cycling. The advocacy platform ITS Finland was deeply involved in this process. Only four years later, a second updated version of this strategy was released, which promoted multi-modal travel behavior and demanded high level of flexibility and functionality within transportation systems. Sharing schemes and demand-responsive mobility offerings were proposed (Audouin and Finger, 2018a; Audouin and Finger, 2018c).

Simultaneously, the government published a National Energy and Climate Strategy. In terms of transport-related climate protection, it was often referred to proposed measures and ICT-facilitated innovations as a way to reduce GHG-emissions (Audouin and Finger, 2018c).

In 2013, the city of Helsinki published its 2050 city vision incorporating MaaS-like ideas. The city described its future transportation system with the following characteristics:

> *"..uncomplicated public transport network with cycling, private cars, DRT, shared vehicles, city bikes and walking into a seamless whole and where city residents can purchase the 'transport package' of their choice, similar to current mobile call/data packages"* (Helsinki City Planning Department (2013) adopted by Audouin and Finger (2018c))

Afterwards, Helsinki hosted the European ITS congress with focus on mobility apps in 2014 and commissioned reports as well as a master thesis on how MaaS could turn into reality. Meanwhile, an informal network governance process took place with various private and public stakeholders. As a result, the company MaaS.fi was founded in 2015 by 23 involved companies from the transport and communication sector. Headed by the former CEO of ITS Finland, Sampo Hietanen, the company was renamed to MaaS Global in 2016 (Audouin and Finger, 2018c).

In comparison to Sweden and Austria, where MaaS was first promoted by transport companies and private actors, it was quite early on the political agenda in Finland

– on both, national and local level. In addition, MaaS was not only seen to solve transport-related issues and cater climate change, but also to develop a new industry sector. Hence, MaaS was also set on top of the innovation program in order to become a global front-runner in ITS and MaaS in particular. MaaS can be considered of prime importance for the Finish public sector (Interviewee - Academia, 2018; Smith et al., 2018).

In the beginning, the local PT company in Helsinki, HSL, was very reluctant concerning MaaS. After various months of negotiations, the city administration and MaaS Global achieved a collaboration and HSL opened up the interface for single tickets.

In 2017, MaaS Global finally completed their test operations and launched its service Whim in Helsinki. It is a full level 3 MaaS service. The 'Whim Unlimited' package costs 499€ and contains a mobility flat-rate with PT, bike sharing, car sharing, car rental and taxi rides (5 km radius). The basic option 'Whim Urban' for 49€ covers unlimited access to PT and bike sharing as well as special fares for other modes of transport. Including suburban areas within PT, an additional charge up to 100€ is calculated (Audouin and Finger, 2018c; MaaS Global Oy, 2018b).

However, Whim users had unlimited PT, they were obligated to activate a ticket for each ride due to the provision of single tickets only by HSL. This procedure not only reduced the usability of the app, but also was economically problematic for MaaS Global. After 23 PT rides per month, a customer was already a loss-making deal (Audouin and Finger, 2018c).

Industry partners and political actors quickly realized that the single ticket issue and a general lack of data exchange is a key barrier of MaaS developments. Therefore, the Ministry of Transportation and Communications elaborated a transport-related legislation in order to pave the way for the age of data-driven transportation. The developed Finnish Transport Code was implemented in two phases. First stage ensured digital third-party resale of single-trip tickets for road and railway transport. The second phase of the Finnish Transport Code came into force in January 2019 incorporating also serial and seasonal tickets (Audouin and Finger, 2018c; Interviewee - MaaS operator, 2018).

Beside mandatory resale interfaces, the Finnish Transport Code claimed additional obligations to enhance transparency and collaboration between digital mobility services. For instance, price information of taxi and DRT services must be provided in advance. In terms of algorithm-based pricing, a calculated estimation needs to be indicated. Moreover, all MSPs have to periodically submit information regarding their supply and demand to corresponding authorities. This obligation facilitates a comprehensive date-base for further transport management and planning activities (Finnish Ministry of Transportation and Communications (LVM), 2017; Interviewee - MaaS operator, 2018).

So far, such regulatory intervention is unique in Europe. According to Audouin and Finger (2018c), this ’governing by authority’ approach took place, because network governance did not unfold the desired effectiveness in pushing MaaS forward. In the fear of loosing control and power, it appears that PT as regime actor in the field of transport is cautious regarding MaaS services by private third-parties. A complex stakeholder constellation in the case of HSL, where various municipalities are owning and leading this organization could additionally account for the preliminary refusal.

Through political and legal pressure HSL changed its view and ultimately committed to MaaS. Firstly, they set up a MaaS strategy in 2017 and launched its ’OpenMaaS interface’ providing resale for any interested third-party. In November 2018, the service was extended to seasonal tickets (Audouin and Finger, 2018c).

After Helsinki, Whim is now also operational in Birmingham (UK) and Antwerp (Belgium). Singapore and Amsterdam, Netherlands are already announced as upcoming cities in 2019. Even first roaming approaches among these cities are implemented and are going to be extended in the near future (Durand et al., 2018; Interviewee - MaaS operator, 2018).

However, it is currently the most advanced MaaS scheme available, Interviewee - MaaS operator (2018) noted that the current offering is not the end goal. In long-term perspective MaaS Global aims to establish global roaming and fosters on a SLA approach like depicted in section 2.3.

2.4.4. Antwerp, Belgium

Similar to Munich, the city of Antwerp has been facing serious congestion issues in the last years. Furthermore, major construction works are realized, which heavily impact on road traffic and accessibility in and around the city. Antwerp plays a crucial role in the international freight system due to its harbor. Therefore, a working transportation system is of prime importance and economically relevant (Interviewee - City administration, 2018).

In order to cope with expected restraints on the infrastructural system and address congestion issues, the city board launched a mitigation program six years ago. The initiative called ’Smart Ways to Antwerp’ covers over 40 different projects focusing on behavioral change in mobility and new provided solutions (Van Der Pas, 2017).

One key project consists in the development of a multi-modal travel planner and information system to provide alternatives for commuters, visitors and citizens. Over the last three years this municipal service was elaborated and subsequently expanded. By now, it contains a web as well as a smart-phone application in four languages, which informs regarding ongoing road works and provides travel suggestions (Interviewee - City administration, 2018; City of Antwerp, 2018).

A real-time map shows the congestion level of important city roads and ongoing construction works, complemented by information on car parks, stations of sharing schemes and low-emission zones. Tackling private car use, the multi-modal travel planner offers route information including walking, cycling and PT. Within the city center active modes of transport are highly encouraged (City of Antwerp, 2018).

Nevertheless, Interviewee - City administration (2018) noted that the PT-system is limited and could not be modified overnight. Moreover, information only does not result in behavioral changes. Thus, the necessity for new solutions in terms of transport was clearly stated by the city administration and the project 'Marketplace for Mobility' was created. It is a stakeholder approach consisting of three different tracks and actively incorporates private actors.

However private partners were quite interested in collaborating with the City of Antwerp, a procurement procedure was associated with risk and preparatory effort – especially by start-ups. For that reason, the first track of 'Marketplace for Mobility' simply consists in teaming up and exchanging brands, which can be considered as network governance. Through events and communication the city administration supported brand awareness and introduced partners to local companies (Interviewee - City administration, 2018; Van Der Pas, 2017).

The second pillar is a project partner track and has sustainability-related issues as core element. It funds subsidies to innovative ideas, which are catering the congestion level in the city or around the port, independent of passenger transport or freight. However it is not a procurement procedure, the companies have to apply and submit a business plan as well as a monitoring and evaluation approach that directly measures reduction in terms of congestion. In the beginning, they received a small amount of man-hour to get everything started, but the general funding is directly linked to generated impact. In return they get support by the city administration concerning communication and stakeholder aspects. A traditional tendering process presents the third track of 'Marketplace for Mobility' with special focus on reducing congestion during peak-hours. (Interviewee - City administration, 2018).

In terms of MaaS, this municipal support mainly consisted in convincing local MSPs and PT to open up their real-time data and ticketing interfaces. Therefore, the city of

Antwerp strongly promoted the reciprocal payoff regarding a MaaS ecosystem. Gladly, the city itself acted already as a local trailblazer, because the municipal travel planner within 'Smart Ways to Antwerp' required the same information channels. Thereby, data protectionism of private and public stakeholders was already partially alleviated (Interviewee - City administration, 2018).

Furthermore, the city of Antwerp initiated an 'Open Data Agreement' with all participants of the 'Marketplace for Mobility' and new MSPs entering the city. This arrangement allows companies to test and develop their services in Antwerp, although they have to provide their data to third-parties and MaaS providers (Interviewee - City administration, 2018).

MaaS Global launched its service Whim in October 2018 in Antwerp offering a basic subscription (PT and bike sharing as flat rate, special fares for other modes) as well as a pay-as-you-go option. In contrast to Helsinki, there is no 'Unlimited' package available (MaaS Global Oy, 2018b).

Beside of governance approaches and subsidies for innovative mobility solutions, City of Antwerp utilized incentives for end-users to tackle private car use. Monetary support is perceived as an effective measure to speed up the process of behavioural change by local authorities. Initial funding supports the first 1 000 Whim users in Antwerp with cash backs for their subscription. Another city action to stimulate the MaaS ecosystem explicitly addresses private car ownership. By resigning off their car admission and handing over the number plate, citizens receive a 20€ reduction for their MaaS-subscriptions over the next two years (Interviewee - City administration, 2018).

Generally, Antwerp appreciates to have as many MaaS-providers as possible operating in the city. Beside MaaS Global from Finland and Olympus Mobility, which is a local B2B MaaS operator, it is expected that more actors will join the market soon. Therefore, Antwerp can be considered as a global pioneer in establishing a local MaaS ecosystem, where different providers are competing on a playing field. However, MaaS is not seen as all-in-one solution. It only represents one element within a broad range of over 40 transport-related measures in the city of Antwerp (Interviewee - City administration, 2018; Interviewee - MaaS operator, 2018).

Due to the recent implementation, there are so far no comprehensive results and impact studies available examining the case of Antwerp and its private public partnering approach.

2.5. Preliminary studies and impact assessments

Even though some results related to the MaaS fields trials are already presented in section 2.4.1 and 2.4.2, this section aims to present a brief overview on studies examining MaaS and its potential impact. Due to late emergence of the phenomenon and immature market conditions, there is so far no empirical data regarding the transportation system as a whole. Existing studies investigated effects on particular components like car sharing or ride hailing, but not within the context of MaaS.

San Francisco County Transportation Authority (2018) and Hensher (2018) showed that in certain US cities ride hailing services like UBER and Lyft even increased the congestion level in urban areas. Certainly, US transportation systems and mobility behavior differ significantly from European conditions, but such services are capable to even worsen transport-related issues. Furthermore, Probst, Utzmann and Kipp (2015) among others extenuated the hype on car sharing schemes remarking rebound effects and limited behavioral change in Germany. All in all, sharing system's impact depends on wide-ranging factors. There are clear, sustainability-related potentials and positive effects detected being reliant on target group, system design, operational area, pricing, etc. Nevertheless, shared mobility and ride hailing are essential elements of MaaS and its contribution to sustainable mobility is controversially discussed. Their impact is assessed more positive in the context of bundled services than offered separately (Sochor et al., 2017b; Kamargianni et al., 2018).

Beside isolated studies on new mobility services, there are impact assessments on bundled MaaS services considering individual travel behavior. Those publications contain field trials, questionnaires, focus groups and Stated Preference (SP) experiments. While field trails might approximate real conditions, the hypothetical choice situation of attitudinal research methods is a shortcoming highlighted by Durand et al. (2018). Another study weakness is the lack of representativeness. Especially within the two major field trials, participants were mainly considered as early adopters of new mobility services. Indeed, Kamargianni et al. (2018) stated that exactly this demographic target group becomes a major part of the labor market within the next years demanding a high level of mobility.

Apart from a reported decrease in private car use within the context of SMILE (21%) and UbiGo (44%), 40% of non-car-owning survey participants in London indicated they would not buy a private car in the case of an existing MaaS scheme (Kamargianni et al., 2018). Further 36% would at least postpone to buying a car. Also Interviewee - MaaS operator (2018) expected MaaS rather to prevent from buying a car than to abandon private car-ownership. In contrast, 50% of all car-owners stated that MaaS would not help to depend less on private cars. Concerning private car usage, Durand et al. (2018) additionally revealed findings that MaaS highly addresses urban areas and second cars are more likely to be resigned.

Generally, a positive attitude towards sustainable modes is reported in the context of MaaS, but some interviewees stated they would partially substitute PT by taxi and car sharing due to convenience of bundled services. Although regular PT users are the key target group, they might impede a sustainable transition. Mode shifting within MaaS is reliant on surrounding conditions and multi-dimensional influences, which reveals the dichotomy of MaaS (Durand et al., 2018). Hensher (2018, p.6) remarked that MaaS-related added value could lead to a conflict of aims representing "*possibly desired impact on an individual level, but an undesired impact on a societal level with negative implications for emissions as well as congestion.*"

Among all studies on travel preferences and behavioral changes, attendees highly appreciated and demanded flexibility, tailored offerings and usability of MaaS. Fullfilling those key characteristics, can be considered as essential prerequisites in an implementation (Durand et al., 2018). Bundled modes of transport in packages favors shifting people's travel choice. Kamargianni et al. (2018) revealed that respondents would choose car and bike sharing in context of a MaaS subscription, even though they never used it before.

Matyas and Kamargianni (2018) as well as Ratilainen (2017) observed a high price sensitivity in terms of MaaS subscription models. Convenience and reliability ranked as main criteria to legitimate higher prices.

In terms of sociodemographic issues, high education and income favor a MaaS adoption. Both, ICT-related access and subscription models are perceived as barrier among elder population. In return, those elements are highly appreciated in the context of MaaS by young people (Durand et al., 2018; Kamargianni et al., 2018). Thus, a potential MaaS diffusion might follow a societal and digital divide.

Coping with different sustainability-related variables and aims, Sochor et al. (2017b) developed an impact assessment framework for MaaS. By defining relevant Key Performance Indicators (KPIs) for impact dimensions and matching those criteria set with the classic three-dimensional impact area of the sustainability concept, a tentative impact matrix was elaborated.

Analyzing various MaaS implementations (e.g. SMILE, UbiGo, Hannovermobil, Tuup) and additional sharing schemes, a preliminary impact assessment was generated. The expected implications were separately stated for three different levels: end-user perspective, business & organizational dimension and societal level.

Table 2.4.: Tentative impact assessment for MaaS considering the user level by Sochor et al. (2017b)

KPIs	Environmental	Economic	Social
Total number of trips	+ / -		+
Modal shift	+		
Number of multi-modal trips	+		
Attitude towards PT & sharing schemes	+		
Perceived accessibility to transport			+
Total travel cost per individual		+	+

(**Explanation:** '+' = overall positive; '+ / -' = positive and negative effects; '-' = overall negative)

Table 2.4 - 2.5 show the conducted findings by Sochor et al. (2017b) respectively the impact dimensions. Kamargianni et al. (2018) assessed similar impact fields for the case of London with largely congruent results. Consequences through MaaS adoption by end-users are mainly considered environmentally friendly (table 2.4). Only possible rebound effects due to more trips are associated with negative impact. Sochor et al. (2017b) value social and economic aspects positively. If appropriately designed, Kamargianni et al. (2018) added minor favorable impacts on individual health due to less pollution and more active mobility.

Table 2.5 shows ambivalent impacts in terms of accessibility. It refers on the one hand to ICT-related access of MaaS, and on the other hand to spatial issues. Current operational areas of sharing schemes are mainly located in city centers due to economic reasons. MaaS clearly focuses on urban areas, but even inhabitants of urban outskirts could be excluded by this service. Both, Sochor et al. (2017b) and Kamargianni et al. (2018) indicated uncertainties regarding revenues for PT and sharing services depending on business and operator model. In the London case, economical benefits are expected due to transport-related time savings and new business opportunities.

Table 2.5.: Tentative impact assessment for MaaS considering the societal level by Sochor et al. (2017b)

KPIs	**Environmental**	**Economic**	**Social**
Emissions	+		
Resource efficiency	+	+	
Citizens accessibility to transport		+ / -	+ / -
Modification of vehicle fleet	+ / -		

(**Explanation:** '+' = overall positive; '+ / -' = positive and negative effects; '-' = overall negative)

Table 2.6.: Tentative impact assessment for MaaS considering the business & organizational level by Sochor et al. (2017b)

KPIs	**Environmental**	**Economic**	**Social**
Number of customers		+ / -	
Customer segments (age, gender etc.)		+	+
Level of collaboration in value chain		+	
Revenues / turnover PT & sharing schemes		+ / -	
Level of data sharing		+	
Organizational changes		+	

(**Explanation:** '+' = overall positive; '+ / -' = positive and negative effects; '-' = overall negative)

Although Hensher (2018) and Pangbourne et al. (2018) declared comprehensive concerns and threats, neither Sochor et al. (2017b) nor Kamargianni et al. (2018) allocated overall negative effects to any KPI. Both impact assessments highlighted explicitly the tentative character and mentioned a lack of empirical data. Expressed statements are mainly based on assumptions and experts' valuations with a high level of vagueness. Thus, presented results should be contemplated carefully.

Summarizing, preliminary studies on changes in travel behavior and impact assessments in the context of MaaS tend to see positive effects. However, complex and multi-dimensional variables result in hardly predictable developments (Durand et al., 2018). Sarasini, Sochor and Arby (2017) added that MaaS probably comes along with modal shifts in both directions and design, initial conditions, location and actors who drive MaaS are decisive to channel the system the right way. Hensher (2018) depicted the lack of sustainability in car-centric MaaS schemes and Audouin and Finger (2018b) noted that changes towards sustainable transport systems rely on the way relevant actors of disruptive mobility trends unfold. In short term perspective, the often promoted reduction in car-dependency is primarily considered as preventing early adopters from purchasing private cars – even among MaaS front-runners.

3. Methodology

This chapter presents the applied methodology for this study entailing principal research design and its intention, considered sources, applied tools, analysis procedure as well as result formulation.

3.1. Research design and general proceeding

The general study design combines qualitative transport-related research and the approach of municipal masterplans. Thereby, the creation of a comprehensive knowledge base can be directly transferred in an actionable framework.

Since the thesis' overall goal is to provide an application-oriented solution approach to a local problem statement, the conventional process of municipal strategies is applied. It consists in the declaration of local challenges and deficits, their analysis (e.g. future study, impact assessment, statistical evaluation, scenario approach) and a concluding course of recommended action or planning (Kamargianni et al., 2015; City of Munich, 2018; City of Munich, 2006).

Due to lacking state of needful knowledge, suitable insights are gained through scientific methods to cope with the analysis part of the abovementioned municipal procedure. This represents the main research part of the thesis and makes primarily use of conducted expert interviews. The qualitative method was used to get along with late developments and shortage in scientific literature. Moreover, Pfadenhauer (2010) stated that expert interviews are not only valuable to examine causes and problem patterns, but in particular to obtain possible solutions, which fits perfectly to this thesis' scope. Interview preparation, execution and examination is described more detailed in section 3.3.

Certainly, transportation holds the center point, but it is an explicitly interdisciplinary research approach considering diverse scientific fields and their interdependency. Even if Götz (2011) categorizes mobility-related research itself as interdisciplinary, this study further deals with IT and data-related topics, sociopolitical issues and change management. Additionally, it examines on the one hand the transportation system in its entirety, and on the other hand individual mobility behavior.

The study does not consider any empirical evaluations or statistical calculations, it makes exclusively use of qualitative tools and conceptual elaborations. Applied research design depicts also aiming features (Lucas, 2013) subsumed under the term 'action research approach'. It is described as "*...bringing together action and ongoing reflection through theory and practice. The primary role of the academic is to engage the necessary 'actors' in order to facilitate a process of learning and reflection in relation to a set of practical challenges, in particular those which are considered to be complex...*" Lucas (2013, p.2). However, this research type can not be contemplated as 'action research approach' due to lacking participation of relevant actors.

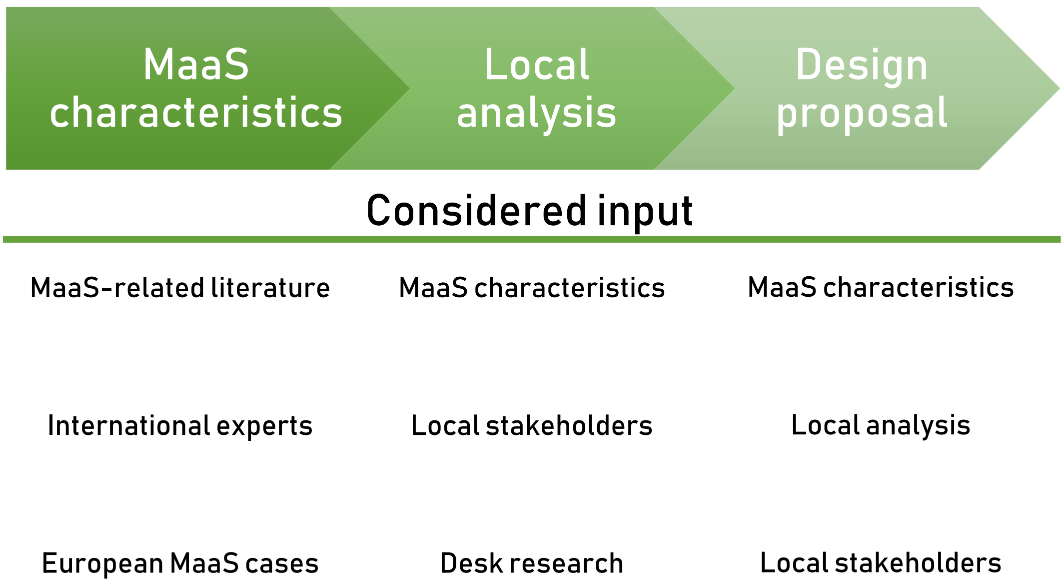

Figure 3.1.: Schematic study procedure (own elaboration)

Figure 3.1 depicts the main procedural steps and their essentially considered input. Determination of municipal MaaS elements in a first step compromises the most effort due to its extent and scientific ambition. As a result, six inherent scheme prerequisites, seven MaaS promoting drivers and eight sustainability indicators are assembled, which serve as a knowledge base for following local analysis and the design proposal. Output of this major research component is represented by chapter 4, while its applied analysis is depicted in section 3.4. Before the interviews with international MaaS experts took place, related literature (section 3.2) and MaaS case studies had already been analyzed to gain fundamental comprehension. Hence, chapter 2, its state-of-the-art presentation and in particular the European MaaS cases can be understood as a first result of the research segment.

Beside expert interviews, further input was part in defining and describing the MaaS characteristics. Also from second stage interviews with local stakeholders (section 3.3.3) valuable information could be derived. And, since MaaS is predominantly accessed by hand-held devices, relevant smart-phone applications were explored (section 3.2).

Step two and three within the study's procedural sequence represent the local analysis and the subsequent design proposal (figure 3.1). Apart from the research results regarding MaaS components, their elaboration was based upon interviews with local stakeholders and further desk research (e.g. related city strategies and R&I projects). Chapter 5.1 illustrates their conceptual process in-depth.

Table 3.1.: Objective-tool-matrix of the thesis

Study's sub-objectives	**MaaS literature**	**Case studies**	**International experts**	**Local stakeholders**	**App Examination**	**Further desk research**
Fundamental knowledge	✓	✓			✓	
Prerequisites	✓	✓	✓	✓	✓	✓
Drivers	✓	✓	✓	✓		✓
Sustainability criteria	✓	✓	✓	✓	✓	✓
MaaS design features	✓	✓	✓		✓	✓
Munich's conditions				✓	✓	✓

Table 3.1 provides an overview of methodical tools, which were taken into account by particular study objectives. Prerequisites, drivers and sustainability criteria assemble the MaaS characteristics. Design features refer to additive services, front-end elements or proposed scheme features, which go beyond fundamental attributes. Munich's condition compromises all MaaS-relevant aspects on local level.

3.2. Considered sources

So far, there are no educational books that specifically deal with the phenomenon of MaaS. Some address fundamentals of ITS, smart mobility or smart city in general and broach MaaS partially. Those were used for fundamental knowledge and background information. Several peer-reviewed journal articles exist on different MaaS aspects and were taken into account, but the desk research mainly based upon conference proceedings. In the last three years, a couple of research conferences emphatically addressed this topic. The 1st International Conference on Mobility as a Service (ICoMaaS), which took place in Tampere, Finland in late 2017, is even presented by multiple conference papers within this thesis.

Further, certain reports and drafts by public actors and project releases were contemplated – in particular for the understanding of strategic assessments and policy recommendations, but also for retrieving official figures. Addressing fast moving and dynamic developments, newspaper articles and press releases were used to cope with late updates and announcements. Those sources did not affect the scientific research process, rather were used as exemplifying and additive information base.

Since the MaaS paradigm emerged quite recently, considered sources are also released quite lately. Three quarters of all included literature were published in 2017 or 2018. Since scientific reviewing processes are time consuming, this is assumed as core reason for the lack of MaaS within research journals and educational books.

In order to examine ongoing MaaS schemes in Europe and related services in Munich, several smart-phone applications were downloaded and evaluated. Thereby, existing features, design elements and service functionality could be examined.

3.3. Qualitative interviews

Since expert interviews are the thesis' principal method, this section illustrates their application in-depth. Before presenting both interview stages, the universal procedure is depicted in its sequence.

3.3.1. Procedure

Interview execution adopts the principles of qualitative research by Mayer (2012). The applied method is considered as 'guided expert interview', wherein the conversation follows a previously assembled guideline. During the entire interview process new insights and knowledge were gained and stated questions had been slightly adjusted due to new information by time. Hence, the interview method is oriented to 'theoretical sampling', but also contains many features of a 'pre-set survey'. Theoretical sampling is primarily used, if attributes and extent of the investigatory object are widely unknown (Mayer, 2012, p. 39), which was definitely the case.

Thus, replicability and comparability among conducted interviews is not given. Provided interview guidelines (Appendix A.1 - A.2) are rather a skeletal structure containing fundamentally addressed topics, than a precise listing of asked questions.

To cope with postulated representativeness by Mayer (2012, p. 41), diverse professional domains and stakeholders were pickedas interview partners. Their limited quantitative extent results from restricted thesis scope and time frame. In total, seven interviews were held, four with international MaaS experts and three with local players. Concerning anonymity requests of some MaaS experts, only their role and function is named. In the case of approved naming, it can be retrieved from the bibliography.

Interviews were either executed through voice-over-IP with the software Skype (Skype Communications SARL, 2018) or face-to-face. After the obtained permission, all interviews were audio recorded for a subsequent textual transcription. In order to accelerate the process of transliterating, Google's voice recognition of its cloud office tool was used (Google LLC, 2018). By repeating the recorded interview loudly, large extents could be converted in written output without typing. Certainly, several corrections had been made, but the time consuming process could be clearly accelerated. Nevertheless, it should be noted for further works that Google's underlying Artificial Intelligence (AI) is far more advanced in English than German due to the amount of training data.

The interview evaluation was carried out with the software tool MAXQDA, which is explicitly designed for mixed method research and qualitative text analysis (Foxit Software Company, 2018). By using appropriate labels and codings for the interview transcripts, important sequences could be extracted and aggregated for corresponding topics.

3.3.2. Expert interviews

Based upon preliminary literature review and elaborated fundamental knowledge, an interview guideline was drawn, which is attached in appendix A.1. As already mentioned, this guideline was slightly reassembled during the research process and partner-specific questions were added concerning corresponding background and MaaS-related occupation.

Interviewee selection aimed to incorporate relevant disciplines and domains. Table 3.2 gives a brief overview of the conducted expert interviews. MaaS was illuminated by representatives of city administration, MaaS operator, academia and IT-consulting. All interviewees are deeply engaged in MaaS projects and place best expert knowledge in this thesis.

Table 3.2.: Conducted expert interviews on MaaS

Sequence	Professional domain	Date
1.	City administration	02/10/2018
2.	MaaS operator	09/10/2018
3.	Academia	18/10/2018
4.	IT-Consulting	25/10/2018

Consulted interviewees assess MaaS and related topics from their professional point of view. This comes along with constricted empirical value, occupational-related mindsets and possibly own business interests. Although it was attempted to illuminate relevant issues from all facets, it was obviously not possible to all extents. Addressing this issue within the outcome, interview references are indicated with its originated professional domain (e.g. Interviewee – Academia). Thereby, information and statements can be directly placed within the adequate context without consulting bibliography or this chapter.

3.3.3. Local stakeholder

Local stakeholders were consulted with the intention to gather information about Munich's MaaS-related challenges, ongoing developments and local conditions. Nevertheless, they placed also relevant information to some specific MaaS feature. Since their role and particular occupation was an essential field of interest, the used guideline was even more interviewee-specific than in the first stage. Appendix A.2 provides an overview of mainly considered aspects. Especially, the question concerning sustainability impact was always queried – independently from interview stage.

Equally to the expert interviews, it was intended to consider wide-ranging facets and diverse stakeholders. Therefore, interviews with two deeply MaaS-related city departments and a locally operating MSP were arranged (table 3.3). Unfortunately, various interview requests were denied by the local PT operator, which excluded the consideration of this important local perspective.

Table 3.3.: Conducted interviews on local actors

Sequence	Occupation	Date
Local stakeholder #1	City of Munich – IT-Strategy	23/10/2018
Local stakeholder #2	City of Munich – Transport planning	09/11/2018
Local stakeholder #3	CleverShuttle (MSP)	21/11/2018
Local stakeholder #4	not available	–

3.4. Analysis and result preparation

After establishing a fundamental knowledge base, six categories of MaaS features were determined for a further analysis, which are defined below:

#Policy / Governance: This label subsumes all aspects dealing with governing and managing aspects of governments, organizations and citizens. It refers to a strategic, conceptual or regulatory level. In many cases it addresses public sector activities, even though it is not mandatory.

#Stakeholder: It appoints characteristics that demand actor-specific assignments or actions within multi-stakeholder constellations. It mostly refers to the provision of system requirements to enable a collaborative approach.

#Business Model: Aspects referring to economic viability and revenue streams are considered by this category. It not only includes financial issues, but in general organizational structures and division of work.

#Data: It represents the label that relates to technical issues within this ICT-driven phenomenon.

#User: Facets that directly relate to end user issues. Those mainly consider the individual level and mobility behavior, instead of the urban transportation system in its entirety.

#Sustainability: All issues that generate or contribute to sustainable urban mobility are consolidated under this label – independently from their qualitative or quantitative character.

Within a matrix, extracted MaaS elements and factors from literature review or interview evaluation were labeled with those categories, wherein multiple references were possible. Certainly, its allocation was open to interpretation, but focus was on key areas and relations. During desk research and interview stages, a continuous process of clustering, feature combining, and splitting took place. Sometimes new information led to encouragement of a certain MaaS criterion, in some cases it induced to split a characteristic in two separate features.

In the end, all elaborated aspects were assigned in three dimensions: intrinsically needful MaaS components (chapter 4.1), driving and pushing factors (chapter 4.2) as well as sustainability-related elements (chapter 4.3). The last sections accounts for all features whose proper consideration would enhance the sustainability impact and were marked with the category. In total 21 elements could be derived through the qualitative analysis, which are important or at least supportive to take into account establishing a sustainable MaaS scheme. All those features are described in detail within the following chapter. Labeled categories and core sources are provided for each criterion. Since a clear assignment was not possible, no label indication was applied concerning sustainability criteria.

4. Prerequisites, drives and sustainability criteria of MaaS schemes

This chapter presents results from the mixed method analysis containing literature review, expert interviews and inspected case studies (chapter 2.4). It further replies to the RQs 1 and 2. The chapter is divided in four major sections: prerequisites, drivers and finally a short overview and summary.

Every single subsection starts with assigned categories and a short key message that summarizes the following content briefly. Those abstracts are highlighted by boxes with grey background color. In order to highlight main sources and provide further information, each criterion completes with an indication of referred interviewees and core literature.

4.1. Prerequisites

This thesis segment presents absolutely essential preconditions that need to be full-filled to actually facilitate a MaaS scheme. Through fundamental key questions and determinations, this section serves as a groundwork for section 4.2 and 4.3.

4.1.1. System architecture and operator business model

#Stakeholder #Business model #Policy/Governance

> The elaborated prerequisite consists in two inherently interconnected sub-items. First of all the determination of a system architecture, which aligns to local policy and governance as well as relevant stakeholders. Secondly, setting up a corresponding business model, which ensures and distributes sufficient economic revenues to all participating actors. Especially in defining the framing system characteristics, the public sector holds a key role within this requirement.

Since MaaS is a multi-stakeholder approach consisting of collaborative business activities, the operator model and its corresponding organizational structure is an elementary key question and intrinsically linked to the business model. Furthermore, this aspect and its determination affects almost every other facet of a MaaS scheme. Thus, operator framework and viable business options are the first point to be discussed within this chapter.

Referring to the RQs, this study focuses on MaaS at local level. Nevertheless, the roll-out on a larger scale with more administrative and regulatory power could come along with various advantages. Experts are discordant on this issue. In any case, relevant actors have more room for maneuver on a city level and framing conditions are promising. Therefore, current initiatives are mainly identified on this spatial stage. In addition, one can argue that the local level could serve as appropriate initial point of emergence before it evolves to a larger scale (Interviewee - IT-Consulting, 2018; König et al., 2016; Holmberg et al., 2016).

In order to provide a theoretical basis, three fundamental system architectures are presented and discussed.

Closed single system: In this case the MaaS operator is acting as full-stack service provider and owns the customer relationship from all participating MSPs as shown in figure 4.1.

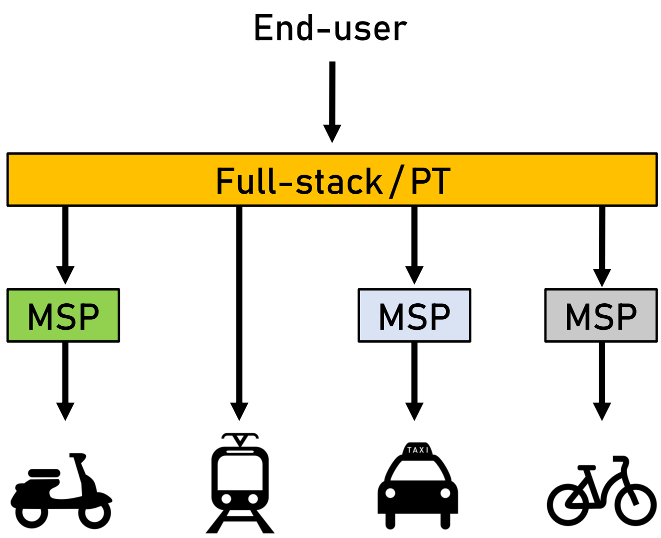

Figure 4.1.: Closed single system architecture with PT as integrator (own elaboration)

It is a closed system, where data exchange is only taking place bilaterally with the integrator. The single platform operator offers multi-modal services, bundles offerings and provides an exclusive user interface. If the whole system is operated by PT, it could be considered as multi-modal service extension (König et al., 2016; Holmberg et al., 2016).

This approach is associated with either a winner-takes-it-all scenario or a PT-driven MaaS schemes (chapter 2.3). However, further constellations are considerable. For instance, private companies could run such a system through classic tendering or contracting by public authorities. For instance, the PT company in London, TfL, contracted a service provider to implement and operate their smart-card system in the city (Interviewee - Academia, 2018; König et al., 2016).

Already existing service infrastructure, historically gained experience, front-end as well as back-end systems and comprehensive financial and human resources are reasons favoring PT as MaaS full-stack. Putting MaaS into practice by public actors would also enable a coherent alignment of the transportation system and assure the ambition towards societal goals (Holmberg et al., 2016; Interviewee - Academia, 2018).

Regardless, there are several concerns in terms of a closed single system. Firstly, high system complexity suggests an unbundling on the organizational level. It is argued that different specialists focusing on several aspects of a MaaS would result in higher performance and efficiency (Interviewee - MaaS operator, 2018; Interviewee - Academia, 2018).

Secondly, it is glaringly obvious that it would result in a MaaS monopoly and hence impede any competition. Customer options would be restricted and might limit costumers' value proposition. Complemented by potentially repressed innovations due to traditional patterns and mindsets. It is argued by transition literature that system innovations should not be driven by regime actors in order to generate a real impact. Otherwise, MaaS might result in an add-on without any systemic change due to a lack of structural transformation (Interviewee - Academia, 2018; Interviewee - MaaS operator, 2018).

Within a feasibility assessment for London, Kamargianni et al. (2015) proposed PT as potential integrator and all-in-one provider for MaaS, which should also benefit local MSPs due to market expansion. Though, this study was commissioned by the municipal transport department.

The majority of existing MaaS schemes are PT initiatives, even though all of them are currently limited to level 2 integration. Experts noted that additional bundling and integration might be incompatible with actual transport laws. Depending on national legislation, PT-driven MaaS require an adjusted transport legislation – especially in the case of flat-rates and mobility packages. Also the willingness of private MSPs to participate within such a closed system is doubtful (Interviewee - Academia, 2018; Holmberg et al., 2016; König et al., 2016).

Broker / aggregator model: Within the aggregator model a mobility broker serves as intermediate layer between end-user and MSPs as well as PT (figure 4.2). The service provider maintains the entire MaaS-related customer relation and does not own or operate any physical assets (Eckhardt, Aapaoja and Sochor, 2017; Interviewee - IT-Consulting, 2018).

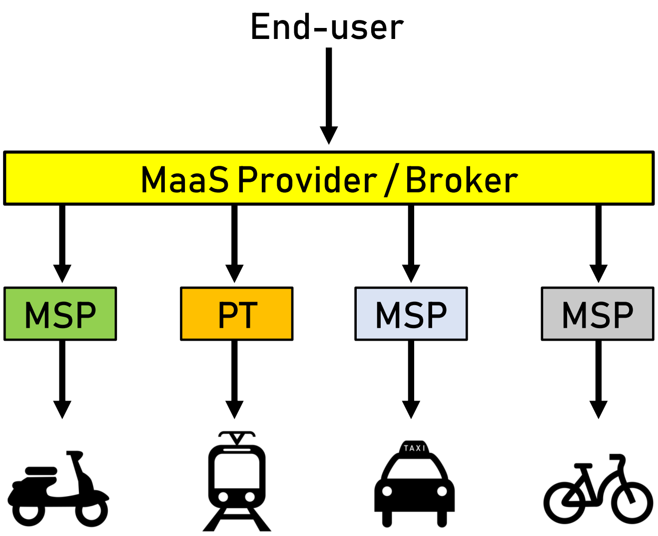

Figure 4.2.: System architecture of the broker model (own elaboration)

This option is likely market-driven and often associated with the proposed open MaaS ecosystem (chapter 2.3). Hence, it explicitly claims competition with various aggregators, which could even deal the same transport assets. Facing a competitive environment, a high level of collaborations and alliances is expected.

Prime example of the system architecture is the service Whim provided by MaaS Global (chapter 2.4.3). Its corresponding business model is composed of reselling and packaging transport assets. This could include either commission-based revenues or brokerage earning due to bilateral contractual arrangements. Through acquisition of high amounts the MaaS provider might arrange better conditions similar to traditional wholesaling (Eckhardt, Aapaoja and Sochor, 2017;

Interviewee - Academia, 2018; Sarasini, Sochor and Arby, 2017; Giesecke, Surakka and Hakonen, 2016).

Even though, the economic viability is questionable among experts. Currently, there is no profitable scheme of this type. Economic success of Whim would serve as a proof-of-concept, but in its immature stage the business is not in profit. Some argue that profitability is mainly linked to scale Sarasini, Sochor and Arby (2017). Interviewee - Academia (2018) estimated that a broker model with its services limited to only one municipality, might bear fruits in mega-cities like London or Paris, but unlikely in smaller cities like Helsinki with 600 000 inhabitants.

König et al. (2016) added that by incorporating delivery into MaaS economic viability and sustainability performance might increase. They also created a business model canvas for the broker model, where advertisement as potential revenue stream is mentioned. Indeed, non-transport-related services like events, sightseeing fees or retail issues could represent an additional income for MaaS aggregators in the future. Furthermore, data insights regarding travel behavior and transportation system are possible business opportunities (Sarasini, Sochor and Arby, 2017), although Interviewee - MaaS operator (2018) highlighted to not track their end-users or collect any further information.

According to Interviewee - MaaS operator (2018) a SLA approach (chapter 2.3) would support a broker model, because the decoupling would enable allocating the modes of transport in MaaS provider's economic interest. If possible, a broker would tend to provide economic modes like PT and bike sharing, which are also the sustainable ones. In case of a PT breakdown or bad weather conditions, the MaaS provider would be in charge to offer alternatives in order to full-fill the service promise. Though, a highly advanced and reliable system is inevitable to turn SLA into practice.

A potential business model solution would also emerge with new ways in subsidizing transport. In the beginning of the MaaS discourse, some front-runners argued to subsidize end-users instead of transport operators, but this view is hardly hold nowadays. Anyhow, in case of proofed positive impact through MaaS, new opportunities in the way how we fund transport should be considered to enable a corresponding business viability (Audouin and Finger, 2018a; Interviewee - Academia, 2018).

Open platform: It can be assessed as a hybrid of the previous two scheme options. Key element represents an open data platform, where services are interconnected through open data. Generally, it is assumed that the platform is operated and regulated by the public sector. Thus, the approach relocates the competition to the front-end side as shown in figure 4.3. Upon the data aggregating back-end structure MSPs and MaaS operators maintain customer relation and could run services within the scope of the platform rules (Interviewee - Academia, 2018; Interviewee - IT-Consulting, 2018).

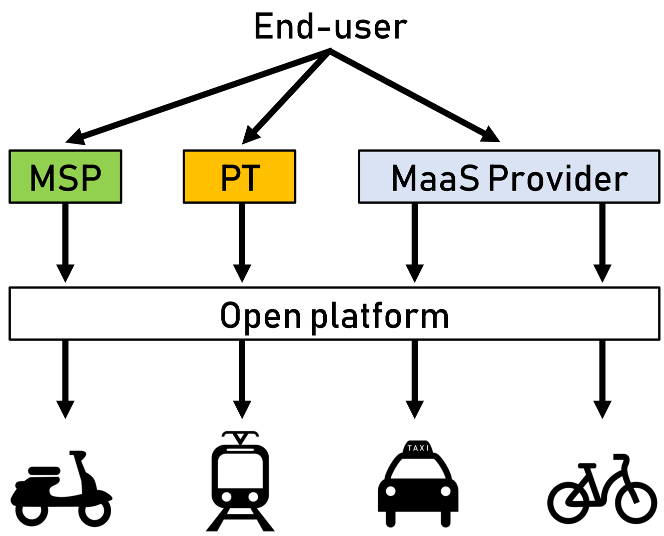

Figure 4.3.: System architecture of an open platform approach (own elaboration)

By operating the platform, the public sector could enforce societal goals as well as transport management and planning. It even enables public players to run a business model through platform provision. Contrariwise to the closed single system, competition is assured for private MSPs. Hence, among experts it seen as quite forward-looking and successful approach of public-private cooperation in terms of MaaS (Hoadley, 2017; Interviewee - IT-Consulting, 2018; Interviewee - Academia, 2018).

Regardless, so far this approach exists only in a conceptual stage, but Barcelona as well as Vienna already tend to focus on this system architecture in the future. Though, potential system implications base upon assumptions. In the case of Vienna, the public sector is additionally operating a public front-end (chapter 2.4.2). It represents a partial level 2 integration and aims to provide comprehensive travel information including CO_2-emissions in order to nudge citizens towards sustainable modes (Interviewee - IT-Consulting, 2018; Interviewee - Academia, 2018).

> Since viable business models and value creation is tough, potential activities limited to the front-end side might constrain business innovations and market developments. Moreover, it is assumed that such schemes are regulated more severely. For this reason, MaaS operators might prefer municipalities with more liberal conditions for their market entry. Although this system architecture does not dictate specific amount and sharpness of mandatory data, it generally requires open corporate data to some extent. Sharing data with public authorities and competitors could lead in a further barrier (Local stakeholder #3, 2018; Local stakeholder #2, 2018).

Concluding, potential system architectures mainly vary in the role of the public sector. Presupposed the closed single system is run by PT, it is a strongly regulated, monopolistic scheme and would follow a traditional role allocation, wherein the public sector acts as regulator and provider, and partially as operator. The complete opposite represents the broker model, which can be considered as liberal, relatively unregulated market, wherein private actors are highly encouraged to offer their service and compete in the transport market. The open platform approach aims to combine respective advantages by assuring regulation and control, but without acting as MaaS provider.

Value creation and viable business models within MaaS are afflicted with vagueness and doubt. So far no MaaS scheme with high integration could proof economic profitability, hence this issue is assessed as a key challenge within MaaS (Interviewee - Academia, 2018; Kamargianni et al., 2015; Smith, Sochor and Sarasini, 2017). While Audouin and Finger (2018c) and Giesecke, Surakka and Hakonen (2016) emphasize the necessity of further development and research on potential business models, Sarasini, Sochor and Arby (2017) highlights that MaaS value creation should not be limited to economic issues, but rather incorporate social and environmental dimensions.

Since literature (Giesecke, Surakka and Hakonen, 2016; Hoadley, 2017; Li and Voege, 2017; Smith, Sochor and Karlsson, 2017) consider mainly public players in defining the framing system architecture, this prerequisite is also labeled with policy and governance issues. In particular to assure societal goals and to determine own functions within a scheme, local authorities should actively engage in this task – even if they only act as enabler. Of course, all relevant actors should participate, but the public sector definitely holds a key role in the conceptual stage (Li, 2018).

Main sources / further reading:
• **Experts:** Interviewee - Academia (2018), Interviewee - City administration (2018), Interviewee - IT-Consulting (2018) and Interviewee - MaaS operator (2018)

• **Literature:** Hoadley (2017): Mobility As a Service: Implications for Urban and

Regional Transport; Holmberg et al. (2016): Mobility as a Service - Describing the framework; König et al. (2016): Business and operator models for MaaS; Sarasini, Sochor and Arby (2017): What characterizes a sustainable MaaS business?

4.1.2. Collaboration readiness

#Stakeholder #Business model

> MaaS requires a multi-stakeholder cooperativeness, which comes along with sharing and linking user bases, data and revenues. Such a collaborative approach also presupposes assigned responsibilities and competences among business partners. Although voluntary participation and network governance are desirable to establish MaaS, certain actors might be forced by law. Costumer ownership and related topics are identified to be key issues.

Obviously, collaboration readiness is an implicit part of system architecture and business model, and is hence deeply linked and dependent on the previous prerequisite. Though, this section focuses more on corporate attitude towards MaaS.

Both, reviewed literature (Audouin and Finger, 2018a; Audouin and Finger, 2018c; Smith, Sochor and Sarasini, 2017; Smith et al., 2018) as well as all consulted experts (Interviewee - Academia, 2018; Interviewee - City administration, 2018; Interviewee - IT-Consulting, 2018; Interviewee - MaaS operator, 2018) consistently consider railway companies and PT as reluctant stakeholders. However, it decisively depends on the system architecture and the single case. Denial by public players mainly refers to the broker / aggregator model, because regime actors tend to maintain the status quo. By ultimately recognizing MaaS opportunities, PT and railway companies often foster own schemes. MSPs are assessed to be more MaaS-friendly, but might avoid a closed single system with high integration level on the other hand.

But what are they afraid of? Generally, the overall reluctance consists in the fear of loosing market share and customers. Since PT and railway usually have a public funding body, but are run like private companies, they consequently follow profitability ambitions. By providing their data and engaging possibly disruptive competitors, regime actors are worried about a lack of their relevance within a future transport system (Interviewee - Academia, 2018).

Interviewee - IT-Consulting (2018) highlighted that their doubts are not unsubstantiated. For instance, within a complex system with many variables and uncertainties, a season pass owning user base is a substantial element of PT planning reliability. To resign the corresponding customer relationship could be financially and strategically risk-afflicted.

In addition, the PT sector itself is a complex and heterogeneous stakeholder field with differing interests. The SMILE project exemplifies disagreement between public actors regarding MaaS (chapter 2.4.2). Even smaller challenges like restructuring the tariff scheme could lead to tough and long negotiations on local public level (Interviewee - IT-Consulting, 2018; Local stakeholder #2, 2018; Audouin and Finger, 2018a).

The key question of corporate readiness is: who owns the customer? Of course, MaaS participants seek for higher integration and expanded services, but contemporaneously they fear to give up direct customer relation. DB for instance is using their extremely comprehensive user baser to negotiate high commissions for reselling local PT tickets through their MaaS-like front-end. Hence, customer ownership comes along with bargaining power, planning reliability and marketing advantages (Interviewee - IT-Consulting, 2018).

A further reason for a MaaS refusal relates to financial issues, which in particular applies to small and non-profit-making MSPs. Only the IT-integration in a MaaS system easily costs 10 000 € excluding maintenance. Small MSPs might not be willing or capable to invest such an amount of money – especially, if added-value and revenue streams are unforeseeable (Interviewee - IT-Consulting, 2018).

According to Interviewee - City administration (2018), reluctance of PT as well as MSPs can be overcome by establishing trust and proofing reciprocal payoff. Dialogues, round table discussions and network governance in general are considered to be adequate measures in achieving bilateral agreements and contractual arrangements. Smith et al. (2018) referred to transition management, which claims cycles of learning and continuous adaptation to resolve the lock-in effect of regime actors. Both highlighted multi-stakeholder engagement and discourse as key criteria of a successful transformation process.

Nevertheless, the case of Helsinki (chapter 2.4.3) showed that in the end regulatory intervention was inevitable to ensure MaaS implementations (Smith et al., 2018). However Interviewee - MaaS operator (2018) added that the Finish Transport Code is a general adaption to data-driven transport sector, it explicitly facilitates a technical integration of PT and MSPs independent from their MaaS attitude.

Concluding, a positive viewpoint towards MaaS and participation by choice is highly encouraged. A common appreciation and business approach are considered as success factor for MaaS.

However, disruptive approaches might require other activities like political and bargaining force or involuntary adjustments by regulation in order to overcome systemic barriers.

Main sources / further reading:
• **Experts:** Interviewee - Academia (2018), Interviewee - City administration (2018) and Interviewee - IT-Consulting (2018)

• **Literature:** Audouin and Finger (2018a): Empower or Thwart ? Insights from Vienna and Helsinki regarding the role of public authorities in the development of MaaS schemes; Smith et al. (2018): Governing Mobility-as-a-Service: Insights from Sweden and Finland.

4.1.3. Multi-modal and digital mobility services

#Stakeholder

> The availability of certain MSPs, which are bundled in a MaaS offering and serve as car substitution, is mandatory. Furthermore, those services need to maintain ICT-supported access opportunities. Due to economic issues of emerging MSPs, this necessity limits MaaS to highly populated cities.

Since MaaS intends to facilitate urban mobility without private car-ownership, appropriate and wide-ranging alternatives are required. Of course, PT could serve as principal mode of transport, but there is consensus that this alone would hardly reduce car-dependency. Especially for occasional trips, last and first mile as well as periods outside of PT operation, additional services are crucial (Interviewee - City administration, 2018; Interviewee - IT-Consulting, 2018; Local stakeholder #3, 2018).

The phenomenon of sharing schemes and new transport approaches like DRT is mainly limited to densely populated areas due to economic reasons and sufficient demand. The two biggest car sharing companies, Drive Now and Car2go in Germany, are only operational in a few German cities. Even in less-populated cities car and bike sharing are nowadays often available to some extent, but spectrum and progressiveness of new mobility services is inherently linked to the city size.

Beside PT, Interviewee - MaaS operator (2018) indicated taxi or ride sharing and a car alternative for occasional rides as a minimum condition for MaaS. Also bike sharing is often mentioned as an intrinsic MaaS element. Interviewee - Academia (2018) as well as Li and Voege (2017) noted that the range of included modes should be as wide as possible. In any case, MaaS requires the existence of MSPs covering relevant aspects of the local transport system. The corresponding extent depends on MaaS the ambition itself as well as PT system and geographic aspects.

To be integrated in MaaS such MSPs not only have to be available, but also possess ICT-related service infrastructure. E-ticketing, e-hailing or unlocking of vehicles through a smart-phone application should be part of their service features. It is already given in the most cases and in the context of future digitization rather implicit than a separate requirement (Interviewee - IT-Consulting, 2018; Li and Voege, 2017).

Another reason for local emergence of digital mobility service offerings is related to socioeconomic terms. Within the field of marketing, Antwerp is historically known as test-bed for new products and services due to a supposedly high share of early adopters (Interviewee - City administration, 2018). Therefore, start-ups highly welcomed the city administration's initiative to launch innovative transport solutions as pilots (chapter 2.4.4). This phenomena could also be transferred to other sectors. For instance, the availability of food delivery services highly correlates with a neighborhood's socioeconomic pattern.

High population density and an appropriate residential milieu can be identified as breeding ground for emerging MSPs, which lead to a very limited spatial availability. Currently, MaaS on municipal level is mainly conceivable in big cities. Given the actual spread of MSPs in Europe, comprehensive MaaS systems are considered to require metropolitan areas with at least 500 000 inhabitants – concerning only the existence of MSPs (Interviewee - Academia, 2018; Interviewee - City administration, 2018).

Main sources / further reading:
• **Experts:** Interviewee - Academia (2018), Interviewee - City administration (2018), Interviewee - IT-Consulting (2018) and Local stakeholder #3 (2018)

• **Literature:** Li and Voege (2017): Mobility as a Service (MaaS) – Challenges of Implementation and Policy Required.

4.1.4. Data availability and integration

#Stakeholder #Data

> In order to provide bundled and interconnected MaaS services, data exchange and digital authorization processes need to be established among participants. This

> requires appropriate gateways and specific real-time data sets embedded in the IT-system.

This requirement illuminates the technical aspects of corporate readiness. In order to interconnect and bundle different services in an ICT-driven multi-stakeholder system, transmission and processing of information in real-time is mandatory. In comparison to data bases, which deal with rather static information, dynamic IT-systems are an intrinsic component. Technically, such data exchange is realized through Application Programming Interfaces (APIs), which are: *"...a way of building connections between systems, devices and applications. An API includes commands that can be used, for instance, to retrieve data or use the functions of a back-end system... An API is typically needed when the data being utilized is real-time"* (6Aika, 2017, p.7-8).

APIs enable system interconnectivity and data gateways, but also the respective information itself is needed. Kamargianni et al. (2015) summarized key data sets and obligations for each stakeholder. The minimum data provision for a MaaS scheme is compromised in table 4.1. While sharing of timetable information via API is easily realized, unlocking a bike is already a more advanced integration task. Authorizing a user's drivers license and accessing a car sharing vehicle is highly complex. Hence, requirements and complexity of necessary data exchange apparently increase with the integration level of MaaS. This further correlates with financial expenditures and legal demands (Interviewee - IT-Consulting, 2018).

Table 4.1.: Minimum key information for MaaS schemes (Kamargianni et al., 2015)

Data set	**Relevant stakeholder**
Instantaneous timetable	PT
Real-time location	MSPs and end-user
Price information	PT and MSPs
Vehicle availability and characteristics	MSPs
Booking / ticketing access	PT and MSPs

Additional information could significantly enhance the entire MaaS system and its usability. Such data might include health data, sustainability information, congestion level, approximate arrival time or real-time location of PT vehicles (Kamargianni et al., 2015; Karlsson et al., 2017).

Since data is considered as a key source of value creation within digital businesses, companies are quite protective in sharing operational information. Similar to the more general corporate readiness, measures to achieve data access range from bilateral negotiations to regulatory interventions. Commonly, Non-disclosure Agreementss (NDAs) between MaaS actors are used to clearly define rules for data exchange, processing and collection. (Interviewee - City administration, 2018; Interviewee - IT-Consulting, 2018).

Karlsson et al. (2017) highlighted that an additional service layer requires further technical administration tasks, incorporating clearing processes, service monitoring as well as security issues.

Main sources / further reading:
• **Experts:** Interviewee - City administration (2018) and Interviewee - IT-Consulting (2018)

• **Literature:** 6Aika (2017): API Toolkit; Kamargianni et al. (2015): Feasibility study for "Mobility-as-a-Service" concept in London; Karlsson et al. (2017): Technology for MaaS; Transport Systems Catapult (2016): Mobility as a Service - Exploring the opportunity for mobility as a service in the UK.

4.1.5. Network coverage / internet accessibility

#User #Data

> This prerequisite deals with user's accessibility to MaaS. Mobile network coverage need to facilitate ubiquitous internet availability with adequate data traffic. Wireless Local Area Networks (WLANs) and offline tickets are possible interim solutions, but to be competitive with private car-ownership in the long run, advanced, pervasive and reliable mobile networks are inherent components of MaaS.

Since MaaS services are commonly accessed by hand-held mobile devices, ubiquitous internet availability to any given time is necessitated. Network existence on its own is not sufficient, it further needs to enable data transmission for demanding applications and services. It is an user-centric precondition independent from system architecture. Beside any transport-related needs, mobile data infrastructure should ensure MaaS accessibility. Especially when addressing car-dependency as key a promise, necessary reliability and qualitative user-experience is inevitable (Interviewee - Academia, 2018; Interviewee - MaaS operator, 2018; Transport Systems Catapult, 2016).

The fourth generation (4G) of mobile network technology is currently state of the art. However, its installation and roll-out is mainly business-driven and subsequently coverage is related to population density. As a result, this standard is not ubiquitous available, especially in rural areas anterior mobile networks are predominant. Karlsson et al. (2017) and Transport Systems Catapult (2016) assessed third generational mobile networks (3G) as absolute minimum in terms of MaaS-related data rates. Additionally, network congestion, limitations of data consumption and expensive data pricing might be inhibiting factors in developing MaaS.

There are attempts to cope with such deficits and coverage holes. The possibility to show purchased e-tickets for railway and PT offline is already commonly implemented in applications. Though, unlocking sharing bikes or cars without data traffic is so far not possible. This phenomenon is already numerously reported in the context of big events, and thereby congested networks (Interviewee - MaaS operator, 2018; Karlsson et al., 2017).

Interviewee - MaaS operator (2018) accentuated that transport-related applications, which not monetize customer data significantly enhance such problems. Relinquished user tracking mitigates data traffic and battery consumption. Furthermore, points of interest like railway stations or crowded places are increasingly covered by WLAN (Local stakeholer #1, 2018).

Main sources / further reading:
• **Experts:** Interviewee - MaaS operator (2018)

• **Literature:** Karlsson et al. (2017): Technology for MaaS; Transport Systems Catapult (2016): Mobility as a Service - Exploring the opportunity for mobility as a service in the UK.

4.1.6. Legal requirements

#Policy / Governance

> MaaS schemes entail high system complexity on a business and technical level and therefore face multiple regulatory demands. Legal requirements can be split up in

> three fields: transport, competition and data usage. Compatibility with current law is largely uncertain and depends on design and location.

All consulted interviewees and a wide range of literature expressed legal uncertainties regarding MaaS. Since legislative conditions could vary significantly on national and even on municipal level, relevant issues are hardly to assess. Due to late emergence and high complexity, legal situation of MaaS aspects is largely unclear – even among experts.

Generally, relevant legislation is divided in three fields: transport-related regulations, competition law and data-related aspects. However a precise assessment is not feasible, the main topics and its key issues are briefly depicted in the following section:

Transport-related regulation: In many countries publicly funded transport is heavily regulated. Thus, Li and Voege (2017) and Transport Systems Catapult (2016) assessed unclear legal situation regarding third party resell of PT and railway tickets, which is a crucial key feature of MaaS. Within PT-driven closed single systems such possible impediment is avoidable.

The new Finish transport code, whose second phase came into force in January 2019, not only assured third party ticket resell, but also demanded appropriate APIs for digital service provision by law (Finnish Ministry of Transportation and Communications (LVM), 2017).

Reselling and repackaging tickets is often linked to subsidy issues, which also could lead to legal limitations. This was the key barrier, why UbiGo could not continue its operation under regular business conditions (chapter 2.4.1). It is assumed that in many cases current law requires adaptation regarding subsidy-related handling (Interviewee - City administration, 2018; Smith, Sochor and Karlsson, 2017).

In particular highly integrative MaaS schemes might face liability issues. By providing interconnected trips with different modes of transport, MaaS operators could turn into travel agencies from a regulatory point of view. It would come along with comprehensive legal claims in case of technical disturbances and missed connections. Some experts assumed that amplified passenger rights might be the reason, why PT companies still not offer interconnected trips with bike or car sharing. Instead, they keep PT and sharing schemes separately even if they operate both segments (Interviewee - IT-Consulting, 2018; Transport Systems Catapult, 2016).

Contrariwise, Whim explicitly wants to provide transport warranties, because it facilitates car-associated reliability to some extent. It is a first step towards a SLA approach (Interviewee - MaaS operator, 2018).

Moreover, transport regulations often do not consider new services and offerings. DRT rarely is defined within corresponding laws and hence its treatment allows interpretation by authorities and business partners.

Competition law: Multi-stakeholder business constellations might face challenges in competition law – in particular if public actors are involved. Interviewee - IT-Consulting (2018) mentioned the necessity of procurement procedures and co-operation prohibitions when it comes to public expenditures. In the case of MaaS providers operating by order of city administrations, transparent tendering would be inevitable.

Such aspects could undermine efforts in network governance, which is based upon unconstrained processes. It reveals the bias of network governance in general. On the one hand it might drives innovative approaches due to unconventional proceedings, one the other hand its informal character might end in market discrimination.

Therefore, Interviewee - City administration (2018), Interviewee - MaaS operator (2018) and MaaS Alliance (2017) highlighted advantages of an open MaaS ecosystem, wherein all participants could act under predefined and equal conditions. Likewise, approaches of open APIs and open data (chapter 4.2.4) aim to enable a fair market situation through common data availability. In this regard, once again the Finish transport code serves as prime example assuring equitable MaaS access on a legal base for any interested party.

Data-related legislation: ICT-driven systems are based upon data collection, aggregation and processing. Beside entailed enhancements, user privacy and consumer protection need to be addressed. Collaborative and interconnected service approaches like MaaS necessitate access to personal data by various stakeholders.

Such issues are particularly regulated by the European General Data Protection Regulation (GDPR), which finally came into force in May 2018. Individual movement data was awarded with a highly protective status, but type and usage determine allowance of certain data processes and the necessity for user agreement. In particular, non-inherent service features are restricted in order to avoid data abuse. Furthermore, GDPR claims a ‘privacy by design’ approach regarding software architecture and demands a user right for handing-over collected data (Interviewee - IT-Consulting, 2018; Karlsson et al., 2017).

Another area of the GDPR covers security issues. Within 72 hours all data breaches have to be announced publicly and liability is extended to all parties making use of personal data (Interviewee - IT-Consulting, 2018; Karlsson et al., 2017).

In addition to GDPR, other data-related legislation might apply to MaaS schemes. On the European level further relevant regulations (e.g. e-privacy directive) are already drafted and will be passed by the European Commission in near future. So far influences on transport-related data issues are currently difficult to be predict (Interviewee - IT-Consulting, 2018; MaaS Alliance, 2017).

Interviewee - IT-Consulting (2018) argued that highly advanced transport algorithms might be limited due to privacy issues, but general features and services are not compromised. Nevertheless, MaaS software development requires high caution, sophisticated concepts and detailed risk estimation to cope with complex legal requirements.

Relevant legislation is wide-ranging and depends on MaaS design and involved partners. Concerning differences and singularities, each implementation requires its own evaluation and prohibits general statements. Thus, legal MaaS requirements are highly afflicted with vagueness.

From a legal point of view, MaaS-specific rules are highly appreciated to clearly determine relevant transport, competition as well as data issues. Even though the Finish transport code presets system architecture and framing scope, it definitely facilitates legal certainty, which is a fundamental precondition for MaaS implementations.

Main sources / further reading:
• **Experts:** Interviewee - IT-Consulting (2018) and Interviewee - MaaS operator (2018)

• **Literature:** Karlsson et al. (2017): Technology for MaaS; MaaS Alliance (2017): White Paper - Guidelines & Recommendations to create the foundations for a thriving MaaS Ecosystem.

4.2. Drivers

While the previous section presents minimum requirements for MaaS schemes, elaborated key drivers are depicted in this segment. However those elements are characterized as non-inherent to MaaS, they unfold the potential to decisively thrive MaaS. Such system drivers relate to process acceleration, acceptance, multiplier effects and technical compatibility.

Originally, drivers as well as barriers were mapped within the evaluation, but it turned out that the non-existence of a driver could be understood as barrier in the most cases. Even tough, a lack of described elements should not necessarily be considered as an explicit impediment in reverse conclusion.

As well asLikewise elaborated prerequisites, drivers are derived from literature review, guided interviews and analyzed case studies.

4.2.1. Leadership

#Stakeholder #Policy / Governance

> Leadership plays a crucial role in enabling MaaS, because disruptive approaches are pushed by visible front-runners. Commitment by political decision makers generates highly thriving influence – especially on municipal level.

The prevailing opinion among experts clearly stated leadership as a key factor of success. Advocates in form of individuals or organizations promoting benefits in public could significantly push and accelerate MaaS. Leadership refers to idea visibility as well as multiplying and pervading new approaches cross-sectoral (Interviewee - Academia, 2018; Interviewee - City administration, 2018; Interviewee - IT-Consulting, 2018; Local stakeholer #1, 2018; Smith et al., 2018).

Who should act as MaaS promoter? Of course, industry partners and Non-governmental Organizations (NGOs) are appreciated, but literature and interviewees agreed on policy-makers to be the most powerful MaaS drivers. Since it requires public actor involvement, political decision-makers are associated with high action capability. A MaaS advocating mayor or governing party would enormously increase the realization probability of such projects. Nevertheless, MaaS advocates could also be presented by administrative executives or entire organizations (Interviewee - Academia, 2018; Local stakeholer #1, 2018).

ITS Finland as a representation of interested groups definitely played a crucial role in developing MaaS. By promoting this approach through events and conference agenda setting, the association took on leadership (Audouin and Finger, 2018c).

However, interviewees highlighted that in particular on a municipal level decision-makers currently fear to acknowledge MaaS due to unpredictable impact. Political decisions and measures on transport-related issues are perceived as highly sensible and controversial, and hence largely avoided by persons in charge. In the case that political commitment is given, network governance is significantly more effective (Interviewee - Academia, 2018; Local stakeholder #2, 2018).

In Finland, political commitment was omnipresent – on national as well as on local level, and can hence be assessed as key driver towards a successful implementation (Interviewee - MaaS operator, 2018). Antwerp's city council put MaaS on the agenda due to external factors like threatening transport disturbances (Interviewee - City administration, 2018). In contrast, initial discontinuation of MaaS pilots in Gothenburg and Vienna attributed partially to lacking political encouragement (Interviewee - MaaS operator, 2018; Audouin and Finger, 2018a; Smith et al., 2018).

Main sources / further reading:
• **Experts:** Interviewee - Academia (2018), Interviewee - City administration (2018), Interviewee - IT-Consulting (2018), Interviewee - MaaS operator (2018), Local stakeholer #1 (2018) and Local stakeholder #2 (2018)

• **Literature:** Audouin and Finger (2018a): Empower or Thwart ? Insights from Vienna and Helsinki regarding the role of public authorities in the development of MaaS schemes; Smith et al. (2018): Governing Mobility-as-a-Service: Insights from Sweden and Finland.

4.2.2. Coordinating and administrative unit

#Policy / Governance

> Within the public sector well coordinated MaaS competences and activities accelerate and drive developments. Coordinating units and open administrative structure is favorable.

Bundled governmental competences are assessed as crucial influence by Interviewee - MaaS operator (2018) as well as Smith, Sochor and Sarasini (2017). The Finish Ministry of Communication and Transport (LVM) is capable to elaborate activities deeply linked between transport and ICT without other external intervention. Hence, LVM was mainly responsible for setting up the Finish transport code and coordinating MaaS-related activities. Competence merging is a main reason for rapid Finish MaaS-related actions on governmental side.

In the case of fragmented competences, a coordinating unit is highly recommended. Its function would consist in detecting relevant activities in functional departments, assuring exchange and discourse and merging them into a coherent overall picture. In Austria, a federal state already established a MaaS responsible commissioner in their administration (Interviewee - IT-Consulting, 2018; Local stakeholer #1, 2018).

At least when MaaS development is changing from a conceptual and vision-based stage into a realization phase, such coordination should extend its assignment. Real MaaS implementation requires governmental coordination and management beyond administrative processes, which comes along with comprehensive financial and human resources (Interviewee - MaaS operator, 2018).

Interviewee - City administration (2018) emphasized that in order to realize complex and multi-disciplinary projects, an open and network-like administration is supportive. Antwerp's unit of communication and participation is well interconnected to the business and innovation department as well as to local participation managers in the neighborhoods. Hence, they are for instance capable to easily report difficulties, which certain neighborhoods or employers are struggling with. This approach of an open administration structure enables the involvement of a wide range of stakeholders outside as well as inside the local authorities. Additionally, the creation of a multi-disciplinary team is supportive that includes experts from all relevant departments like transport, city planning, marketing as well as business and innovation.

Main sources / further reading:
• **Experts:** Interviewee - City administration (2018) and Interviewee - MaaS operator (2018)

• **Literature:** Smith, Sochor and Sarasini (2017): Mobility as a Service: Comparing Developments in Sweden and Finland.

4.2.3. Common vision

#Stakeholder #Policy / Governance

> Commonly shared visions serve as value-based guidelines for public and private actors. Its contribution to MaaS development is shown by case studies. Moreover, it is proposed that municipal city strategies contain quantitative targets in order to enable tailored solutions like MaaS.

While leadership rather consists of advocating and promoting an issue in general, shared vision focuses on its strategic elaboration based upon common values and needs.

Many cities around the world have future visions and corresponding policy papers, but most of them do not contain any quantitative-based goals. When tackling climate change, some cities claim to achieve carbon neutrality, but do not define any targets regarding transport in terms of congestion, emissions, etc. (Interviewee - Academia, 2018).

Multi-stakeholder collaborations often face differing ambitions and business interests, which might compromise MaaS. A commonly shared vision among partners obviates discord and serves as a guideline. Of course, such a vision enhances task assignment and coordination within the public sector, but also private actors need guidance and a local purpose in realizing new ideas and approaches (Interviewee - Academia, 2018; Local stakeholer #1, 2018).

Interviewee - Academia (2018) proposed that a city vision should include quantitative goals like specific transport-related GHGs-reductions, whose accomplishment might be achieved by MaaS. Policy-makers tend to evade such precise statements. Nevertheless, for instance London's ey-mayor determined certain targets within the city transport strategy. Subsequently, e-ticketing and smart cards as corresponding measures were suggested and implemented through services and products of the private sector. If a vision or city plan is set up in this way, it definitely drives solutions like MaaS.

Local governments are normally in charge to initiate and develop such transport-related strategies. Within this process all relevant dimensions should be pictured and niche actors need to be involved (Audouin and Finger, 2018a).

The Helsinki case showed that such strategy and policy papers are conducive on national and local level (chapter 2.4.3). In Vienna and Gothenburg a lack of commonly shared visions was reported (Audouin and Finger, 2018a; Audouin and Finger, 2018c; Smith, Sochor and Sarasini, 2017).

Main sources / further reading:
• **Experts:** Interviewee - IT-Consulting (2018) and Interviewee - MaaS operator (2018)

• **Literature:** Audouin and Finger (2018a): Governing Mobility-as-a-Service: Insights from Sweden and Finland; Audouin and Finger (2018c): The development of Mobility-as-a-Service in the Helsinki metropolitan area: A multi-level governance analysis.

4.2.4. Open APIs / open data

#Stakeholder #Policy / Governance #Data

> Due to the reduced entry hurdle, publicly accessible data and interfaces significantly push MaaS as a market. However, APIs require sophisticated design and predefined obligations in order to prevent negative consequences and unfair competition.

As chapter 4.1.4 depicts, MaaS deeply relies on data availability and exchange, whose provision could be realized through bi- or multilateral access. Such approaches enable closed MaaS systems and assures data ownership by stakeholders at once. However, it is associated with isolated systems and limited business opportunities.

In order to push data-driven markets and innovations, all sources agreed that liberated data access is highly promoting. New solutions and added value are enabled by opening up data streams and information for third parties. Vollers, Berends and Carrara (2017) even described data as raw materials within digital value creation.

In the whole smart city discourse data access is a principal issue. Advocates emphasize transparency and economic growth of publicly available information. For the same reasons the European Union encourages this approach (Interviewee - MaaS operator, 2018; 6Aika, 2016a; Vollers, Berends and Carrara, 2017). Such information liberating trends are subsumed under the terms 'Open API' and 'Open Data'. Since data is an intrinsic component of APIs and it further incorporates a real-time character, the term is mainly used within this study. Open API characteristics are summarized by 6Aika (2016b, p.15):

> "*An open API, is an API whose all features are public and which can be used without restricting terms and conditions. This requires that the API description and any related documentation must be openly available and that the API can be freely used to create and test applications. The use of an open API is free of charge. The user does not need to ask permission from the API provider or indicate the intended purpose of usage in advance.*"

In terms of MaaS, especially advocates of the open ecosystem promote an open API approach, because it supposedly sets equitable conditions and enables fair competition. Experts further argued that it eliminates a critical barrier for entering the MaaS market. An open ticketing API for instance facilitates digital resale and repacking by any third-party service provider. In the end it probably leads to an improved value proposition for users (Interviewee - Academia, 2018; Interviewee - City administration, 2018; Interviewee - MaaS operator, 2018; Li, 2018). Karlsson et al. (2017) highlighted systemic enhancements by third-party developer access and simplified technological interconnectivity.

Recent regulations focus primarily on public data to be provided, while private companies still act highly protective. Since MaaS is dependent on data from MSPs, the Finish transport code forced them to open up as well. This not only includes real-time information and price details, but also the provision of booking and ticketing APIs (Interviewee - MaaS operator, 2018; Finnish Ministry of Transportation and Communications (LVM), 2017).

Nevertheless, Local stakeholer #1 (2018) highlighted threats linked to openly shared data. Operational data insights might reveal business secrets and lead to unfair competition. New players could precisely analyze current MSPs and their activities to enter the market with advantages. Therefore, poorly designed open data access might cause the exact opposite of a fair level playing field. In addition, such an approach tends to concentrate MaaS on socio-economically relevant areas and is a source of danger regarding data privacy abuse. In order to avoid negative consequences sophisticated mechanisms are postulated.

Concluding, an open API paradigm is highly appreciated from an innovation and business perspective, but implicates also threats. Facing this dichotomy, Vollers, Berends and Carrara (2017) recommended to primarily develop an open data strategy that defines goals, scope and obligations. Independent from other issues, open APIs definitely drive MaaS as a market.

Main sources / further reading:
• **Experts:** Interviewee - MaaS operator (2018) and Local stakeholer #1 (2018)

• **Literature:** 6Aika (2016b): Open API recommendations for cities; Vollers, Berends and Carrara (2017): Analytical Report 6: Open Data in Cities 2.

4.2.5. Datainteroperability / Standards

#Stakeholder #Policy / Governance #Data

> Interoperable data and standardized APIs enable MaaS to scale and assure high performance. Industry consensus on standards are time and cost saving, and serve

> as multiplier. Its elaboration is a common responsibility for all stakeholders.

MaaS-related data interconnectivity entails the need for commonly used data formats, configurations and programming languages. Even though nowadays nearly all formats are readable and could be processed, harmonization causes effort and limits possibilities. In order to run a multi-stakeholder IT-system interoperable and highly performative, data and API standards are inevitable. Thus, lacking interoperability and standardization was indicated as a potential MaaS barrier (Interviewee - Academia, 2018; Interviewee - City administration, 2018; Karlsson et al., 2017; Smith, Sochor and Sarasini, 2017).

Furthermore, Interviewee - MaaS operator (2018) and MaaS Alliance (2018) mentioned that in some cases standardized open APIs are available, but certain features are missing or provided data is incomplete. Apparently, lack of interoperable data types is even used as excuse by various stakeholders for not participating in MaaS (Interviewee - City administration, 2018).

Referring to MaaS Alliance (2018), standards currently do not exist by now, which impedes to scale MaaS. Data harmonization is considered time and cost consuming. In addition, companies and public actors might be prevented in sharing valuable information due to missing interoperability.

MaaS front-runners are tackling deficient interoperability in different ways. MaaS Global provides documentation, configuration settings and system information openly accessible. Thereby, MaaS interested MSPs can easily set up an appropriate API provision. It further serves as transferable open innovation for other potential third-party service providers (Interviewee - MaaS operator, 2018; MaaS Global Oy, 2018a). Antwerp's city administration defined certain data standards and APIs for companies, which want to participate within the municipal mobility marketplace (Interviewee - City administration, 2018). MaaS Alliance (2017) proposed framing key principles for data interoperability, which should serve as orientation.

Interviewee - IT-Consulting (2018) and Local stakeholer #1 (2018) concluded that there are certain challenges in terms of datainteroperability, but all of them are solvable and assessed as minor issues. In gaining importance, appropriate MaaS standards are probably established within the next years. Nevertheless, in case of implementing a municipal MaaS scheme this issue should be explicitly taken into account.

In general, standardization requires collaborative efforts and open discussions on various levels (MaaS Alliance, 2017). MaaS advocates need to foster interoperable and widely used standards in order to thrive the whole approach.

Main sources / further reading:
• **Experts:** Interviewee - MaaS operator (2018), Interviewee - City administration (2018), Interviewee - IT-Consulting (2018) and Local stakeholer #1 (2018)

• **Literature:** Karlsson et al. (2017): Technology for MaaS; MaaS Alliance (2017): White Paper - Guidelines & Recommendations to create the foundations for a thriving MaaS Ecosystem; MaaS Alliance (2018): Data makes MaaS happen - MaaS Alliance Vision Paper on Data.

4.2.6. Promotional programs and incentives

#Policy / Governance #User

> Start-up grants, R&I activities as well as end user incentives serve as substantial MaaS drivers. Beside funding aspects, communication issues and public awareness are key issues. Promotional activities do not imperatively consist in direct financial support, also branding, campaigning and advisory packages are valuable measures.

All MaaS pilots presented in sections 2.4.1 to 2.4.4 arose from publicly funded R&I projects or at least received financial support in the initial stage. Thus, consensus exists on a supportive character of funding and incentivizing MaaS. Demonstration projects, strategic and conceptual elaborations as well as financial support are thriving immature innovation processes (Interviewee - Academia, 2018; Interviewee - City administration, 2018; Audouin and Finger, 2018a; MaaS Alliance, 2017).

Nevertheless, Audouin and Finger (2018a) referred to transition literature and its caution in terms of excessively funding single projects. Thereby, niche actors might be prevented from competing and MaaS development is limited to particular players.

To drive MaaS on municipal level Interviewee - City administration (2018) highlighted the importance of incentivizing implementations in an early stage – namely for MaaS actors as well as end users. By engaging companies providing MaaS solutions, Antwerp pursued an impact-related approach, wherein improvements regarding congestion or emissions need to be proven in order to obtain financial support. In order to engage end users, first MaaS-subscribers are awarded with cash-backs. By resigning their car in favor of MaaS, Antwerp's citizens obtain 20€ reduction for MaaS-subscriptions over two years.

Another way of governmental MaaS promotion consists in branding and communication aspects. Addressing MaaS-related brand awareness or enhancing public sensitization are activities, which do not subsidize MaaS actors or end users directly. Antwerp's city administration encourages visibility and perception in public and among industry partners. In addition, the municipality specifically advises start-ups in terms of marketing and communication. Also the establishment of an umbrella brand around MaaS or smart mobility and transport-related awareness raising through events and campaigns are considerable MaaS support (Interviewee - City administration, 2018; Hoadley, 2017).

Interviewee - Academia (2018) stated that redistribution of transport-related budget needs to be discussed in case MaaS is gaining importance. To unfold its whole potential, Li and Voege (2017) added that MaaS requires equal treatment to other public transport modes in terms of taxation and subsidies.

Main sources / further reading:
• **Experts:** Interviewee - Academia (2018) and Interviewee - City administration (2018)

• **Literature:** Audouin and Finger (2018a): Technology for Empower or Thwart? Insights from Vienna and Helsinki regarding the role of public authorities in the development of MaaS schemes; MaaS Alliance (2017): White Paper - Guidelines & Recommendations to create the foundations for a thriving MaaS Ecosystem.

4.2.7. Corporate mobility

#Policy / Governance #User

> MaaS and its characteristics matches with corporate mobility demands. Through substitution of company cars, MaaS acceptance and market entry could be significantly promoted. However, unequal taxation handling impedes overcoming private and corporate car-ownership.

Transition processes are mostly driven by particular change agents. Often, customized and service-oriented ICT approaches were initially adopted within corporate patterns – particularly in the case of economic sense. Due to flexibility and customization, MaaS perfectly fits to company needs and could be established as an enterprise-related offering. MaaS as a solution for employees might stimulate the market and enhance acceptability. It is further estimated that travel behavior is more likely to change outside of private mobility. In addition, transport aspects play an increasing role in the context of Corporate Social Responsibility (CSR) activities (Interviewee - Academia, 2018; Interviewee - City administration, 2018). Kamargianni et al. (2018) even expected significant advantages for companies in terms of tailored corporate mobility packages and cost savings.

Antwerp's project 'Smart ways to Antwerp' explicitly addresses employers. The municipality offers advice and training regarding corporate mobility issues. Also products like bike service boxes are provided. In addition, two applications from the project partner track are encouraged. Beside a Business-to-Business (B2B) MaaS solution, an app called TimesUpp warns of possible delays and suggests other departure times or alternative transport modes. Currently, already 80 local employers in the region of Antwerp are participating (Interviewee - City administration, 2018; City of Antwerp, 2018).

Not only public spending is subordinated by specific rules, but also taxation aspects. Nowadays, car-based commuting as well as company car-ownership is financially favored in many countries. Readjusting this issue towards shared, multi-modal mobility would promote MaaS and reduce car-dependency. Unless corresponding taxation and subsidies are modified, MaaS hardly gains relevant importance within corporate dimensions due to economic reasons (Docherty, Marsden and Anable, 2018; MaaS Alliance, 2017; Sochor et al., 2017a). In Belgium, new legislation is already being drafted that allows companies to deal with a multi-modal mobility budget equally to company cars (Interviewee - City administration, 2018).

Regime actors and car-industry influence is indicated as impeding factor for legislative adjustments. In most countries the corresponding law is out of municipal scope and need to be tackled on national level (Interviewee - City administration, 2018).

Main sources / further reading:
• **Experts:** Interviewee - Academia (2018) and Interviewee - City administration (2018)

• **Literature:** Docherty, Marsden and Anable (2018): The governance of smart mobility; City of Antwerp (2018): Smart Ways to Antwerp.

4.3. Sustainability criteria

While abovementioned prerequisites and drivers mainly refer to implementing and establishing MaaS, this section focuses on system design and features. As chapter 2.5

shows, those aspects are decisive regarding MaaS-related sustainability impact. Hence, analyzed and clustered indicators are depicted based upon interviews and literature review.

What entails a sustainable MaaS system? Referring to the study's problem statement (chapter 1.3), preliminary assessments (chapter 2.5) and Giesecke, Surakka and Hakonen (2016), it should be environmentally friendly in terms on local and global issues, economically viable, and socially inclusive. Referring to Sochor et al. (2017a), it can be further considered as a level 4 MaaS integration.

The fulfillment of some criterion might be difficult in an early stage and impede to scale up. To generate sustainable impact on long-term perspective, initial trade-offs could be unavoidable. Sustainable development itself expresses a process-related character. Nevertheless, the presented indicators are assessed as main contributor to a more sustainable transportation system in general and MaaS in particular.

4.3.1. PT as backbone

> To generate sustainable impact, PT needs to be the principal component covering the majority of MaaS-related trips. Its transport capacity, space efficiency and low emissions are indispensable for enabling sustainable mobility. However, serving as MaaS backbone comes along with certain PT-related preconditions.

Relating to sustainability criteria, interviewees and literature consistently identified extremely high relevance of PT within MaaS. It is by far the most mentioned sustainability promoting characteristic among all sources. In the context of urban transportation systems, PT's role is often described as 'backbone'. High transport capacity and low emissions are main reasons for its sustainability driving quality (Interviewee - Academia, 2018; Interviewee - MaaS operator, 2018; Local stakeholder #3, 2018; Local stakeholder #2, 2018; Matyas and Kamargianni, 2018; Smith, Sochor and Karlsson, 2017).

Average car-occupancy in highly developed countries is beneath two persons per vehicle, which results in low corridor capacity. This index indicates the maximum number of carried persons in one infrastructural direction per mode of transport. An urban one-lane street manages 2 000 - 5 000 travellers per hour. In contrast, PT's corridor capacity ranges from 9 000 (bus line) up to 80 000 (heavy rail transit) according to Figueroa et al. (2012, pp. 623). Due to the multiple transport capacity, mass-transit is competent to effectively tackle congestion and space-related urban issues. Certainly, active modes like walking and cycling are further components, but out of scope for long-distance commuting (Local stakeholer #1, 2018; Local stakeholder #2, 2018; Li and Voege, 2017).

PT subsystems (e.g. light rail transit, subway, etc.) mostly run on electricity and hence do not emit pollutants in urban areas. In addition, PT companies increasingly use renewable energy sources in order to decarbonize transport. Regarding emissions per capita, even railway and bus lines with combustion engine are low-emission modes of transport. Promoted EVs definitely improve local air quality, might address climate change, but neither enhance congestion problems nor space-related livability in the case of private ownership (Interviewee - Academia, 2018; Local stakeholder #2, 2018; Figueroa et al., 2012).

Aiming for societal goals and urban attractiveness in the context of a MaaS integration level 4, Sochor et al. (2017a) declared PT as decisive element. Thus, car use needs to shift significantly towards PT. Otherwise, Holmberg et al. (2016) and Hensher (2018) pointed out that MaaS could even affect sustainability negatively. Li and Voege (2017) even stated that in case of a non-adequate PT system, MaaS is not feasible.

Serving as backbone, PT service accounts for certain key requirements. Firstly, it necessitates high accessibility within the operational area. Secondly, to cover mobility needs in most instances a high PT service quality is inevitable. This includes well scheduled services with regular head-ways, comprehensive hours of business and high interconnectivity. Ultimately, PT should be capable to absorb additional capacities from private car use (Interviewee - Academia, 2018; Interviewee - IT-Consulting, 2018; Local stakeholder #2, 2018; Sochor et al., 2017a).

Routine trips should be largely realized by PT, while other MaaS components are considered to provide occasional travel needs. Concerning inter-modal mobility, Local stakeholder #2 (2018) assigned first and last mile to new MSPs, but with the intention to mainly improve PT accessibility.

Even though PT needs to accomplish being the backbone of an urban transportation system, it lacks in various aspects and requires appropriate supplement. The sustainability question is, if bundled MaaS offerings coherently complement PT or cannibalize its service (Interviewee - MaaS operator, 2018; Local stakeholder #2, 2018; Local stakeholder #3, 2018).

Main sources / further reading:
• **Experts:** Interviewee - Academia (2018), Interviewee - MaaS operator (2018), Local stakeholder #2 (2018) and Local stakeholder #3 (2018)

• **Literature:** Hensher (2018): Tackling road congestion – What might it look like in the future under a collaborative and connected mobility model?; Smith, Sochor and Karlsson (2017): Mobility as a Service: Implications for future mainstream public transport; Sochor et al. (2017a): A topological approach to Mobility as a Service – A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals.

4.3.2. All-embracing integration

> The more integrative MaaS is designed, the more sustainable impacted can be assumed. Not only the integration level itself is decisive, but also a high number of included modes and involved MSPs, as well as flexible options within certain modes are favorable.

The first aspect of this criteria refers to MaaS integration levels according to Sochor et al. (2017a). Based on preliminary studies, it is assumed that level 3 MaaS users are more likely to shift towards sustainable modes than without a single service offer. Moreover, monthly packages allow to incentivize walking and private bike use in contrast to pay-as-you-go models (Sarasini, Sochor and Arby, 2017). Survey respondents tended towards using modes of transport, which they never used before, in a subscription model. Also Matyas and Kamargianni (2018) suppose increasingly sustainable mobility behavior correlating with MaaS integration features.

MaaS as niche phenomenon does not unfold impact. An exceptionally sustainable MaaS system, which attracts only a small user group, would not solve any addressed issue. Contributing to sustainability, mass diffusion is necessary. According to Durand et al. (2018) as well as Kamargianni et al. (2016), MaaS becomes significantly more appealing to customers with higher integration. Improved convenience, extended choice as well as cost and time savings come along with at least level 3.

Interviewee - Academia (2018), Interviewee - City administration (2018) and Interviewee - MaaS operator (2018) emphasized the importance of a high number of participating MSPs. Certainly, as many modes of transport as possible should be covered. Especially, existing car rental was often mentioned to enable occasional day trips without private car-ownership. Beyond that, various MSPs of the same mode are appreciated from a sustainability perspective (Interviewee - MaaS operator, 2018). It would enhance availability, service coverage and costumer's value proposition. Varying MSPs fit to different needs or attract other societal groups to MaaS. However, Interviewee - Academia (2018), Local stakeholer #1 (2018) and Holmberg et al. (2016) noted that on the long run various MSPs of the same mode might cannibalize each other, which is critical from a business and competition point of view.

Stepping even into a smaller level of detail, Interviewee - IT-Consulting (2018) remarked wide-ranging product options within the context of particular modes. Lacking availability of child's seats, no vehicles permitted for pets or inappropriate cars for skiing trips are just a short selection of numerous individual barriers for using shared modes. Overcoming this issue through all-embraced, costumer-tailored offers would truly shift people away from private car-dependency. It is a challenging task and not feasible to realize overnight, but its fulfillment would enable MaaS to have a significant sustainability impact.

Main sources / further reading:
• **Experts:** Interviewee - Academia (2018), Interviewee - IT-Consulting (2018) and Interviewee - MaaS operator (2018)

• **Literature:** Durand et al. (2018): Mobility-as-a-Service and changes in travel preferences and travel behaviour: a literature review; Matyas and Kamargianni (2018): The potential of mobility as a service bundles as a mobility management tool; Sarasini, Sochor and Arby (2017): What characterizes a sustainable MaaS business model?;

4.3.3. Low-emission transit

> Preventing local pollutants and noise as well as tackling climate change, MaaS-related propulsion technology needs to be decarbonized.

Beside behavioural changes towards PT and active modes of transport, technology-based enhancements are inevitable. MaaS relies also on a car-based share, whose environmental impact should be reduced to the absolute minimum. Such transformation requires to continuously replace cars powered by combustion engines with EVs and Fuel Cell Electric Vehicles (FCEVs). Such substitution prevents locally emitted pollutants in urban areas and significantly reduce transport-related noise. Inhibiting climate change calls for further acquisition of renewable energy sources. Current, only partially convincing life cycle assessments in terms of electric mobility are expected to clearly improve due to future innovation and mass adoption (Interviewee - Academia, 2018; Local stakeholder #3, 2018; Giesecke, Surakka and Hakonen, 2016; Sochor et al., 2017a).

Low-emission goals not only applies to car-based services, but also for rail-borne transport and PT-related buses. Spreading of electric propulsion enables the creation of new transport services. E-scooters, pedelecs and e-kick-scooters are incrementally provided in urban sharing schemes. Those vehicles meet to full-fill specific mobility needs, but might substitute more sustainable modes on the opposite. For instance, pedelecs are promoted to significantly extend bike-associated distances and reduce physical effort, and hence might substitute car-based trips – independent from MaaS.

Nevertheless, new challenges arise from decarbonizing urban transportation systems. However, not only range is considered as a crucial barrier for urban trips, also lacking availability of charging infrastructure might impede EVs diffusion within MaaS. Assuring sufficient battery of free-floating vehicles necessitates additional service tasks and maintaining issues. Furthermore, limited hydrogen infrastructure for FCEVs is reported as a limiting factor (Local stakeholder #3, 2018; Hensher, 2018; Holmberg et al., 2016).

Decarbonized transport should be clearly favored within MaaS schemes in order to promote environmental sustainability. In this regard, incentives and subsidies are conceivable. The other way around, new business approaches and transport services are considered to unlock the general potential of EVs (Local stakeholder #3, 2018; Sarasini, Sochor and Arby, 2017).

Main sources / further reading:
• **Experts:** Interviewee - Academia (2018) and Local stakeholder #3 (2018)

• **Literature:** Giesecke, Surakka and Hakonen (2016): The potential of mobility as a service bundles as a mobility management tool; Sarasini, Sochor and Arby (2017): What characterizes a sustainable MaaS business model?; Sochor et al. (2017a): A topological approach to Mobility as a Service – A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals.

4.3.4. Regulation on MSPs

> Private MSPs need to operate under the terms of local regulation to enforce societal goals of MaaS. Discordance exists on how those rules are to be applied and executed. Preventing overregulation and pushing MaaS towards sustainability is a regulatory

> challenge. Data-driven approaches are stated as a promising mechanism, but not appreciated by all sources.

All interviewees agreed on MSPs regulating mechanisms, however their proposed intensity and design differed noticeably.

Shared mobility, DRT and ride hailing are essential MaaS components, which could contribute additional benefit. Nevertheless, too unregulated MSPs might undermine societal goals due to market forces and economic interests (Goodall et al., 2017). According to Local stakeholer #1 (2018), sustainable MaaS requires policy-makers to clearly enforce rules assuring systemic coherency. Such mechanism needs to link attractive operational areas and business hours with less lucrative assignments. Cannibalizing PT and other sustainable modes must be prevented in any case with appropriate control (Interviewee - IT-Consulting, 2018).

Many cities already limit vehicle number of MSPs or link it to operational area. Other municipalities appoint licenses similar to taxi admissions, often containing certain quality conditions. Even Antwerp, which is considered as open MaaS ecosystem, applies relatively strict rules in terms of shared modes facing very limited public urban space (Interviewee - City administration, 2018; Local stakeholder #3, 2018).

To contribute to sustainable mobility the urban transportation system as a whole needs to react dynamically to short-term influences and variations. During major events, stressing weather conditions or PT disturbances an extended offering by MSPs is beneficial. Therefore, Interviewee - Academia (2018) and Interviewee - IT-Consulting (2018) highly appreciated data-driven real-time approaches to enable high efficiency and dynamic system response. Primal mechanisms emerged recently, and many more are expected to come.

2014 the arrival of UBER in São Paulo, Brazil resulted in taxi driver protests and negative congestion impacts in the city center. Nevertheless, potential improvements through ride hailing were recognized. In order to positively complement São Paulo's transportation system, a credit system was established. Thereby, UBER drivers required purchased kilometer credits and corresponding MSPs were forced to provide all their data in real-time. The credit system was designed to explicitly promote trips during off-peak hours, in outskirts and with high occupancy rate. Due to political issues and design weaknesses, this data-driven regulation could not unfold its entire effectiveness, but clearly showed the potential of data-driven approaches (Interviewee - Academia, 2018; Audouin and Neves, 2018).

Even though existence of shared e-kick-scooters in Vienna was perceived quite positively, complaints regarding disturbances within pedestrian areas arose. In cooperation with local authorities, MSP defined non-parking streets and limited velocity zones. When entering such areas, the e-kick-scooter automatically decelerates to pedestrian compatible speed (Rachbauer, 2018).

An open MaaS platform would offer perfect conditions to implement data-driven regulation by authorities. Interviewee - Academia (2018) and Interviewee - IT-Consulting (2018) assessed publicly operated back-ends with data-driven regulation as powerful and promising tool in order to guarantee sustainability within MaaS.

Interviewee - MaaS operator (2018) and Local stakeholder #3 (2018) stated the need to proof impact of MSPs, but articulated doubts in terms of real-time data-driven control due to business secrets and competition issues. Regularly sharing insights on demand information and covered areas with local authorities is preferred, the same way the pioneering Finish Transport Code is dealing this issue.

In contrast, overregulation needs to be avoided to assure needful private sector participation. Since many MSPs struggle with profitability by providing shared modes and innovative offerings, defining appropriate rules poses a tightrope walk (Interviewee - City administration, 2018; Goodall et al., 2017; Montero, 2018). Hence, City of Antwerp tends to avoid regulatory declarations from the beginning, because they might exclude further possibilities. Formulating regulations are rather based upon empirical experience than assumptions and considerations. This 'learning by doing' approach aims to provide space for innovations and demonstration projects on smaller scale, but allows subsequent adjustments to exclude negative effects (Interviewee - City administration, 2018).

Main sources / further reading:
• **Experts:** Interviewee - Academia (2018), Interviewee - City administration (2018), Interviewee - IT-Consulting (2018), Local stakeholer #1 (2018), Local stakeholder #2 (2018) and Local stakeholder #3 (2018)

• **Literature:** Audouin and Neves (2018): What are the regulations for ICT-based mobility services in urban transportation systems? The cases of ride-booking regulation in Sao-Paulo and Rio De Janeiro; Goodall et al. (2017): The Role of Mobility as A Service in Mobility Management; Montero (2018): Regulating Transport Platforms: The Case of Carpooling in Europe.

4.3.5. Complementary transport actions

In order to unlock the whole sustainability potential of MaaS, consistent and complementary measures are necessary. Car restrictive policies are considered to promote sustainable urban mobility and MaaS at once.

MaaS might contribute to sustainable urban mobility, but is not an all-in-one solution to fix complex and many-sided weaknesses of current transportation systems. Coherent and comprehensive transport-related actions are required, and MaaS could represent one of them. Well-complemented measures are considered to reciprocally strengthen their impact. Thus, sustainability of MaaS is linked to general efforts in transforming urban transportation (Interviewee - City administration, 2018; Local stakeholder #2, 2018; Local stakeholder #3, 2018).

Since the overall goal of sustainable mobility is a high degree of urban livability, low-emission transport and reduced congestion, MaaS complementing actions should in particular address private vehicle traffic. Pricing of parking space and low-emission zones are commonly established in European cities. Facing serious transport issues, an increasing number of municipalities even applied a congestion charge (e.g. London, Milan, Stockholm) or even banned private car use entirely in city centers (e.g. Madrid). Such exemplified measures are highly effective in terms of sustainable urban mobility and would significantly favor MaaS. In addition, promoting actions for active modes (e.g. bike lanes) are favorable (Local stakeholder #2, 2018; Local stakeholder #3, 2018; Hensher, 2018).

Even though municipalities are in charge for local actions, their feasibility often depends on national legislation. This might prohibit certain tools. Another barrier consists in political reluctance in terms of car restrictive policies (Local stakeholder #2, 2018; Local stakeholder #3, 2018).

Local stakeholder #2 (2018) emphasized the need for coordinated planning and management to harmonize transport-related activities. Consistent actions require appropriate strategies and integrative planning. When developing new neighborhoods, area-specific mobility plans are nowadays well-established. Such interlocking approaches should be applied in more fields and municipal actions.

Also Interviewee - City administration (2018) highlighted that Antwerp is tackling this issue with over 40 different and wide-ranging measures, because MaaS is only considered as one component among many to enhance urban mobility. Beside ICT-related projects, a low-emission zone was established and cycling is heavily promoted. To ensure consistency, all transport-related actions are derived from a comprehensive transport strategy (City of Antwerp, 2018).

Main sources / further reading:
• **Experts:** Interviewee - City administration (2018), Local stakeholder #2 (2018) and Local stakeholder #3 (2018)

• **Literature:** Hensher (2018): Tackling road congestion – What might it look like in the future under a collaborative and connected mobility model?

4.3.6. User acceptability

> Enabling mass adoption, MaaS should provide an appropriate design addressing multilayer and user-friendly characteristics. Those quality elements refer to the registration process, front-end design, service performance, package offering and cost structure.

Even the most sustainability promoting transport characteristics within MaaS hardly unfold positive effects, if acceptability is lacking. Hence, this criterion focuses on user-side design and subsumes key elements, which thrives mass adoption (Interviewee - IT-Consulting, 2018; Interviewee - MaaS operator, 2018; Durand et al., 2018).

Relevant aspects are depicted into five categories. Their fulfillment might lead to conflicting interests in some cases. Ease-of-use and high customization can be mutually exclusive to some extent. Therefore, following characteristics are not indispensable for sustainability itself, their best fit and user-sided design support wide-spreading usage.

Registration and payment: According to Interviewee - IT-Consulting (2018), first contact and impression of an application is decisive for long-term usage. Before purchasing a single ticket or accessing a shared car, MaaS users need to register, authenticate driver's licenses, accept general terms and conditions as well as deposit a payment method. This starting process is irreplaceable and a usage barrier. Therefore, it should be uncomplicated and as easy as possible.

User effort and inconvenience needs to be minimized. Ideally, the above-mentioned process is undertaken once, and not for every participating MSP. However, it depends on the integration level and legal requirements. An appropriate Single Sign-On (SSO) might be a solution. Google, Facebook etc. provide such features to avoid register processes for third-party services. There are already intentions and first services aiming to apply this approach in other business fields. In the context of MaaS, it will probably play an essential role in future applications and Upstream Mobility is already tackling this issue (chapter 2.4.2) (Interviewee - IT-Consulting, 2018; MaaS Alliance, 2017; Kleinz, 2018).

Interviewee - IT-Consulting (2018) emphasized that developing the registration section deliberately and well-designed might cost half of the whole front-end effort from an IT-perspective. Unless, end-users might resign before using transport within MaaS.

Reliability and trust: Interviewee - IT-Consulting (2018) and Interviewee - MaaS operator (2018) mentioned reliability and trust as key issues for MaaS, which comes into effect in many aspects.

Transport-related trust and reliability comes with the certainty to be always and for every purpose covered. It refers to car-based options, PT punctuality and 24 hours service availability by taxi or DRT. Customers are even willing to pay significantly more for reliable service offers (Interviewee - IT-Consulting, 2018; Durand et al., 2018; Ratilainen, 2017).

Reliability and trust could also be improved through costumer support and information systems. Within the UbiGo pilot, users highly appreciated the service hotline (Karlsson, Sochor and Strömberg, 2016). Comprehensive information and adequate alternative routing in the case of disturbance are identified to gain reliability by Local stakeholer #1 (2018) and Karlsson, Sochor and Strömberg (2016).

Beyond regulatory terms, assured data privacy is a crucial factor to win confidence. Analyzing costumer data is helpful to improve service quality and identify customer needs. Abusive data relaying and commercial using of personal data should be omitted under any circumstances to guarantee trustworthy services (Interviewee - IT-Consulting, 2018; Interviewee - MaaS operator, 2018).

High internet security not only relates to data privacy, but also to service performance in general. For example, so called Denial-of-Service (DoS) attacks are assessed as potential threat within ICT-based transportation systems. A DoS attack aims to temporally interrupt a service and is mostly achieved by flooding the service with enormous amounts of service request to overload the IT-system (Yuan and Bayen, 2018). It is reported that some ride hailing companies were already affected by such DoS attacks. In addition, UBER lost information sets of 57 million drivers and users due to a data breach (Conger, 2018).

Disregarding negative headlines, Interviewee - IT-Consulting (2018) and Local stakeholer #1 (2018) emphasized that by applying certain security standards and accurate operation, the risk is relatively small. However, it entails appropriate cost and time. Maintaining internet security of a small system, takes already a day per month with screening and patching. Complex, multi-stakeholder systems in the case of MaaS require many times more security-related resources.

Usability: Since MaaS is a highly user-centered transport approach, usability is an important prerequisite to attract and retain customers. Intuitive design, sophisticated features and high performative IT-systems are considered as key elements. The whole customer journey containing routing, mode choice, booking, ticketing and payment should be seamless and uncomplicated (Interviewee - IT-Consulting, 2018; Interviewee - MaaS operator, 2018; Durand et al., 2018; MaaS Alliance, 2017).

Karlsson, Sochor and Strömberg (2016) mentioned ease-of-use for facilitating changes in travel behaviour according to their UbiGo evaluation. Interviewee - MaaS operator (2018) even stated 'top priority' in terms of user-experience for MaaS. Therefore, MaaS Global is partially perceived as a design and service company. Even small features can enhance usability. In the case of Antwerp's travel planner app, multiple language options (English, Dutch, French and German) significantly improved user-friendliness among Belgium's highly international audience (City of Antwerp, 2018).

Flexibility and customization: Several pilots, surveys and focus groups showed that flexibility and tailored service offering is top rated to adopt MaaS among users. An one-fits-all solution is not considered to be a successful system. Individual mobility is divers and requires user-tailored services. The current high usage of private cars resulted mainly from full-filling flexible and individual transport. In order to be mass-adopted MaaS needs to cover so far private car-related advantages (Interviewee - IT-Consulting, 2018; Haahtela and Viitamo, 2017; Durand et al., 2018).

In contrast to commercial MaaS systems, wherein the user can choose between two or three packages, participants of UbiGo were able to tailor their package individually. According to Karlsson, Sochor and Strömberg (2016) it was a decisive aspect for high satisfaction and more sustainable mobility behavior. This highlights the need for high level customization.

Some respondents of surveys also indicated they feel uncomfortable with subscriptions in general or trapped within an inappropriate package. Others reported worries to potentially run out of credit. Especially, elder people are reluctant towards subscription-based services (Kamargianni et al., 2018). Addressing this issue, Durand et al. (2018) proposed the possibility to easily change plans and to offer certain trialability introducing this new approach.

Pricing and convenience: Referring to Interviewee - IT-Consulting (2018) as well as Giesecke, Surakka and Hakonen (2016), mass adoption is mainly accomplished by price or convenience. Therefore, MaaS needs to be superior in at least one of them.

SP experiments and surveys conducted high price sensitivity among MaaS users (Matyas and Kamargianni, 2018; Ratilainen, 2017). Hence, tariffs and subscription pricing needs to be economically competitive to be customer attractive. Interviewee - IT-Consulting (2018) added that real cost structure of private car-use is widely unknown or not perceived. Only car purchase itself is noticed as high expenditure. For this reason, Interviewee - MaaS operator (2018) stated MaaS' potential in predominantly preventing people from car acquisition in short-term perspective.

However private car-ownership is continuously loosing its status symbol, PT or cycling is not considered to be quite convenient. MaaS rather provides a service-related convenience based on information, user-experience and flexibility. On front-end side, high data-driven convenience features within MaaS are expected in near future. For instance travel recommendations based on preferred modes, weather forecast and appointment calendar (Interviewee - IT-Consulting, 2018).

Main sources / further reading:
• **Experts:** Interviewee - IT-Consulting (2018), Interviewee - MaaS operator (2018) and Local stakeholer #1 (2018)

• **Literature:** Durand et al. (2018): Mobility-as-a-Service and changes in travel preferences and travel behaviour: a literature review; Kamargianni et al. (2018): Londoners' attitudes towards car-ownership and Mobility-as-a-Service: Impact assessment and opportunities that lie ahead; Karlsson, Sochor and Strömberg (2016): Developing the 'Service' in Mobility as a Service: experiences from a field trial of an innovative travel brokerage.

4.3.7. Nudging and gamification

> Service design should not only favor MaaS adoption, but also push users towards sustainable travel behavior. Nudging and gamification are two approaches aiming behavioral change through design and considered to enhance MaaS' sustainability impact.

Affiliating the previous indicator, this criterion emphasizes on additive features and design-enabled behavioral changes. Even if MaaS is widely used, sustainable modes needs to be favored, because mobility behavior is deeply linked to confirmed habits and framing conditions. Hence, mechanisms like nudging and gamification are assessed to support sustainable urban mobility (Interviewee - City administration, 2018; Durand et al., 2018; Sochor et al., 2017a).

Thaler and Sunstein (2008), who are dealing with behavioral economics, characterizes the dependency in people's decision process on psychological, cognitive, emotional and social factors. They proved that chosen options are often irrational, habit-based and favoring short-term advantages. One of those effects is called status quo bias, which psychologically proofs that people tend to prefer options they had already often chosen, even if alternatives are rationally more reasonable. Also Durand et al. (2018) identified behavior maintaining effects in reviewed MaaS surveys.

Intervening in this decision process through design-related modification, instead of choice limitation is called nudging. According to Thaler and Sunstein (2008, p. 15) a nudge is *"... is any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives. To count as a mere nudge, the intervention must be easy and cheap to avoid. Nudges are not mandates..."*. A famous example for nudging is the arrangement of food in supermarkets or cafeterias, and how this affects customer's decision.

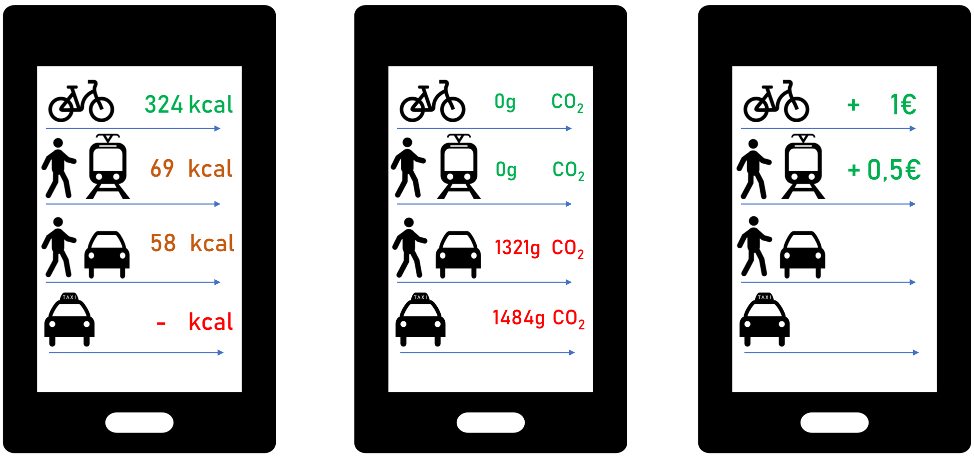

Figure 4.4.: Possible nudging approaches in MaaS front-ends (own elaboration)

Since MaaS is significantly amplifying customer's mobility choice, nudging might be a crucial mechanism towards sustainable travel behavior. In terms of MaaS, already some smaller nudges are applied. WienMobil provides the possibility to rank possible routes by CO_2-emissions in order to uncover GHG-emissions and promote sustainable choices in Vienna (Wiener Linien GmbH, 2018). The multi-modal travel planner Citymapper displays potentially burned calories of active modes to appeal health and fitness issues (Citymapper Limited, 2018). MaaS Global even wants to economically incentivize their customers for choosing sustainable modes in near future, because it is in their business sense (Interviewee - MaaS operator, 2018; González et al., 2017). Figure 4.4 exemplifies schematically the three abovementioned nudging attempts. So far, MaaS-related impact of those measures is vague, but Namazu, Zhao and Dowlatabadi (2018) proved in terms of car sharing that transport-related nudges have the potential to be quite effective.

"[The] the use of game design elements in non-game contexts" is often described as gamification, which is a similar approach to nudging and wants to appeal people's desires for socializing, competition and achievement (Yen, Mulley and Burke, 2018). Such motivations can be used for behavioral changes and encouraging sustainable modes. London's smart-card operator Oyster implemented a PT game to retain customers and award free bike sharing credits in cases of capacity limits. A controlled experiment in Rovereto, Italy demonstrated that gamification is able to shift towards sustainable urban mobility (Kazhamiakin et al., 2015).

Nevertheless, nudging and gamifaction are faced by criticism ranging from ineffectiveness to unethical manipulation. In any case, Yen, Mulley and Burke (2018) emphasized need for further research and development. Namazu, Zhao and Dowlatabadi (2018) stated that simply improving customer service might be more effective in some cases.

Main sources / further reading:
• **Experts:** Interviewee - City administration (2018)

• **Literature:** Kazhamiakin et al. (2015): Using Gamification to Incentivize Sustainable Urban Mobility; Namazu, Zhao and Dowlatabadi (2018): Nudging for responsible car sharing: using behavioral economics to change transportation behavior; Thaler and Sunstein (2008): Nudge: Wie man kluge Entscheidungen anstößt

4.3.8. Social inclusion and accessibility

> Sustainable MaaS systems are socially inclusive and do not discriminate any user due to external circumstances. Excluding obstacles for an all-including service range from lacking ICT-skills to physical barriers. Appropriate solutions exist, but

needs to be enforced and improved.

Addressing the social issues, a sustainable MaaS system should be equally accessible and usable by all societal groups. Transport-related exclusion can result from monetary issues, physical barriers, lacking skills or geographical inaccessibility (Giesecke, Surakka and Hakonen, 2016; MaaS Alliance, 2017).

Durand et al. (2018) assessed lacking ICT-skills of elderly people as main risk in a MaaS-related exclusion. This digital divide needs to be tackled clearly. Due to customization, enhanced information and extended mode choices, physically disabled person are considered to be well addressed by MaaS.

Potentially geographical exclusion depends on system architecture and MSP regulation. A purely market driven MaaS system would probably limit its operational area to economic viable neighborhoods (Local stakeholer #1, 2018). On the other hand, rural and poorly populated areas can hardly be operated with profit by MSPs. Hence, Li (2018) considered the municipalities to be responsible in assuring services for the public and establishing appropriate policies and actions.

The City of Freyung with only 7 000 inhabitants provides a best practice example for social inclusion. Within the rural, administrative area, a DRT system was established entailing 230 virtual pick-up points. From a regulatory point of view, it was classified as bus route and receives public subsidies to largely ensure operational costs. Thereby, service price is also equal to conventional PT. For less ICT-skilled users, the service is additionally bookable through a service hot-line. Within this ICT-related transportation project City of Freyung covers all major inclusion aspects (City of Freyung, 2018).

Main sources / further reading:
• **Experts:** Local stakeholer #1 (2018)

• **Literature:** City of Freyung (2018): FreYfahrt: Shuttle für Freyung; Giesecke, Surakka and Hakonen (2016): Conceptualising Mobility as a Service.

4.4. Summary and overview

Table 4.2 presents an overview of minimum prerequisites concerning municipal MaaS schemes, which are largely interdependent. Four out of six requirements are labeled with stakeholder aspects, which concurs to the overall interviewee assessment. All consulted experts considered stakeholder issues as key part for MaaS development. Even though this study focuses on municipal schemes, elaborated prerequisites point out that not all mandatory elements could be concerned on local stage.

Table 4.2.: Key prerequisites of MaaS schemes

Precondition	Category	Description
System architecture & business operator model	#Stakeholder #Business model #Policy / Governance	*Determination of framing system and public role as well as development of viable business model for economic profitability*
Collaboration readiness	#Stakeholder #Business model	*Securing multi-stakeholder cooperativeness and defining how to handle costumer ownership*
Multi-modal and digital mobility services	#Stakeholder	*Existence of wide-ranging and multi-modal MSPs with digital access provision*
Data availability and integration	#Stakeholder #Data	*Technically enabled real-time system interconnectivity by APIs and appropriate data sets*
Network coverage and internet	#User #Data	*Assured user accessibility through pervasive and qualitative internet availability*
Legal requirements	#Policy / Governance	*Ensuring compatible regulations for MaaS-related businesses and data processing*

Table 4.3 clearly highlights MaaS' collaborative character and its complexity as socio-technical approach. All drivers entail policy and governance elements and the majority is labeled with stakeholder issues. According to elaborated requirements and drivers, a MaaS implementations not necessarily demands high collaboration intensity by the public sector, but definitely drives its progression significantly. In overcoming traditional patterns and pushing disruptive innovations, multi-sided efforts and learning effects are favorable – in terms of technical, economical and political issues.

Table 4.3.: Drivers for MaaS development

Driver	Category	Description
Leadership	#Stakeholder #Policy / Governance	*MaaS commitment by visible front-runners for public promotion and discourse*
Coordinating and administrative unit	#Policy / Governance	*Well coordinated competences and activities accelerate and drive MaaS developments*
Common vision	#Stakeholder #Policy / Governance	*Commonly shared visions (e.g. municipal MaaS strategy) serve as value-based guidelines for public and private actors.*
Open APIs / open data	#Stakeholder #Policy / Governance #Data	*MaaS-related APIs, which publicly accessible and usable by third-parties push MaaS as a market and drive innovation*
Datainteroperability / Standards	#Stakeholder #Policy / Governance #Data	*Interoperable data and standardized APIs enable MaaS to scale and assure high performance*
Promotional programs and incentives	#Policy / Governance #User	*Start-up grants, R&I activities as well as end user incentives substantially thrive MaaS. Also branding, campaigning and advisory are supportive*
Corporate mobility	#Policy / Governance #User	*Through substituting company cars, MaaS acceptance and market entry could be significantly promoted*

As sustainability itself, criteria of table 4.4 are manifold concerning transport-related, technical, economical, regulative, planning, behavioral and social aspects of MaaS. While some of them explicitly focus on system impact (e.g. PT as backbone, low-emission transit), other rely on diffusion effects to gain importance and actually generate any impact (e.g. user acceptability). Hence, it refers to general sustainability assessment. Beside multiple content-related aspects, it mostly entails bi-dimensional impact evaluations – quantitative and qualitative.

Table 4.4.: Sustainability MaaS criteria

Criterion	Description
PT as backbone	*PT needs to be principal component covering the majority of MaaS-related trips. Its transport capacity, space efficiency and low-emissions are indispensable for enabling sustainable mobility.*
All-embracing integration	*The more integrative MaaS is designed, the more sustainable impacted is assumed. Also high number of included modes and involved MSPs as well as flexible options are supportive.*
Low-emission transit	*Preventing local pollutants and noise as well as tackling climate change, MaaS-related propulsion technology needs to be decarbonized.*
Regulation on MSPs	*Private MSPs needs to operate under the terms of local regulation to enforce societal goals of MaaS without overregulating and impeding MaaS development*
Complementary transport actions	*In order to unlock the whole sustainability potential of MaaS, consistent and complementary transport-related measures are necessary.*
User acceptability	*Enabling mass adoption, MaaS should provide an appropriate design addressing multilayer and user-friendly characteristics*
Nudging and gamification	*Using behavioral economics MaaS' design should promote decisions towards sustainable modes of transport*
Social inclusion and accessibility	*Sustainable MaaS systems are socially inclusive and do not discriminate any user due to external circumstances*

5. Conceptual design of for the City of Munich

While the previous chapter elaborates general findings on MaaS prerequisites, drivers and sustainability criteria, this segment focuses on local specifics and conditions for the city of Munich.

It responds to RQ 3 by defining local MaaS objectives, analyzing the status quo and proposing a design guideline with related recommended actions. In the beginning, the applied conceptual procedure is depicted with method and content-based characteristics. The four phases of the framework elaboration are described in the following sections 5.2 - 5.5.

This chapter's content is highly relevant for MaaS in practice. It transfers comprehensive, scientific findings into an applicable and action-based concept. Through a design framework and proposed actions, strategic as well as activity-oriented aspects of a MaaS implementation are addressed. Therefore, this chapter might serve as a valuable and guiding source for MaaS developments in Munich.

5.1. Approach and conceptual process

So far, municipal MaaS-specific frameworks do not exist, and hence no established procedure can be derived. If at all, MaaS is treated in a more general transport strategy or policy. Only Kamargianni et al. (2015) elaborated a conceptual MaaS framework for the City of London, but rather focused on feasibility aspects than design elements. Supposedly, some cities are currently drawing local MaaS concepts, but none of these is publicly released.

Hence, the applied procedure in this study adapts partially methodology and elements of London's feasibility study by Kamargianni et al. (2015) and other transport-related municipal frameworks. The conceptual process consists of four essential steps: goals, analysis, design and actions. The conducted sequence is illustrated in figure 5.1 including the considered input of each particular stage.

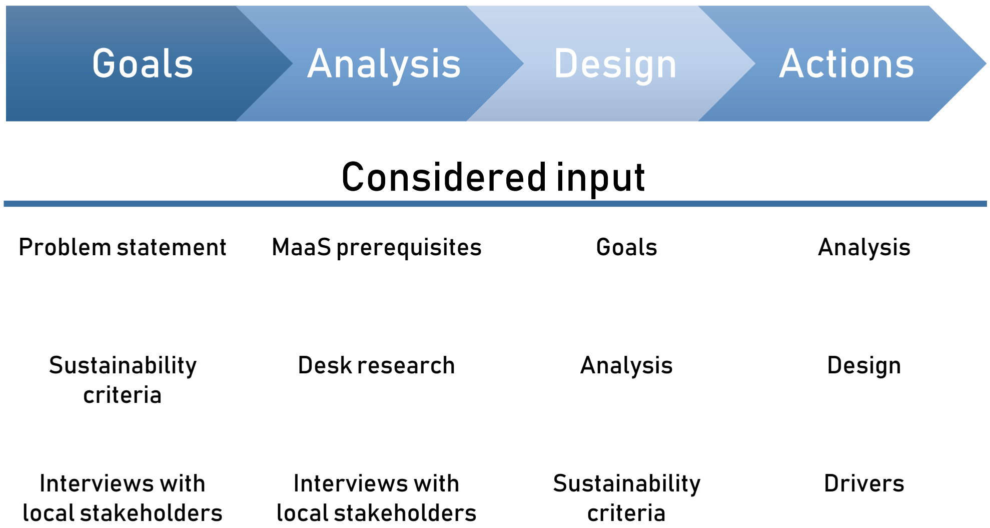

Figure 5.1.: Conceptual process for MaaS framework

Firstly, principal objectives are defined, which respond to problems Munich is facing and determine desired effects through a MaaS implementation. Relevant impact dimensions are derived from elaborated sustainability criteria (chapter 4.3). Followed by a section analyzing local MaaS conditions. This includes existing city strategies as well as transport-related visions, state of MaaS mandatory precondition according to chapter 4.1 and possibly relevant stakeholders. Beside the general prerequisites, it mainly considers interviews with local stakeholders and a further desk research.

The proposed design guideline in section 5.4 already presents a result with added value. It incorporates goals, the conducted analysis as well as elaborated sustainability indicators. Linking proposed design elements with the current status quo (section 5.3) and complemented by general MaaS drivers, a set of favorable action proposals is deduced.

5.2. Goals

The purpose and objective of a MaaS system needs to be defined on the basis of fundamental questions: What challenges should be addressed? Which impact is desired? Which negative concomitants should be prevented?

Since the scheme should contribute to the enforcement of societal goals, it can be in any case considered as a level 4 integration according to Sochor et al. (2017a). In order to specify MaaS-related goals for the city of Munich, several sources are considered. In the first place, local challenges and problems stated in chapter 1.2 and 1.3. Complemented by information and assessments which were assembled through interviews with local stakeholders (chapter 3.3.3). The third part consists in the elaborated sustainability criteria for MaaS schemes (chapter 4.3). These reveal potential MaaS-related impacts, sustainable characteristics and counterproductive threats.

Especially from a transportation point of view, the two core challenges are congestion and air quality. If continuing with business-as-usual, both are considered to get even worse. Demographic and economic growth in Munich's metropolitan area is a main driver and focuses more and more towards suburban municipalities. Acknowledging that transport is the only sector without reductions in terms of GHG-emissions, rises the need for a game-change regarding climate protection.

In addition, citizens tend to progressively claim urban space for non-transport-related purposes and aim for livable neighborhoods. This also includes transport-related noise, which is assessed as urgent problem. In comparison to other municipalities, social inclusion and accessibility is relatively well-covered. Though, those aspects might suffer from ICT-driven, disruptive transport approaches and have to be taken into account – particularly concerning flexible and individual lifestyles as well as working conditions.

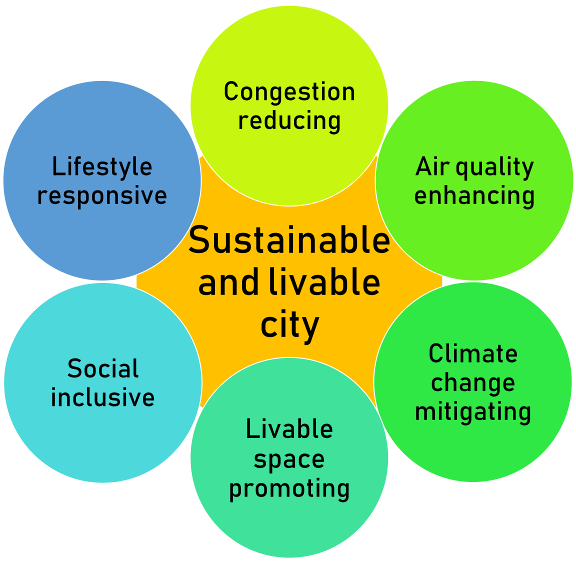

Figure 5.2.: Core objectives for a MaaS scheme

Coping those challenges, sets the necessity for a sustainability-oriented system. The following objectives for a MaaS scheme in Munich can be subsumed under the overall goal of a sustainable and livable city development and are illustrated in figure 5.2.

Tackling congestion: MaaS in Munich contributes explicitly to overcome road congestion and PT bottlenecks. It reduces car-dependency and simultaneously assures to cover all mobility needs – in the city and in its suburban areas.

Enhancing air quality: Munich-based MaaS scheme significantly improves air quality and avoids emissions of hazardous pollutants – especially in highly dense urban areas.

Mitigating climate change: It notably reduces transport-related GHG-emissions to inhibit global climate change. Low-emission and renewable energy are substantial elements.

Enabling livable public space: MaaS accounts for facilitating conversion of transport-related urban space towards livable neighborhoods and housing.

Assuring social inclusion: Implemented services cover all societal groups and are accessible by anyone – in terms of economic, physical, geographical and skill-related issues.

Coping with flexible lifestyles: MaaS adopts to increasingly flexible living and working conditions, without restricting convenience and service quality.

5.3. Analysis

After determining goals for a sustainability-oriented scheme in Munich, the status quo needs to be captured in order to properly design and channel MaaS. Moreover, framing conditions are examined. This section deals with the following questions: What is the current state of MaaS prerequisites in Munich? What are developments and processes to be considered? Who are relevant MaaS actors? What are municipal goals in MaaS-related fields? Are there already ongoing MaaS-like initiatives and projects?

Beside the elaborated, needful preconditions from chapter 4.1 and interviews with local stakeholders (chapter 3.3.3), further desk research was indispensable to accomplish the analysis. Firstly, MaaS-related municipal strategies and visions were reviewed. Secondly, current state of MaaS prerequisite was analyzed and related developments were explored. The third and fourth part identified MaaS-related initiatives and stakeholders, who might be involved in a local MaaS scheme. A final conclusion summarizes and interprets the conducted analysis.

Back coupling, linking and complementing between following segments was inevitable. Thus, these subsections are not built on each other. The given structure arises on content and contains inevitably doublings at some points.

5.3.1. City vision and strategy

Within a city development guideline, certain superordinate principles are defined that serve as guidance for sectoral actions. Beside universal values like equity, openness, participation, etc., more specific and transport-related aims are declared. Those consist in assuring and improving inclusive mobility, prioritizing environmentally friendly transport and fostering traffic reduction. Also the attractiveness of urban spaces and responsibility in climate protection are explicitly mentioned (City of Munich, 2015).

In terms of transport and mobility, the City of Munich addresses MaaS-related topics through multiple actions programs and planning activities. Containing for instance a PT plan, a masterplan for transport and traffic, a city development program, an anti air pollution scheme or a walkability map. Often, connected mobility and ICT-driven measures are proposed, but due to recent emergence, MaaS as an explicit transport measure is not considered among Munich's city plans (Local stakeholder #2, 2018).

A transport-related city vision elaborated by a private public consortium called Inzell Initiative (section 5.3.3) largely picked up MaaS promises. The vision 'Modellstadt 2030' depicts highly attractive urban spaces in Munich's city center, well supplied local neighborhoods and high interconnectivity within the entire region. Characterized by multi- and inter-modal mobility behavior, integrative information- and ticketing option and PT as central element. Even a digital mobility platform is emphatically addressed (Inzell Initiative, 2018).

The City of Munich acts quite ambitious in terms of climate protection and reinforced its GHG-reduction aim. Declaring CO_2-neutrality by 2050, the city council even leveraged 2030 targets (Stadtrat der Landeshauptstadt München, 2018, p.11). An expert report published by the city administration suggested traffic-reduced city planning, enforcing sustainable modes of transport or behavioral changes as effective actions regarding transport-related climate protection (City of Munich, 2018). Although transport accounts for large share of Munich's CO_2 footprint (Stadtrat der Landeshauptstadt München, 2018, p.20), realized measures under the integrated action program for climate protection are inadequately addressed.

5.3.2. Status of prerequisites and related developments

Initially, assembled MaaS requirements are evaluated for the case of Munich. Complemented by further relevant aspects and influencing developments.

System architecture & business operator model: Currently, there is no discussion or dialog about MaaS in Munich – at least not in public. Possibly, several organizations are dealing with MaaS behind the scenes, but no visible process is identifiable. Thereby, determination of system architecture and business operator model is far-off or managed behind closed doors.

As of late, Munich's PT company is operating an own DRT system and expanded its service. Its white label solution for bike sharing is still the only one, which is not accessible by other customers of the same provider in Germany (Local stakeholder #2, 2018). They are considered as quite data protective and were not available for a MaaS-related interview. Those circumstantial evidences suggest that the local PT is at least not favoring an aggregator / broker model.

Beside the fact that viable MaaS business models are lacking in general and compromise a barely full-filled issue, this MaaS requirement is not complied in Munich.

Collaboration readiness: Proved by various European examples, private MSPs are considered to be relatively open for the collaborative business approach of MaaS. Some in Munich operating MSPs are already part of MaaS integration in other cities. Local stakeholder #3 (2018) declared private MSPs to be comfortable with MaaS under appropriate conditions. CleverShuttle is going to be integrated in various MaaS applications in 2019. on a long-term perspective, even to be totally merged into a subordinate MaaS service is a considerable option for the start-up. Assuming a transferability to similar companies, MSPs tend to welcome MaaS in general.

However, in the most cases of involved MSPs, integration is not superior to level 2 and all actors manage customer relation by their own. Dealing with this issue, might impede their attitude towards MaaS in Munich. Possible business alliances among transport players are another concerning influence.

Even though local PT apparently shares the same transport-related vision with many actors, it is contemplated to be quite unwilling in terms of a MaaS collaboration due to comprehensive data protectionism and stringent business interests. (Aaltonen, 2017) showed significant backlog demand in Munich's shared use of PT and stated no active collaborative connection with other transport players.

Although administrative and political actors articulated some concerns and threats towards MaaS, they are assessed to be partially ready for a MaaS collaboration, as long as it contributes contribute to societal goals.

Munich satisfies this requirement to some extent, but definitely demands higher collaborative readiness for a MaaS implementation.

Multi-modal and digital mobility services: Section 5.3.4 largely covers this criterion and reveals the wide range of locally operating MSPs. Beside PT, Munich's transport supply covers car sharing, car rental, e-scooter sharing, bike sharing, cargo-bike sharing, DRT, conventional taxi as well as ride hailing. Most of these modes entail various operators.

The vast majority provides digital services and front-ends to access their service via smart-phone. Since providing shared modes is an immature market, some MSPs already stopped their operation. Thanks to an appropriate socioeconomic ambience in Munich, the bottom line is that more and more services and modes are operational in Munich and spatial coverage increases steadily. MVG Bike is expanding its operation even in municipalities of the rural district of Munich (MVG, 2018). This assumes the precondition as accomplished for the most part.

Data availability and integration: Aaltonen (2017) evaluated MaaS readiness of four European cities. Due to a lack of transport-related data platform, this criterion was rated with zero out of five points in Munich. Beside platform inexistence, private as well as public transport operators are considered to be quite data protective – especially in an international context. MaaS-related data is hardly shared among stakeholders in Munich (Interviewee - IT-Consulting, 2018; Local stakeholder #2, 2018; Local stakeholer #1, 2018). In the context of a gap analysis regarding smart and connected mobility, Münchner Kreis e.V. (2017a) expressed substantial drawbacks in terms of transport-related data issues beyond Munich's borders.

Nevertheless, there are several promising activities going on. Both projects, Smarter Together as well as VVDM (section 5.3.3), deal explicitly with MaaS-related issues. In this context not only multi-stakeholder platforms are established, but also indispensable MaaS skills are acquired. Those contain technical aspects like datainteroperability, information processing and storage, but also conceptual and legal aspects (e.g. regulation on data access among multiple stakeholders). Complemented by an incremental importance of data-related issues on strategic level expressed by relevant actors in Munich (e.g. Inzell Initiative, Münchner Kreis), rapid progression might happen. However, political decision-makers are largely considered as little engaging in data related fields (Local stakeholder #2, 2018; Local stakeholer #1, 2018; Inzell Initiative, 2018; Münchner Kreis e.V., 2017a).

In the future, a regulatory framework might control provision of relevant PT data. The European PSI-directive handles digital information which is generated by the public sector. In order to facilitate new technologies like artificial intelligence and economic growth, EU commission aims to extend open access to public data. A proposed revision of the PSI-directive also includes wide-ranging PT data, if it is run publicly (European Commission, 2018a). Fearing powerful players of the private sector, various German PT companies expressed an urgent reminder to the Federal Ministry of Transport and Digital Infrastructure in Germany to put pressure on political decision-makers (Frankfurter Allgemeine Zeitung, 2018). At present, progression of this future EU-legislation is unpredictable.

However, Munich's data availability and integration is not given, there are progressing developments with good prospects in all facets – disregarding the political dimension.

Network coverage: Within the city center sufficient network coverage is provided to large extents, but serious deficits are reported regarding Munich's direct surroundings incorporating 3G as well as 4G networks. However, significant differences can be identified in terms of different mobile communication operators (Local stakeholer #1, 2018; OpenSignal, 2018).

State and federal government are in charge of extending and improving mobile communication. Munich as a municipality does not have direct intervention options. By providing more and more WLAN hot-spots on significant locations as well as on-board of PT vehicles, Munich's city administration aims to tackle this issue (Local stakeholer #1, 2018).

Since mobile communication networks are mainly addressed on a national level, corresponding ratings and reports consider primarily cross-national comparisons. In the European context, OpenSignal (2018) and research (2018) revealed Germany's miserable status in terms of network coverage, transmission speed and pricing. In all those criteria, Germany ranks in the last third among European countries. Contrariwise, Finland not only acts as MaaS front-runner, but also holds a leading role in mobile communication. Despite its low population density, high speed networks are wide spread and mobile data caps as well as prices are multiple times more user-friendly than in Germany. In Finland, mobile data usage per average is almost as high as a typical consumption of residential German internet usage. Moreover, the world's first commercial 5G network is installed in the metropolitan region of Helsinki.

Germany's auction of 5G frequencies, taking place in 2019, is linked to tightened coverage obligations. Especially, railways and major roads are considered to be better covered, which possibly will enhance Germany's unprogressive status quo in mobile communication within the next years (Briegleb, 2018).

Concluding, network coverage in the city of Munich shows some shortcomings, but it is mostly provided within the operational area of the most MSPs. In particular, Munich's surroundings have a lot to catch up regarding mobile communication networks and are partially unprepared for a comprehensive MaaS scheme.

Legal requirements: Chapter 4.1.6 clearly states vagueness and wide-ranging uncertainties regarding MaaS's legal feasibility, which also applies for Munich. Elaborating detailed regulatory conditions for MaaS in Munich exceeds this study's scope.

Local stakeholder #2 (2018) highlighted a fundamental issue Munich is facing in regulatory aspects, which consists in its municipal status. While big cities as Berlin and Hamburg are capable to intervene in state competences, Munich acts within municipal legal boundaries. In enabling innovative approaches, this might come along with additional barriers.

Apart from a revising PSI-directive, further legislative adaptions are favoring MaaS by trend. There is consensus that the German law on passenger transport needs to be revised to cope with recent developments and ICT-driven approaches. Its adaptation is further expressed in the coalition agreement of the federal government and tends to explicitly incorporate approaches like ride hailing and DRT, which are currently not considered. While in other European countries sharing systems of e-kick-scooters are already operational, this vehicle type is incompatible with German law. Due to legal adjustments, such sharing schemes are likely to be installed in Germany, extending the possible modal range of MaaS in Munich (ARD, 2018; Gies and Lindlof, 2018; Meck, 2018).

5.3.3. MaaS-related initiatives and projects

This section aims to reveal Munich-based initiatives as well as R&I projects, which are already engaged in related fields. Although they deal with innovative and disrupting approaches within transportation, none of those is currently acting as an explicit MaaS promoter. Though, by placing the topic on the agenda, these players and formats could play an essential role in driving MaaS. Such initiatives often serve as breeding ground and multiplier for innovations and actions on local level. Due to its multi-stakeholder attribute, MaaS is predestined to evolve from suchlike constellations.

Inzell Initiative: A public private cooperation founded in 1995 by BMW and the City of Munich, which nowadays incorporates decision-makers from politics, business, research and the non-governmental sector. It serves as an open working platform for transport-related issues in Munich. The Inzell Initiative aims to enable dialogue and information exchange for a diverse stakeholder constellation. Within this collaborative forum, participants identify important challenges, initiate projects and measures, and use the initiative as networking stage.

In order to address specific fields appropriately, six focus themes were formed on: electromobility, delivery traffic, parking space, company mobility and traffic outside city limits. Working groups elaborate policy guidelines and potential solutions on corresponding challenges.

Besides various pilot projects on innovative concepts, the Inzell Initiative collaborated to a large extent in transport-related vision processes, which are presented in section 5.3.1 (Mailer et al., 2014; BMW AG and Landeshauptstadt München, 2018).

Europäische Metropolregion München (EMM): To coordinate and collaborate activities on larger spatial scale, this platform unifies players from the whole metropolitan area. The association consists of 25 counties, 6 cities and nearly 40 county communities as well as actors from industry, science and several NGOs. Declared main objective is a "*sustainable economic development in harmony with nature and the environment*" (Europäische Metropolregion München e.V., 2018).

EMM organizes events, elaborates policy recommendations and commissions relevant studies. Facing rapid growth in terms of population and economy in the whole region, a working group on mobility was created, which in particular focuses on commuters' travel, urban-rural relations and interconnectivity. In 2018, the first metropolitan conference on mobility took place (Europäische Metropolregion München e.V., 2018).

Digital Hub Mobility: The Federal Ministry for Economic Affairs and Energy established various sector-specific innovation centers in Germany to promote digital developments and connect relevant stakeholders. The so called Digital Hub for mobility-related issues is located in Munich and coordinated by the entrepreneurship center of the Technical University of Munich. Beside serving as network and advisory service for digital mobility, it is actively engaged in various projects (Bundesministerium für Wirtschaft und Energie, 2018; UnternehmerTUM, 2018).

Münchner Kreis: As a non-profit-making association Münchner Kreis acts as interdisciplinary competence platform for digital transformation. It organizes conferences and networking events as well as conducts studies and vision processes. One working group explicitly engages in smart and connected mobility and consists of decision-makers from academia and the private sector. Its released future study 'Zur Zukunft der Mobilität 2025+' analyses shortcomings and provides action recommendations for a successful digital transformation within the transport sector (Münchner Kreis e.V., 2018; Münchner Kreis e.V., 2017b).

Smarter Together: It is a R&I project funded by the EU with Lyon, Vienna, Munich as lighthouse cities. Smarter Together focuses on smart city demonstrations and field tests for new technologies. Within the project area in western Munich, several mobility stations are installed and new sharing modes are tested. Central element is a smart data platform, which collects, stores and distributes smart city information. In order to handle multi-stakeholder access, transparency issues as well as data privacy, a data gatekeeper function is developed and applied (Local stakeholder #2, 2018; Local stakeholer #1, 2018).

VVD-M: Inspired by Singapore's transport data platform, this project aims to improve data availability in Munich for management and planning purposes. Among others it involves several city departments, Digital Hub Mobility, Münchner Verkehrsgesellschaft (MVG), BMW and the Technical University of Munich. The platform should provide comprehensive transport data from various stakeholders to run traffic models and enhance knowledge basis for decision-making. Three stakeholder circles for data access define levels of obligation and competence. Gained knowledge from Smarter Together's data gatekeeper function is proposed to use ensuring multi-stakeholder compatibility. However it primarily focuses on public sector planning and controls, in a long-term perspective this platform might open up for MSPs. The project was explicitly initiated by political actors of Munich's city council (Local stakeholder #2, 2018; Local stakeholer #1, 2018).

TUM-LLCM: Supporting digital transformation in transport from an academic point of view, the project Living Lab Connected Mobility (LLCM) conducted transport-related IT research. Various transport and IT chairs of the Technical University of Munich studied and developed smart mobility issues like platform architecture, data analytic, service monitoring and security engineering. In addition to scientific work, LLCM aimed to link-up several enterprises and actors to establish a smart mobility ecosystem in Munich. The project was initiated by the Bavarian Ministry of Economic Affairs, Regional Development and Energy and ended in 2018 (Amini et al., 2017).

MaaS-like applications: Some MaaS-like front-ends are already available in Munich, which can be considered as a partial level 2 integration. MVG provides an app for its bike sharing scheme including information and booking functions on car sharing vehicles, parking lots, taxi stops and charging points (SWM Services GmbH, 2018). Beside PT routing and ticketing, the local DB app 'München Navigator' provides live tracking of suburban trains and maps available vehicles of the company-owned sharing system Flinkster and Call-A-Bike . Those public front-ends are complemented by 'Free2Move', which bundles several MSPs incorporating car sharing (peer-to-peer, free-floating and station-based), bike sharing, scooter sharing DRT. However the user has to maintain separate accounts for each included MSP, Free2Move offers to carry out additional registration processes (Free2Move, 2018).

5.3.4. Local stakeholder

This section briefly names possibly relevant actors of a Munich-based MaaS system. Ranging from PT and MSPs to local authorities.

One of the most important players is the organization Münchner Verkehrs- und Tarifverbund (MVV) which coordinates and manages all PT-related transport in the region of Munich. It further ensures uniform tariffs and ticket validity across incorporated providers. Counting two public transport providers MVG (subway, light rail transit and bus) and DB (suburban transit and regional rail) as well as private operators (Alex, BOB, privately operated bus routes and taxi companies). The organization is assembled by representatives of Bavarian State, City of Munich and bordering counties (Münchner Verkehrs- und Tarifverbund, 2018).

Furthermore, MaaS would affect several resorts within Munich's city administration. In particular, traffic planning and management and regulatory agency, which deals with permits, concessions and compliance with local prescriptions. Also city planning, the environmental agency and other local authorities might be alluded.

In case of Vienna, technical issues like mobility platform and IT-structure is completely handled by local authorities (Interviewee - IT-Consulting, 2018). Commonly, private actors providing IT-infrastructure are considered to play a role within a municipal MaaS scheme (Holmberg et al., 2016). Also in the context of the Smarter Together project (section 5.3.3), City of Munich is in charge of the platform, but it is technically operated and provided by a private company (Local stakeholer #1, 2018). Thus, a platform provider is likely needful. Due to the ongoing MaaS hype, such specific service companies are currently emerging in several European countries.

Table 5.1.: Operational transport services in Munich. (Source: Information is based on corresponding web pages and smart-phone applications, hence no further citation is provided)

Transport company	**Mode**	**Type**	**Smart-phone app**
MVG (public)	PT		✓
DB (public)	PT and rail		✓
Alex	rail		
BOB / Meridian	rail		✓
DriveNow	Car sharing	free-floating	✓
Car2Go	Car sharing	free-floating	✓
STATT AUTO	Car sharing	station-based	✓
Flinkster	Car sharing	station-based	✓
Drivy	Car rental	peer-to-peer	✓
Oply	Car rental	neighborhood-based	✓
Sixt	Car rental	station-based	✓
Hertz	Car rental	station-based	✓
Europcar	Car rental	station-based	✓
Emmy	Scooter sharing	free-floating	✓
MVG Bike (public)	Bike sharing	free-floating	✓
Call-a-Bike (public)	Bike sharing	free-floating	✓
Donkey republic	Bike sharing	free-floating	✓
LastiBike	Cargo-bike sharing	station-based	
Freie Lastenradler	Cargo-bike sharing	station-based	
MVG Tiger (public)	DRT		✓
CleverShuttle	DRT		✓
UBER	Taxi / DRT		✓
Taxizentrale München	Taxi		✓

Table 5.1 shows an overview of operating transport providers in Munich. The listing does not claim to be complete, rather intents to illustrate high stakeholder diversity and wide-ranging mobility services, which are currently offered separately to Munich's citizens. Furthermore, the market is highly dynamic. Service launching, operation abandoning and coalition creating of MSPs is fast moving. Therefore, table 5.1 presents only a brief snap-shop of the local transport landscape. Additionally, information on type of shared mode and smart-phone accessibility is provided. As table 5.1 shows, the spectrum of operational MSPs is broad and Munich's center is well covered by all modes, probably supplemented by e-kick-scooters in 2019 (section 5.3).

5.3.5. Conclusion:

Munich's city and transport visions as well as ambiguous climate protection goals draw a future picture, which largely shares MaaS promises. Especially, Munich's declared CO_2-neutrality by 2050 and the vision of 'Modellstadt 2030' showed consensus regarding Munich's values and ambitions by relevant local players. It is assumed that a well-designed MaaS scheme could drive such a desired sustainable city development. However, so far it is not perceived as a potential tool towards those goals.

Munich accomplishes required MaaS preconditions only partially. System architecture and business operator model are considered as general deficits, which are not only related to the local level of Munich. Nevertheless, in terms of appreciative MaaS perception and data-related issues (among stakeholders as well as on the user-side) Munich must considerably catch up. While a broad range of multi-modal MSPs are existent in Munich, relevant legal requirements can hardly be assessed without a professional evaluation. In any case, expected future developments tend to favor those two criteria.

Due to various multi-stakeholder initiatives with transport-related topics and ongoing projects with MaaS-like solutions, Munich offers an excellent breeding ground for MaaS developments. Essential competences, player panels and aligned technologies are present or set up in Munich. Current efforts constitute a good groundwork for further MaaS developments. The prime example MaaS G lobal showed that MaaS likely evolves out of such constellations. However, Munich's political decision-makers and their commitment is missing in most instances among stakeholder activities.

5.4. Design

Based upon the defined goals (section 5.2), the conducted analysis (section 5.3) and the elaborated sustainability criteria from chapter 4.3, this segment proposes a design guideline for MaaS in Munich. Figure 5.3 shows key characteristics, which are depicted in more detail below.

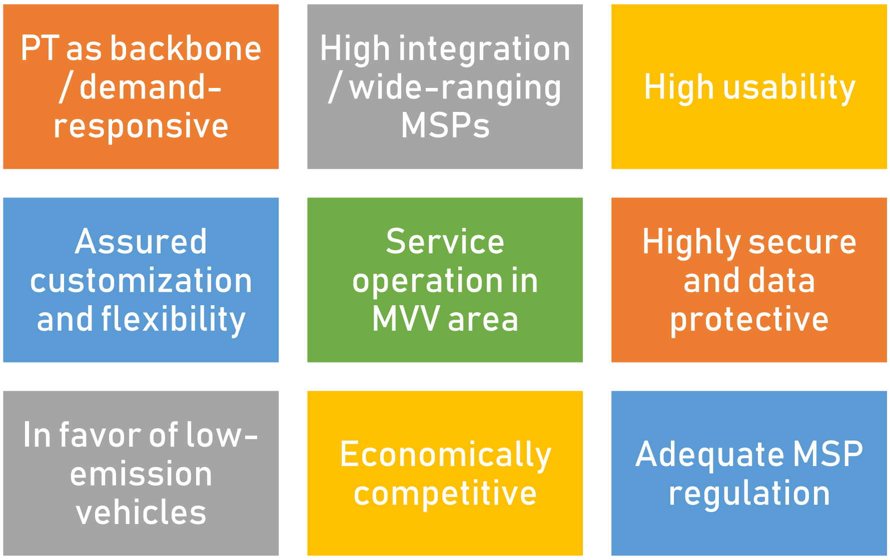

Figure 5.3.: Design features for sustainability-oriented MaaS in Munich

PT serving as backbone is probably the most essential element of a sustainability promoting MaaS scheme in Munich. Transportation system, MaaS service packaging and price structure should promote PT to cover the majority of travelled distances, which largely entails routine mobility. Accomplishing this feature significantly contributes to all defined goals. MSPs should predominantly address first and last mile as well as occasional trips. Beside the MaaS offer itself, nudging and gamification approaches might help to full-fill this principle. Nevertheless, PT alone is not capable to meet mobility demand to any given time and purpose. Hence, it is needfull that MaaS can react dynamically to systemic increase of demand. Especially, concerning PT's capacity issues and operational hours in Munich. It is a crucial element in order to overcome Munich's profound road congestion – especially impending the demographic and economic growth. Also in terms of tackling air pollutants and noise issues, PT is the most effective way to deal with it.

In order to increase sustainable travel behavior and reduce car dependency, level 3 integration would be highly appreciated. Otherwise, MaaS is not able to unlock its sustainability potential. Included MSPs should be as wide-ranging as possible and cover all available modes of transport to assure reliability and convenience. To gain user's confidence car sharing as well as car rental should be part of the service offering, but not be explicitly promoted.

Impacting on Munich's sustainability performance, a significant share of local citizens needs to use MaaS. Therefore, its sign-up and app handling should be as easy and intuitive as possible. High usability is not only supportive for mass adoption, but also favors social inclusion. To cope with lacking IT-skills of certain societal groups, even two or more front-ends for the same MaaS scheme are considerable or offline access options like applied in Freyung (section 4.3.8).

Nevertheless, essential characteristics for MaaS' attractiveness comes along with user-tailoring and flexibility. It incorporates for instance customized mobility packaging and operational hours of included services. Taking WienMobil as a prime example for a flexible and customized front-end, ranking options and indication of private bike-ownership is highly appreciated in order to become a holistic, all-inclusive mobility app. Furthermore, tailored services for niche groups are favorable (e.g. specific travel planning for physically disabled persons). Linking pervasive flexibility and customization with sustainable travel behavior, nudging and gamification approaches might be favorable. Uncomplicated features (e.g. calorie indication) should be included in early stage.

Due to its high share of private car in-commuters as well as Munich's demographic and economic forecast in its surroundings, MaaS should be definitely available within the entire MVV-area. This probably requires PT complementing service provision in Munich's outskirts and surroundings to be appealing and meet sufficient mobility needs. In this term MVG Bike acts as front-runner launching its service in municipalities around Munich.

The IT-system needs to be designed carefully and highly sophisticated. More than in other European countries, data privacy plays a crucial role in Germany and its compliance is necessary to gain trust of Munich's citizens. Linked system security not only contributes to data protection, but further assures system reliability. Appropriate human and financial resources should be provided to deal with this demanding challenge.

Tackling Munich's major air quality issues, low-emission vehicles are of prime importance including PT buses and car-based services. In order to additionally mitigate climate change, power supply of MaaS should consists of renewable resources – independent from mode of transport. MVG is already accomplishing this criterion in terms of subway trains and tram lines. Assuming a shift from car-based traffic towards low-emission PT-services, high reductions in transport-related GHG-emissions are possible.

Another key aspect for MaaS instead of private car use consists in its economic benefits. In order to prevent people from purchasing private cars or even promote to abandoning their car, MaaS's value proposition needs to be economically beneficial. Thus, pricing should be highly attractive and consider various target groups through different offerings. A beneficial cost structure should be explicitly promoted.

Beside PT relevance, adequate regulation of MSPs is the most important MaaS characteristic to promote sustainability. The challenging tightrope walk between overregulation and enforcing societal goals is decisive regarding possibly generated impact. Appropriate regulation should promote MaaS and innovative mobility approaches, facilitate profitability of MaaS operators and MSPs, assure social inclusion, area-wide coverage and prevent PT cannibalization. Data-driven approaches might be a supportive solution to cope with this wide-ranging requirements. Also temporarily concessions, which are not written in local law might be an adequate handling to face this challenge (referring chapter 4.3.4).

The design proposal compromises multi-layered aspects concerning transportation system, spatial issues, user demands, technological elements as well as legal and economic attributes. Though, this guideline is rather generally assembled. Since neither a specific addressee is considered nor any predetermination is given in Munich, the design amplitude is broad in order to prevent any exclusions. For the same reason, no favorable system architecture is recommended. Such fixings would allow to propose a sustainability-oriented design in Munich more precisely. Nevertheless, the proposed framing components serve as a preliminary groundwork.

Undeniably, it is hardly feasible to accomplish all those proposed design features in an early stage. Some of them might even impede an up-scaling. Therefore, this design proposal serves as guideline to take relevant characteristics into account in order to contribute to sustainable mobility. As sustainable development itself, a sustainability-oriented MaaS scheme consists in continuous improvement, wherein those elements are considered as design-related principals.

5.5. Actions

Recommended actions basically contain necessary activities to close the gap between Munich's status quo (section 5.3) and proposed design (section 5.4). Furthermore, it includes identified drivers from chapter the 4.2 to enforce MaaS in Munich and contribute to sustainable urban mobility. However those actions do not address a specific stakeholder, many of them are part of municipal responsibilities.

1. **Massive PT extension:** Even without MaaS, Munich's PT system is likely to reach some capacity limits in the near future. Coping with demographic and economic growth in Munich's surroundings and the necessity to serve as backbone within MaaS, a comprehensive and rapid system extension is indispensable to assign PT its important role. It is absolutely mandatory for a future-oriented sustainable urban transport system in general and for a MaaS implementation in particular. In addition, improved service reliability should be addressed. The initiated large-scale projects like second trunk route, new central station and U9 establishment are crucial long-term issues. Therefore, effective short-term measures and enhanced connectivity to Munich surroundings is probably favorable, and might be addressed by the current continuation process of Munich's PT plan.
2. **Dialog and vision process:** Recently, ICT-solutions play an increasing role within Munich's transport-related discourse, but MaaS should explicitly be addressed as possible solution to accomplish ambitious goals. It needs to be discussed publicly and among relevant stakeholders. Subsequently, a common vision should be drawn as a fundamental basis to determine system architecture and assign roles of all stakeholders. Gladly, there a already various possible platforms and MaaS-related initiatives, which perfectly fit to shape this process. Initiating a participatory MaaS dialog and vision process is proposed, which could result in a masterplan-natured outcome. In the case of a broad consensus, such preliminary elaborations might even serve as an initial point for creating a local scheme.
3. **Legal evaluation for local MaaS:** Due to legal uncertainties a comprehensive, preliminary evaluation of regulatory MaaS requirements is needful for the case of Munich. The assessment should not only address MaaS operation itself, but also provide regulative options (also ICT-driven), and propose regulatory adjustments on all relevant legislative levels.
4. **Fostering open data In Munich:** Sharing of data in general and among transport companies in particular is perceived as quite reluctant in Munich. Therefore, advantages of open data and third-party access to APIs should be stimulated and openly discussed among the public sector, academia, private sector and citizens.

Nevertheless, possible threats and negative impacts need to be considered and prevented. Network governance, conferences, research activities, hackathons and workshops are considered to be adequate media. Ongoing MaaS-related initiatives and projects (e.g. Smarter Together, VVD-M) could serve as local drivers in order to create an open data culture.

5. **Munich MaaS leadership:** Individuals or groups who actively promote MaaS in public are quite supportive to accelerate the entire development in Munich. Ideally, political decision-makers act as local MaaS front-runners. Though, also local transport-related companies or NGOs are conceivable.

6. **Municipal MaaS coordinating unit:** Currently, several departments in Munich are in charge for transport-related issues. Thus, Munich's major already proposed a competence-bundling resort within the city administration to cope with increasingly demanding challenges and improve coordination (Schubert and Effern, 2018). This suggested department would perfectly serve as MaaS managing unit for local authorities – in a conceptual stage as well as during operation. Furthermore, network-like administration structure and a multi-disciplinary task-force could be be effective.

7. **MaaS-related research and development** Due to the lack of knowledge regarding MaaS business opportunities and the need for dynamic and highly demanding regulation options, further research and development is recommended. Though it applies to MaaS in general, Munich specifics should be taken into account by corresponding progression. The locally diverse research and innovation landscape fits perfectly as knowledge provider and might lead to reciprocal pay-off. It would favor local competences, innovations and value creation, and lead to a multi-dimensional MaaS ecosystem in Munich.

8. **Car-restrictive measures and planning:** Car-restrictive measures are highly recommended. Those would directly tackle air quality issues in Munich, climate change, promote people shifting to car alternatives due to price, inconvenience or inaccessible destinations. Reciprocally, such actions would significantly drive service offerings like MaaS. Disregarding their promotional effects, under no circumstances MaaS by itself is capable to transform Munich's transportation system. It could only provide an attractive mobility option to Munich's citizens, but needs further interventions from planning, regulation and city management. Such measures should effectively turn private car use unattractive to end users – especially within the city center.

9. **Incentives and funding activities:** To initially support MaaS-related projects and start-ups public funding is appreciated. Also on the user-side incentives can

significantly promote a MaaS adoption and its acceptability, once it is established. In order to not losing track of ambitious goals, incentives and funding could be impacted-related like in Antwerp (chapter 4.2.6).

10. **Promotion of low-emission vehicles:** Consequent and comprehensive promotion of low-emission vehicles is considered to be improving sustainable urban mobility – especially among car-based MSP like taxi, DRT and car sharing. This includes financial incentives, tax privileges, concession preferences and charging infrastructure for EVs and as well as filling stations for FCEVs.

11. **Branding and public awareness:** In order to raise public awareness for the need of transforming the transportation system as well as explicitly promoting MaaS as a solution, local campaigning activities are recommended. It could entail public events, branding issues, social media promotion as well as outdoor advertising.

12. **Detecting local adopters:** Innovative and disruptive approaches are initially adopted and spread by certain societal milieus. Detecting relevant socio-economical target groups and neighborhoods in Munich is important for pilot operation and marketing issues. Due to its pervasive supply of operational MSPs, Munich's citizens are considered as relative MaaS exposed. Furthermore, corporate mobility is considered as a possible keyhole to scale MaaS. Munich's business landscape incorporates numerous big players and medium-sized companies, which could serve as early adopters. Advisory services, company awards or financial benefits might drive this proposal.

The numbering does not express importance or chronology. Some of the proposed actions imply a continuous process, others are unique activities. Likewise as design features, several aspects address to drive MaaS in Munich, while others in turn assure its sustainable impact. How and when those actions should come into force depends on how MaaS unfolds and which actors are involved. Even timing affects their implementation significantly. An aimed Munich-based MaaS scheme by 2020 demands a different procedure than in 2030. In the first instance, the abovementioned set serves a summary of locally needful and supportive actions, whereof specific measures could be derived.

6. Discussion

Chapter six deals with a methodical and content-related study discussion. Conducted thesis results and applied methods are depicted in terms of limitations and benefits. In addition, MaaS as solution approach is critically illuminated.

6.1. Methodical limitations

The thesis' study design interconnects qualitative research and a practically oriented framework elaboration. In order to avoid interdependence on methodical and content-related aspects, it is appreciable to elaborate those two parts separately. Ideally, the firstly conducted research study is later on picked up by different and independent stakeholders dealing within a use case in practice. Thus, certain mutual influences could not be completely excluded within this thesis.

Possibly the most profound study limitation results from the small number of interviews. Since the evaluation of MaaS characteristics is mainly derived from guided interviews with experts, their representativeness and selection were crucial to the research part. Even if differing professional domains and additional literature review were taken into account, subjective assessments shaped the thesis' outcome to some extent. In addition, interviewees tend to slightly euphemize their stakeholders-specific perspective, which in particular comes into effect in a small sampling.

Considering an extended domain spectrum and several representatives for each class, would be advisable to gain well-balanced insights. This issue further applies to the second study part, where even the perception of a substantial key player in Munich is missing.

The applied mix of interview methods would hardly full-fill the needs of in-depth social research. In context of 'pre-set surveys' it is important to choose interview partners based on a comprehensive criteria set. Congruent interview guidelines are suggested in order to assure the comparability of statements (Mayer, 2012, pp. 37). Contrariwise, 'theoretical sampling' purposes that the next interview partner is chosen by a reflection of the entire research process. Even though the executed method deals with defined

RQs and limited study extent, it raises shortcomings from a scientific point of view. Those might result in path dependence and restricted insight coverage.

Coping with the recent MaaS emergence, deficits in terms of literature quality could be stated. Peer-reviewed journal papers make up a limited share of considered sources. Desk research based mainly on conference proceedings and MaaS-related reports. Due to lacking literature availability in some fields, a few master theses were consulted.

The development of MaaS is enormously fast-moving – in terms of practical implementations as well as related research. Therefore, the thesis faces difficulties in grasping the state-of-the-art. During the the study process, the MaaS landscape run through several changes in terms of legislation, political agenda setting, technological issues and operational spread. Also within the scientific community, new publications are released at frequent intervals pushing the state-of-the-art continuously forward. Thus, this study contains only a snap-shop of MaaS and related aspects. Furthermore, slightly differing states of knowledge in terms of different thesis aspects could not be totally precluded.

Certainly, in order to gain a fundamental knowledge base and sustainability criteria, qualitative research methods and guided interviews are suitable. Nevertheless, a proper evaluation and precise impact assessments require quantitative methods. For this reason, elaborated sustainability criteria can only be considered as a general and preliminary assembly.

6.2. Benefits and shortcomings of the study

Chapter 2 in particular offers a comprehensive overview regarding the conceptual approach of MaaS. By depicting its preceding and enabling developments, it is placed in the context of important background information and fundamental theoretical frameworks. It presents key features, its promises and future ambitions. Complemented by illustrating case studies and a preliminary impact assessment, this thesis provides a benefit through an extensive knowledge base regarding MaaS, which could serve for further in-depth work or informatory purposes.

Basically, the assembly of MaaS requirements and promoting factors do not contain novel findings, though their gathering and structured preparation for municipal purposes entail added value. In addition, those aspects are enriched by state-of-the-art expert knowledge. In return, sustainability criteria have hardly been considered and elaborated before. Numerous publications mentioned certain aspects in their work, but none of them addressed an embracing identification and evaluation. The research-related thesis outcome benefits to proceeding works in MaaS-related sustainability. Conducted characteristics in its entirety are further transferable to conceptual frameworks in other municipalities.

Considering Munich and its transport-related challenges, the thesis assesses MaaS' local potential. The proposed design guideline aims to channel and frame a proper local implementation in advance. However further elaborations are mandatory, the study serves as preliminary work for the city of Munich. Furthermore, recommended fields of action benefit as practical advice pushing this approach and its adequate arrangement. Thereby, the thesis further kicks off a local discourse on MaaS as a possible solution approach.

The thesis explicitly focuses on municipal MaaS schemes. One could legitimately argue that a system initiated on larger scale might even come along with a higher value proposition. Although, there are certainly various advantages assumed with such a roll out, it would had not been compliant with the research design due to in-existing information. Currently, MaaS schemes are mainly limited to the municipal stage.

Elaborated MaaS characteristics as well as Munich's framework deal with rather generic elements. Since differing system settings and evolvements are discussed, MaaS could unfold differential attributes and impacts. A precise evaluation and action recommendation require a high degree of predetermination. A given system operator model would allow more specific statements and propositions. Thus, all results refer to a MaaS perception in general and do not allow an unrestricted transfer to any MaaS embodiment. Moreover, citizens' mobility behavior and transportation systems highly depend on local specifics and wide-ranging factors consisting of geographical influences, topography, socio-economic milieu, cultural aspects, infrastructural conditions, etc. Adopting principal MaaS characteristics to Munich might already lower their validity.

6.3. MaaS discourse

This section deals with general critique and risks in terms of MaaS and discusses possibly interfering developments. Sustainability-related discussion is already part of chapter 4.3, and hence not repeated. Since the approach is considered as a part of the smart city concept, firstly criticism in a broader picture and on a meta-level is expressed. Kitchin (2014) concerned various aspects of smart cities and their subsystems. He stated the threats resulting from an exaggerated neoliberal character. Coping with more diverse, complex and multi-layered problems, challenges the public sector and its obligations. However, pervasive interventions by private stakeholders might endanger societal goals by undermining public domains through their business interest. Due to highly sophisticated IT systems and necessary expert knowledge, private companies play an important role in running smart cities – on the strategic, the tactical and the operational stage.

Secondly, Kitchin (2018) fears that decision-making increasingly depends exclusively on data. By handing over such processes to automated IT-systems based on available data and algorithms, valuable human capability is neglected. This handling furthermore does not consider unforeseen cases, neither enables compromises. Moreover, he highlighted that there is no pretended neutrality of data-driven procedures. Every algorithm applies a subjective basis for decision, values input and its efficient processing velocity might shift conditions even more rapidly. In this context, Gitelman and Jackson (2013, pp.1) noted that "*'raw data' is an oxymoron*" and its generation, storage and processing is affected by multiple, non-neutral influences.

Richard Sennett (2006) argued that high efficiency, over-determination as well as pervasive recording and monitoring of multi-layered processes do not result in livability. He pointed out that urban attractiveness, cultural creation and social cohesion depend to some extent on a lack of perfection, scope for development and gray areas. In terms of smart cities, he used the term 'closed systems' to describe the phenomena. Therefore, he proposed an 'open city' as an alternative draft to exaggeratedly determined smart cities.

Privacy International, an NGO campaigning for human rights in a digital age, expressed serious concerns regarding smart city applications. According to its report, datafication of urban processes is undermining sustainability and efficiency promises in many cases. By enabling surveillance and worsening social imbalances, smart cities often generate dystopian characteristics. Though, Privacy International's criticism primarily does not address the concept itself, but rather how it usually unfolds. Thus, several actions for local governments are recommended in order to prevent negative consequences of smart city applications. Those compromise human right impact assessments, risk assessments and several controlling mechanisms (Privacy International, 2017). Such privacy concerns are also raised in terms of MaaS.

Also Morozov and Bria (2018) proposed to readjust the smart city paradigm on an operational level by enforcing democratic principles like transparency, openness, etc. Their main postulation is that the smart city should be owned by its citizens. In rethinking smart urbanism, Barcelona serves as prime example with its approach called 'city data commons'. However the City of Barcelona follows a pervasive digitization strategy, its realization consists of open data, open standards and a municipal code of conduct for digital services and technological products. Moreover, it is proposed to transfer all administrative IT-systems into open source software in order to decouple from the private sector.

All these concerns referring to smart cities in general, might also affect MaaS as a specific solution embedded in this context. Respectively, MaaS might contribute in strengthening such risks by gaining importance in citizen's lives.

Referring to the abovementioned neoliberal concerns by Kitchin (2018), one could argue that MaaS is just an attempt of private companies to have a foot in the door of transportation – conventionally a public domain. Tough, consensus was in evidence that the public sector is hardly capable to meet increasingly demands and challenges by oneself. Nevertheless, MaaS is in danger to be excessively driven by marketing claims and business interests.

In long-term perspective, small MSPs could face competition difficulties or end up in strong dependence of MaaS providers. This threat refers to basic mechanisms of platform economy. Being part of it, might limit freedom of action and independence. Not being part of it, might lead to a shrinking customer base. All that is worsened by big players struggling for market share.

Linked to this platform approach, the question of a viable business model remains largely unanswered. MaaS Global as commercial pioneer of the broker model acts as a proof-of-concept, if simple up-scaling could result in profitability. If not, the whole concept how it is proposed at present, is in danger. Certainly, alternative operator models might emerge and also the aimed SLA approach is considered to favor economic viability. Nevertheless, it would significantly constrain the MaaS paradigm.

Two major technological developments, which might interact with MaaS in the future are AVs and blockchain. Since their impact as stand-alone technology is largely unclear and an immature state-of-the-art does not permit a temporal projection, those issues were hardly considered within the thesis. The MaaS evaluation, which is already based upon many assumptions and subjective expert assessments, would have become even more vague.

Nevertheless, both technologies constitute relevant key features that could enrich MaaS as a solution. Li and Voege (2017) pointed out that fully realized AVs and MaaS would reciprocally maximize their benefits. Such a system might unfold high efficiency, convenience, enhanced safety and social inclusion. The other way around, it would probably lead to more travelled distance by car and might worsen congestion and energy consumption.

Apart from the controversially discussed hype around cryptocurrencies, blockchain as technology could offer an appropriate solution to certain use cases within datafied urban processes (Speed, Maxwell and Pschetz, 2018). Concerning the mobility sector, Gösele and Sandner (2018) defined parameters, which denote a possible blockchain suitability. Multi-stakeholder systems, missing trust, intensive data matching and an open ecosystem are constituted, which all apply to MaaS. Depending on the intended purpose, Gösele and Sandner (2018) accentuated wide-ranging blockchain attributes to be possibly relevant. Many of them relate to contractual processes and validation of information. For this reason, one of the few blockchain ambitions in terms of MaaS is dealing with some kind of SSO (Li, 2018). Similar issues could be increasingly addressed by blockchain applications in the future.

In addition, other ICT progressions might interfere with MaaS. While AI could play a crucial role in enhancing system's efficiency, augmented reality might be deployed in user-sided fields.

Apart from technological development, regulatory frameworks will decisively shape a MaaS unfolding. Without legislative adjustments a universal breakthrough is unlikely. It remains to be seen, if other countries follow Finland by installing an ICT responsive transportation law. Described regulatory revising on all stages tend to generally favor multi-modal and demand-responsive transport. If this also applies to the specific concept of MaaS is unclear.

Also from a business perspective, it is relative uncertain in which scenario the market develops. Through successful front-running schemes and actors, multi-national big players might express interest. Even a public initiative on larger scale is considerable – however less probable. If an increasing popularity of MaaS also triggers the discourse in Munich is deeply linked to local stakeholders and how they perceive this transport paradigm.

On the societal level, the gaining importance of millennials is considered to significantly push MaaS-like approaches. This generation is entirely digital native, used to subscription models and service orientation. Moreover, they significantly value private car ownership less than previous generations. By entering labour market and decision-making domains, alternative ways in access and handling mobility are more likely to become reality. If at all, the key promise of MaaS, which consists of reducing car-dependency, is going to unfold its full potential in a long-term perspective. In an early stage, car purchase might be delayed or prevented in the best case. Thus, a possible MaaS breakthrough is hard to predict, but its probability increases over time due to generational shifting.

7. Conclusion

This last chapter summarizes the thesis and provides open research questions that have emerged throughout the work.

7.1. Summary

Picking up the initial problem statement and defined RQs, the thesis provides a comprehensive response, elaborates valuable information and paves the way for an adequate solution approach in Munich.

The query regarding inherent requirements and promoting drivers of municipal MaaS schemes resulted in six crucial components for a realization and seven supportive factors. Mandatory preconditions consist of an indispensable system setup linked to participants' ambitions, business opportunities as well as pervading data and legal issues. Their accomplishment notably requires stakeholder actions and collaborative efforts. Not all of them could be addressed by local responsibilities. In terms of some aspects, readjustments on larger scale are necessary.

MaaS can be decisively driven by policy and governance efforts. Supportive leverages relate to multiplying mechanisms, consensus finding and lowering entry barriers. Among others, local leadership, a commonly shared MaaS vision, open APIs and promotional programs are identified as crucial implementation drivers. The public sector in particular holds a key position to significantly promote and shape a MaaS progression.

In terms of sustainability, evaluated properties are multi-layered and relate to differing system dimensions. In particular, PT serving as MaaS' backbone, adequate regulation mechanisms and high user acceptability are considered of prime relevance. Within the assembled list, some of the indicators refer to a qualitative and sustainable unfolding, others to quantitative mass adoption in order to actually generate impact. In comparison to prerequisites and drivers, sustainability criteria rely even more on assumptions and estimations. However their general relevance is stated, ultimate effects are afflicted to vagueness and depend on wide-ranging parameters – including local conditions. Due to the high diversity in attributes and incorporated stakeholders as well as differing system evolvements, MaaS design is crucial when it comes to sustainability impact. Thereby, this thesis' outcome emphatically underlines this already existing statement, which was expressed by preceding research.

By assessing Munich's MaaS disposition, a differential picture is drawn. Inherent requirements are only partially accomplished and lack in terms of data-related issues, system determination and unclear legal preconditions. On the contrary, Munich acts ambitiously on a strategic level aiming for objectives to which MaaS could contribute in order to make them successful. Furthermore, it contains an outstanding MSPs landscape and a possible MaaS breeding ground due to numerous existing projects and private public initiatives. Those are encouraging in MaaS-related fields, gaining relevant knowledge and might serve as a starting point. However, political level is deemed to act hesitantly in fields related to transport and data issues.

The derived MaaS design guideline mainly picks up universal features complemented by certain local specifics, like the need to incorporate the whole tariff and ticket zone (MVV). Even though some attributes might impede a local up-scaling, all proposed design attributes should be taken into account within a continuous improvement process.

To cater the gap between actual state and identified system requirements as well as the design components, twelve fields of actions are suggested. Massive PT extension, a dialog and vision process, legal evaluation and fostering to share data among stakeholders are detected of prime importance. To large extent these issues address administrative and local actors.

Likewise all rapidly emerging and disruptive approaches, the way they unfold is decisive. MaaS is afflicted by high expectations and a lack of knowledge, therefore private business interest could result in misleading developments. Regime actors and disruptive newcomers create a field of conflict that all together results in a challenging transition task. Thus, an adequate execution of the system's design is crucial and assures an impact on sustainability and a co-existence of stakeholders.

This applies to Munich in the same way. Properly designed and well implemented, MaaS supports the city in transforming its transportation system towards sustainability and in coping with current transport-related issues. However, even the best MaaS system can only serve as one contributory factor among many measures within the transformation process.

7.2. Outlook

On the one hand urgent challenges require an immediate change process, on the other hand well planned and properly established solutions by time are more likely to generate the desired outcome. MaaS is facing exact this dichotomy. Apart from the serious need for action, many aspects are unclear and require further effort and investigation.

This thesis clearly identifies additional research need. Firstly, empirical evaluation from operational schemes is absolutely important to evaluate MaaS properly. Current assessments are based on pilot tests, surveys and questionnaires. Quantitative analytics with comprehensive data samples regarding transportation system and travel behavior is inevitable to precisely rate MaaS and its possible impact. Thereby, also the importance of particular sustainability criteria might be determined in more detail.

It still very vague if a MaaS system can be economically profitable. Therefore, a better understanding of MaaS business models and operator constellations by scientific research would be highly appreciated. Such work conducted in the future should respond to the question, if scale alone enables profitability and what kind of alternative collaborative approaches are.

Even tough experts stated general feasibility, sophisticated IT approaches and mechanisms need to be developed in practice. These are required in order to get along with multi-dimensional demands of advanced MaaS schemes. Dealing with security issues, data privacy, multi-stakeholder access while assuring high degree of user experience and customization, is a challenging assignment for developer and system architects. It should be tackled soon to provide a highly advanced technology base for the ongoing MaaS progression.

Moreover, it is recommended to focus on data-driven regulation approaches in R&I as this is considered a quite promising approach to cope with smart city applications as well as complex regulatory settings. Well designed, its application might assure the enforcement of societal goals within smart cities, which are predominately operated by private actors – even beyond MaaS.

Probably, already the progress within the next years will show if MaaS can truly live up to its promises. If so, MaaS is definitely an important long-term solution in transportation to exclude negative externalities and push the system towards sustainability – also for the city of Munich.

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A. Appendix

A.1. Interview guideline – international experts

1. Can you briefly present yourself and your role within the organization?
2. Currently, what are main challenges of a MaaS scheme?
3. What are MaaS driving factors?
4. What are relevant issues regarding business model and stakeholders?
5. Are there technical and data-related challenges within MaaS?
6. Are their policy and legal issues to be considered?
7. According to your opinion, what is mandatory for a MaaS implementation in order to generate sustainable impact?
   – transport-related?
   – in terms of regulation?
   – stakeholder-related?
   – concerning the end user?

A.2. Interview guideline – local stakeholders

1. Can you briefly present yourself and your role within the organization?
2. How is the MaaS phenomenon assessed within your organization? Are there already ambitions towards this approach?
3. What challenges face Munich's transportation system?
4. How deal local policies with MaaS-related developments?
5. What are impeding and driving factors in terms of ICT-driven mobility in Munch?
6. According to your opinion, what is mandatory for ICT-driven mobility in Munich in order to generate sustainable impact?
    – transport-related?
    – in terms of regulation?
    – stakeholder-related?
    – concerning the end user?