TECHNISCHE UNIVERSITÄT WIEN Vienna | Austria

Ph.D. DISSERTATION

"MaaS or no MaaS, That is The Question!"

Developing a Mobility Decision Tree to Help Cities Navigate Their Mobility Roadmaps and Build Their Ecosystems

Carried out for the purpose of obtaining the degree of the Doctor technicae (Dr. Techn.), submitted at TU Wien, Faculty of Architecture and Planning by

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Affidavit

I declare in lieu of oath that I wrote this thesis and performed the associated research myself, using only literature cited in this volume. If text passages from sources are used literally, they are marked as such.

I confirm that this work is original and has not been submitted elsewhere for any examination, nor is it currently under consideration for a thesis elsewhere.

[redacted]

Berlin, 09.09.2021

Acknowledgements

"No one who achieves success does so without acknowledging the help of others.
The wise and confident acknowledge this help with gratitude."
Alfred North Whitehead

With gratitude and appreciation for
my supervisor and his continued support and motivation,
my assessors and their constructive feedback,
my mentor and her great impact,
my interviewees and their deep insights,
my family and their endless encouragement,
and all those who jumped in and helped along the way,
without you all, this journey would not have been accomplished,
I would like to say,
Thank you!

Abstract

Does every city need MaaS (Mobility as a Service)? Does every city need the same MaaS? Do MaaS-ready cities need MaaS? And do unprepared cities have to give up pursuing the concept? What factors answer these questions?

With the transport industry being one of the main economic pillars and one which interacts with multiple sectors, this research aims to understand why cities develop different structures, which in turn define their urban travel. The research analyzes the interaction between the existing city structure, the transport/mobility system offered and the role of the city and how it evolved under global phenomena – such as the industrial revolution earlier and the digital revolution now – in terms of transport, resulting in the necessity of exploring cities' mobility needs from a new perspective.

To collect the data needed, the grounded theory method is used to conduct a comprehensive literature review and qualitative analysis in the form of expert interviews with MaaS stakeholders from both sides of the Atlantic from the public and the private sector. The collected data is documented, coded, clustered and analyzed to develop the content. It soon became clear that cities do not have a clear system/protocol to identify and thus serve their real mobility needs; and it was also clear that cities do not have an established system that exhaust existing resources first before adding new ones. It follows that applying MaaS that is not based on need is unlikely either to solve problems or result in a sustainable approach. Moreover, not all relevant actors in this particular area are involved in the decision-making process and existing MaaS indices either cover the phase of the MaaS journey after the decision is made – and not whether a MaaS system is needed in the first place – or cover only certain factors. The research questions were formulated on the basis of these gaps, and to answer them a decision tool in the form of a mobility decision tree (MDT) was designed to help cities navigate their roadmaps more easily and identify their ecosystems. Answering these questions not only has the potential to offer cities a logical and comprehensive assessment tool but can also contribute to avoiding planning mistakes or fallacies and reducing or eliminating potential rebound effects. The mobility decision tree assesses the status quo in an area, suggests call-to-

actions where needed and, based on the outcome, recommends solutions. As a demonstration, the MDT was applied to three different cities and the findings are discussed to gain new insights and draw conclusions that fill in knowledge gaps and highlight paths for future research areas.

The analysis indicates that the city structure influences, shapes and determines the type of mobility concept (e.g., MaaS) needed and that the city role is the key to the decision whether or not to implement that concept. These facts in turn elaborate on how the ecosystem and model may vary from one city to another within the same country and likewise how cities separated by oceans can adapt the same concept. The analysis minimizes the importance of national geographical boundaries and emphasizes the importance of existing urban structures and local players. The solutions cities can offer are as varied as the cities themselves.

The research discovers that there is no correlation between the need for a MaaS concept and the city's readiness for it, and acknowledges the importance of upgrading cities to be more sustainable by the implementation of mobility concepts that suit their real needs. It also identifies political support as a principal factor in the implementation and development of a (new) mobility concept in a city. With that in mind, it is crucial that political decisions are based on well-informed data, and hence the research highlights the important role of the various stakeholders in the ecosystem to contribute collectively to update those in charge with all the relevant information. In this area, their collaboration is vital. Hence, it is essential that cities rely on a suitable assessment process/protocol.

Further research is therefore needed to investigate and explore ways to involve policy makers from the beginning in order to facilitate a quicker and better-informed decision, as well as easier and more efficient ways for cities to assess their pain points based on existing resources and goals – from exploring their mobility needs, strength and weaknesses, identifying the components of the ecosystem, to planning their roadmaps. In this way, the cities utilize their existing services first before adding new ones. For long-term results, this process needs to be linked with the goal of reducing potential rebound effects and errors in the planning. Further research is also needed globally into the various layers of the mobility ecosystem, especially in terms of the horizontal incorporation and integration of other services such as deliveries and goods transport, and especially with the emergence of teleworking and home office.

Keywords

MaaS, MoD, city structure, city role, transport system, mobility, political instrument, industrial revolution, digital revolution, ecosystem, urban accessibility, collaboration, grounded theory method, mobility decision tree, fallacies, rebound effect

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List of Abbreviations

AV	Autonomous (Connected) Vehicles
API	Application Programming Interface
B2B	Business to Business
B2C	Business to Customer
B2G	Business to Government
BRT	Bus Rapid Transit systems
DB	(Deutsche Bahn) Germany Federal Train Network
ERTICO	European Road Transport Telematics Implementation Coordination Organization
USDOT	United States Department of Transportation
GT	Grounded Theory
HOV	High Occupancy Vehicles
ITS	Intelligent Transport Systems
MaaS	Mobility as a Service
MDT	Mobility decision tree
MoD	Mobility on Demand
PPP	Public-Private Partnership
PT	Public Transport
TfL	Transport for London, local government body responsible for the transport system
TaaS	Transportation as a Service
TNC	Transport Network Company

Glossary

City, Town and Rural Area – according to “the new method, called ‘the degree of urbanization’ (DEGURBA), the entire territory of a country is classified into three classes. First, grid cells are classified based on population density, population size and contiguity. Subsequently, local units are classified according to the type of grid cells their inhabitants live in.” (European Commission, 2020):

Cities (or densely populated areas) – “Local units that have at least 50% of their population in urban centers* (or a high-density cluster). (The urban centers* are subsets of the corresponding urban clusters**)” (European Commission, 2020).

Towns and semi-dense areas (or intermediate density areas) – “Local units that have less than 50% of their population in urban centers* and less than 50% of their population in rural grid cells***” (European Commission, 2020).

Rural areas (or thinly populated areas) – “Local units that have at least 50% of their population in rural grid cells*** (mostly low-density cells)” (European Commission, 2020).

CO_2 Emissions – “Carbon dioxide (CO_2) is a colorless, odorless and non-poisonous gas formed by combustion of carbon and in the respiration of living organisms and is considered a greenhouse gas (a group of gases contributing to global warming and climate change). Emission describes the release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time. CO_2 emissions are emissions stemming from the burning of fossil fuels and the manufacture of cement; they include carbon dioxide produced during consumption of solid, liquid, and gas fuels as well as gas flaring” (Eurostat, Statistics Explained, 2017).

Collaborative mobility – Shared and on-demand modes and rides.

Collective mobility – mass transit - public transport.

Combined mobility/transport – “offering integrated mobility services with public transport as a backbone complemented by other modes such as car-sharing, bike-sharing, taxis, cycling and on-demand services – is the only mobility solution able to compete with the private car in terms of flexibility, convenience and cost-structure," Caroline Cerfontaine, UITP Combined Mobility expert (Cerfontaine, 2020).

Demand responsive transport – such as taxis, on-demand shuttles/vans and ride hailing services

Edge City – An urbanization pattern presenting some features of city center employment mixed with suburban form. Edge cities tend to have large concentrations of office and retail space often paired with multi-family residences (Meyer and Shaheen, 2017).

Exurban – Low-density residential development within the commute shed of a larger and denser urbanized area (Meyer and Shaheen, 2017).

Inductive reasoning – aims at developing a theory, while deductive reasoning aims at testing an existing theory (Charmaz and Belgrave, 2012).

Internet of Mobility (IoM) – A mode-agnostic, global approach to Mobility as a Service, based on an open protocol framework for discovery, booking, and payment for mobility services (Dalton, 2018).

Mobility as a Service (MaaS) – An innovative transportation and mobility concept where consumers access mobility, goods and services on-demand by dispatching or using shared mobility, courier services, unmanned aerial vehicles and public transportation strategies (Shaheen and Cohen, 2017).

Mobility on Demand (MoD) – A system whereby a journey or the movement of goods and services can be made through a network of services accessible on-demand, rather than through a privately-owned vehicle (Dalton, 2018).

Private mobility – Individual vehicles.

*****Rural grid cells (mostly low-density cells)** – "cells that do not belong to an urban cluster. Most of these will have a density below 300 inhabitants per km². Some rural cells will have a higher density, but they are not part of a cluster with a large enough population size to be classified as an urban cluster" (European Commission, 2020).

Soft Modes – walking and cycling.

Transportation Network Companies (TNC) – are ride-sourcing/ride hailing providers.

***Urban center (or a high-density cluster)** – "Consists of contiguous grid cells with a density of at least 1,500 inhabitants per km^2 and has a population of at least 50,000. Gaps in these clusters are filled and edges are smoothed. If needed, cells that are 50% built-up can be added" (European Commission, 2020).

****Urban cluster (or moderate density clusters)** – "Consists of contiguous grid cells with a density of at least 300 inhabitants per km^2 and has a population of at least 5,000 in the cluster. (The urban centers are subsets of the corresponding urban clusters.)" (European Commission, 2020).

1 - Introduction

This chapter introduces the research, highlights the problem, states the purpose of the study and summarizes its significance as well as describes the framework and the methods used. Thereafter, it defines the research questions, objectives and restrictions.

1-1 Research Introduction

Since the 19th century (Transatlantic Perspectives, 2010), the connection between city development and the transportation of people and goods has played a major role in city economies. Cities grew in different ways and their transport systems had to mature as well. Additionally, due to the interrelation of the transport industry with other sectors such as tourism, economic, environmental, social politics, etc., it grew even beyond its own geographical boundaries and thus it became vital for cities to improve their infrastructure and services.

With the various ways city structures developed, the role of the city became more sophisticated and complex. And with the emergence of the industrial revolution (Meyer and Shaheen, 2017), cities globally faced, on the one hand, huge expansion due to the increased population in major cities, meaning their transport systems needed to cope and evolve, and, on the other hand, cities began to realize that an endless expansion of the city road network and public transport system would neither be sufficient nor efficient to cover their ever increasing requirements, especially with the transport section being one of the reasons for the increase in CO_2 emissions -- mostly in urban areas – (European Commission, urban mobility package, 2013) and thus responsible for a negative impact on the environment. Consequently, they started taking active steps to encourage alternative, more environmentally-friendly and sustainable transport and mobility solutions. These solutions are not merely to replace the existing ones but rather to reuse them more efficiently and add to them where needed.

Among the multiple solutions introduced, is the concept of MaaS (Mobility as a Service) and MoD (Mobility on Demand) which, as multiple and intramodal forms of transporting people, goods and deliveries (Shaheen and Cohen, 2017) are expected to be at the forefront of sustainable transport and so help to reduce traffic jams, urban sprawl and CO_2 emissions while enhancing the travel experience by shortening the journey and improving the quality of life. But although in theory the potential of MaaS is clear, in practice it still has not achieved a breakthrough.

Moreover, many big cities face the dilemma that the increasing attention MaaS has received – both at the national and global level – which triggers their worries about being left behind in the mobility race, has not yet been met with the same enthusiasm from the user's side. It is not clear whether this is due to the city's perspective on the problem, the city structure, the lack of a clear definition of who is responsible for which role, the lack of public information on MaaS, or the absence of satisfactory solutions for particular cities. Thus, cities started to compete to position themselves in the new mobility era, but as they vary, so do the approaches they take, a fact that must be taken into account both by their planning and administrative departments in order to avoid joining a race blindly and unprepared. Gradually the fever of competition subsided and the spirit of the marathon took over and it became clear that they all needed to improve their transport systems both by enhancing what is available and implementing what is missing.

Due to the fact that MaaS is a relatively new concept, researchers have investigated a number of different aspects of the concept: types of ecosystems, the advantages and challenges of MaaS as well as its threats and weaknesses, solutions, requirements, and user acceptance of new services. They have also analyzed the various layers, modes involved, data-sharing policies, the importance of horizontal cooperation and the paradigm of car use. Nevertheless, some regions remained uncharted. Going beyond the existing research categories, it becomes clear that cities lack both a comprehensive process/protocol to identify their mobility needs and a connection between city planning and mobility development. It is important to first assess the existing status of the resources available, identify which type of a city needs which type of mobility system (be it MaaS, MoD, a combination or something else) and thereafter investigate the roadmap and factor/s that influence its availability and development. Accordingly, we need to explore MaaS's deeper and long-term impact, and understand why the breakthrough has not yet taken place – despite the efforts of the various stakeholders – and thus fully utilize its potential.

To get a comprehensive overview, the research studies three factors that impact city development – city structure, the transport system and the role of the city – and analyzes contemporary research on both sides of the Atlantic into these factors as a case study. It highlights the reasons for the existence of a particular transport system in relation to the city structure and the role the city plays, as well as the gaps the city structure and transport system faced with the rise of the industrial revolution, and examines how accordingly the role of the city evolved. Finally, the study investigates the influence of climate change awareness, globalization and the new digital era, how they have affected both supply and demand in the cities and led to the introduction of multiple alternative intermodal concepts such as MaaS and MoD. Following this, the study elaborates on why cities develop particular types of Maas/MoD and the impact they have.

To obtain the insights needed, the grounded theory (GT) method is used. The research conducts a literature review on global good practices and qualitative research in the form of experts' interviews with various MaaS ecosystem stakeholders in both the public and private sector. This research method has been selected because it offers the flexibility required by the dynamic nature of the concept and makes it possible to analyze the problem from various sides and at different levels. To answer the research questions, a decision tool in the form of a mobility decision tree (MDT) has been developed.

Three cities, Vienna, San Francisco and Singapore, are analyzed using the MDT. This tool supports cities in the decision-making process by assessing the status quo, detecting the pain points, suggesting calls-to-action where needed and recommending solutions to overcome/reduce the problems. The tool makes it quicker and easier for cities to explore the question of whether a particular (new) mobility concept is needed; and, if there is a need, the tool provides facilities for choosing the appropriate type of mobility system and the elements needed to implement it.

These recommendations are intended to address mobility challenges and to show how not every MaaS/MoD-ready city needs MaaS/MoD; how not every MaaS/MoD-unprepared city needs to reject the idea of having one; and how the need is not correlated to the city's readiness. Thereafter, the research identifies the factor/s responsible for the existence or termination of MaaS which represent the key or wedge for the new mobility era.

A clear vision contributes to more effective use of available resources to implement and expand MaaS and so reduce CO_2 emissions, enhance travel and serve a real need. It also contributes to improving alternative sustainable solutions in cities where MaaS is not needed and for which alternative solutions are more suitable and have the same benefits in terms of saving resources, serving users’ needs and in their impact on climate change.

1-2 Research Questions

Which cities need MaaS, what type of Maas do they need, which do not, and why? Likewise, do MaaS-ready cities automatically need MaaS? Do cities that are not prepared for MaaS have to give up pursuing the concept? What factors answer these questions?

1-3 Research Objectives

With the transport industry being one of the main pillars of the economy and interacting with multiple sectors, this research aims:

- to understand why cities, develop different city structures
- to explore how city structures, define urban travel
- to examine which factors, shape the transport system
- to investigate how the role of the city evolved in response to global developments in transport systems
- to elaborate on how the cities’ mobility needs, require a new perspective
- to demonstrate how the MDT supports cities in their mobility decision-making process by navigating their mobility roadmaps and building their mobility ecosystems

1-4 Research Thesis

Whether cities need MaaS or not stands independently and is not influenced by whether they are MaaS-ready or not.

Local factors determine the city structure and transport system and the role of the city shapes them – the MaaS type developed is a projection of this framework.

These factors are only subordinate elements. The determining factor – for MaaS (if needed) to exist – is the political decision. This decision is taken on the basis of the input of multiple stakeholders.

The MDT developed in this study helps cities meet their mobility needs easily and effectively.

1-5 Research Restrictions

This research was conducted before COVID 19.

The research investigates MaaS but in certain areas where it interacts with MoD, MoD is mentioned as well.

Due to the interaction of city structures, transport systems and city roles, the research explores their development within three timelines: past, present and future.

The research focuses on Europe and the US but as cities learn from each other and in order to gain a comprehensive overview, examples from Africa, Asia, South America and Australia are included too.

Among the three degrees of urbanization (European Commission, 2020), cities, towns and rural areas, the research concentrates on investigating cities because the major challenges and the highest levels of CO_2 emissions are in urban areas. But as towns and rural areas also face challenging pain points, the MDT developed is designed to fit all three types.

2 - State of the Art

This chapter concentrates on shedding light on the key research components. It highlights their development, the interconnections and factors that shaped them and concludes with a good practice catalogue and a section on research gaps which have impacted the formation of the research questions.

2-1 City Structure - Rise of the Cities

2-1-1 Urban Planning

Urban planning was developed as a transnational discipline that extended over cities, countries and continents in the second half of the 19th century (Transatlantic Perspectives, 2010) where the contacts between city planners in Europe and the US were a significant factor. As international networks began to emerge and urban planning had only just emerged as a discipline, these city planners were able to set the international framework for the study of methods to deal with universal urban problems. In the period between 1930 and 1980, these professionals, who often attained influential positions, shaped urban development globally (Transatlantic Perspectives, 2010).

Nivola (1999) explains how cities generally grow in one of three directions: “in by crowding, up into multi-story buildings or out toward the periphery“ (Nivola, 1999). Although cities develop in each of these ways at various times, European cities differ from American ones. In Europe, the urban settlements do not decentralize as they do in the US. In 1930, less than 25% of the US population lived in suburban areas. Now over 50% do (Nivola, 1999). Most European cities remained compact compared to the American ones, which extended further.

Another factor that led to different urban development was that the initial American economy was agriculturally based while Europe was more industrialized, therefore it was crucial that the people lived near the factories where they worked. It is worth mentioning that cities within the US also vary according to when and where they were built. Cities in the North and the East like New York, Boston, or Chicago developed before the automobile era and therefore were built around their mass transit systems while cities in the South and the West like Houston, Atlanta, and Los Angeles are more spread out because they expanded during the automobile age (Le Galès and Zagrodzki, 2005).

In America, the more fortunate class often lived in the suburbs away from the city, while in Europe, the rich lived inside the city (Bühler and Kunert (2008). The reason for that was that before the car and the train era, people relied on walking as their main transport mode for travel to the city. The wealthy therefore settled closer to the city center. Looking at a map from the 1500s (Bühler and Kunert, 2008), one can see how the city was divided into rings around the city center with the wealthiest in the inner rings and the less fortunate further out. Additionally, Europe's population is denser than the US's due to lack of transport when these cities were built; people needed to settle as near as possible to the city center, whereas in the US, cities were built when both cars and trains already existed. These new transport modes were very expensive and were not affordable for everyone. For this reason, only the wealthy could afford to settle in the suburbs (Bühler and Kunert, 2008), while the poor lived as close as possible to city centers.

Moreover, while most European railroads were government-owned, American railroads were private. Thus, it was easier to use trains in Europe as a public transport mode, while in America trains were more commonly used to transport freight, a state of affairs which supported the widespread use of private cars as the dominant mode of transport (Bühler and Kunert, 2008).

Despite the different approaches on both sides of the Atlantic, both city models faced big changes in their urban structure due to political and physical realities (Bühler and Kunert, 2008) such as urban sprawl, decay, and renewal.

2-1-2 Urban Accessibility vs. Urban Density

One of the bases of economic development in cities is the access to services and goods as well as information (Meyer and Shaheen, 2017). As a consequence, cities which were based on the concept of their urban planning and transport systems, developed certain patterns that reflected their needs, whether in terms of the shape of the city, its urban mobility or technological innovation. And as Urban travel represents over 60% of all kilometers travelled worldwide (Meyer and Shaheen, 2017), it was important to consider the interrelationship between transport and urban form. These patterns evolved with respect to the most common combinations of urban spatial structures and transport and ranged from active travel (walking/biking) to public transport in compact cities and individual transport in (car-centric) decentralized cities.

According to Brimont et al, (2015), urban accessibility in cities is generally achieved in two ways: either by the physical concentration of people, work, services and economic activities, or by increasing the travel speed by using more rapid motorized modes of public or private transport.

On the one hand, the development of public transport and/or availability of owning a car supported the reduction in mobility costs, but also, on the other hand, allowed the de-densification of cities and their horizontal expansion, which led to an increase in the substitution of accessibility by proximity (Meyer and Shaheen, 2017) with movement. While transport systems required compact, dense urban development, cars facilitated suburban development but at far lower density levels, as cars needed significantly more space to operate. In other words, "public transport requires urban density whilst car-use requires space" (Meyer and Shaheen, 2017). This has led globally to enormous tensions and differentiations.

Nevertheless, the mobility paradox (Pettys, 2014) reached both city models. In compact cities, where space is already limited, the population increased rapidly and city centers became extremely dense, but the management/distribution of urban space and urban accessibility, based on the new demographic changes could not cope well with these changes (Brimont et al, 2015). And car-use required even more space (curb space, parking area) resulting in extra challenges facing cities and out-spacing road infrastructure provision and public transport alternatives.

In decentralized, sprawling cities, the introduction of car-use created other big challenges. As these decentralized cities require fast transport modes to decrease the journey time, cars developed as the dominant transport mode for urban areas with low density (Brimont et al, 2015). As a result, these car-based transport systems required more space to operate and for parking. The space requirements of private vehicular traffic not only led to greater de-densification of cities, and the expansion (and continuous maintenance) of roads and highway networks, but were also a major contributor to congestion, which in turn led to more commuting and parking pressures on public space and had a negative impact on climate change (Meyer and Shaheen, 2017). The outcome lacked a sustainable, environmentally-friendly effect, and exhausted the public funds enormously, leading cities to seek financial support from the private sector. This policy offered the stakeholders the opportunity to actively participate in the transport policy-making (Brimont et al, 2015).

2-2 Transport System

2-2-1 Development of Urban Travel

The main categories of urban travel are public (collective), non-motorized (soft modes), informal (community) and private (collaborative, individual) transport (Meyer and Shaheen, 2017). Depending on the urban accessibility approach cities decided to follow, different urban mobility modes developed. Where in some cities the trend towards motorization increased, new and alternative patterns of urban planning and transport systems emerged in others.

To reduce car ownership, many developed cities like Berlin, London and New York, promoted and expanded public transport and soft modes as well as upgrading the inner cities to be more attractive.

More users went back to using public transport, but for significant changes, cities had to play an active role and support the concept at the policymaking level to facilitate the change as the various factors involved are interdependent (Brimont et al, 2015).

In Europe, the tendency was more towards inner city neighborhoods, quality of life, social capital and historical preservation, and cities concentrated on developing transport policies away from the private car. In America, cities were concerned more about road safety due to the increased rate of road accidents. As a result, in contemporary street designs and infrastructure, the focus was more on developing safer and more attractive walkable and cycling streets (Brimont et al, 2015).

Other factors such as environmental awareness, personal mobility demand, increasing congestion and the costs of car maintenance, shifted millennials and the next generation to collaborative transport options (Brimont et al, 2015). The digital era and the continuous connectivity it provided also played a significant role in the shift to these alternatives and made car-free travel more appealing.

In the second half of the 20th century (Brimont et al, 2015), traveling became more important in daily life due to the emerging shared-economy concept. Trends like the "transport paradigm" (Brimont et al, 2015) and "mobility as a right" (Brimont et al, 2015) enabled the mobile society to experience transport as a basic right. Cities took action but in various ways. European countries developed public transport services, while in America investments were made in road infrastructure. But both faced a challenging dilemma, the rebound effect (Seebauer S. et al., 2018) and the "sustainable mobility" paradigm (Brimont et al, 2015). The demand (number of journeys) increased drastically but the supply could not cope in terms of offering appealing public transport modes as an alternative to car-use.

It was then understood that the right solution for cities no longer lies in providing uniform public transport services, but in offering a range of modes to meet different demands – a more holistic approach to mobility practices. Additionally, the power of the community was rediscovered. These collaborative modes (informal carpooling and car-sharing) have existed for a long time and still represent the predominant forms of transport in some parts of the world (Meyer and Shaheen, 2017).

Cities took active steps to offer sustainable and seamless services within the mobility paradigm in the early 2000s (Brimont et al, 2015). They encouraged private parties (shared car actors) to move away from individual mobility by collaborating with local authorities. Private parties were supported in this policy either through the B2G model, where they were fully financed or through subsidies from the local authorities. In addition, they were offered reserved parking spaces or benefited from the construction of carpool parking areas (Brimont et al, 2015).

The city supported these "first generation" actors and partly integrated them into public policies. This was a policy that was not easy to apply for some other private groups (for example short-distance journey actors). The city could not integrate them into the system for various reasons, such as not being aware of their existence, or not wanting to risk supporting a business model that might not always serve the general public, be sustainable and could cease to exist (Brimont et al, 2015).

And as this collaboration was still in its infancy and the role of the city was not yet clearly defined, the deployment of shared and on-demand modes remained limited in terms of areas and population categories (Brimont et al, 2015).

2-2-2 Innovative Urban Transport

Eventually both city models faced challenging ‘lock-in effects’ in the urban planning and transport system, as well as gaps in their urban accessibility coverage. The steps cities took varied depending on the city model, but one factor remained constant – planning and managing land-use without considering the transport system would not only be inefficient but would also lead to further stalemate (Brimont et al, 2015). The complexity of planning urban transport lies, on the one hand, in the involvement of various actors such as urban planners, transport systems developers, policy makers, etc., and, on the other hand, is a consequence of the fact that it defines the urban space and provides urban accessibility to the general public.

Moreover, modern trends in big cities have led to certain negative effects globally such as rapid urban population growth in big cities connected sometimes with informal urban city development, imbalances in the demographic structures between cities and rural areas and in the ratio of younger to older generations, increases in CO_2 emissions and greenhouse effects, traffic congestion, commuting and the waste of resources like fuel, time and money (ADL, 2018). These changes require greater consumption of natural resources and are not supported by the existing urban infrastructure (McKinsey & Company, 2015). Increasing the number of vehicles on the road to cover the demand would mean that investment in urban mobility would have to quadruple worldwide by 2050 (McKinsey & Company, 2015) in addition to increasing space-requirements for cars which spend most of the time parked in public areas.

That is why cities, both compact and decentralized, have considered alternatives, such as switching to innovative transport solutions and reducing the de-densification of cities. Additionally, globalization has led to new developments, such as the spread of the concept of “mobility as a right” (Meyer and Shaheen, 2017), which has enhanced mobility demand and opened up the potential of the digital era. This in turn has facilitated permanent connectivity and the availability of new services such as routing apps, e-ticketing and offering tailored intermodal mobility services based on the customer information, and has increased the use of smartphones in everyday life, giving greater access to customers' data, This was a development that helped companies understand the user's needs and enabled some private companies to offer partly tailored mobility services to compensate for the lack of coverage of the public transport. Other advantages of smartphones include the active engagement of the community, which led to various uncategorized MaaS and MoD developments such as informal mobility modes (Luebke, 2016). These modes developed to fill in the gaps in both public and private transport and varied enormously depending on the city (shared cars, car/vanpool, rickshaws, micro transit/minibus, paratransit) (Xie and Wagner, 2010) but they all played an integral part in the mobility ecosystem in many countries globally. Also, increased awareness of the environment on the city side led to the development of new objectives such as reducing air pollution through restricted policy measures for car-use and encouraging sustainable urban mobility design with environmentally-friendly mass transit.

2-3 The Role of the city

2-3-1 Development of the Role

The modern trend to introduce mobility as a right (Brimont et al, 2015), has shifted the supply-oriented transport approach to a demand-oriented mobility approach. When the effects of the global financial crisis were first felt, cities started to look for alternatives and collaborative/combined mobility were appealing options. But that meant that cities needed to take some steps and risks to enhance the shift through experimentation and innovation, and also to evolve so that they could take on other roles in terms of contracting (management of the different actors) and steering (articulation with public transport, data management, etc.) The most crucial thing was to avoid losing control over the development of the urban transport industry (Brimont et al, 2015) and end up being overwhelmed. This would mean another party would be able to take over if it moved faster and offered services the city did not cover.

In theory, in order to take these steps, the cities first needed to establish precisely what was going on. They then needed to shift their mobility mindset in order to develop adapted policies and regulate/manage the disruption, to exchange data and be aware of users' demands and thus develop the flexibility to shape the core of the new mobility era. These factors would enable cities to take the leading role, influence the process and make relevant and timely decisions to create a meaningful impact by changing two fronts, one on the external policies and one on the internal performance (Brimont et al, 2015).

External Policies

These involve shifts of various kinds and successful execution through new approaches to internal performance, such as new ways of doing business and a new mindset (Brimont et al, 2015).

Internal Performance

This includes new activities which help structure the mobility world, such as collaborating with the private sector, drafting regulations, upgrading the system to accommodate innovative technologies, and digitizing the system, as well as having the leverage and support needed for organizational and cultural transformation (Brimont et al, 2015).

In practice, intermodal concepts such as MaaS promote giving up private cars and shifting to collective (public) and collaborative transport modes, but cities realized that to achieve this goal, appealing services must be available on the market to substitute for the convenience of the car.

Of particular concern was the fact that the current situation offered customers either classic public transport services in the form of mass transit, which did not cover all their needs, or private sector offers which, though modern, lacked some major functions. But the user desired an all-in-one service, which could be operated comfortably wherever and whenever needed. And this was the backbone for the development of integrated mobility services such as MaaS and MoD – offering "Mobility as a Service" or "Mobility on Demand".

2-3-2 Factors Behind the Evolution

With MaaS, MoD and other alternative integrated mobility services, a new era is coming where mobility is consumed as a service and the traditional transport market is completely disrupted. The cards are going to be mixed and distributed differently and the game will have new rules. One rule is already fixed; for MaaS to function, the cooperation of all relevant stakeholders is vital. Each stakeholder plays a unique role and together they form the MaaS ecosystem.

The necessity of taking this step (enabling MaaS) became even clearer with increased awareness of the fact that both cities and the users' demands are changing, so the supply needs to adapt or it risks becoming obsolete. It was then understood that a sole provider (public or private) cannot cover the diverse demands of the modern user. Local factors are essential as well as the acknowledgment of the potential of the new providers. But most of all, for this cooperation among the various stakeholders to function, a leader is needed.

The role of cities therefore shifted from merely the technical provision of transport to attempting to take action regarding the spatial organization of the city in order to reduce travel needs. This mobility-based approach, says Brimont et al, (2015) is aimed at better integrating the issues of externalities, urban accessibility and financial sustainability. Moreover, it offers alternatives to cars by developing public transport solutions and soft modes (walking, cycling). The new concept is based on keeping the existing mode as the backbone and integrating the other modes into it, taking into account the fact that all modes, whether public, shared, on-demand, ride sourced or private are unable to cover all the mobility demand alone.

2-3-3 Influence of the New Players

Public transport has its limits, such as the cost for public finances, first/last mile, etc. Collaborative modes are also limited in terms of areas, mass coverage and population categories and thus should only be deployed to complement the public transport system, or in its absence, at the end of the mobility chain (Brimont et al, 2015). Similarly, private cars not only have a negative effect on the environment, but they are also limited in terms of their higher costs and parking problems. This gap between public and private services offered new entrepreneurs such as collaborative mobility actors and third parties the opportunity to develop new solutions.

The innovative approach of these mobility solutions lies in how existing technologies were reutilized, for example, by turning a bus rapid transit system (BRT) (Meyer and Shaheen, 2017) into a high-capacity urban transport system, or by changing collaborative mobility pick up/drop off stops into mobility hubs.

Likewise, new technologies such as electrification and digitization emerged from outside the car industry and were used innovatively in the urban mobility sector to drive the change. They impacted the existing public transport systems and made a more enhanced approach possible in terms of information, use and management (Meyer and Shaheen, 2017).

In consequence, cities started gradually to encourage and promote digital urban accessibility by substituting physical travel with digital communication and virtualization by, for example, changing public transport ticketing to contactless payments through smart cards or smartphone apps, which offered convenience and reduced costs (Meyer and Shaheen, 2017).

Another influential factor was the acknowledgement of the community, which led to various crowdsourcing ideas. These new disruptive services, smart infrastructure and open and big data allowed the community to participate actively and to improve the services in terms of providing real time data and updating the network. Equally, digitization offered major opportunities for collaborative mode providers to benefit from functions such as real time information on vehicle availability and on-demand smartphone applications (Meyer and Shaheen, 2017).

Accordingly, it is expected that the introduction of autonomous vehicles will facilitate the integration of additional services such as goods delivery, post pick up, tourism, health, etc. on the (same) platform with the existing personal transport services (Meyer and Shaheen, 2017).

2-4 Mobility as a Service

Stakeholders from across the world have been dealing with MaaS intensively in the past few years. They have ideas in common and also opposing ideas about its concept, how to implement it and who should play which role. However, a common definition that all parties agree on has not yet been reached. Still all agree that MaaS has the potential to improve transport, serve the underserved, be eco-friendly and support the economy.

For a better overview, the research highlights some of the main definitions

“An innovative transportation and mobility concept where consumers access mobility, goods and services on-demand by dispatching or using shared mobility, courier services, unmanned aerial vehicles, and public transportation strategies” (Shaheen et al., 2017).

“MaaS has the potential to fundamentally change the behavior of people in and beyond cities, hence it is regarded as the biggest paradigm change in transport since affordable cars came into the market”, according to Rasmus Lindholm, ERTICO's Director of Communications and Partnership Development (2014), (Ertico, 2014).

Sampo Hietanen, CEO MaaS Global (2014) stated, “Mobility as a Service (MaaS) is a mobility distribution model in which a customer’s major transportation needs are met over one interface and are offered by a service provider” (Hietanen, 2016).

The MaaS Alliance defines MaaS as “the integration of various forms of transport services into a single mobility service accessible on-demand. To meet a customer’s request, a MaaS operator facilitates a diverse menu of transport options, be it public transport, ride-, car- or bike-sharing, taxi or car rental/lease, or a combination thereof. For the user, MaaS can offer added value through use of a single application to provide access to mobility, with a single payment channel instead of multiple ticketing and payment operations. For its users, MaaS should be the best value proposition, by helping them meet their mobility needs and solve the inconvenient parts of individual journeys as well as the entire system of mobility services.
A successful MaaS service also brings new business models and ways to organize and operate the various transport options, with advantages for transport operators including access to improved user and demand information and new opportunities to serve unmet demand. The aim of MaaS is to provide an alternative to the use of the private car that may be as convenient, more sustainable, help to reduce congestion and constraints in transport capacity, and can be even cheaper” (Ertico, 2016).

Cole, president of Cubic Transportation Systems (2018) says “MaaS represents the Netflix of transportation – a subscription service that allows customers to choose from a number of different transportation options and pay for them via a monthly or yearly subscription or as pay-as-you-go”

(Cole, 2018).

Dalton, Principal - Method City and Chief Technology Officer (CTO) - TravelSpirit (2018) sees MaaS from a different perspective as the ""Internet of Mobility" where one finds on the MaaS platform/s all the transport modes. Also, with the parallel existence of multiple MaaS platforms, the user still can find on each MaaS platform all the modes - just like one can choose which internet engine (google, yahoo, firefox, opera) to surf on to reach his goal. An open API integration is required for this concept -the fact that its details are not yet agreed on- implementation, etc. After all, data is not the fuel but the infrastructure", adds Dalton (2016), (Dalton, 2018).

MAASiFiE (Mobility as a Service for linking Europe) (2016) defines MaaS as, "multimodal and sustainable mobility services addressing customers' transport needs by integrating planning and payment on a one-stop-shop principle". Koenig, MSc, Mobility Systems & ITS Deployment (2017) adds, "MaaS is a new concept aiming to provide consumers with flexible, efficient, user-oriented and ecological mobility services covering multiple modes of transport on a one-stop-shop principle. MaaS could offer multimodal route planners and different services under one fare and on the same ticket. As well as traditional public transport, MaaS could also cover various rental and sharing services. MaaS could combine passenger and freight transport operations, especially with respect to urban delivery and distribution in rural areas" (Koenig, 2017).

MaaSifest - Mobility as a Service is the future for Mobility (2016) says, "Mobility as a Service refers to a transition in the field of mobility where consumers purchase mobility rather than investing in means of transport themselves. An essential change here involves thinking in terms of service levels. New services will be a combination of public transport, demand-driven transport and private vehicles. ITS is an important part of Mobility as a Service, as it links all elements of multimodal transport – passengers, goods, vehicles, information and communication technology, infrastructure, etc." (Hsu, 2016).

Deloitte defines MaaS as a transportation service – a journey planner and an integrated travel information platform. "At its core, MaaS relies on a digital platform that integrates end-to-end trip planning, booking, electronic ticketing, and payment services across all modes of transportation, public or private" (Cole, 2018).

KPMG defines MaaS as a paradigm where "every public and private transport option is presented in a single app, handling payment and bookings through the same platform and providing dynamic route planning information to users" (Cole, 2018).

The transit industry defines "Mobility as a Service simply in terms of the few MaaS applications that are in operation today, such as Whim, and to a lesser extent, CityMapper, Waze, TripGo or Moovit" (Cole, 2018).

CUBIC defines MaaS as "Mobility as a Service is a combination of public and private transportation services within a given regional environment that provides holistic, optimal and people centered travel options, to enable end to-end journeys paid for by the user as a single charge, and which aims to achieve key public equity objectives" (Cole, 2018).

Moovel and Juniper Research define MaaS as "Urban transport solutions that are integrated into a single platform by which users can determine the best route and price across several end-to-end travel services and modes, according to real-time data such as traffic conditions, time of day and demand" (Moovel, 2018).

Nehrke (2017) from the German Association of CarSharing defines MaaS as "offering mobility as an on-demand service. It is opposed to providing mobility on the basis of personally owned means of transport. The future of MaaS will be an integrated urban mobility ecosystem made of mainlines of mass transport, smaller on-demand ride sharing vehicles and car sharing vehicles for special purposes such as transport of heavy goods or trips to the countryside. The aim is to make this environment accessible via one online-system with diverse touchpoints both personal and public throughout a city". Nehrke (2017) thus recommends that for a better physical integration those cities facilitate collaborative modes to have stations in the streets, especially in highly condensed inner-city areas to enable more accessibility to those modes, (Nehrke, 2017).

2-5 The Good Practices Catalogue

With their eyes on the prize, cities are racing globally to develop suitable concepts to enhance their mobility systems and enable an intermodal concept, for example, MaaS and MoD, to reach the usability stage and so be in a better position to deploy AVs later. For this reason, already existing units of MaaS reflect the interconnection of the research's three components: the role the city plays, the grid of the local city structure and the existing transport modes. These components are considered good practices for benchmarking.

2-5-1 Europe

UK - London

London is a global city and a MaaS role-model as described by the experts below. It is a city where the public transport system belongs to a number of public authorities, which are not networked together and the national train network belongs to a different entity and is not integrated on the Oyster platform. Nevertheless, a digital infrastructure exists already in the form of a digital platform, where ticketing is integrated with access to the hubs in the form of the Oyster card/App. The next steps are the integration of all payment mechanisms for other modes like bike-sharing and taxis as well as journey planning and adding missing services like car-sharing and on-demand services on the platform to complement the bus services (Macbeth, 2016).

"Innovation comes from inspiration", Neckermann, MD Neckermann Strategic Advisors (2016) says. The missing pieces in the MaaS puzzle are due to a lack of suitable offerings, for example, a service that would provide information about how to find a parking spot, etc. But these missing building blocks are then substituted by a variety of collaborative modes such as ride hailing. Uber in London is one of the important components in the MaaS picture and the service is regulated by the PT authority – Uber drivers are licensed and insured by TfL (Transport for London) (Neckermann, 2016).

There is a flexible open data policy as the APIs are offered for free on the TfL website so that other developers can dock on the platform, explains Bailey, Head of Marketing, Stratageeb (2017), and adds that London has invested in innovating the transport system (Bailey, 2017).

The city adopted taxation, says Datson, Senior Technologist Transport System Catapult (2016). For example, bus transport providers have to pay 20% when they have buses with more than 10 seats. Therefore, using minibuses with 7-9 seats was a good solution. Transport for London (TfL, 2016) integrated the APIs and offered open data – accessible for all developers in the UK. The city also invested in the internet network, offering 4G net which will soon be followed by 5G (Datson, 2016).

"In terms of MaaS, to a certain extent we already operate a Mobility as a Service (MaaS) type platform in the form of Oyster," says Macbeth, (2016) Transport for London TfL, Automotive & Intelligent Mobility (Macbeth, 2016).

Macbeth (2016) explains the roadmap for MaaS in London. It includes consolidating all payment mechanisms into a single interface, for example, bringing the Santander Cycle scheme into the contactless/Oyster portal (CUBIC technology, (Cubic, 2016)), as well as payment for the congestion charge. Other ideas include introducing contactless payment into the London black cab taxi fleet and looking into incremental additions to the platform, so that car clubs (for example, Zipcar and BMW Drive Now) could be invited into the Oyster platform and given access to the TfL brand as long as they meet specified criteria. There are further plans to explore and introduce innovative forms of demand-responsive transport such as taxis, on-demand shuttles/vans and ride hailing to see how these types of services might complement the existing bus network. Cooperation with Waze and others in terms of journey planning and app development already exists. (Macbeth, 2016).

Germany - Berlin

Berlin is both a capital and a state inside another state. The Berlin-Brandenburg Metropolitan Region has a strong unified PT network, together with some shared and on-demand modes. Many services existed already and it is a neutral global city in terms of policy and industry when compared to other German cities, which host an automotive brand. These factors have encouraged many stakeholders to relocate to Berlin, for example, Tesla (Tesla, 2019). This boost has transferred the city into a hub for various sustainable projects and a field for many MaaS Pilot projects, such as the Insel Project, TXL Project, Smart Sustainable District, Smart Hub SuedKreuz, etc. (Mienkus, 2016), (Smart City Berlin, 2019). But despite being a technology hub, the city lacks a startup culture and a digitalized system, a drawback that slowed down the development in this field for a while. Mass transit and car sharing represent the two biggest components of a MaaS ecosystem, leaving less room for ride hailing providers. Uber is limited here – it has been partly banned from the city, but taxi companies have cooperated with it to some extent.

Jonuschat (2017), Senior Advisor by Innovation Centre for Mobility and Societal Change (InnoZ), says that in order to enhance MaaS, the DB (German Railway Company) implemented Flinkster (2017) a car-sharing service Germany-wide in more than 400 cities. The service was integrated into the DB app together with bike-sharing and PT to offer an intermodal service, (Jonuschat, 2017).

Qixxit is a DB trip planner for the whole of Germany. Kellner (2016), Qixxit's CEO, explains its greatest plus point, namely that it is one of the MaaS projects that has the best conditions for an all-in-one MaaS, based on the fact that it already belongs to the public transportation sector, which is the backbone for MaaS. This means that a great many problems are solved immediately, such as how to deal with customers' data. It will offer fully integrated door-to-door routing within Germany (Kellner, 2016).

Berlin used the tax-card too but in a different way compared to Stockholm as seen below or London. Providers offering services within shorter distances than 50km pay 7% tax, while for more than 50km the tax increases to 19% as Krueger, a tax consultant, explains, (Krueger, 2018).

Dr. Ackermann (2016), Head of the Economic Department for the Association of German Transport Companies VDV (Verbands Deutscher Verkehrsunternehmen) explains how MaaS has had a long tradition in Germany, but it has been known by other names, like the call-a-bus service. Now the smartphone will make this step easier. With increased CO_2 emissions and lack of extra budget for renewable energy sources, MaaS was the next logical solution. He sees a big advantage in the public sector developing the MaaS platform as they have the foundation already. With the development of the new concept of commercial transport, the VDV is discussing with the municipalities the idea that the VDV should develop a MaaS platform for all modes (Ackermann, 2016).

Netherlands - Amsterdam

Amsterdam is an incubator city for various resilient projects. The city's structure is used in a number of ways to enable it to become a smart sustainable city (deliveries, multifunctional hubs, etc.). The involvement of the various communities as test beds for pilot projects is crucial. Open-source data is used to deliver up-to-date services in terms of roads and congestion and thus suggest better and faster routes and there is tele/smartwork with free wifi and multiple locations. The latter concept has had great feedback, especially as bikes play an important role in the user's daily transport and this function has helped users to navigate the city more easily (Hsu, 2016).

"Connekt, an independent network for smart sustainable and social mobility" was initiated with the ITS Netherlands, Hsu (2016) Project Manager, Connekt explains (Hsu, 2016). In partnership with the Ministry of Infrastructure, the Environment and the City of Amsterdam, Connekt has launched the Smart City Embassy, which is a digital portal for (foreign) delegations interested in discovering smart city solutions in the Netherlands. The website aims to make it easy for delegations to find out what is happening in the Netherlands in terms of smart cities, and clear filters on the site guide delegations to solutions that actually interest them (Hsu, 2016).

Sweden - Stockholm

Stockholm has developed a public mobility app that combines PT, car-sharing, rental car services as well as taxis and on-demand mobility services. Customers can book flexible monthly subscriptions with an account that is shared among the members of one household. This project was based on a successful MaaS pilot project, which took place in 2014 in Gothenburg (Socher et al, 2014).

MOAI (2018) explains in "MOIA Mobility Championship: 5 mobility facts about Stockholm" the measures the city took to reduce the increasing congestion and develop a sustainable transport system - a traffic tax was introduced in 2006, which varied according to the time of day and day of the week. The city then used the money raised to expand the PT network/infrastructure and co-finance the city's sustainable transport development concept. The traffic tax led to a significant reduction in traffic in the city (almost 40% less traffic), and this in turn made the roads more attractive and eco-friendlier, which led to an improvement in the quality of life. The expansion of the PT network covered new bus lines, the underground, suburban railway systems and bike lanes and ferry lines (MOAI, 2018).

To attract tourists and more residents to use the public transport network, the city introduced e-tickets to the train/underground services which are also the entrance tickets to some sightseeing tours, galleries, etc. (MOAI, 2018).

Finland - Helsinki

Helsinki is a smaller and less dense capital with a PT network and shared and on-demand modes. The MaaS company (MaaS Finland rebranded it as MaaS Global) emerged as a venture project, with a commercial business model and a tailored price offering in the form of an intermodal app. As the city and MaaS Global were open towards a data sharing concept, mobility providers were integrated into the platform through the connection of their APIs, offering adaptable services according to the demand. MaaS Global owns the user's contact information and represents the contact point to the user. The majority of the customers of this business model are businessmen. The city promotes MaaS widely, but is not involved with the private company, says Hietanen (2016) CEO MaaS Global (Hietanen, 2016).

Hietanen (2016) CEO - MaaS Global, explains the positive role the city played in enabling MaaS. The city supported the political side, adapted the legislation and pushed the concept commercially. Accordingly, some providers like taxi and car-sharing adapted their offering to fit with Whim (Whim, 2016). Hietanen (2016) says MaaS is the enabler and needs to be organized before AV hits the market. It will then herald the end of car ownership (Hietanen, 2016).

The question which will have to be answered in the near future is how a commercial business model can survive in bigger cities where it will be facing much bigger challenges and how the business model will evolve to adapt to these challenges.

Austria - Vienna

Vienna is also smaller and not a dense capital, but unlike Helsinki, it has a unified PT network, together with shared and on-demand modes. As a result, the MaaS company here emerged as a PT subsidiary.

Lichtenegger (2017) MD Wiener Stadtwerke, Neue Urbane Mobilität Wien GmbH-NeuMO, explains the Vienna model in which the city is actively involved. The Wienerstadtwerke runs the Wienerlinien (Public Transport) and NeuMO (research center). The two entities established Upstream (digital platform). The Wienerstadtwerke also runs the Wienerlokalbahn (local train) and WiPark (public garages) which are also integrated into the platform. Upstream is an aggregator for all the services including information, registering, ticketing, billing, payments and parking. The offers of the various mobility providers (PT, collaborative modes, garages, etc.) are consolidated into the platform via one app. Upstream offers a white label platform where every provider keeps his customers' data, sets his prices and remains the contract partner. Lichtenegger (2017) says, although it is expected that both local and global platforms will develop, it is important that the users still trust the local ones - fairness and transparency is the motto - and that is the advantage of such public providers. In the future, Lichtenegger (2017) says that the integration of goods transport into the model will follow. By 2050, the city wants to ban petrol manual cars. The OEBB (Austrian federal railways) is not part of the platform (Lichtenegger, 2017).

2-5-2 North America

In the US, one finds that transportation is mainly organized at city and country level and concentrates on big cities and city centers, which makes a regional approach even harder for MaaS. At ITS International's MaaS Market in Atlanta, June 2018 (ITS Atlanta, 2018), the future of MaaS was the center of all discussions and especially how to deploy it in the US market. Pöllänen (2018) from MaaS Global, states that three factors stand in the way of MaaS in the US: the PT is incomplete/basic, the car is the dominant mode and a city/country transport management exists instead of a regional focus. In addition, there is a lack of digitalization such as open APIs in the system. But she also highlights the three positive things the US market offers, the innovative culture, the pro-business concept towards private providers and the willingness to embrace the new model (Pöllänen, 2018).

Draa, Global Product Director by Cubic Transportation (2018), explains that "getting transportation providers - especially private operators- to join MaaS networks will take some convincing. The business models need to make sense for everyone involved," she said. "And for that trust is needed" (Draa, 2018).

Cities which developed after the industrial era

San Francisco (SF), California, is a typical, sprawling American city where the private car is the dominant mobility mode. Nevertheless, San Francisco, and especially the Bay Area, has emerged recently as a pioneer in enhancing collaborative mobility projects, adopting new transportation technologies and innovative services like car-sharing, bike-sharing, ride-sharing, transportation network companies (TNCs), and smart parking management, as well as the user acceptance of alternative fuel vehicles which Shaheen (2016) professor, Sustainable Transportation and Research Director, UC Berkeley, explains is the focus of her work (Shaheen, 2016).

The permanent connectivity encouraged providers (public and private) to develop various apps to facilitate physical and digital urban accessibility.
For example, the Center for Neighborhood Tech (CNT), a technology and innovation hub to improve urban sustainability, developed the AllTransit app, a game-changing piece of research, offering tools and solutions to create sustainable and equitable communities (CNT, 2017). NextBus -a public transit vehicle tracking system, tells users when the next bus is coming (Nextbus, 2017). The contactless and reloadable Clipper Card in the Bay Area in SF is used for transport e-payments. As a pilot project, it was introduced as TransLink in 2002 (rebranded in 2010) by the Metropolitan Transportation Commission (MTC) (Clippercard, 2017).

And like San Francisco, other sprawling cities, which developed during the industrial era, have the private car as the dominant mobility mode. The Smart City Challenge -organized by DOT in 2016- encouraged many states to consider their stronger sides and work on their weaker sides by presenting a future concept to transform the city into a smart city. Columbus, Ohio won the challenge. The proposals included promoting shared mobility as a solution to compensate for the lack of the PT offering through the development of a shared mobility toolkit (Shared Mobility Benefits Calculator, Shared Mobility Policy Database and Interactive Shared Mobility Mapping and Opportunity Analysis Tool) (SCC, 2016), developing and implementing technology and world-class solutions for transforming mobility enhancing transit information, and offering a wider variety of cost-effective, convenient, and tech-enabled commuter options. Other proposals involved enabling mobility-oriented land use and city development to achieve societal goals and ultimately shifting from a fossil-fueled, personal-vehicle-based mobility system towards clean energy and one defined by fully autonomous, electrified, on-demand mobility (SCC, 2016).

Gil Friend, (2016) former Chief Sustainability Officer in the City of Palo Alto, California, highlights some of the cities' approaches, "The best I've seen so far are Austin, Denver, San Francisco, Palo Alto". An extra trial to keep up with the convenience of the TNC, the PT sector in Austin, Texas, offers as a pilot project an on-demand bus to pick up the users from their places of residence and drop them at their destination - hailing via a ride hailing app (Friend, 2016).

St. Diego, California took an active role in helping people share rides by enhancing cooperation among various networks. For example, overlaying credit cards onto a city's transit system to analyze how citizens are moving and why and so plan the smart city better. They could then be offered tailored mobility solutions in the form of a cloud platform based on their economic activities (Cubic, 2017).

Cities which developed before the industrial era

New York, in comparison with the sprawling Californian cities, was developed earlier and before the car era. It is a compact city, which has a functioning PT network. The city concentrates on sustainable future development projects.

Simon (2016) Director, Alternative Fuel Programs, Transportation Planning & Management Division, New York City Department of Transportation (DOT) explains that New York owns the country's best PT network, which pushes it to the top of the list as a candidate to develop a MaaS ecosystem based on the availability of shared-use and on-demand modes that could substitute for the ownership of the car. UBER drivers must be licensed from DOT. The high city density inspires the walkability-concept (modifying the roads for better walking services) and supports the resilience concept combined with the acceptance of innovation on the city level, which enabled the development of various pilot projects for AV and commercial high-speed connectivity. It has also encouraged multi-zone districts and mixed-use development. For example, Buffalo NY has the best commute times because the residents live near their work, with direct access to the various facilities needed, i.e. there is no single use zone (Simon, 2016).

2-5-3 Africa, Asia, South America and Australia

In these continents, with the exception of the big developed cities, the lack of infrastructure has led cities, communities and individuals to take shortcuts to reach their goal. In addition, the results obtained in other places are adapted to fit locally. Here, the individual on-demand varies, depending on the existing PT services.

Africa

There is a difference between rural areas and cities. In the rural areas the concept of the off-grid system has started to emerge, while bigger cities, which are vast and have normally no (or only poor) transport infrastructure and PT services, have only basic modes concentrated in city centers, which are dense in comparison. The lack of public transport services that cover the demands of the users has encouraged the emergence of informal transport, on-demand and hail services. And the liberalization of the system as a result of the absence of strong PT, has made it possible for the owners of vehicles (car/minivan) to use them to transport customers.

The transport network varies from city to city and covers big, mid and mini buses (most common), taxis, shared taxis and tuk tuks. There are also tramways, train lines, water transport and bigger buses as well as existing and planned transport infrastructure such as bridges, bus stops, mobility hubs, etc. Bigger and more developed cities have metro networks, classic trams and fancy trains (Gautrain) which are not accessible to all, like in Johannesburg (Johannesburg, 2017).

More and more private car owners use their vehicles for peer to peer shared-use modes Recently a wide range of local TNC providers like Tirhal in Khartoum, Sudan, (Tirhal, 2017) have deployed their services via Smartphones. Generally, certain regulations control the process and need to be fulfilled before operating. Although the city regulates the prices, the main problems they face are the various standards between state and city.

As it is still in the infancy phase of the mobility revolution, the continent has become an attractive location for international investors, providers and researchers. This has meant that locals are empowered in terms of pilot projects for tracking apps, community sourcing & open-source data, AV test roads, logistic and delivery innovative services, etc. The various projects represent an example of a positive public-private partnership (PPP) between the local authorities, the universities, local communities and the international investment parties – the World Bank- by the "Power of the Community - Crowdsourcing" (Couto, 2016).

Asia

In Asia there are typically, large countries with a very dense population and limited financial resources, where non-motorized modes are widely spread. Thus, the interest in shared sustainable e-Mobility was big.

The clear definition of shared spaces supported, Schwitalla (2016) innovative city planner, architect and owner of Studio Schwitalla, explains, the acceptance of the on-demand services combined in some cities with a very high acceptance of innovation on the city level and taking an active role in enhancing and improving public transport. All these things facilitated the spread of a strong advanced PT network as in the cases of Hong Kong and Singapore (Schwitalla, 2016).

Such an active role encouraged local and international providers like Daimler (Car2Go) to introduce a car-sharing fleet as Felizeter (2016) Head of Department Building, Energy & Environment - Econet China, says. China is leading the electric revolution worldwide and that is for the following reasons he explains: China is a vast but very dense country, combustion engines have polluted the air and it is expected that even more citizens will move from rural areas to cities, thus producing more emissions, and considering the fact that China is already the largest car producer in the world, it is only logical that the solution lies in clean energy, for example in Shanghai and Chongqing (Felizeter, 2016).

Other innovative approaches are peer2peer and AV services in the form of Robo-taxi, says Declercq (2016) - Executive Vice President, Europe Middle East and Africa, by Local Motors, as Japan, another leading country in the auto manufacturer field like China, introduced while making plans for the 2020 Olympics. Robo-taxi and other peer2peer modes are considered the next generation of the present car-sharing and normal taxi services; they are also expected to push the prices down, which will enable them to be offered more cheaply (Declercq, 2016).

Also, in the UAE, Dubai and Abu Dhabi the focus is on Smart Cities, renewable energy and collaborative mobility modes. One example of a future smart city is Masdar in Abu Dhabi. There are plans for it to rely on solar energy and other renewable energy sources (Masdar, 2016). Careem is a transportation network company (TNC) based in Dubai (Careem, 2016) with a forward-looking agenda.

Generally, in Asia with the absence of the direct private sector and in the presence of better infrastructure, one already sees collaborative modes and with the presence of two of the world's biggest Auto Manufacturers (China and Japan), there is a big push towards e-cars and AV fleets, especially as these big cities are threatened by extreme car pollution.

Other models are the new cities like Singapore and those in Malaysia, where the cities were developed from the beginning on a smart city concept.

Other smaller cities and towns use, in the absence of a functional PT system, active modes - walking or cycling.

South America

Different worlds are evident here too between big cities where the infrastructure is developed and there is a modern PT system with maps and schedules in the form of buses, trains, subways and on-demand modes, as in Brazil, Chile and Santiago and other smaller cities where urbanization took place without a clear plan.

Vorstenbosch, (2018) Business Integration, Digital Development Management, explains more about Brazil in general (the continent's biggest country) and about Rio in particular. In Rio, the majority of people go to work by PT; an option that is sometimes dangerous and crowded, but in the absence of other alternatives and the limitation of financial resources, represents one of the only available options.

For the Olympic games, the city was upgraded, a bus rapid transit (BRT) and a metro network were introduced to the city, which has given more people access to affordable and better connections into and out of the city.

Owning and driving a car is not a cheap option and is limited to people with a reasonable income. UBER is very common as a cheaper, though not safer, alternative to taxis and represents at the same time a second income for the drivers.

In spite of this, the citizens avoid these forms of PT, regional trains and other collaborative modes (e.g., carpooling) for safety reasons. In order to promote and enable a sustainable mobility revolution, the city has to find fundamental solutions to make these modes safe, appealing and friendly (Vorstenbosch, 2018).

Colombia took a different approach. In Bogotá, in an initiative called Ciclovia, which was designed to enhance sustainability, the city has banned vehicles once per week for a distance of over 75 miles. It has also developed over 200 miles of bike lanes and started in 2013 to implement a program called Peak and Plate, which bans driving for cars with certain license plates during peak traffic hours on certain days of the week (Garfield, 2018).

Australia

The car is the dominant mode in these vast but less dense cities; thus, one tends to look at the American model in making the city more sustainable, but the transport offering is also tailored in big cities in a similar way to European cities with MaaS – in the form of MaaS Australia, (MaaS Australia, 2016), a partner company of MaaS Global. The tendency in the cooperation with MaaS Global is to implement MaaS in Australia with an adapted concept – not like the European model because PT and shared-use modes are not common except in big cities like Melbourne and Sydney (Somers, 2016).

2-6 Research Gaps

In a world getting smaller through globalization and technology, trends spread faster and the increasing rush to join and win the mobility race has pushed cities into planning and preparing for the next phase, which requires unusual kinds of research, thinking outside the box and going outside the comfort zone. But to avoid being carried away by a blind race, fall into a rebound effect trap (Seebauer et al., 2018) or tap into fallacies (Millonig and Haustein, 2020) in the planning or the implementation, it is important to plan strategically and start with defining which mobility model is really needed based on the existing and potential city structure, transport system and the role of the city. Often it is not a simple clear supply and demand approach, as the transport sector interacts with various other industries. Therefore, it is crucial to objectively analyze the planning of new mobility models in terms of relevant components, local added value, their role in the ecosystem, goals, pain points, partners and most of all assess the city's need for the particular (new) mobility model in order to discover who can facilitate the paths.

Gaining these insights is vital in order to reach the goal, hence, the research explores and summarizes the main factors which have the potential to prevent such a comprehensive process.

2-6-1 Standardized Method for Planning and Implementing Mobility Concepts

"MaaS is a solution but for what problem?" This statement has often been made and even more often discussed. Some focus on the logical aspects of the question as in asking the reason why people drive. The answer to this question is then seen as the problem. In this case, the problem could be the lack of suitable alternatives in rural areas and the flexibility and freedom in urban areas. Accordingly, if good public transport is the solution, then the problem will cease to exist once it is available. Therefore, the problem MaaS is solving is the usability of public transport in urban areas and mobility services in rural areas (Möttö, 2015). Others argue that it should not only be about cars (reducing congestion and improving social equity) but more about giving people more flexibility and choice on how to move around. In this case, the focus lies in the interconnected models, human acceptance, the perceived value and examining the pain points faced on the different journeys and whether the demand is met (Watts, 2017). Others state that due to the growth in the population in cities, existing problems of traffic congestion will increase and that expanding the infrastructure will not solve the problem. MaaS is promoted to reduce/manage congestion, reduce journey time, enhance travelling, encourage a shift in commuting schedules from rush hours and impact climate change positively. Another motivation lies in the market value of MaaS, which is predicted to be worth around $US600 billion in the US, EU and China by 2025 and $US 1 trillion in the global market by 2030 (Keaveny, 2018).

It became clear that the way in which cities' problems are perceived can vary widely and that city planning is not connected with the desired MaaS concept, although these factors are interconnected and thus, they need to be developed as a package. In a world becoming ever smaller due to globalization and the digital era, and where many ties are interrelated, more research is needed on developing common ground on how to assess cities' problems and clarify what the cities are trying to solve. Bypassing a main factor or a player/facilitator while developing a solution that has not been analyzed well could lead not only to major conflicts on the urban accessibility front but also to a waste of resources, inefficient services and a negative impact on climate change, i.e., all areas which the potential of MaaS is expected to reduce/eliminate. This in turn will indicate that not only has MaaS not achieved its goals, but it has been counterproductive and caused more problems than before.

2-6-2 The Rebound Effect and Fallacies in Transport and Mobility Planning

Rebound effect

In an ideal world, MaaS would enhance transport, contribute positively to climate change and meet the demand of the users. But it is precisely these positive factors that could lead to negative effects, for example, when users adapt their mobility habits and consumption patterns (Seebauer et al., 2018) to the new services. They could overcompensate for the efficiency advantage resulting in the more affordable and convenient model backfiring and leading to more rides, traffic jams, urban sprawl and increased CO_2 emissions, resulting in a rebound effect (Seebauer et al., 2018).

Rebound effects in the mobility world can have multiple side effects, such as in the following examples: instead of contributing to meeting the climate goals and reducing the individual use of private cars and travel time, improved car engines, attractive subsidies and accessibility to integrated services, new cars, e-cars, on-demand and shared vehicles could lead to increased energy consumption, traffic and urban sprawl (Seebauer et al., 2018).

Although deliveries can potentially reduce shopping traffic, they may increase delivery traffic (VCÖ - Rebound, 2018).

Autonomous vehicles are expected to secure road safety, improve traffic and increase sharing services, but they could lead to more problems like running with no passengers, leading to longer trips and shifting users away from public transport (VCÖ - Rebound,2018).

Even private cars are not excluded from rebound effects. For example, replacing an old vehicle (150 gCO_2/km, 6 l petrol/100 km) with a new and more efficient one (100 gCO_2/km, 4 l/100 km) means every kilometer traveled now needs a third less gasoline. Due to the lower cost, the new car is used more, from 10,000 km to 12,000 km per year. The CO_2 emissions should drop from 1.5 t (150 g*10 000 km) to 1 t (100 g*10,000 km), but in fact 1.2 t are produced (100 g*12 000 km). Hence, only 0.3 t is saved instead of 0.5 t. The direct rebound is 40% (expected savings which are not realized) and if the money saved is used for a plane trip, which produces 0.4 t of CO_2, the indirect rebound is then 80% (the CO_2 produced from the plane offsets 80% of the saved 0.5 t CO_2) (Seebauer et al., 2018).

Hence the risk of the snowball effect may not be visible at the start and therefore, there is a need for a comprehensive proactive action plan to reduce the boomerang (MaaS Blog, 2019) and more research and analysis on the temporal dynamics of the rebound (Seebauer et al., 2018), as well as the development of political frameworks and regulatory measures to avoid setbacks and complete cannibalization of the benefits.

Fallacies

A fallacy is “an “argument” in which premises given for the conclusion do not provide the needed degree of support” (LaBossiere, 2002). Fallacies are errors in reasoning, i.e., bad logic. They could lead people to make poor decisions as they are common in both everyday life and the scientific world. Knowledge helps to prevent bad reasoning and although this solution seems to be easy, in reality, it cannot be taken for granted.

Transport planning is complex and involves multiple levels in the planning decisions. They branch out to cover more than driving alone, and include other objectives than congestion reduction, and some may have undesired consequences. Litman (2012) explains that roadway expansion often only shifts congestion problems to other locations, because expanding roadways result in increasing traffic speeds, which in turn reduce walking and cycling and promote additional vehicle travel resulting in increased urban sprawl. For this reason, it is crucial to explore all the relevant factors and their impact (Litman, 2012).

Some of the fallacies in transport planning (Tyrologos, 2016) occur due to the use of faulty/invalid reasoning or logic to construct an argument that appears sound and reasonable and thus ends up being misleading. While technical skills are easy to examine and there is a general framework and protocol to assess the abilities needed, less attention is paid to evaluating the logic and rhetoric needed in the industry. This in turn could lead mistakenly to logical fallacies in transport planning. If cities and stakeholders cannot build their decision-making on a strong and robust analysis, fatal errors could be the consequence, which will require resources, time and effort to correct (Tyrologos, 2016).

These fallacies could occur in all phases of a project. For example, the McNamara fallacy (Tyrologos, 2016) occurs when ignoring the qualitative variables and depending solely on the numbers. The Sunk Cost fallacy (Tyrologos, 2016) occurs when cost outweighs the expected benefit. The Planning fallacy (Tyrologos Kyriakos, 2016) occurs when the real time and cost required is underestimated due to wishful thinking, self-serving bias, etc. (Tyrologos, 2016). Another fallacy, which when occurring, could start an avalanche effect is what is commonly known as “correlation doesn't mean causation” or the Causal fallacy (Tyrologos, 2016). It occurs either when identifying the incorrect reasons for a parameter due to correlation or because two actions followed each other.

MaaS/Mod and other integrated, digitalized services are relatively new and thus their impact and influence as well as their long-term effects remain uncharted. For this reason, many of the common fallacies are based on misconception and miscalculation. For example, there could be underperformance of these new modes because users' reactions to new technologies are not as expected (Millonig and Haustein, 2020). That is why more research is needed into the effect of human factors, user’s behavior, insecurities and acceptance in order to prevent fallacies. This step is vital for the success of the project and thus needs to be implemented in all phases from the planning stage till deployment. It is worth mentioning that considering the human factor in the planning is not easy as it is only an anticipation of the most logical reaction. Collaboration from various fields could contribute to minimizing errors in planning (Millonig and Haustein, 2020).

Another common fallacy in MaaS is the 'Appeal to Common Practice' (LaBossiere, 2002), when an action is done merely because most people did it, it is taken as evidence to support the action. Cities which share some attributes e.g., compact, decentralized, etc. tend to adapt a mobility concept based on the fact that many other "similar" cities did so without examining its local suitability. As cities are unique, their challenges are also unique and thus deeper research is needed to investigate the real needs before adopting a common solution.

Other MaaS fallacies that hold the concept back are anchored in the as yet unclear framework of how to govern and regulate its emergence (MaaS Alliance, 2020). For example, it is assumed that MaaS requires a free market to thrive (MaaS Alliance, 2020), while in reality the concept benefits best from balanced regulations, a backbone and an ecosystem to rely on. It is also assumed that MaaS cannot be developed in the existing regulatory framework (MaaS Alliance, 2020). The major obstacles facing MaaS though, are trust and collaboration among the various stakeholders, and missing blocks at the operational level such as data and technical services (MaaS Alliance, 2020). Based on the previous assumption, it is also assumed that MaaS needs a completely new regulatory framework (MaaS Alliance, 2020). But development of services in the transport industry is normal and is already part of upgrading any services. For this reason, it is more important to develop frameworks that guarantee equity and avoid market fragmentation. It is also assumed that MaaS risks developing a monopolistic market (MaaS Alliance, 2020). That is why cities have the role of managing the emergence and control of an open, balanced competition and a harmonized ecosystem for the good of all the community.

The risk of the accumulation of such fallacies can outbalance its potential and hold back its benefit or worse, leading to a defragmented and monopolistic service that does not serve people's needs, wastes resources, leads to urban sprawl and cannibalizes on the other suitable services. Consequently, there is a need for a comprehensive approach in terms of research and analysis to assess the needs of the city, the existing resources, develop the missing blocks in terms of regulations and readiness before defining the mobility concept that is needed and subsequently planning and implementing it.

2-6-3 MaaS Navigation Tools

On the quest to explore and accomplish MaaS, various layers and levels were researched and investigated and due to the fact that MaaS involves multiple industries and diverse stakeholders, many attempts were made to draw a roadmap to navigate a way around with the aim of finding the best way to implement it.

Some of the best practices include McKinsey & Company's (2015) framework to understand how a city's mobility system will evolve through underlying relevant forces and how they interact. Accordingly, the framework identifies the kinds of cities which will lead the mobility revolution (McKinsey & Company, 2015). MaaS Global's (2016) MaaS Readiness Index offers a framework to identify cities' readiness for MaaS by assigning grades to certain factors that in turn branch out to cover more detailed sub-factors. The main factors are customer demand, the availability of transport services and government regularity. The grades go from 0 till 3, where 0 means non-existent or exists but is very unfavorable for MaaS and 3 is ideal for MaaS (MaaS Global, 2016). MaaS Lab's (2018) MaaS Maturity Index measures a city's readiness for MaaS implementation based on certain characteristics like a transport operator's data sharing and openness, the ICT infrastructure, policies and legislations, citizens' readiness and transport services and infrastructure (Gouldinga and Kamargianni, 2018). Travelspirit - TFWM (2018) Openness Maturity Index assesses cities' readiness for an open concept by assigning grades from 1 which is legacy closed systems to 5 which is an advocate for open source and APIs as well as a toolkit which includes the MaaS provider, MaaS customers, Transport operators and Data providers (TravelSpirit -TfWM, 2018). Global Open Data Index (2018), which tracks the state of open government data, is meant to provide an update on the openness of the data publication (Open Knowledge Foundation, 2018). ERTICO – ITS Europe's (2019) MaaS and Sustainable Urban Mobility Planning presents actions and elements essential for MaaS implementation in terms of sustainable urban mobility planning (ERTICO – ITS Europe, 2019). Fluidetime's (2020) MaaS Canvas and Positioning Guidelines, which assess MaaS ecosystems in terms of multiple factors such as transport providers, MaaS regulatory service providers, transport service providers, MaaS consumer service providers. It also enables service providers as well as looking at challenges, offerings and the target group, which makes it possible to form an overview of the potential ecosystem. The Position Guidelines walk cities through the following steps to implement MaaS through a series of more detailed assessments (Fluidetime, 2020).

These navigation tools cover different approaches and each tends to focus on certain aspects, e.g., some focus on certain cities and thus are not comprehensive and do not include all types of cities or degrees of urbanization (European Commission, 2020), whereas others focus on certain components or infrastructure, etc. Moreover, although they provide details meticulously and shed light on many pain points, they cover the phase after MaaS is selected, i.e., they focus on the best way to enable cities to implement MaaS and not the phase before the decision is made.

But to join the mobility marathon, the first step is to prepare and be ready for it. This step not only guarantees a better long-term performance but also delivers more comprehensive and accurate results. That is why more research is needed to explore how to assess the need for a future mobility system (be it MaaS/MoD or an alternative solution). The inquiry needs to be open-ended and based on the status quo to meet the requirements. Before assuming that MaaS is the solution and thus moving directly to how to implement it, cities need to identify the problem and verify if MaaS is needed (and if so, what type of MaaS). Thereafter, the existing indexes and roadmaps come into play. This ensures that they serve the right needs and their framework fills in the gaps and makes it possible to accomplish the goal.

3 - Methodology

This Chapter describes the research methods used, the reason behind their selection and how they led to the formation of the research questions.

3-1- Research Method

To explore the main challenges cities face, a comprehensive literature review is conducted. To have a clear vision, it was important to investigate the status quo in order to understand cities' roadmaps, the reasons behind the way they look and what factors played a role in their different development. Doing this makes it possible to assess and anticipate the future, being aware not only of those cities which have the ability to make changes but also what changes are needed. After the exploratory phase in order to gain deeper insights and fill in the identified research gap, international interviews with experts on MaaS are conducted. The data collected from both primary and secondary sources are analyzed with the Grounded Theory (GT) method.

This method is used as it allows the collection of data from various sources. It offers a better understanding of the dynamic and fast-changing concept of MaaS and it provides specific relative insights and helps identify the key factors while allowing flexibility and creativity. With its open-ended nature, it accommodates available/incoming/or other data formats for future research and the data collected are more reliable and accurate when used to create content. Due to the complexity and diversity of the topic, the selected interviewees represent the stakeholders of the various MaaS ecosystem layers from different industries from both the public and private sector.

The results identified some gaps such as the fact that cities lack a clear, comprehensive system for how to assess and identify their mobility needs, and that they also lack a clear system for developing their solution through suitable calls-to-action and based on the results of their assessments. The concept of bridging between urban planning, urban travel and the desired MaaS model is also not recognized and is not embedded in the process. No correlation between the need for MaaS (or another alternative) and the readiness of the area being considered for it has been found, and not all relevant stakeholders are involved in the decision-making process. Moreover, the existing MaaS navigation tools as presented in chapter 1, focus on the phase after the decision to implement MaaS is made and not on whether to implement MaaS in the first place (i.e., does the area under study need MaaS, and if so, what type and what would MaaS solve for them?). The research uses the knowledge gained and the gaps identified in serving the mobility requirements, to formulate the research questions and to fill these gaps; a decision tool in the form of a mobility decision tree (MDT) is designed.

The MDT is designed to provide cities/towns/rural areas with a comprehensive decision-making tool to help them navigate their mobility roadmap and identify their mobility ecosystem. The tool systematically combines and assesses all the relevant layers in the area under study based on the outcome from the analysis of the literature review and interviews with experts. It offers calls to action to fill in any gaps, identify needs and recommend solutions. The selected assessments cover the three main components, which are relevant and crucial for transport planning in any area, the city structure, the transport system and the role of the city. The outcome is clustered into attributes in terms of the various city layers to be examined along multiple branches. Linking need and readiness, the MDT enables informed decision making as to whether MaaS is appropriate and thus makes it possible for decision makers to understand what form of MaaS (or alternatively a different solution) to implement as shown in Figures 7-4-1 - 7-4-6. The answers from the MDT are filled in the MDT assessments table as shown in table 7-4-7. For the evaluations, scores and weights are assigned to the assessments based on their significance. The outcome is filled in the MDT evaluation table as shown in table 7-4-8. Table 7-4-9 MDT score index shows the four categories of the score index.

As a demonstration, the MDT is applied to three cities - Vienna, San Francisco and Singapore. Although the research focuses on cities where the main challenges are concentrated in terms of population size, CO_2 emissions, urban sprawl, etc., the MDT is created to fit all degrees of urbanization (European Commission, 2020).

3-2 Technique

3-2-1 Literature Analysis

The literature review aims to explore the current State of the Art in terms of the research's main components: the city structure, the transport system and the role of the city. The research explores the course and reason for their development, their interaction with one another and the main factors that influenced them. It covers cities' roadmaps on both sides of the Atlantic, their need for an urban transport system, the main players and how their roles evolved through looking at the past, the present situation and the outlook for the future. The research also examines the effect of global phenomena on cities such as the industrial revolution, globalization and the digital era, and how each in turn influenced the city structure, and how the last was projected on the transport system. The study highlights the reasons behind the emergence of MaaS (and MoD) and how differently stakeholders perceive its diversity, the rollout of international good practices. It also reflects on the role of the main players and the outcome that gradually led to the utopian vision of the MaaS city.

For the analysis, various sources were consulted including scientific publications, research reports, case studies, pilot projects and surveys.

3-2-2 Interviews with experts

This method is selected as studies have shown that it is the most suitable data collection technique when using the GT method for the analysis, as the participant-researcher interactions lead to generating new knowledge (Charmaz and Belgrave, 2012).

The GT interview questions differ from normal interview questions in that they are broad enough to cover a vast range of experiences, thoughts, actions and feelings, but also narrow enough to extract and investigate the relevant data (Charmaz and Belgrave, 2012). Follow-up and probing questions make it possible to get more details whenever needed. GT interviews are also more flexible and could be informal or conversational (Charmaz and Belgrave, 2012), which could lead to a more relaxed atmosphere that invites the interviewee to open up and add more details.

Nevertheless, like normal interview questions, GT interview questions could also be structured in blocks to maintain a common thread and prevent the interviewee jumping back and forth between different topics. One starts with easy general questions about the interviewee such as position, reference to the topic, experience with it so far, etc. The central question is derived from the thesis and the answers help confirm/expand/refute the thesis. Towards the end, the interviewer asks more open questions to enable the interviewee to add whatever he/she thinks is important.

To fill in the gaps and understand the situation from the inside, the interviews explore the stakeholders' perspectives in terms of MaaS and its components based on the city structure, the role of the various players, especially the city, the requirements, but also the challenges for both horizontal or/and vertical cooperation, their goals, obstacles and pain points along the way, what they lack and how they overcome it. The stakeholders are also asked about the expected added value of MaaS for the city and the user.

The main focus lies in understanding why and how cities and their various stakeholders' approach MaaS. The ”why” delivers the motives that may or may not reflect the city's need for a MaaS concept and the “how” conveys the perspective of the main facilitator and how they approach him/her. Bypassing that factor leads not only to major conflicts on the urban accessibility front, but also to a waste of resources, inefficient services and a negative impact on climate change, i.e., all areas in which the potential of MaaS is expected to be reduced/eliminated. This, in turn, will indicate not only that MaaS did not achieve its goals, but that it backfired and caused more problems than before.

The interviews possess a high confidence level, as the 31 interviewees were selected based on their role in the MaaS ecosystem and represent global stakeholders in various positions in the MaaS ecosystem. These included actors in the city halls and mayoral offices, public transport providers, shared modes and on demand providers, (TNC) transportation network companies, public and private transport associations, car rental companies, MaaS operators and alliances, mobility companies and subsidiaries of automotive concerns, third parties such as university professors, urban planners, mobility journalists, mobility advisors, managers of pilot projects, motoring associations, telecommunication companies, mobility research centers, information technology and intelligent transportation services. Depending on the location of the interviewees, the interviews were carried out either face-to-face or online.

3-2-3 Grounded Theory Method

For the analysis of the collected data from both the secondary and primary sources, the development of the research questions and content, the GT method is used, as this methodology provides understanding of concepts not yet researched deeply, where a fresh opinion could lead to a new perspective and enable theories to be constructed from the collected data analysis based on their logic. Its flexible nature accommodates not only theory but also practice, which is ideal for such a diverse subject and helps to identify problem areas and provide theories that explain them. For the analysis, the collected data are coded and clustered according to the GT concept to deliver content. Data collection and analysis follow in cycles, i.e., after collecting the first wave, code it and thus start developing the theory, then more data are collected and analyzed and used for the theory and hypotheses. The process therefore represents a cumulative method that continues until new data do not contribute any longer to new clusters (Charmaz and Belgrave, 2012). The research followed the GT research method in the evaluation of the interviews and the delivery of the content and there is no statistically-based discussion as it lies outside the scope of this research and is not a requirement for the evaluation of GT research interviews (Charmaz, 2003) and (Vollstedt and Rezat, 2019).

As the GT is a systematic method which uses data to construct a theoretical analysis, this (the theoretical analysis) in turn represents the product. Its flexible strategy enables researchers to study various phenomena, collect and analyze data, and develop an abstract theoretical structure to explain the phenomenon.

Due to this flexibility and abstractness, the GT is not standardized. It is an inductive (aims to develop a theory), comparative, iterative and interactive method (Charmaz and Belgrave, 2012). Researchers evaluate their inductive data using a meticulous comparison analysis that helps them see beyond the known facts to read between the lines and develop new insights and understanding from the data. The process of iteration follows, which is an algorithm-like process based on the repetitiveness of the data collected for each relative category. Researchers predefine these categories and explain why they were selected. The iteration acts also as a check on the accuracy of the data as the amount and depth of data collected offsets the negative effects (Charmaz and Belgrave, 2012) of misleading data and so ensures that the researchers have enough accurate data to provide deeper insights. It is especially important that the GT method enables researchers to collect data that has both depth and breadth (Charmaz, 2003).

One depends on theoretical sensitivity to make sense of the data., Corbin J. and Strauss A. (2019) describe sensitivity as “having insights as well as being tuned into and being able to pick up on relevant issues, events, and happenings during collection and analysis of the data” (Vollstedt and Rezat, 2019). Hence, Glaser B.G. and Holton J. (Vollstedt and Rezat, 2019) state that the essence of theoretical sensitivity is the “ability to generate concepts from data and to relate them according to normal models of theory in general”.

Techniques used to develop theoretical sensitivity, according to Corbin J. and Strauss A. (Vollstedt and Rezat, 2019), are questioning, analyzing single words, phrases or sentences, and comparing the techniques which form the GT in general.

Using the GT, data collection, data analysis, and theory development are not successive steps in the research procedure as in other methods; they are interconnected and interdependent. The three steps develop alternately and do not follow each other. Data collection and analysis lead to theory development. Then more data will be collected and analyzed based on the existing theory so far, which is called theoretical sampling (Vollstedt and Rezat, 2019)92). This, in turn, results in a wider focus for research, which facilitates the development of the thesis.

Theoretical sampling represents a cumulative sampling method (Vollstedt and Rezat, 2019). The selection is not open-ended as in the first round of the data collected, it is guided more by the development of the theory. The reason behind the selection of the cases varies; in the first stage, they are picked to facilitate the discovery of new materials. In a later stage, they are picked so that they support and contribute to the details of the categories. The two processes - theoretical sampling and theory development- continue until new data do not provide any new knowledge to elaborate the categories. This phase is then called theoretical saturation (Vollstedt and Rezat, 2019).

Two pillars carry the GT methodology, coding and memos.

Coding

The main goal of the GT is to develop a theory using the data collected and its analysis. To reach that goal, the collected data are evaluated using codes which imply conceptual abstraction by assigning general concepts (Vollstedt and Rezat, 2019) (codes) to small parts of the data at a time.
Corbin J. and Strauss A. (Vollstedt and Rezat, 2019) divide the code procedures that are used to develop the theory into three groups, open, axial, and selective coding. It is important to understand that due to the nature of the research, these three procedures are neither clearly separated from each other, i.e., are not precisely distinguishable (Vollstedt and Rezat, 2019) nor do they represent consecutive phases or order, i.e., one can combine them and/or start with the one needed.

Generally, through open coding, the data is broken up into smaller sections. It represents a word for word and line for line analysis to extract the core and understand the idea; it is then described in the form of a code. These codes could be part of the data or with reference to literature. These various small parts (broken up from the data) are compared and those with similar parts get the same code.

Codes according to Corbin J. and Strauss A. (Vollstedt and Rezat, 2019) share the same concept or concept of higher order (category). Categories then merge to present a comprehensive idea. In this phase, a great many codes which describe the data are generated using a matrix of sensitizing (Vollstedt and Rezat, 2019) questions. This in turn leads to new discoveries (Vollstedt and Rezat, 2019). The questions include what, timeline/when, source/who, why, how/whereby (approach/ method), outcome/what for, keywords and citation.

By axial coding, the relationships between the concepts are integrated into a more general framework that has one category. In this phase, this relationship between concepts and categories is investigated using various conditions called coding paradigms (Vollstedt and Rezat, 2019) such as context, interactions, etc. Here new links are developed between the categories (which represent the phenomenon) and the causal conditions, context/action/interaction and consequences/outcomes (Vollstedt and Rezat, 2019)9. In other words, axial coding makes it possible to find the relations among the phenomena described in the categories developed in the open coding phase.

Lastly, by selective coding, the various categories developed and connected in the axial coding phase are integrated into one theory. Selective coding is similar to axial coding as both results from the former phase are further described, integrated, and evaluated. But they differ from each other in that selective coding is more abstract. The categories are integrated into a more general framework that connects all other categories addressed to it in the axial coding phase. This phase helps define the core category, the central phenomenon (Vollstedt and Rezat, 2019), which is connected to all other categories.

The codes used include all relevant aspects of the thesis such as city structure, urban planning, function, components of the ecosystem, transport system, challenges, cooperation, etc. (Appendix 7-3). They are rearranged so that relevant topics are clustered together based on relevant categories such as location (US, Europe, global), role, pain points, cooperation, business model, etc.

Identifying the core category, which represents the central phenomenon of the research, enables the researcher to address and form the research question/s. The research product of the 3-step process is the GT that developed from the collected data.

Memos

Although it is only for the researcher's benefit, writing down memos between/during the coding phases is a central part of the GT. Memos are special notes and documentation of the data and the connection between the categories which enable the researcher to keep track of all the steps e.g., the analytical process. Writing these memos and sometimes sketching diagrams as visual tools to elaborate the relationship between concepts represents a core stage in the development of the theory (Vollstedt and Rezat, 2019). Memos that contain code notes and theoretical notes are the most important types for the development of the GT (Vollstedt and Rezat, 2019). While analyzing, codes can be interpreted so that code notes can develop into theoretical notes. Writing memos starts at the beginning of the coding phase and continues till the development of the final GT.

3-2-4 Mobility Decision Tree

The MDT is a support tool in the form of a tree-like structure (CFI, 2015). It helps model probable outcomes while handling non-linear data sets effectively by presenting algorithm-like results (CFI, 2015) i.e., the tree represents rules to answer a specific question (Lorenz, 2018) and is based on binary decision classification (Lorenz, 2018). The structure includes branches that represent decision-making steps and nodes that represent tests or attributes at each stage. From top to bottom, every branch represents an outcome for the previous attributes and from bottom to top, every path from a leaf (result) to a root represents rules for classification (CFI, 2015).

This decision tool is selected as it delivers clear results and visible alternatives that can be used to deliver valuable insights. In addition, this method does not require an intensive data cleaning phase and outliers have less significance on the data (CFI, 2015). But to be effective, ready information needs to be available to enable the generation of new variables (CFI, 2015). One can distinguish generally between two types of decision tree; a categorical variable decision tree which includes target variables that are divided into categories, where each stage of the decision process will fall into one of the defined categories (e.g., yes/no), and a continuous variable decision tree, which contains continuous target variables (CFI, 2015).

The process consists of several steps. First, one needs to define the question which the decision is to be made about i.e., which mobility concept (e.g., MaaS, MoD, etc.) suits the particular city/town/rural area based on its assessed mobility requirements. To answer the question or come to a decision (Lorenz, 2018), one goes from one node at the top of the tree to the bottom. At each node, a relevant attribute is assessed and a decision is made based on the following branch which leads to the next node and attribute. At the end of each branch, the leaf represents the decision (classification) (Lorenz, 2018).

Cities which face similar challenges are likely to have similar opportunities and adopt similar solutions (McKinsey & Company, 2015), and can learn from each other despite their differences. The MDT assessments were selected based on the outcome of the literature review and the interviews with experts. Due to the diverse and branched-out nature of MaaS, they include various layers and actors, where relevant attributes are used as clusters to assess a certain level as shown in figures 7-

4-1 till 7-4-6.

As city structures, transport systems and city roles impact mobility concepts globally, the recommendations are categorized accordingly to serve as a roadmap/overview, and a checklist to what already exists and what is missing. They are listed under the bottom line in the MDT table, as shown in figure 7-4-7.

Although all factors are important, their significance differs depending on their context. Nevertheless, certain factors tend always to play a principal role and have a bigger impact or function as a deal breaker for the implementation of MaaS (or an alternative solution). This is why scores and weights were assigned to the assessments as shown in table 7-4-8 (Lorenz, 2018) and (Polo et al, 2008). These are based on the outcome of the literature review and interviews with experts as shown in the presentation of the grounded theory method in 4-1 and appear as variables (UK Data Service, 2014) which assign values to each layer/factor indicating its impact. They range here from most important to least important. This method is used as it provides a clear yet simple model for the important factors without impacting the accuracy (Polo et al, 2008), i.e., it helps to correct for any selection's unequal probabilities and compensate for survey non-response (Lavrakas, 2008). The evaluations are based on the feasibility of a certain solution from 'already existing' to 'no particular solution'. The individual rating of each area under study follows by multiplying (Polo et al, 2008) the weight of the layer/factor by the equivalent evaluation.
For demonstration purposes, the MDT is applied to three selected cities, Vienna, San Francisco and Singapore.

The Layers

The MDT features ten layers as shown in figures 7-4-1 till 7-4-7, and starts with key facts and mobility options (layers 1-2), resources and readiness (layers 4-6), roles, collaborations and policies (layers 7-8), and concludes with general and specific needs, potential solutions based on the identified needs (layers 9-10), which together will form the suitable mobility concept for the particular area of study. Every layer is divided into sub-questions and all the questions are listed in the MDT assessments table as shown in table 7-4-8, where the results of the tool will be filled in. Scores and weights are assigned to the assessments as shown in tables 7-4-9 and 7-8-10. Although all factors are important, their significance depends on the context. Hence, some factors have a major function and role, and their presence is vital for the implementation of MaaS (or an alternative solution). Those factors are given higher scores and weights than those whose absence would not stop the project or cause its failure.

Figure 7-4-1 shows an overview of the 10 layers of the MDT. The first layer, as shown in figure 7-4-2, assesses urban planning and city structure according to the degree of urbanization (DEGURBA) method, (European Commission, 2020). This new method classifies territories of any country into three categories: cities (or densely populated areas), towns (or semi-dense areas/intermediate density areas) and rural areas (or thinly populated areas) (European Commission, 2020). Reflecting the binary structure of the MDT, the questions are designed to first ask whether facts about urban planning and city structure are being assessed. If so, the MDT table will be filed accordingly and the decision-making process moves to the next layer; if not, the user is asked to proceed only after assessing this layer and the arrow brings them back to the previous layer. After this, the process moves to the next layer. This concept is followed for all ten layers: answering 'yes' leads to the next layer, and answering 'no' leads to further clarification, back to the previous layer, or a call to action. The second level, shown in figure 7-4-2, assesses the population in terms of number and average income per capita. The third layer, as shown in Figure 7-4-2, focuses on urban travel in terms of the existing modes: collective, collaborative, individual, informal, and soft. The user is encouraged to look at the existing modes and differentiate between the principal modes and other modes used, modal share, other transport and travel components, travel time and the motorization rate. The fourth to eighth layers, as shown in Figures 7-4-2, and 7-4-3, include calls to action in cases where an aspect has not yet been assessed. These layers – fourth to sixth – as shown in Figure 7-4-2, cover the existence of physical and digital infrastructure, data-sharing concepts and policies, and users' needs and readiness respectively.

Next, the seventh layer, as shown in figure 7-4-3, focuses on the authorities' role in terms of active or passive involvement, as well as the involvement of the other relevant stakeholders in the decision-making process and their collaboration. If this step has not yet been assessed, the user is urged to assess first before proceeding. Once the assessment has been made, and due to the impact of this layer, the user is led to further clarifications, such as calls to develop schemes to identify relevant actors, bring them on board, and find ways to exchange knowledge between them. The eighth layer, as shown in figures 7-4-2, is dedicated to the emergence of city policies and legislation for building trust and effective management.

The focus of the next layers lies in exploring mobility gaps in terms of problems (highlighted in red) and practical solutions (highlighted in green). The ninth layer, as shown in figure 7-4-4, identifies cities' general pain points and potential general solutions based on local factors (compact vs. decentralized). This layer serves as a guideline for the tenth layer, which is divided into two sublayers, as shown in figures 7-4-5 and 7-4-6. They assess the specific pain points in terms of policies, technical/digital/sustainable coverage and mobility modes respectively. Each pain point is associated with a potential solution/recommendation and multiple selections are possible, because in reality, cities suffer from multiple pain points and thus can combine the various solutions into their intended mobility concept to deliver their strategy.

Evaluation of the Assessments

The MDT evaluation (Polo et. al, 2008) table explains the process, scores and weights of the assessments as shown in table 7-4-9. The ten layers are grouped into input layers (1 and 2), ranking layers (3-8) and output layers (9-10 and bottom line). The input and output layers play no part in the ranking and thus are in grey. The evaluation (José et. al, 2008) of the ranking layers (3-8) is obtained by assigning grades 0-3 to them. 0 means there is no particular solution, 1 - don't know, 2 - there may be a solution and 3 - it already exists. For these 6 layers (3-8) weightings which are based on the outcome of the literature review, interviews with experts and the good practice catalogue are assigned. These weights (Polo et. al, 2008) are ranked from 1-6, where 6 is a 'must have' layer, 5 is a 'should have', 4 is a 'good to have', 3 is a 'need', 2 is a 'not bad to have' and 1 is 'not a must have'. The highest ranks are assigned to those that are essential, without which one cannot proceed, while the lowest ranks are assigned to those which are not essential for the development of a concept.

After assessing the particular layer, the weight multiplied by the evaluation score yields the final score for this layer. The total of these scores is added together at the end of the table to present the city's potential to develop MaaS (or an alternative solution). The highest score attainable is 63 and the lowest is 0. Table 7-4-10 explains the ranges of the scores. Between 63-43 indicates MaaS (or an alternative) is most suitable for the particular area, 42-22 indicates the area could develop MaaS (or an alternative), 21-1 indicates it would require effort to develop MaaS (or an alternative) and 0 indicates it cannot develop MaaS (or an alternative).

The tool developed is intended to support cities, towns and rural areas as they attempt to become more sustainable and resilient. It helps to assess the status quo quickly, easily recognize any existing gaps and efficiently identify what is required, and thus objectively and systematically develop suitable solutions. Additionally, this process has the advantage of facilitating the allocation of resources and channeling them towards the areas they are needed. The MDT concludes by summarizing the process, highlighting the importance of taking all relevant factors and actors into consideration, and emphasizing the uniqueness of each solution developed and its suitability for the particular area. While some areas will select full integrations, others will settle for partial or no integration, and others will develop additional and alternative services, depending on the outcome of the tool.

Significance and Selection of the Cities

As a demonstration, three different cities, Vienna, San Francisco and Singapore, are selected and assessed with the MDT. Although these cities are very different from each other, they share a high level of commitment on the side of the city, transport companies and municipal stakeholders in terms of developing and implementing an integrated and comprehensive mobility plan and being among the pioneers in their specific and respective approaches. At the same time, their differences in terms of the city structure, the transport system, the role of the city, users' needs and involved actors, deliver diverse content to benchmark the usability of the MDT in terms of providing a universal unified logic to fill gaps based on the relevant local factors, existing resources and needs. This in turn will help all areas in general and areas where the mobility approach is not yet (fully) developed or the process and ecosystem are not yet (fully) defined in particular. In addition, stakeholders will not only have a comprehensive overview, but will be able to directly and easily identify their needs, tackle the pain points and develop suitable solutions.

3-2-5 Software Used

In the first phase, word processor and spreadsheet templates were used and in the second phase, flowchart and vector graphics applications were used.

4 - Data Analysis and Findings

This Chapter presents the findings and analysis of the GT method, reflecting both the literature review and the experts' interviews as well as the results of the MDT assessments.

4-1 Presentation of the GT Method

MaaS is one of the topics that branches out to cover multiple sectors and levels, includes various stakeholders and partners and thus tends to get complex and diverse, especially when exploring the various definitions of MaaS given by stakeholders. The concept incorporates the past, the present and the future. That is why the research analyzes and presents results based on aspects from all three timelines and the interaction and influence of the research's three components: the city structure, the transport system and the role of the city. Their influence is, in some cases, not entirely clear or obvious, but nevertheless, plays an important part in the emergence of (new) concepts. Moreover, the research underlines the pain points, highlights the experts' suggested solutions and relevant opinions supported by the help of global good practices.

4-1-1 City Structure

4-1-1-1 Impact of the City Structure

Cities will lead the mobility revolution in various ways depending on their urban density and transport system. Table 4.1 shows the four types of cities McKinsey and Company (2015) concentrated on (McKinsey & Company, 2015).

	City 1	**City 2**	**City 3**	**City 4**
Category	Established megacities	Rising megacities	Car-dominated, mature cities	Mature, advanced cities
Situation	Big-wealthy	Big-middle income	Middle-wealthy	Small-wealthy
Urban density	Dense	Dense	Low	Low
Public transport system	Well-functioning	Existing/improving - not covering the demand	Basic	Well-functioning

Car-ownership	Low	High	High	Low
Innovative mobility	Emerging	Gradually emerging	Emerging	Emerging
Development	car use -	car use --	car use -	car use --
	PT use =	PT use ++	PT use +	PT use =
	collaborative ++	collaborative +	collaborative ++	collaborative ++
	active modes +	active modes -	active modes +	active modes +
Examples	New York, London, Tokyo, Berlin, Paris	Mexico City, São Paolo, Shanghai, Moscow, Beijing	Most US cities	Most European cities-Helsinki, Vienna, Vancouver

Table 4.1 Mobility evolution depends on the city types - (Adapted from McKinsey & Company, 2015) (-) Slowly decreasing, (+) Slowly increasing, (=) remains the same, (--) Strongly decreasing, (++) Strongly increasing

City 1 (Table 4.1) is immense, wealthy and has a dense population, with an efficient, functioning public transport system. These cities concentrate on managing traffic and expanding the infrastructure of the active modes. The emergence of the digital era in the mobility branch has enhanced new mobility services, which has helped the reduction of the private car and an increase in collaborative modes (McKinsey & Company, 2015).

City 2 (Table 4.1) is medium large and less dense with a public transport system that is struggling to cover the increasing demand. The use of the private car here is widespread and connected with congestion and an increasing city population. Cities therefore tend, especially with the emergence of the new mobility services, to expand the PT infrastructure and improve the technology needed to encourage the use of public transit systems in combination with the other collaborative modes (McKinsey & Company, 2015).

City 3 (Table 4.1) is decentralized and horizontally spread out. PT is basic and the private car is the dominant mobility mode. As giving up their own car with no appealing alternative is a dead-end, cities encourage the spread of new mobility services which enhance the spread of collaborative modes based on private car-use to reduce congestion, city pollution, commuting time and also to increase road safety (McKinsey & Company, 2015).

City 4 (Table 4.1) is rather small but wealthy and compact with a less dense population. The PT system is functioning. Cities actively encourage the use of collaborative and active modes, especially with the available connectivity needed for the new mobility services. Cities concentrate on solving the challenges of peak-hour travel by offering various measures like special prices for travelling at different times, and facilitating workspaces along the mobility hubs to encourage teleworking (McKinsey & Company, 2015).

The new mobility concepts are expected to pave the way for AVs, forming a sustainable mobility system that enables physical and digital urban accessibility. For this reason, cities are competing to be the first to establish MaaS and MoD in order to be able to deploy AVs correctly afterwards. And in this process, cities will probably change as Shaheen and Cohen (2018) explain - the result is two opposing concepts.

- Densification of city centers. With car-oriented facilities (parking, gas stations, car agencies) relocating outside the city, more human-oriented facilities will be present in city centers and the roads will get narrower and more walkable.
- Suburbanization of cities and emergence of edge cities – suburban and exurban sprawl. The digital and social trends in the AV era will facilitate teleworking and telecommuting, which will enable horizontal urban expansion towards more affordable areas - the further one gets from the city center, the cheaper the land gets.

Thus, prices of the types of land-use will change. Prices for parking are estimated to decrease as cities will be more walkable with integrated urban transport systems and car ownership will decrease. Also, it is expected that new businesses will develop as peripheral centers to serve the new demand (Shaheen et al., 2018).

4-1-2 Transport System

4-1-2-1 Development of Urban Travel

Many sustainable innovative ideas which we use now started with a vision. Some decades ago, no one expected to enter a glass box and let it drive them vertically through the building. It needed a pilot and many test phases before it became driverless and known as the elevator, says Declercq (2016) - Executive Vice President, Europe Middle East and Africa, Local Motors.

Considering future narratives and the intensive search for improvement, for example, in terms of sustainable solutions to save the environment, cities had to learn to think outside the box and investigate beyond their own territory. And soon it was clear that leaving the conventional mindsets behind and exploring freely could lead to positive results.

In the mobility world, it was no different. Cities stopped looking only locally or even at neighboring countries and started to consider other continents and cultures. The results were surprising, not only in that the developing countries learned from the developed ones, but that it worked the other way round as well. In continents like Europe, North America and some of Australia where rules are defined, standards are set and thinking in many ways is cast into a frame, many things are taken for granted. This means that flexibility is automatically limited. On the other hand, in Africa, Asia and South America, the lack of formalities, standards and infrastructure, pushed individuals to come up with innovative ideas and futurist concepts that skipped many generations compared with other more developed areas, where they had to stick to a defined plan. This enabled these places to obtain new results directly.

The mobility revolution and the local solutions (single and aggregated) developed in some countries in Asia, Africa and South America are thus considered pioneers and have inspired some European and American countries to adapt them locally. Singapore's smart city plan, UAE's clean-energy city, South Africa's mobility plan and China's sustainable public transport system are only a few to mention.

4-1-2-1-1 Single Solutions

In this context, three concepts, one dating back to the past, one emerging in the present and one developing in the future, all influenced the new mobility era: informal (public) transport, the power of the community, and autonomous (connected) vehicles

Informal Public Transport

Informal public transport emerged to empower the community and enable the citizens to move from A to B. In many cities, it is still the most common and widespread transport mode. It covers various modes like shared cars, car/vanpool, rickshaws, micro transit/mini- and micro buses and paratransit. The biggest advantages for the users were the easy accessibility, the on-demand request, the affordable price and the fact that it is fast, reliable and flexible - in other words, the benefits align with the present smart-city transport plan. But on the other hand, being informal and privately organized, the modes were not regulated, did not cope adequately with the demand at peak times, offered irregular/random supply and were neither environmentally-friendly, nor safe. Nevertheless, these modes closed the gap between the insufficient PT services and the unaffordable private car, not forgetting that they created an income source for the drivers (Xie and Wagner, 2010).

Inspired by this idea, transport network companies (TNCs), like UBER and Lyft, introduced a digital alternative to these modes organized on one platform and accessible to a wider public than their predecessors.

The cities' role here is to acknowledge the benefits of these informal modes, upgrade them and integrate them with suitable rules into the mobility ecosystem to serve the demand and cover the gaps (Xie and Wagner, 2010).

Power of the Community - Crowdsourcing

One of the results of the sharing economy is that individuals started actively to communicate and organize services to fil the gaps in supply that cities could not cover - be it in mobility, finance, real estate or retail.

The active role of the community enabled cities not only to focus on the needs of the users, update the data in real time and meet the demand, but also to use resources economically and more productively. For example, real time data in open-source apps can inform people about delays, accidents and road changes. Such integrated transport services have helped to plan, filled in empty seats, improved costs and offered scalability, flexibility, and diversity. Crowd Urbanism is nothing new in itself. What is new about it is that it emerged in the digital era as a tool to sense the needs of the city with the potential to cover the gaps and meet demands affordably (New Cities, 2018).

Bailey (2016), Head of Marketing, Stratageeb, explains that some companies like Travel Spirit encourage open source and open data to empower the community and interested companies to engage/find partners with the goal of establishing a public open-source platform, e.g., Simply Connect, a pilot in Manchester, provides small vehicles for shared rides which are run by the community. (Bailey, 2017).

Couto (2016), E-Business Developer at door2door, explains their experience at door2door in Dar El Salam/Tanzania, a community-sourcing/community capacity building and open-source data project as a collaboration with Ramani Huria (Ramani Huria, 2018), HOTOSM (Hotosm, 2018), the World Bank (WB, 2018) and volunteers from the University of Dar (Uni of Dar, 2018) to implement TrackYourCity (TrackYourCity, 2018) to map the PT system of the city as well as publish and open the data on OpenStreetMap. The efforts of local organizations and communities have led to better results. Empowering the volunteers and showing them how their work makes a difference, has encouraged the use of appropriate tools and kept the open-source going. The project is fully developed. Almost 300 routes have been mapped and digitized. The data was open-sourced in OpenStreetMap for organizations and individuals to develop solutions for problems of accessibility, e.g., medical services, the most flood-prone areas of the city, etc. (Couto, 2016).

Autonomous Connected Vehicles

The development and introduction of AVs will disrupt the transport/mobility system in cities and at the same time, open up various innovative possibilities.

Among other things, AVs can enable de-privatization of vehicles, and so increase their utility by offering, for example, one-way, door-to-door PT services in comparison with the current taxi services. With the younger generations being less eager to own a car, the door has opened for new approaches, especially towards AVs. Older generations' attitudes towards cars have changed slightly too. Owning a car has become less of a status symbol and is increasingly seen in pragmatic terms.

The change is partly due to the development and spread of collaborative modes, reflecting the fact that people are becoming less attached to car ownership (Meyer and Shaheen, 2017).

The actors in this sector are not traditional car manufacturers, but international actors such as Google and Apple as well as other stakeholders from IT, energy and telecom. AVs have the potential to radically change the way people use and view cars; more as a service than a product which individuals no longer own but use (Brimont et al, 2015). They are expected thus to become an integral part of the mobility (MaaS/MoD) ecosystems either as first/last mile mode (pods, shuttles), as collaborative mode (cars, vans), or as private vehicles (cars).

Their integration as collaborative mobility modes gains the most attention and emerges as a positive, modern mobility solution and more acceptable than, for example, the alternative of restricting car use. These new digital mobility services are moreover environmentally-friendly, covering the various social demands (carpooling is now seen for instance as a positive choice rather than one dictated by financial necessity), modern, efficient and practical (Brimont et al, 2015).

A different point of view suggests that AVs will facilitate MoD (Mobility on Demand) services on a new scale and with more profit so that they might replace different business models like car-sharing with real MoD solutions using an increased number of operating fleets, says Breitstadt, (2017) MOIA- Head of Ride Hailing Business (Breitstadt, 2017).

Nehrke (2017) from the association of car-sharing in Germany, on the other hand, expects that AVs will lead to an integration of car-sharing and taxi services. The new "robo-taxi" will be much cheaper than today's taxis – about the price of today's free-floating services. Peer2peer sharing offers could also be integrated into the car-sharing context to enhance the peer2peer product and to become part of the mobility ecosystem (Nehrke, 2017).

AVs are a complex topic though and still in their infancy, especially because it spreads out to include other topics like vehicle driving, service provision, consumer protection, data exchange, liability and equal access (Goodall el al, 2017) and thus it is hard to predict its impact.

Milakis et al (2018) explore the urban accessibility impacts of AVs in cities based on the four accessibility components (land use, transport, temporal and individual). They state that all four components are going to be influenced by MaaS and MoD as well as by AVs, but the benefits are not certain at this stage nor is it expected that the various demographic groups will benefit from AVs equally. In the long term, AVs will cost less considering the increased demand for travel. Cities will become more compact but urban sprawl will also increase which will lead to relocation of residency (cheaper places), work and modes of transport. The longer commuting time will be used for other functions like working, communicating or relaxing. As for the social equity which is a basic requirement for PT, it is not clear how the benefits of AVs will be distributed equally, depending on the demand. Cities therefore have the role of ensuring equity in the service (not only the mode) as well as considering the possible dangers, for example, the risk of AVs backfiring i.e., the rebound effect (Seebauer S. et al., 2018) , which could mean more vehicles on the road due to the increased demand, which will mean customers waiting in traffic jams even longer, unless AVs are used as shared modes (Milakis, et al, 2018).

Neckermann (2016) adds that AVs will offer up Level 2 safety factors that position it in the core of the mobility offering. This will be in the form of a robo taxi for providers like UBER, Lyft, Google, Apple, etc. and shared modes like pods or mini buses in semi-public spaces for others. The hardware will continue to evolve to cope with the mixture on the street between combustion and AVs. But it is expected that – as in aviation – a human being will still be behind the steering wheel or the driver's seat, for the psychological comfort of the users (Neckermann, 2016).

Declercq (2016), Local Motors's Executive Vice President for Europe Middle East and Africa, explains how AVs will not replace mass transit, but complement it. They partnered with DB (a German Railway Company) to implement Olli (Autonomous Shuttle) in Berlin, and in the future smaller or bigger models will also possibly be deployed and integrated. Declercq (2016) expects a positive adaptation and acceptance of the fact that vehicles can operate driverlessly as happened with the evolution of the elevator (Declercq, 2016).

Providers were initially racing to win the first mover position, now it is more widely understood that "it is not a race but a marathon", said Lukas Neckermann (2016), in which everyone should take part but no one can win. Experiences over the years have showed that "leading edges are bleeding edges" and the late movers can find the way paved for them; compare UBER vs. Lyft or DriveNow vs. Car2Go (Neckermann, 2016). That is why cities have to plan wisely how to introduce AVs into the transport system as an integrated piece of the puzzle in its mobility concept depending on the role of the city, its structure but most of all its need, in the form of collaborative micro and mass transport (cars, vans), on-demand individual transport modes, the first-last mile services (pods, shuttles), logistics and delivery or even, in some parts of the world, private vehicles (cars) or maybe not at all.

Examples

Thanks to technology and globalization, cities have started to explore what is going on globally, learn from each other and try to adapt the concept locally. For example, developing an Oyster system in the US, which is mainly used in London, UK or offering more on-demand models in Europe, which are more commonly developed in the US (Neckermann, 2016).

Developing self-sufficient off-grid cities in rural areas solves some transport problems through active modes together with the private car but not in cities where they face bigger challenges.
In very dense cities, for instance, like Bombay and Mexico, with quite a basic public transport infrastructure, one finds that shared/on-demand and TNC modes make a difference, while AVs would not serve people's needs due to the lack of the pre-infrastructure needed.

On the other hand, in dense cities like Chicago and Berlin, where a public transport system already exists and the cities are walkable, shared modes and AVs solve the problem of the first/last mile.

For fast cities like Los Angeles and San Francisco, where spaces are immense and cars are dominant, one thinks more of adapting the city into a smart city to support the change as well as offering collaborative sustainable transport services, like AV as on-demand individual PT as well as shared modes for the whole trip.

4-1-2-1-2 Aggregated Solutions

Mobility as a Service

As the various definitions of MaaS stated in Chapter 2 show and although stakeholders acknowledge its positive potential, a standard definition has not been agreed upon yet. The reason behind this dilemma could be because MaaS includes various services and thus multiple stakeholders and each has their own vision of it. This fact, in turn, reflects the diversity and dynamism of the concept, implying room for flexibility and individuality, especially as the concept is still evolving.

From the various definitions, one can extract that the MaaS concept, which is used for both individual and goods transport as defined by Shaheen et al., (2017), Hsu, (2016) and Nehrke, (2017), is based on the integration of the services of various PT and private providers (mass transit and collaborative services, driven vehicles and AVs, passenger and goods transport/delivery) into a one-stop-shop market to offer the consumer a tailored service based on his needs via a simple user interface which is suitable for all classes. It also covers various functions from routing, trip planning, ticketing, payment and billing i.e., MaaS provides one multimodal fare via an integrated fare system for all modes through one web-based and app interface, displaying schedules and updates in real time. For intermodal tailored journeys one could deal with more than five modes. The consumer can choose between a pre/post pay-as-you-go method or a flat rate through one account. Moreover, the roaming function, which is anticipated for the future (Hietanen, 2016), will enable the use of the local service abroad. In addition, other services such as parking, insurance, tourism and access to WIFI will gradually be added to the services. As well as the previously mentioned digital urban accessibility to the various integrated services, MaaS will also provide physical urban accessibility to mobility hubs in the form of smartphone apps and smart cards where needed. Essentially, MaaS is a potential digital and physical urban accessibility tool.

Another point stakeholders also had different opinions about is the goal of MaaS. Here too, one can recognize diversity depending on whom is asked (Neckermann, 2016).

For City Authorities and City Planners

They seek better infrastructure to improve the quality of life, to reduce congestion, to develop the city so it obtains a higher ranking, etc.

For Stakeholders

Stakeholders want to offer a new business model to position themselves in the market and gain more sales – it is a platform to offer their goods (technical, hardware, software, service, network, research, etc.).

For Users

Users seek the best combination of comfort, cost and time, depending on who is going and for what reason. The car offers more comfort, more costs but/and less time (depending on the city). PT offers less comfort, lower costs but/and more time (depending on the city). If multiple options are available, the reason for the trip is also a factor, Neckermann (2016) explains. When going alone, the subway is less comfortable and might take time but costs less and so could be an appealing choice, whereas when picking up an elderly person for example, the car, though it takes more time and costs more money, is the best option because comfort is the priority here (Neckermann, 2016).

Cohen (2018) Iomob (Internet of Mobility on Blockchain) co-founder and professor at EADA Business School Barcelona, describes the development of MaaS as a continuum evolving from the single provider model common in the past to a future decentralized, blockchain-enabled Internet of Mobility (IoM).

Cohen (2018) divides the journey of MaaS into four steps:

- Single provider model - a single mobility provider offers a subscription service to a mobility solution, like Toyota Mobility
- Single provider, multimodal MaaS - a single mobility provider offers a subscription service to multiple modes with integrated payments, like the Oyster card in London (bus, train, tram).
- Multi-provider, multimodal MaaS - public and private providers together offer a range of mobility solutions, like Whim (PT, taxi, car-sharing) and UbiGo (PT, taxi, car-sharing, bike-sharing).
- Decentralized Internet of Mobility (IoM) - it is believed that smart cities will embrace more decentralized blockchain protocols in the mobility world to increase efficiency and quality.

Mobility on Demand

While Europe is busy preparing for MaaS, the US is researching MoD and considering TaaS. But what is MoD (Mobility on Demand), what is TaaS (Transportation as a Service) and why do they seem different from MaaS (Mobility as a service)?

Dalton (2018) defines Mobility on Demand as “a system whereby a journey or the movement of goods and services can be made through a network of services accessible on-demand, rather than through a privately-owned vehicle” (Dalton, 2018).

TaaS is more common in the US. It incorporates a broader framing of other services such as goods delivery (Shaheen et al. 2017), not only passenger mobility as commonly assumed for MaaS. Nevertheless, it is expected that MaaS will also cover future goods delivery, post and other services as seen in the definitions of MaaS (Shaheen et al., 2017), (Hsu, 2016) and (Nehrke, 2017). But due to the fact that in the US, MaaS is seen from a different perspective and researchers promote MoD based on the local need, city structure and existing transport system, it was important to analyze how they see MaaS and what they understand by MoD, i.e., whether MaaS in Europe is MoD in the US or whether they are parallel mobility concepts.

The USDOT compares MaaS and MoD as follows (Table 4.2) (Shaheen et al. 2017)

Category	MaaS	MOD
Definition according to Shaheen et al. (2017)	“Mobility as a Service (MaaS): emphasizes mobility aggregation, smartphone and app-based subscription access, and multimodal integration (infrastructure, information, and fare integration). MaaS tends to emphasize the integration and convergence of	“An innovative transportation concept where consumers can access mobility, goods, and services on demand by dispatching or using shared mobility, courier services, UAVs, and public transportation solutions. Passenger modes are facilitated through MoD

	passenger mobility services, mobile devices, real-time information, and payment mechanisms. i.e., MaaS emphasizes a digital platform integrating curb-to-curb trip planning, booking, electronic ticketing, and payment services across all modes of transportation (public and private)”	providers and can include shared modes, public transportation, and other emerging transportation solutions (e.g., aerial taxis). Goods delivery facilities through MoD can include app-based and aerial delivery services (e.g., drones). i.e., MoD focuses on commodification of transportation services. -A distinct concept based on principle that transportation is a commodity where modes have economic values that are distinguishable in terms of cost, journey time, wait time, number of connections, convenience, and other attributes -Includes passenger travel and goods delivery -A recognition that goods delivery and digital delivery could serve as a substitute for passenger travel”

Business Model	"Emphasizes mobility aggregation, smartphone and app-based subscription access, and multimodal integration (infrastructure, information, and fare integration)"	"Strong emphasis on both personal travel and goods delivery as it relates to commodified transportation services, as well as system management (i.e., supply and demand)"
Functionality	Integration of multifunction (routing, booking, payment access to public and private mobility services) all in one place	
Cooperation	Cooperation between public and private stakeholders	
Goal	Increase urban accessibility, reduce travel costs, reduce single-occupant vehicle travel, reduce congestion and improve air quality	
Pricing model	Fixed budget monthly to use the mobility services they need (as pre- or post-paid system)	All you can ride - a fixed monthly fee (flat rate for the specific modes one needs)
Target group	Passenger mobility	Personal and goods transport
Cultural concept	Sharing-based behavior	Ownership-based "all you can use" consumption
Accordingly, and based on the impact of the different cultural notions on sharing vs. ownership/unlimited consumption, the questions to be considered are	-Would MaaS include goods and freight transport and other services in the future? -Would the flat rate concept be rentable? -How would MaaS enable social equity for those who are underprivileged - e.g., no	-Could MoD offer the pay as you use concept (per trip/distance) or a monthly mobility pass? - Would MoD compete with or complete PT? - Would MoD lead to more goods trips due to delivery

	smartphone?	transport or to less mobility services due to the goods transport?

Table 4.2 MaaS vs. MOD, (Adapted from Shaheen et al. 2017)

Dalton (2018), Principal, Method City and Chief Technology Officer (CTO), TravelSpirit, believes the differences between the single definitions are fairly self-explanatory. MaaS = service-based mobility rather than asset-owned-mobility / MoD = on-demand services rather than fixed/pre-scheduled, or self-taken. And he adds that MoD focuses more on the supply/operations side, a shift to mobility management rather than traffic management for example, while MaaS focuses more on the service and business models being deployed. Both concepts are a service mix (MoD via "what's the right supply mix for this area" and MaaS with its focus on integration) and both are concerned with getting people out of their private cars (Dalton, 2018).

Considering the long-term concepts of MaaS and MoD, it can be seen that the gap between the two models is narrower than it appears at first glance and it is important to remember that both models are evolving and branching out dynamically to cover various services.

While in Europe, goods delivery (food, retail, post) is becoming more and more relevant, cities are working on implementing new innovative solutions to cover the demand in this field as well as for the on-demand services. Breitstadt (2017), MOIA's head of ride hailing, a VW startup company in Germany, explains that their focus is MoD, providing mobility solutions where the cars are not the centerpiece of the service (in contrast to the vehicle-on-demand services of the VW Group brands). MOIA is developing and implementing on-demand services besides their ride hailing line (Breitstadt, 2017).

In the US, the environmental issues and the increasing PT funds have led cities to think about alternative solutions to the private car, introducing collaborative modes to the public as an integrated service as well as upgrading mass transit and reintroducing it to the customers as an appealing complement to the other modes.

Dalton (2016), highlights the differences saying, "a transit partnership with Lyft and Uber that provides local connections to and from transit stations would be an example of MOD. A community outreach event about the partnership hosted by the local transit management association (TMA) would be considered transportation demand management (TDM). An app that allows users to cover both the transit fare and cost of the ride to the transit station with a single payment would be an example of MaaS. Together, these overlapping concepts mean big changes for governments, transit agencies, car companies and consumers alike" (Dalton, 2018).

Whether MaaS and MoD are two sides of the same coin, which are developing in different timelines based on city structure, the existing transport system and the role of the city, or whether MoD is a sub of MaaS or MoD is an adapted MaaS US model will become apparent in time. As local factors define both concepts, in the same country, different MaaS/MoD models could develop depending on the urban structure, transport system and city policies.

Meanwhile, MoD like MaaS will continue to develop as Shaheen et al. (2017) reports how technology and data focused initiatives, the USDOT, are launching to leverage existing technologies to help with the advancement of MOD

- "Transportation integration and operations management initiatives that integrate different transportation systems to more efficiently and effectively manage operations.
- Policy-focused initiatives that tend to focus on environmental justice and equity goals.
- Pilot programs that test technologies and proofs of concept (e.g., MoD sandbox program)".

(Shaheen et al. 2017)

The federal transit administration (FTA)'s MoD sandbox demonstration program explores MoD in the real world by providing the various actors (public, community and private) with testbeds to explore MoD solutions. The city is actively involved in various ways such as designing new business models, integrating transport and mobility innovative solutions, funding cross teams and investigating smart technical solutions (FTA's MOD, 2018).

4-1-3 City Role

4-1-3-1 Upgrade of the City Role

4-1-3-1-1 Role Types and Maturity Stages

Cities' classic mono roles have evolved and branched out; five stages of maturity have been identified (Table4.3). These stages help them ascertain at which stage they are now and where they are heading (ADL, 2018): aware, engaged, uneven transformation, holistic transformation, and embedded.

These new city roles will fall into one or a mix of the following four categories as ADL (2018) explains,

- Strategist, design strategic policies and define the transport system landscape
- Operator, provide integrated transport and mobility services
- Convener/catalyst, actively enable and encourage other stakeholders and influence the mobility ecosystem
- Regulator, act where needed to avoid market risks and unintended users' impacts as well as define transport system regulations

These roles cover the provision of a strategic infrastructure which connects planning and regulation policies. This role represents one of the most critical that cities face (Meyer and Shaheen, 2017). It incorporates the need to define the roadmap, manage the cross team to bring everyone to the table, act as brokers by public-private corporations, provide a test area, conduct pilots and users' scenarios for the various modes, set standards, build suitable ecosystems, upgrade the city to a sustainable/smart/resilient city, organize the user's data exchange, empower the crowd i.e. support crowdsourcing, win the general public over, encourage new players as well as innovation, invest in/subsidize new players and support the integration of their offers (digital and physical urban accessibility), enable cities to learn from each other – as the result is not as important as the process, proactively support the establishment of technological experiments by providing legal and technical assistance, build future urban policies based on the cross team and planning processes for short/long term shift, i.e. redesign urban spaces accordingly to enhance maximum use of common areas – like streets, parking and curb spaces.

Best examples of sustainable mobility policies are those which are currently shifting from the concept of “predict and provide” to “optimality and sustainability” (Meyer and Shaheen, 2017) and include the safety and security of the innovative modes while facilitating equity in transportation provision, geographic coverage and urban accessibility for all, especially those who are underserved due to having a lower income.

Examples

The Seattle Department of Transportation and car2go developed a service within two years that guaranteed equitable service delivery to the various city neighborhoods across the entire city (Goodall el al, 2017).

Florida’s Pinellas Suncoast Transit Authority and Uber agreed to start a service which covers areas where the bus service was canceled due to lack of funding (Goodall el al, 2017).

While cities develop and are transformed into smart cities, existing attributes will be upgraded and new capabilities will be gained so that they evolve into their new role as enablers and leaders of the mobility era. Table 4.3 describes the key factors enabling the shift cities need to make - from leveraging existing transit agency functions to bringing staff along the journey.

Category	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Maturity level	Aware	Engaged	Uneven transformation	Holistic transformation	Embedded
Definition	Aware of emerging mobility trends but no clear vision	Mobilizing around emerging mobility trends - introducing	Actively evolving roles and capabilities in parts of the organization	Pursuing firm wide capability transformation to fulfill new roles	Future roles fully embedded, supported by new capabilities

		about how to respond or what its role should be	an agreed - upon future vision and roles		and develop future mobility system goals	across all business functions
Features to develop		existing attributes		enable capabilities	new attributes	
City role	Strategist	-Takes long-term view on projects -Focuses largely on physical infrastructure -Long lead times and fixed intervals between updates		-Ecosystem collaboration and engagement -Sensing and shaping - Flexible planning and policy making	-Engages and consults continuously -Uses incremental and agile strategies with technology embedded -Emphasizes “no regret” short term initiatives	
	Convener and catalyst	-Convinces Stakeholders about key issues -Provides financial support through grants		-Complex relationship ecosystem management -Intellectual property and technology investment models -Flexible procurement procedures	-Provides platforms (technology, funding, communication, data sharing) to facilitate collaboration and integration -Develops incentives (competitions) to spur innovation -Encourages market-led proposals while retaining the authority to engage	

	Regulator	-Prescribes actions based on long-established policy and legislation -Focuses on addressing perceived market failures -Develops mode-specific and hardware-based specifications	-Deep technology and industry knowledge -Diverse private sector engagement -Risk management	-Creates less prescriptive and more agile outcomes-focused regulation -Dynamically balances innovation, economic development, and safety risks -Focuses on delivering an integrated system and competitive choice
	Operator	-Focuses on providing a baseline level of service in an integrated but closed system -Deploys long-term contracts based on cost-plus service specifications -Emphasizes asset utilization rather than service delivery	-Dynamic service planning -Collaborative public-private partnerships -Outcomes-based contract models	-Delivers on-demand, dynamic services driven by customers' needs -Provides seamlessly integrated services with other public and private multimodal operators -Crafts shorter-term and more flexible supplier arrangements supported by shared risk/reward

Table 4.3 Cities future mobility readiness/roadmap - (Adapted from ADL, 2018)

4-1-3-1-2 Hubs or Incubators

After the first wave of the mobility transformation that hit multiple cities calmed down, the first outcomes of the conducted case studies and pilot projects showed, as seen so far, that for intramodal services (including MaaS and MoD) to exist and regardless of whether in compact or sprawling cities, they need a backbone to rely on. This backbone represents the major transport mode in the particular city, combined with the other modes available or that could be offered. Additionally, from a financial point of view, it is easier to integrate the existing pieces of the mobility puzzle first before completing the puzzle with new modes.

Nevertheless, the degree of integration needed and the challenges to be addressed, vary depending on whether it is a large city, or a less densely populated area (small towns, semi-urban and rural areas). In the first, the challenge will lie in accompanying the emergence and articulating the service, while in the latter, the cities' role will be to create the conditions for the emergence of a service that does not yet exist (Brimont et al, 2015).

And when it comes to the business model of the integration of the various private providers, additional attention is required from the cities. These modes could potentially lead to new (public) mobility services. They would no longer be peripheral, but integrated into a system of solutions under one umbrella like CleverShuttle, a startup in Berlin, which has DB (the German railway network) as a strategic partner (Hofmann, 2016). But generally, this shift to public services is controversial. On the one hand, the city expects and counts on the continuity of these services, but on the other hand, the new private providers cannot guarantee this due to their unstable financial situation. That is why these newcomers, in turn, are dependent on the financial support of the city to develop and provide quality services over time to reach the peak mass. Nevertheless, they fear the extensive intervention of the public authorities in return and tend to seek alternative financial means either from the beginning or after the first phases.

That is why cities have to systematically develop a way to support these new players to win them round without taking over, depending on their circumstances (provider, service, advancement), either as an incubator or a hub.

As incubators, cities can intensively and actively follow the development of these startups, act as mentors and set the course if necessary. But, on the other hand, the incubation period is usually limited to short periods of time and these new providers cannot decide on their product alone. The other option, lending support as a hub, offers the startups more freedom to develop and is designed for long-term phases, but the supporter does not get actively involved in terms of taking decisions, mentoring, etc. (Friederici, 2015).

4-1-3-2 Main Key Factors

Teamwork and Collaboration

Actors at the city level are the municipal urban and transport planners as well as urban developers and transport policy makers.

It became clear that smart cities – both compact and decentralized ones – require more than just modern devices, smart sensors and continuous connectivity. Smart cities, says Lakamp (2017), need an orchestration framework, foresight and planning, including features like continuous connectivity, clean energy, as well as metrics such as curbside computation, sidewalk storage, advanced hardware and upgradeability. In addition, sensors, secured/saved customer data exchange, APIs and professional third-party development, convenient/simple and functioning user interfaces are necessary (Lakamp, 2017).

So, if the MaaS ecosystem were a band, the city would be the maestro of the orchestra, who leads the band to play the required melody. The band members would be the various stakeholders in the ecosystem – each actor provides a unique tone and only when they cooperate – will they be able to produce the desired melody.

Breitstadt (2017) , head of MOIA ride hailing business, explains the benefits of cooperation among various stakeholders and says that it is about offering a perfect mobility solution for urban people. As the customer's need for transportation differs, various alternatives for transportation are required. The best way to develop a real network is thus with local partners. The customer should have seamless access to the perfect mobility solution at that moment (Breitstadt, 2017).

Exploring the future of mobility offers cities a great chance to fix major pain points like congestion, urban sprawl, lack of urban accessibility, road safety, rising population and sustainability. For cities to move people and goods faster, more easily, more cheaply and safely, cities have to play their cards right and partner with other private and community stakeholders to be able to manage and regulate the innovative mobility disruption.

Cities have started to take the corporations much more seriously than in earlier phases, especially

after experiencing the risk they may face i.e., if the various players do not cooperate and let the market freely unfold in front of them. For example, transportation network companies (TNC) which are ride-sourcing/ride-hailing providers, such as UBER in New York City, have increased traffic congestion, vehicle emissions, cannibalized PT and left licensed cab drivers feeling desperate (ADL, 2018). Cities were not prepared for the concept, the existing regulations for taxi and rentals did not apply and the PT authorities did not react fast enough. Therefore, their move was successful because they offered services that covered underserved demand (ADL, 2018).
Cities have started to acknowledge the benefits and are now working on regulating and managing the disruption and shaping their role in the future. As Deloitte points out, "Finding the regulatory sweet spot is key. Too much regulation and the private sector may find it difficult to innovate or participate; too little regulation and the public interest is not served." (Salvemini, 2017).

Lange (2017), Business Development Manager, Telefónica Germany Next GmbH highlights the advantages gained from collaborations that could serve MaaS's future needs. "At the moment, various mobility services exist, but these are more or less individual services rather than parts of a chain of interconnected services. Hence, MaaS demands a change of the entire transport system by changing the operating environment and redefining the business models of different stakeholders." For example, the telecom industry can equip the city and the transport sector with data, i.e., advise them to change schedules to fit better according to the data they collect from smartphones. Personal data, Lange (2017) adds, are collected anonymously from the use of the phone. Telecom needs no Apps, the use of the smartphone creates data and cities could make use of the data availability (Lange, 2017).

Gradually, the advantages of public-private-partnership (PPP) also became clear on both sides of the Atlantic and accordingly platforms were developed. They have the goal of offering support, inspiration and connections.

Examples

The European Union, created the MaaS Alliance -an independent mobility service provider and one of ERTICO's (European Road Transport Telematics Implementation Coordination Organization-Intelligent Transport Systems & Services Europe) (2016) activities "to develop and deploy Intelligent

Transport Systems (ITS) and a unified MaaS platform to save lives, protect the environment and sustain mobility in the most cost-effective way" as ERTICO describes it (ERTICO, 2016). PPP operates on the country/continent level, enables MaaS stakeholders to get together and facilitates information-sharing among the players. The MaaS Alliance has four working groups, which are active in diverse fields and encourage governments to invest in relevant programs. Project responsibilities in terms of objectives and risks are shared among the members as well as the commercial achievements and losses, explains Lindholm (2016) ERTICO's Director of Communications and Partnership Development (Lindholm, 2016).

On the other side of the Atlantic, the Smart Cities Challenge was initiated by the USDOT. 78 cities participated in the challenge and developed plans to upgrade their cities. The goal was to promote sustainability and offer the cities a chance to develop innovative future visions and examine new mobility solutions (SCC, 2016).

Therefore, Transportation for America (T4A, 2016) was created as a collaboration between business and civic leaders from various fields to support cities to invest in smart transportation solutions. "We're in the midst of the most transformational shift in urban transportation since the start of the interstate era more than 50 years ago. And just like that era, cities have enormous potential to help or harm their residents with the decisions they make," said James Corless, Director of T4America (T4A, 2016).

Legislations, Management and Cities Strategic Development

The classic approach to urban accessibility mentioned in chapter 2 , either through approximately/densification in compact cities or speed in decentralized cities, is gradually being modified through a wider focus on the city-level policies on urban sustainable transport and promoting socio-demographic shifts (Meyer and Shaheen, 2017), changing public attitudes and technological innovation, as it has been found that policies that consider only one side of the problem, for example, by only supporting carbon reduction through carbon taxes, congestion charges, etc., have lower stabilization.

And as urban planning and development of transport systems go hand-in-hand at all stages, cities have started developing public policies supporting the integration of land-use and transport planning as an effective instrument. This is reflected in promoting dense, transit-oriented urban expansion, especially in (very) dense cities and/or compact cities with public transport systems. In the less-dense and/or sprawling cities, the tendency was to promote solutions/pathways based on the use of individual transport systems as a collaborative concept supplemented by the existing basic public transport.

Historically, the interrelationship and interdependence between urban planning and transport systems was the core for the development of the three key rules of a relatively widespread urban transport policy also known as 'avoid, shift, improve' policy (Meyer and Shaheen, 2017).

- Avoidance and reduction of travel intensity by increasing physical proximity as well as relocating relevant functions and activities.
- Shifting from spatially inefficient and energy intensive car use to public, collaborative and soft modes.
- Enhancing energy and space consumption to increase vehicles efficiency

(Meyer and Shaheen, 2017).

With that in mind, providing strategic infrastructure which connects planning and regulation policies represents one of the critical roles cities face. Transport systems and services shape to a great extent the urban mobility patterns, residency and commuting choices (Meyer and Shaheen, 2017). Modern technological innovations in urban transport can directly transform the scale and type of users' mobility, residency, traveling and working lifestyles.

Hence, using effective management is key to promoting a compact city model when it comes to spatial planning and urban growth, together with other instruments like minimum density standards, mixed-use regulation, emissions standards, car use/parking management, redistribution/design of curb space as well as other measures that help avoid urban sprawl such as PT and soft modes infrastructure, with the focus on higher density, mixed-use areas around mobility hubs, etc. (Meyer and Shaheen, 2017).

Examples

The relocation of one of Copenhagen's offices (over 1,500m²) to within 600m from a train station is an example of the 'Station Proximity Principle' (Meyer and Shaheen, 2017). It influenced the city's future compact urban development plan.

Another example is seen in Ahmedabad (India) town's flexible, comprehensive urban planning. Along the BRT, the constructed government buildings are to be repurposed into low-budget houses at a later stage, and thus combine transport provision with accessibility.

These regulating instruments help cities manage and shift transport and thus upgrade the city and enhance operations and encourage investment in innovative services and infrastructures. Taxes historically played such a role and influenced the mobility landscape, either as encouraging instruments such as tax reductions and subsidies to actively support and incentivize vehicle purchase (Meyer and Shaheen, 2017), or discouraging measures such as increased vehicle purchase taxes, road tax and registration tax. Taxes were also used as a regulating tool to manage vehicle use, road and parking charges. Likewise, fuel pricing plays a major role as an effective fiscal policy (Meyer and Shaheen, 2017).

It is worth mentioning how the influence of taxation could be one of the factors for choosing a specific business model in certain countries.

Examples

Using mini buses with 7-9 seats could reduce taxation by 20% in London (Datson, 2016).
While in some other countries the relevant factor is not the number of seats but the distance, for example, by max 50 km one-way trips on PT, the authority pays 7% instead of 19% for more than 50km, as in Berlin (Krueger, 2016). This supports station-based collaborative modes. Some cities, though, have different sizes, mobility needs and city structure such as Stockholm, Singapore and London, which have adopted a congestion charging plan, which has resulted in less congestion and thus fewer emissions. The revenues were used for transport projects (Meyer and Shaheen, 2017).

A combination of reducing PT prices, while improving their services, increasing the private vehicle operation cost and adapting the land-use regulations demonstrated in some European cities a good example for the advantages of public-private collaborations in terms of pricing policies (Meyer and

Shaheen, 2017). In London, congestion and parking regulations have enabled a faster launch of e-vehicles (Meyer and Shaheen, 2017).

Moreover, cities have the power to mobilize capital investments by attracting additional funds, national/private, which contribute to overcoming the gap in finance and sustainable investment projects.

4-1-4 Three Phenomena Cities Can Learn from

For City Structures - Location is Key

In the case of Los Angeles (LA) for example, it is normal for an average family to own 3-4 cars. The prices of the cars are relatively affordable and so are the taxes, gas, registration and insurance. Additionally, one can park in many areas for free and even find a parking spot. In addition, there is no comparable form of convenient shared transport. These factors offer the first car as the backbone for MaaS, and MaaS can, via shared (autonomous) mobility, replace the second or the third vehicle. And so, the initiatives of the city, like the BlueLA pilot project have been launched in LA to reduce congestion and CO_2 emissions by offering e-shared cars in less advantaged city districts (Neckermann, 2017).

In comparison, London has a population of 10,549,000 according to World Population Review vs. 3,792,621 in LA as published by the World Population Review (WPR, 2017) but half of this population do not own a car in London, which means they need a transport mode in the first place, whereas in LA, the mono transport mode is available. Users can seek a different form of transport but just as an alternative and they need a specific reason to do so. The situation in London makes it easier to compare various modes before picking one over the other, not only when deciding whether to travel by car or shared modes but also what type of multimodal combination. And in Berlin, where the system is supported by a unified PT network with a rich car-sharing offering, it makes the comparison even more appealing. The situation helped the developers in all directions to come up with routing apps that enable the users to go from A to B (Neckermann, 2017).

In London, CityMapper uses open data for multimodal journey planning. This meta-app also offers alternatives when plan A is not working and these are the features that matter the most for the users. The winner, especially in big cities where time matters, is the one who offers the user an alternative when the main plan is canceled or postponed. "Such a travel app that shows in real time the info is gold value", so Neckermann (2016).

While some cities might need only the existing PT offers to be shown digitally and no integration is needed, others need the whole package and the users are willing to share their data.

For Transport Systems Flexibility is Key

Neckermann (2017), MD Neckermann Strategic Advisors explains that UBER being a suitable first-last mile MaaS service, is most likely to be used in London when it is hard to reach the PT station like at night or during the weekend, whereas in a city where the PT is only basic, like in the US, having UBER means fewer customers use the PT services as they are basic and UBER offers a better quality.

Depending on a flexible business model that is adaptable to each city, UBER was able to spread widely in various cities. The starting point depends on what the city offers. In London for example, they used the already existing on-demand service, minicabs, which shared a similar concept to the TNCs. The minicabs operate side by side with the London taxis (Neckermann, 2017). Moreover, UBER started a partnership with a housing developer to offer free UBER services as part of the rent in London and in return the tenants gave up owning a car and so the parking spaces could be used for other purposes (Mascarenhas, 2017). UBER adapted its business model accordingly and depending on the existing network/platform – they did not invent the wheel again. The big plus for them was the existing on-demand service and the decentralization of the PT authorities which helped them to develop various models. "UBER's success secret is that they don't have a central model", said Lukas Neckermann (2017). Bailey (2017), Head of Marketing, Stratageeb adds that UBER's innovative business models need to be complemented with sustainability and transparency to align with the MaaS concept. (Bailey, 2017).

So, in cities like Berlin and Munich, where that is not the case and a unified PT network exists, the on-demand services are not widely used except in rural areas like the call-a-bus service. UBER started to think of a different model, like cooperating with some taxi companies as in the case of Berlin. Where they have an advantage over the classic competition in particular, is that the prices do not vary as in the case of London, where the prices of UBER are almost 50% cheaper than those of a black cab (Neckermann, 2017). Additionally, taxi drivers have to train for the knowledge test for three years, whereas the UBER drivers do not need that and depend on the navigation of the App. Another example of the success of the flexible models is seen in New York where the taxi offering did not improve or develop over the years and so the UBER business model disrupted it and led in a short time to UBER cars outnumbering the yellow taxis in the city. But here again, the influence of other factors is evident, for example sustainability – UBER drivers work only part time, whereas taxis work 24/7, the prices are also no different from those of a regular taxi except that UBER sometime charges more at peak time. These factors mean that more trips are made by taxi (Neckermann, 2017).

Los Angeles is one of the big cities that operates only a basic PT service. In the absence of a developed infrastructure and increasing urban sprawl, ride-sourcing companies were again able to adapt their offering to spread in the city. LA now represents the second city in the US where UBER has spread widely. The city LA DOT started to think about possible sustainable solutions to develop MaaS with an applicable backbone, for example, cars in the form of AV in the future, which will solve a lot of the problems faced by the city such as congestion, gaining the control lost with the increase in the ride-sourcing companies, getting rid of the third/or maybe even the second car (Neckermann, 2017).

For City Roles - the Political Tool is Key

In London, the city invested in digitizing the system and offered a digital platform where ticketing was integrated with access to the hubs in the form of the Oyster card/app. As this option was offered as the sole option, it enabled the public to adjust faster.

When considering the Finnish model vs. the Austrian, political decisions changed the legislation and supported the concept commercially and enabled a third party to function as the sole MaaS provider and operator. This means that the transport providers share their customers' data with the MaaS provider. MaaS Global then bundles the various services into packages, decides the prices and offers them to the users. The city does not interfere in the private company (Whim, 2016). In Vienna, political decisions took a different turn. The city is actively involved too but in a different way. The main PT provider is the MaaS platform operator. The platform is offered as a white label for the private providers who get to keep their users and decide their prices (Lichtenegger, 2017). This, in turn, highlights how there is no one MaaS solution that fits all. Local factors, needs, readiness and acceptance shape the concept. Vienna develops a MaaS concept where the PT services are integrated and bundled in packages and the private ones are not. That is one of the reasons why the Whim concept, although it represents a successful model in Helsinki, would face challenges in Vienna if integrated 1:1, where each stakeholder keeps his users and the PT controls the MaaS platform. Whim in Vienna offers a white label platform where the providers offer their modes and own the data of their users (Whim, 2016).

Such a comparison is also visible when considering Quixxt, the DB (German Railway Company) trip planner for all Germany vs. Moovel, the multimodal trip planner and subsidiary of a global car manufacture, Daimler. The first belongs to a public provider, which is the backbone for integrated mobility concepts in Germany and thus many problems like how to handle customer data are solved. And the latter adapts its offering depending on the city. It offers three complementary products: Moovel app, Moovel transit and Ride Tap, (Moovel, 2017). In Germany, Friedrich (2017) Head of Business Development-Moovel Group GmbH explains, they offer a routing app for various transport modes and some single ticketing. In their own automotive headquarters city, Stuttgart, Moovel is the platform provider and has the customer's data from the PT and other shared modes, whereas in Karlsruhe, they offer only the platform as a white label for the PT sector. In the US, they offer various payment services. That is why MaaS cannot be considered globally or national; it needs to be adapted locally depending on the city structure, providers, meta-apps, platforms, etc. (Friedrich, 2017).

New York was not prepared for UBER, which caused several problems as shown in the research. Later on, the city reacted and started regulating the services; now UBER drivers must be licensed by the DOT. London, on the other hand, integrated UBER into their system from the start and their services are regulated by the PT authority, and their drivers are licensed and insured by TfL.

Taxation is always a political tool that influences the type of mobility in a city. In London, the city adapted taxation, bus transport providers have to pay 20% when having buses with more than 10 seats. Therefore, using minibuses with 7-9 seats was an economical solution, while in Berlin Providers offering services within shorter distances than 50km pay 7% tax, while for more than 50km the tax increases to 19%. In 2006, in Sweden, a traffic tax was introduced, whose charges vary depending on the time and the day.

Cities like Helsinki encouraged the transport providers to open their APIs and so enabled the MaaS provider represented by a third party to integrate the APIs and offer open data on their platform. In London, the public transport provider, TfL, was the one who integrated the APIs and offered open data accessible for all developers in the UK.

Introducing parking and congestion/traffic charges in certain urban areas led to the majority of drivers starting to explore other options, like parking outside that area and using public transport, while only the minority pay the charges. This, on the one hand, reduces cars in a certain area and so impacts climate change, but also collects funds which can be used to improve urban transport and accessibility.

Cities with an already unlabeled MaaS culture like in Germany, which have facilities such as the call-a-bus service, tend to avoid a radical change such as having a private third party becoming the MaaS operator, and for this reason, the public providers are encouraged to grow into that role as the necessary foundation already exists.

And in other cities where the private sector has an active say in the transport industry, like in the US, convincing the private stakeholders to come on board might be more challenging than the public sector, but their acceptance of a pro-business concept towards private providers and willingness to embrace new (commercial) business models like MaaS Global's or TNCs is higher. It is also apparent that in the absence of a (unified) public stakeholder, multiple fragmented private offerings, albeit not integrated, emerge.

4-1-5 Takeaways from the Good Practices' Catalogue

Based on the good practices catalogue, the research distinguishes roughly two main emerging concepts and multiple threats, challenges, achievements and goals cities face in the development of future mobility.

Two Concepts

On the urban planning level, either the city is dense, walkable, provided with bike lanes, green spaces and common areas i.e., a developed urbanism or the city is vast, car-friendly, divided into suburbs and suffers from urban sprawl (Jonuschat, 2016).

On the transport infrastructure level, either a strong public transport network (VDV, MOB Austria, SNCF, SBB, DB) exists with a functional B2C car-sharing and some on-demand services in the form of taxi associations and C2C car-sharing in terms of ridesharing/carpooling, peer2peer as well as TNC ride sourcing/ride hailing UBER and Lyft. Or only a basic PT system (old buses and trains - Amtrak) exists with less B2C car-sharing, and more individual vehicles and/or on-demand services C2C car-sharing in terms of ridesharing/carpooling, peer2peer as well as TNC ride sourcing/ride hailing UBER and Lyft (Jonuschat, 2016).

On the technical level, either some services are already integrated to offer intermodal routing with ticketing (Qixxit, Moovel, WienMobil, e-Ticket Germany, Touch & Travel, Whim, Ubigo), both as PT and private sector web-based apps, or the services are not integrated and offered mainly by private companies as web-based apps (Jonuschat, 2016).

At the same time, comparing the pioneers in the development of urban mobility globally, Europe provides a very convenient PT-oriented approach. But nevertheless, it is clear there are different approaches and roles of the city within the continent/country (Jonuschat, 2016).

In countries like Germany, France, Austria and the Netherlands, the PT system is highly efficient, unified and acts as the main operator. This system still lacks flexible solutions when it comes to the first/last mile as a result of the lack of digitalization in the mobility world. In other European countries such as the UK, Italy, Ireland and Switzerland, digitalization (open data, integration of the

APIs, etc.) has already taken advanced steps, but still the operative PT system lacks the one marketplace shop due to the existence of multiple PT operators. In a different group of countries, such as Sweden and Finland, it is evident that there is already a partnership between the public and the private sector and a shift in the distribution of the typical monopolistic role of the PT to offer one unified service model for the city, whereas in other cities like those in Russia and Scotland as well as in the suburbs and rural areas where the PT is only basic, the private vehicle is the dominant mode as in the American model (Jonuschat, 2016).

Across the Atlantic, on the other hand, the cards are mixed and distributed in a different way and so is the role of the city. The system consists of basic PT services and intensive private transport as well as some unintegrated collaborative modes. One can also see different approaches within the same country. In some cities like New York, Boston, Chicago or Seattle, where the cities are compact and walkable like in the European model, the PT and on-demand modes provide efficient services, while in other American cities like San Francisco, Detroit, Washington DC or Texas the cities are spread horizontally, the PT services are very basic and accordingly private car ownership is the rule.
In some other states like Pittsburgh and Los Angeles, one can see cooperation with transportation network companies (TNC), which are ride-sourcing/ride hailing providers such as UBER and Lyft (Jonuschat, 2016).

Threats

In the first stage, picking the right city to stand as a pioneer for implementation is vital for success. Certain prerequisites must exist such as mature business models, willingness for innovation, a stable political situation, acceptance of the users and which strong players are on the field e.g., automobile companies. In European cities, says Breitstadt (2016) MOIA - Head of Ride Hailing Business, solutions need to be built up in line and in partnership with local partners and authorities. Therefore, they started with a partnership in Hamburg to learn how services can be operated on the basis of mutual interest to influence traffic situations in cities (Breitstadt, 2016).

The winners are only those who offer the customer what they need. Sometimes even metropolises have to wait in line for innovation when the city regulations do not support change as fast as it is needed. Many local stakeholders then tend to explore other cities before coming back at a later stage when better conditions exist like in the case of Qixxit, which will switch to the European market first before coming back to Germany (Kellner, 2016) and Moovel, which deployed their services only in certain cities (Friedrich, 2016). It is clear that policy is a powerful tool to enable or freeze MaaS.

With the new mobility solutions and the integration of the various transport modes, traveling will become easier, enabling more users to commute and commuters to travel longer distances. That is why cities have to make sure that these new modes do not create higher congestion and produce more vehicles on the road, thereby causing more traffic and pollution. Cities have to react to and manage the various modes according to a long-term strategy that on the one hand, covers the users' needs, but on the other hand, does not create bigger problems. Hill (2018) explains the risk of leaving the market to evolve freely. For example, if the number of collaborative modes increase, offering prices that are almost like the PT services, customers are expected to pick these modes but that automatically means that more cars will be on the road as the demand will increase. This will cause more congestion and CO_2 emissions and the user will not arrive at their destination sooner, which will lead to a rebound effect (Seebauer S. et al., 2018) as on the one hand, fewer people will use PT, and on the other hand, they will be stuck in traffic for longer periods. Hence, cities need to ask who the winner is, and what the best solution is to reach a particular goal (Hill, 2018).

Challenges

The dice will roll and disrupt all sectors but the challenge for MaaS is not the technical part, it is to overcome the obstacles that prevent cooperation and collaboration among the stakeholders (Lichtenegger, 2016).

It is clear that no ideal product is possible, but instead there needs to be a local adaptation with general guidelines which are agreed upon. Hence, leaders and policy makers of smart cities need to adapt their policies and regulations to enable these regional sustainable mobility solutions as well as facilitate the collaborations needed among the various businesses as they could only be offered within a partnership between the local providers and the city authorities. The aim is to reduce CO_2 emissions and the greenhouse effect caused by urban sprawl by sharing vehicles and reducing the number of empty seats in individual cars.

Hence, cities need to come up with appealing offers to convince the masses of the concept. The public sector often owns the mass transit system and represents in many cases the backbone of the transport system and also controls the prices. This system is not secure and there is a need to change business models and adapt to the concept of the subsidiary and the partnership. Also, the private sector, like the automobile industry, needs to think of mobility more as a service than as a product, i.e., away from business-as-usual (BAU), as the automotive branch belongs at the top of this list and the business providers in this field are highly dependent on the car industry as a successful and profitable business model.

Cities have to find the balance between promoting the services of both public and private actors as a whole package and offering integrated services which are environmentally-friendly and resilient, for example, reducing cars on the streets, bringing customers conveniently to their destinations without causing more concessions for affordable prices for all classes. It is essential to bundle the strong points of the various modes to offer the new services, otherwise one risks blind competition among the various stakeholders, which will result in fewer PT riders, more cars (shared, on-demand and TNC) on the street, more pollution, a lower quality of life, more sprawl, etc. The bottom line is that only swapping the private car with a shared/on-demand/TNC/AV/e-cars will not solve the problems, but might create new ones.

The status of car-ownership is connected with the suburban lifestyle, social image and safety concerns, especially in the absence of appealing alternatives. In addition, the power of resistance to change is not easily overcome when connected with higher initiative costs to deploy infrastructure to adjust systems that already function differently, particularly in less-dense and car-friendly cities.

Lack of coordination among the various stakeholders can be problematic, whether it is when developing the necessary urban and transport policies on both a national and local level or for long/short term sustainable transport-related investments - redirecting current funding schemes to more demand-oriented projects, etc.

Koenig (2017) explains that some of the problems MaaS is facing now are a lack of commitment by different stakeholders/organizations, proprietary solutions (missing the one-stop-shop principle), regulations, policy instruments and willingness to cooperate (Koenig, 2017).

Achievements

The requirements of the new lifestyle which emerged globally have transformed cities into sustainable factories and mobility construction sites, encouraging them to evolve and mature into a bigger role, and the various actors to evaluate and adapt their products. Users also have to be more aware of what they need.

Returning to the idea of community-power, Prof. Hans-Liudger Dienel (2017) explains that according to Elinor Ostrom in "Theory of the Commons", societies do not always fall back into the trap of appropriating/taking the maximum possible from common resources, even when not needed. It states that societies can also sometimes take care of themselves. This common understanding allies with the basic concept that humans love to share - in some societies more than in others (Ostrom, 1990). This concept goes back in time to policy making, the definition of the city, ownership vs. usage rights, etc. It is reflected globally in the erection of common places, common parking lots, common parks, etc. Even sharing a ride is nothing new; since the development of cars, neighbors all over the world have offered a ride to others who did not have a vehicle. Also sharing a car developed as a common concept in society. All these unlabeled MaaS pieces of the puzzle are now being rediscovered and optimized. In the future, the concept of the mobility hub will play an important role as a common meeting point where the various mobility and transport services/modes are physically integrated to a greater extent by the society's reception to the concept of sharing (Dienel, 2017).

Schwitalla (2017), innovative city planner, architect and owner of studio Schwitalla, compares how urban planning and the transport system directly affects the social interaction of citizens. In cities like New York where the common space is shared (PT, curb, parking spaces, staircases in the building, elevators, parks, etc.) it leads to various social interactions among the citizens, while in cities like San Francisco, the private individual transport mode is dominant and owning a private house is the standard. Interactions and social engagements are actively sought when wanted (Schwitalla 2017).

The advantages of informal (public) transportation globally have become more widely appreciated and cities have begun to plan how to utilize this line of mobility and integrate it into the ecosystem.

The profit in the value chain is gradually unfolding, enabling the various actors to see how in the long run they can benefit and develop. Cities have understood that a lack of clear direction from the (federal) government and cooperation between the state and local authorities, will leave innovative mobility solutions merely as some basic functions scattered among various stakeholders. Many stakeholders (transport providers, car manufacturers, IT startups, etc.) have started to change their strategy.

Goals

Car ownership is comfortable, but on the other hand, people spend a lot of money on it and experience frequent parking problems. That is why sustainable mobility solutions have not only to offer the convenience of the car, but to improve on it by helping the user to save money and not worry about parking. These mobility solutions are expected to be implemented locally first, followed by national and international models based on roaming services, providing a one-stop-shop marketplace (Lange, 2016).

Communication is the key. Cities, with the help of consultancies, have the role of informing on the one hand, those who are in charge of developing urban policies to be able to take the right decisions. And on the other hand, they need to inform the users about the various developed apps that can bring them from A to B. With the various types of apps, which the users sometimes do not even know exist, the cities can support the integration of the sustainable modes into one platform/network to enable the user to find them.

Taxis already benefit from a monopolistic business model but new policies are needed to regulate the deployment of other alternative, innovative, efficient and affordable mobility services. Cities were able to implement taxi services to complement the PT network and regulate the prices and so a scheme could be organized for the other modes as well. These collaborative modes have the potential to solve most of the problems cities are facing, provided that cities set regulations for their deployment, (Hill, 2018) for example, the number of vehicles (shared, on-demand, TNC, AV) in the particular city area as in the case of taxis to enable fair competition, times to promote the use of mass transit at peak hours to avoid congestion, using technology to offer users real time data, and controlling quality to attract more users and maintain their custom long-term.

It is important to support existing urban accessibility pathways (both physical and digital) to enable them to evolve into new, environmentally-friendly and sustainable urban transport systems by adopting innovative technology to their needs. There is also the potential of parking spaces, both curbside and in garages, as future multifunctional shared spaces.

If the public sector directs part of the funds from the subsidiary to finance the intermodal provider, that will reduce the public expenses, the mobility providers will pay taxes and there will be a new fund for the public sector. Investing in the quality of the mobility offering will return in the form of customer satisfaction with the transport provider too, and will also lead to a better quality of life by optimizing the routing of the users depending on their needs.

Finding the midpoint is best as rushing into immature cooperation could lead to failure to establish trust. Operating a truly integrated offer for big cities is quite a complicated activity, which will require a lot of patience to build due to the mix of public and commercial considerations, and particularly how road network management is integrated (Macbeth, 2016).

As Koenig (2017) says, MaaS needs know-how transfer, best-practice learnings, role models on cooperation agreements, organizational and technological frameworks to implement MaaS architectures and a political strategy towards MaaS (national and regional level) (Koenig, 2017).

4-2 Findings and Evaluation from the MDT Assessments

The GT analysis conducted highlights three open topics. Often mobility plans are based on developing a technological solution and integrating possible modes on the platform, but cities lack a comprehensive way to first assess their mobility needs based on the status quo before developing a plan and then implementing it. Transport planning is not always linked to urban planning, relevant stakeholders are not involved with the city to provide insights which support the city in the decision-making process and a clear call-to-action within the planning is often missing. The existing MaaS indices focus on the later phase after the decision to implement MaaS has been made and not on whether the area under study needs MaaS in the first place, or whether if it is the case that Maas is needed, what form it should take and what problems it would solve for them. The MDT was developed to fill these gaps. For demonstration purposes, the MDT is applied to three different cities, Vienna, San Francisco and Singapore. For a clearer overview, the MDT assessments table as shown in table 7-4-8, will be divided into six groups as shown below in tables 4.4 - 4.9. Table 4.10 presents the evolutions of the ranking layers 3-8.

Assessments

Table 4.4 assesses layers 1-3 and focuses on key facts and the existing mobility systems.
While all three areas under study are cities, Vienna is relatively old and a capital city (Wiener Linien - public transport, 2020), San Francisco is newer and a county (Maxwell, 2019), and Singapore is the newest of the three and a state island (National Online, 2021). More diversity is seen in terms of urban density, area, land use, and population. This in turn highlights the impact of local factors which have resulted in the differences in their development. In terms of urban travel, all three cities are regarded in their respective approaches as pioneers.

Vienna is a compact, relatively walkable European capital and province. It offers a unified and integrated PT network, which is one of the most highly-rated in Europe. The affordable annual PT ticket has motivated many users to switch to PT within the city instead of driving their own cars. Collaborative modes, such as cars, bikes, and scooters are also widespread and used for first-/last-mile solutions and short trips. In the suburbs, on the other hand, private cars are still mainly used because of a lack of convenient alternatives. The city is actively involved in the implementation of MaaS and is regarded as a pioneer in its approach (Wiener Linien - public transport, 2020)

(Stadtentwicklung - Wien, 2015).

San Francisco is decentralized, vast and spreads out horizontally. It is in the state of California on the US West coast. Car-use is the dominant transport mode, but PT is available too. In addition, shared and peer-to-peer modes, as well as transport network companies (TNC), are widespread. The city is actively involved, like Vienna, in mobility development schemes, but the private sector also has a major role. San Francisco is one of the first cities in the USA to implement MaaS/MoD and a pioneer in its approach. Hosting Silicon Valley introduced the startup culture and made the city a hub for technological innovation. Soft modes are not widespread because of road safety and the fragmented infrastructure (Shaheen et al, 2018) and (Maxwell, 2019).

Singapore is a relatively new, compact city in comparison with the previous two. It is an island city-state in Southeast Asia. It was developed on a smart city concept from the beginning and is regarded as a pioneer in its approach in terms of innovative projects. The city, which is actively involved, implemented various innovative projects and is connected via road-ways and ferry services to other islands. Its fully integrated PT network, offers very affordable prices, and is ranked as one of the best internationally. Cars are used too but more to commute between towns, especially with the introduction of toll roads in urban areas. Soft modes are popular, and autonomous fleets are used. Singapore also hosts a major port (Schwitalla, 2016) and (Government of Singapore, 2021).

Assessments	Vienna	San Francisco	Singapore
1-Urban planning – type of urbanization			
Degree of urbanization (City, town, rural area)	City and capital, (Wiener Linien - public transport, 2020)	City (and a county), (Maxwell, 2019)	City-state Island, (National Online, 2021)
Type of urban density (Compact, decentralized)	Compact but not dense, (Stadtentwicklung - Wien, 2015)	Decentralized but dense (2nd most densely-populated in the country), (Maxwell, 2019)	Compact but very dense (2nd densest in the world), (National Online, 2021)

Area	414.82 km², (Statistik Austria, 2021)	46.87 square miles (121.39 km²), (United States Census, 2019)	728.3 km², (Data.Gov.SG, 2021)
Land use	32 categories divided into three groups building, grassland and traffic, City of Vienna - Urban development, (2021), 57km² agriculture, 104 km² natural spaces, 19 km² water bodies, 42 km² single-family houses and allotment garden areas, 70 km² mixed residential areas, 21 km² trade and industry, 25 km² "green" infrastructure (parks, sports fields, outdoor swimming pools, cemeteries), 19 km² infrastructure, special uses and construction sites, 57 km² traffic, (City of Vienna, 2021).	Public, residential (house character, mixed houses & apartments), residential-commercial combined, residential transit oriented, downtown residential, neighborhood commercial, neighborhood commercial transit, Chinatown mixed use, Parkmerced use, south of market mixed use, eastern neighborhoods mixed use, commercial, redevelopment agency, industrial, production, distribution and repair districts, (San Francisco Planning Department, 2021).	14 % of land for housing, 13 % for industry, 8% for parks and nature reserves, 19% for recreation facilities, 3% for utilities, 12% for land transport infrastructure, 5% reservoirs, 3% for airports, 8% for defense requirements and 1 % for other purposes, (Ministry of National Development, 2019).
2-Populations			
Size of population	1,921,153 in 2019; (most densely populated province) with 4.631 residents per km², (Statistik Austria, 2021).	881,549 in 2019, population per square mile in 2019 was 17,179.1 (44.494/km²), (United States Census, 2019).	5.69 million in 2019, 8358 population per km², (Department of Statistics Singapore, (2021).
Average income per capita	22,500 EUR in 2019, (Statistik Austria, 2021).	58,048 EUR (68,883 USD) in 2019, (United States Census, 2019).	46,280 EUR (54920 USD) in 2021, (Department of Statistics Singapore, 2021).

3-Urban travel - mobility system (General: collective, collaborative, soft modes, individual, informal) (Specific: subway, tram, bus, car/bike/rideshare, peer-to-peer, on demand, ride hail, etc.)			
3-1- Main used mode	Unified public transport network consists of subway, underground, trams, buses, and regional and national train network (Stadtentwicklung Wien, 2015).	Motorized individual transport (private cars) (Shaheen et Al., 2018; Maxwell, 2018).	Fully integrated public transport network consists of mass transit (Metro), bus network, light rail transit (tram), taxicabs and private hire cars and international railway lines, (Government of Singapore, 2021).
3-2- Second used mode	Private cars, more often used in the suburbs, (Wiener Linien, 2020a).	Public transport (32%), consists of light rail, subway, metro, large buses, trolley coach, a historic streetcar line, and touristic cable cars. Regional rapid transit system consists of heavy rail, and an underwater Transbay tube. Commuter rail system (Caltrain)—shuttle bus—San Francisco Bay ferry, (Shaheen et al., 2018; Maxwell, 2018).	Private cars, mainly as transport mode between satellite towns, (Government of Singapore 2021).
3-3- Other used mode	Shared (cars, bikes, and e-scooters), on-demand, taxi, TNC (UBER), soft modes are popular, (Stadtentwicklung Wien, 2015).	Car/bike/scooter/ride share and on-demand, taxi, peer-to-peer, TNC (UBER, Lyft, etc.). Apple and Google private buses for their employees, soft modes are fragmented, (Shaheen et Al., 2018; Maxwell, 2018).	Soft modes are popular, electric, autonomous, and shared mobility, rideshare and on demand, TNC (UBER), autonomous fleet for older people and autonomous shuttles in campuses, (Government of

			Singapore, 2021).
3-4- Less used mode	Informal, (Stadtentwicklung Wien, 2015).	Informal, (Shaheen et al., 2018).	Informal, (Government of Singapore, 2021).
3-5- Modal share	Public transport 38%, 30% walking, 25% driving private cars, 7% cycling, (Wiener Linien, 2020a).	Drive alone 31%, public transport 22%, walk 22%, carpool 17%, TNC 5%, bicycle 2%, other 1%, (San Francisco Municipal Transportation Agency, 2017).	Public transport 44%, private car 29%, walking 22%, bicycle 1%, (Singapore City Mobility Index, 2016).
3-6- Others	Public garages integrated on the public transport app, park and ride possibilities for commuters, freeway and highway roads network, international airport, (Stadtentwicklung Wien, 2015).	Roads network mixture of surface streets, freeways and state/interstate highways, two international airports, (Shaheen et Al., 2018; Maxwell, 2018).)	Mainly land-based transport within the city-state, roadways connect to other islands and ferry services, two bridges linking to Malaysia, major shipment-container ports, toll roads to most congested city center areas, international airport, (Government of Singapore, 2021).
3-7- Travel Time	26.45 min, (Numbeo, 2021; TomTom–Travel time in Vienna, 2021).	33.8 minutes, (United States Census, 2019).	46 minutes, (Statista–Singapore, 2021).

3-8-Motorization rate	Decreasing, 386 passenger cars per 1,000 inhabitants in 2014, (City of Vienna - Vienna ahead, 2015).	Increasing, 772.76 passenger cars per 1,000 inhabitants in 2019, (San Francisco Municipal Transportation Agency, 2017; Statistik, 2017).	Increasing, 1.7118 passenger cars per 1,000 inhabitants in 2020, (Motorization rate Singapore, (2020).

Table 4.4 Facts and mobility, (own work)

Table 4.5 assesses layers 4-6 and recaps the resources and readiness in terms of physical and digital infrastructure, data sharing and users' needs and readiness, respectively. Because users in Vienna are environmentally conscious and seek sustainable commuting modes, there is an increasing tendency toward soft and active transport modes. Moreover, the city has been involved in the development of integrated mobility and MaaS concepts (Stadtentwicklung - Wien, 2015) and (Lichtenegger, 2017). In San Francisco, the private sector has a strong role, due to lack of public funds. Nevertheless, the city is responsible for providing access to the new providers on public platforms, as long as they fulfill certain conditions, (Maxwell, 2019), (Shaheen Susan et al, 2018), and (Schweiger, Carol 2018). In Singapore, the city has a central and a coordinating role in the decision-making process, and promotes innovation in all aspects. With the increasing emergence of AVs, advanced measures are being developed to guarantee safety, (Government of Singapore 2021), (Smart Nation Singapore, 2021), and (Thales, 2020).

4-Physical and digital infrastructure			
Physical infrastructure	Partly upgraded for public transport and soft modes. Emerging for shared and on-demand modes. Assess needs and schemes for development, (Stadtentwicklung Wien, 2015).	Needs upgrade, public transport does not cover the demand and is not accessible to all. Lack of road safety, accidents while walking and cycling, and traffic collisions due to lack of infrastructure. Assess actual needs and schemes for development, (Maxwell, 2018; Shaheen et al., 2018).	Public transport, on demand, and soft modes are innovative and advanced. Shared autonomous vehicles are emerging, advanced measures to ensure road safety. Toll roads equipped with electronic road pricing systems. Regularly assess needs and schemes for development, (Sustainable Mobility for all, 2021).

Digital infrastructure	private apps exist, public platforms as an integrated platform for public transport modes, city garages, and park-and-ride facilities, and white label for private modes. Private platforms only as white labels. No mobility management approach yet, future-oriented urban mobility concept and policy are planned and in progress, (City of Vienna, 2015).	Multiple public and private apps and platforms exist to enable public transit agencies to incorporate new technologies to complement and support the traditional functions of public transport, e.g., shared mobility, trip planner, open data software (toolkit/platform, approach to deploy shared/electric/connected, and automated vehicles, reduce single-occupant vehicles, connect drivers to commuters, display parking rates, first-/last-mile connections, integrated carpool to transit), and offer providers access to public assets. Future-oriented urban mobility and schemes for data collection and management for use in various projects are emerging, (Maxwell, 2018; Shaheen et al., 2018; Schweiger, 2018).	Public and private apps exist. Integrated public platforms for public transport, on demand, and soft modes. Soft modes' routes, connection to public transport, taxis, and their fares are displayed digitally on the public transport operator website and app. Payments are possible in multiple ways (app, credit/debit card, contactless, and cash). Approach to deploy shared electric, connected and automated vehicles, intelligent transport system emerging, an open data platform for urban transportation, in real-time (schedules, taxi availability, traffic conditions, car park availability), and advanced traffic management tools. Smart nation, multiple digital services via a network of apps, e.g., information for certain target groups such as young families and older citizens, administrative services, hail-automated vehicles, weather notifications and smart meters, (Government of Singapore, 2021; Smart Nation Singapore, 2021).

5- Data sharing			
Concept exists	Each provider retains data on their users, sets their own prices and remains the contact person, (Lichtenegger, 2016).	Data-sharing schemes between public and private actors are standard (City of Vienna, 2015).	Existing data-sharing schemes only within developed public apps and platforms, advanced data compatibility (transport demand and mobility data), the city promotes the trusted data-sharing framework (Addison, 2018).
Concept accepted	Assess need for and acceptance of data-sharing, accordingly update the concept, assess and develop a plan for data compatibility (Lichtenegger, 2016).	Assess data-sharing concept, acceptance, and need, accordingly update the concept and assess and develop a plan for data compatibility (Addison, 2018).	Regularly assess acceptance and need to guarantee quality and provision—update concept accordingly (Addison, 2018).

6- Users' needs and readiness			
Users' needs	City residents mostly use public transport, shared and soft modes; suburbs/peripheral residents use private cars more (lack of convenient public modes), possibility of park and ride at various public and train stations (Stadtentwicklung Wien, 2015).	Blue-collar workers in low-income neighborhoods commute mostly car-free (use carpooling and transit), highly educated, white-collar individuals in expensive developed buildings, solo commuters in private vehicles (Shaheen et al., 2018; Schweiger, 2018).	By 2050, 47% of the population will be 65 or older, and one in four seniors will still be working. High income levels and standard of living, an estimated 90% of the population own smartphones (Thales, 2020).
Users' readiness	Users' high levels of satisfaction with the public transport services reflect the alignment of the supply with the demand. Users are eco-friendly. Need for regular assessments to guarantee quality provision (Stadtentwicklung Wien, 2015).	Assessment of users' needs and readiness is emerging (transport demand and mobility data collection). Need for regular assessment to identify and guarantee the provision needed (Shaheen et al., 2018; Schweiger, 2018).	Assessment for users' needs and readiness is emerging, need for regular assessments to adapt and guarantee quality provision (Thales, 2020).

Table 4.5 Resources and readiness, (own work)

Table 4.6 assesses layers 7-8 and shows roles, collaborations and policies.

The three cities are actively involved but in different ways. Since collaboration among the various stakeholders is crucial for the success of developing integrated and sustainable mobility concepts, the MDT encourages the authorities, whether they play a passive or active role, to dive deeper and assess who is in the field, how to get them on board, what they offer and what they demand as well as regularly exploring legislation that builds trust, promotes collaboration, enables effective management and schemes to include both the relevant stakeholders and the community in the various decision-making processes. Accordingly, it will become easier to design the necessary policies and increase the possibilities of implementing them, (Maxwell, 2019), (Stadtentwicklung - Wien, 2015), (Government of Singapore 2021)

7-Authorities role and relevant players			
Active – schemes to collaborate	Involved through a public infrastructure company (Wiener Stadtwerke), which provides the public transport network, garages, park and ride facilities, platforms, and a regional train (Lichtenegger, 2016). Assess if/how other relevant stakeholders are involved, who they are, and how they are involved. Explore schemes to gain/share relevant knowledge among those in the ecosystem and how to support the decision-makers (Lichtenegger, 2016).	Involved but the private sector plays an important role. The city's municipality established the Office of Innovation. The Transportation Agency (SFMTA) developed the city's transportation platform. The Federal Transit Administration developed the Mobility on Demand (MOD) Sandbox -part of the US Department of Transportation's research agenda. The Mayor's Office for Civic Innovation supports startups. The city is a hub for global technical and social media companies, startups and shared economy culture (Silicon Valley). Explore schemes to gain/share relevant knowledge and how to support decision-makers (Shaheen et al., 2018; Schweiger, 2018).	Plays a central and coordinating role, designed the Walk Cycle Ride SG vision, developed satellite towns and expressways to shift residential development to other parts of the city and thus reduce congestion, introduced the Smart Urban Mobility, which is a strategic national project, focuses on re-skilling and digital inclusion (Government of Singapore, 2021; Sustainable Mobility for all, 2021).
Passive – identify/win main players	-	-	-

8- Policies			
Legislations and regulations exist	Multiple smart city policies have been designed and are emerging. The main focus lies on the zero-emission target by 2050 within the European Green Deal Strategy with local milestones by 2030 and 2040 (Stadtentwicklung Wien, 2015).	The city regulates new mobility providers' access to public platforms and public assets. The city is developing and implementing multiple policies and technology frameworks to manage transport supply and demand and promote sustainability, such as 100% renewables, managing waste, prioritizing smart transport, and ending traffic fatalities by 2024 (Maxwell, 2018).	Future-oriented urban mobility, the policy developed, partly implemented, and regularly upgraded. Has developed various regulations and frameworks-regulates the public platform and public assets, has implemented multiple technology frameworks to manage transport supply and demand, maximizes and utilizes current sustainable systems and eco-friendly transit modes, and has implemented congestion charging schemes to reduce emissions and congestion, (Government of Singapore, 2021).
Plans to establish trust exist	Explore legislation in terms of collaboration, regulations that build trust and effective management, and design the policies needed and possibilities of implementing them (Stadtentwicklung Wien, 2015; Maxwell, 2018; Government of Singapore, 2021) respectively		

Table 4.6 Roles, collaborations and policies, (own work)

Table 4.7 highlights layer 9 which focuses on general needs. These needs vary and are impacted by local factors such as city structure and the existing transport system.

9-General needs			
Compact cities generally lack comprehensive transport coverage and the ability to move people and goods, more quickly, easily, cheaply and safely based on their demand	Hence the need to promote dense, transit-oriented urban expansion especially in (very) dense areas, focus on technology and the integration of transport systems and goods delivery services and hubs.	-	Hence the need to promote dense, transit-oriented urban expansion especially in (very) dense areas, focus on technology and the integration of transport systems and goods delivery services and hubs.
Decentralized cities - generally suffer from congestion, and urban sprawl, lack of road safety, sustainability and the ability to move people and goods, more quickly, easily, cheaply and safely based on their needs	-	Hence the need to focus on the integration of land-use and transport planning policy development with a focus on technology, integration, operations management, environment, justice, and equity.	-

Table 4.7 General needs, (own work)

Table 4.8 presents the specific needs based on the research outcome, in terms of policies, technical, digital, and sustainable coverage in layers 10-1 and mobility modes in layers 10-2. All types of urban environments in reality, suffer from a combination of some of these problems, but will vary in how they implement the recommendations to suit their unique needs, so multiple selections are possible.

10-1- & 10-2- Specific needs			
Integration of existing modes	Bring relevant decision-makers and providers to collaborate and explore suitable provision, be it a public, commercial or hybrid platform		
Digitized system	Invite, as a hub, incubator, or accelerator, relevant stakeholders to introduce, with fair competition, alternative mobility management and pilot projects		-
Infrastructure not upgraded **Suitable transport network, or only basic network exists**	Support articulation/upgrade of existing modes and infrastructure and promote innovation.	Support articulation/upgrade of existing modes and infrastructure and promote innovation. Create conditions for the emergence of the services needed, enhance community transport modes.	-
Suitable resources (financial, administrative, physical, digital, etc.)	-	Partner with stakeholders who possess relevant resources provided these actors share the same goal and vision as the city.	-
Standard, formalities and policies	Collaborate with relevant players to offer policymakers the required insights into how to develop the appropriate measures.		
Pollution increasing drastically	Use alternative, eco-friendly and sustainable modes, introduce hybrid services for personal transport and goods/food deliveries, and post and courier services to reduce the number of trips made.		

Collective modes do not cover first/last mile and are not suitable for bulky transport	Supplement with collaborative modes and rentals.		
Collaborative modes are limited in areas, mass coverage and population categories	Supplement with existing (basic) public transport and integrate the community to support it.		
Private cars are limited, has higher costs, hard to find parking, neither eco-friendly nor affordable	Enhance ride-hailing/sharing and peer-to-peer services, rentals and fleet management, new transportation technologies, shared autonomous vehicles, innovative services, smart parking management, and promote acceptance of clean fuel.		
Active modes are limited, not fast or efficient enough for all types of trips	Develop mixed-use districts to reduce the need to commute and develop walkable areas, bike lanes, and green spaces.		
Informal (public/private) transport, not reliable, not regulated, cannot cover the demand, i.e., random supply and unsafe	-	Develop a providers' strategy to organize, upgrade, and integrate existing services.	-

Table 4.8 Specific needs and problems in terms of policies, technical/digital/sustainable coverage and mobility modes, (own work)

As local factors such as the city structure, the transport system and the role of the city play the main role in the definition of any mobility concept and shape its framework, as seen in the outcome of the research, it is crucial to consider them all when developing any solution. Hence, the MDT tailors the potential solutions - based on the identified needs for the particular area- in these three axes as presented in table 4.9.

Bottom line – potential solutions based on identified needs			
City structure	Prioritizing public transport, pedestrians, and cycling. Promote shifting to sharing instead of owning, and promote sharing the street equitably. Plan mixed-area districts to reduce commuting. Promote and expand the hub concept.	Promote sharing instead of owning. Promote and design mixed areas with eco districts. Promote and expand the hub concept. Tackle the growing housing shortage, good houses are not currently affordable, homelessness is increasing, and the middle class is decreasing (the city consists mainly of two economic classes).	Promote and design mixed areas with eco districts to reduce commuting. Promote and expand the hub concept.

City transport system	Develop schemes to upgrade the public and collaborative transport infrastructure. Utilize/upgrade the existing platforms for diverse services. Design schemes for efficient and smart mobility through mobility management and being responsive to demand. Develop a smart parking management system to accommodate diverse functions. Transform park-and-ride facilities into multifunctional hubs. Offer integrated eco-friendly concepts to commuters (car-sharing/-pooling, bike sharing, and public transport) and deliveries. Assess possibilities of integrating and upgrading waterway transport.	Mobility equity is a major problem, especially with limited sharing/pooling programs. Develop alternative plans such as upgrading the underdeveloped non-motorized transport infrastructure to meet the demand, increase road safety, reduce accidents while walking and cycling, and traffic collisions. Explore schemes to upgrade transport infrastructure. Expand emerging schemes for mobility management and demand-responsive plans and traffic management tools (for public transport and parking policy) and a comprehensive digital mobility approach based on needs. Utilize/upgrade the existing platforms for diverse services (deliveries). Reduce parking needs, develop smart/dynamic parking management systems to accommodate diverse functions. Promote the adoption of zero-emission (eco-friendly) vehicles. Explore plans to bring autonomous vehicles as a shared mode into mainstream travel to serve the underserved. Fill empty car seats by organizing carpooling. Assess the possibilities of integrating and upgrading waterway transport.	The priority is to create a seamless network of intermodal transport and adopt integrated mobility services, develop accessible modal systems for the aging population and last-mile solutions, increase capacity to reduce overcrowded public transport (travel smart program to incentivize commuters to travel during off-peak hours), use real-time open data to channel over-crowded public transport, switch to bikes, and encourage remote working. Utilize/upgrade the existing platforms for diverse services (deliveries). Expand mobility management and demand-responsive plans to meet the increased demand for stronger door-to-door transit due to the high population. Promote the adoption of zero-emission (eco-friendly) vehicles and efforts to bring autonomous vehicles into mainstream travel, transitioning from shared mobility to shared autonomy. Reduce parking needs, develop smart/dynamic parking management systems to accommodate diverse functions. Assess the possibilities of integrating and upgrading waterway transport.

City's role	New approaches in governance administration in terms of responsibilities and resources. Promote effective ways to work from home via rewards and incentives and collaboration with employers. Support innovation, new comers and schemes to collaborate with and involve relevant stakeholders and the community in the decision-making process and assess possibilities of integrating private services with the public after assessing users' acceptance (public–private interactions). Users are eco-friendly; therefore, educate and inform them to support their choices.	New approaches in governance administration in terms of responsibilities and resources. Assess ways to upgrade public transport and soft modes infrastructure in the absence of public funds by collaborating with relevant stakeholders. Prioritize public transport and soft modes by designing offers on need. Schemes to involve different stakeholders in the decision-making schemes for public–private collaboration. Develop effective ways to work via rewards and incentives and collaboration with employers. Involve the community -the city has an active global community. Utilize the city's high pull factor for technology-driven economic growth. Involve automobile R&D centers for autonomous vehicle prototypes as shared modes to serve the underserved. Reduce the number of single-occupant cars by sharing the assets and costs (car ownership is an expense). Assess ways to collaborate with relevant players to collect sufficient funds to upgrade existing infrastructure and implement new smart projects.	New approaches in governance administration in terms of responsibilities and resources. Design a governance framework to tackle congestion, traffic delays, and space constraints. The city is a living laboratory and a test bed for innovative smart pilots for autonomous vehicles - it has to develop plans to support innovation to serve the need. Involve automobile R&D centers for autonomous vehicle prototypes as shared modes. Schemes to involve different stakeholders in the decision-making process for public–private collaboration. Involve the community. Develop comprehensive schemes to re-employ senior citizens. Develop effective ways to work from home via rewards and incentives and collaboration with employers.

	(Elsayed, current Ph.D. research; Wiener Linien, 2020b; Stadtentwicklung Wien, 2015; City of Vienna, 2015; Lichtenegger, 2016).	(Elsayed, current Ph.D. Research; Shaheen et al., 2018; Schweiger, 2018; Smart City San Francisco, 2016; Addison, 2018).	(Elsayed, current Ph.D. research; Government of Singapore, 2021; Deloitte Insights, 2018; Global-is-Asian Staff, 2017; Sustainable Mobility for all, 2021).

Table 4.9 Bottom line – potential solutions based on identified needs, (own work)

Evaluation

The evaluation of the assessments of layers 3-8 as shown in table 4.10 follows, according to the assigned weights and ranking. Vienna scored the highest on urban travel, followed by users' needs and policies and scored low on data sharing schemes. Vienna's score was in the middle for developing physical and digital infrastructure and the authorities' role and relevant players. Users' needs and readiness are weighted the highest due to their huge impact. This yields 49, which puts it into the highest range, which means Vienna is highly likely to develop MaaS. Unlike Vienna, San Francisco scored the highest in developing data sharing schemes but this factor is not weighted high - since many areas develop schemes without agreeing to a data sharing concept. It ranks the highest for users' needs and readiness, followed by urban travel and policies but falls behind in the development of physical and digital infrastructure, the authorities' role and relevant players and data sharing schemes. With a total score of 39, it lies in the second range, that is, it could develop MaaS. Singapore, which has already developed multiple layers of the MDT, ranked the highest in urban travel, users' needs and readiness, physical and digital infrastructure as well as policies, followed by the authorities' role and relevant players and data sharing. It scored 53, hence, along with Vienna, it lies in the highly likely to develop MaaS category.

Assessment	Ranking	Weight	Evaluation				Weight * evaluation		
			Already exists	There may be a solution	Do not know	No particular solution	VIE	SF	SG
Layer 1- Urban Planning – Type of urbanization	Input	-	Input	Input	Input	Input	-	-	-
Layer 2- Populations	Input	-	Input	Input	Input	Input	-	-	-
Layer 3- Urban Travel - Mobility System	Should have	5	3	2	1	0	5* 3	5*2	5* 3
Layer 4- Physical and digital infrastructure	Not bad to have	2	3	2	1	0	2* 2	2*0	2* 3
Layer 5- Data sharing	Not a must have	1	3	2	1	0	1* 0	1*3	1* 2
Layer 6- Users' needs and readiness	Must have	6	3	2	1	0	6* 2	6*2	6* 2

Layer 7- Authorities' role and relevant players	Could have	3	3	2	1	0	3* 2	3*2	3* 2
Layer 8- Policies	Good to have	4	3	2	1	0	4* 3	4*2	4* 3
Layer 9- General needs	Output	-	Output	Output	Output	Output	-	-	-
Layers 10 -1 & 10-2- Specific needs	Output	-	Output	Output	Output	Output	-	-	-
Bottom line – potential solutions based on identified needs	-	-	-	-	-	-	-	-	-
Total							**49**	**39**	**53**

Table 4.10 MDT evaluation table of the three cities, (own work)

5 - Discussion

This chapter discusses the knowledge gained from the results of the MDT, its impact and added value in cities' decision-making process. The research reflects on the new discoveries and how it can solve current gaps in the research.

5-1 Interpretation and New Discoveries

Vienna, San Francisco and Singapore are very different from each other. They span the two extremes in many ways, compact to decentralized, very dense to less dense, vast to small, walkable to car-dominant, land to island, old to new. They have a different mentality in terms of sharing vs. owning and have different target groups. Hence, they represent different patterns and provide a colorful mix of scenarios and their comparison delivers a dynamic reflection to benchmark how these cities tackle mobility problems in general and also they show that there are no universal solutions to the same problem, but instead an adaptation for guidelines is required and, in turn, every city, town and rural area can adapt these guidelines to their needs.

Nevertheless, one can discover some similarities. All three are active cities, which focus on upgrading the mobility concept. They all have an engaged transport provider, a functioning (with constraints in some) PT network, the goal of prioritizing mass transit, and are actively involved in reducing transport emissions and developing eco-friendly neighborhoods. They are all seen locally and globally as being among the leaders in the mobility era.

The interaction between the main factors of the research, for example, the impact of the city structure on the developed transport system, has become more visible. Singapore, being compact but very dense and having pollution issues, has developed satellite towns and introduced congestion charging schemes to reduce traffic in urban areas and emissions. For Vienna, though compact but less dense, decentralization was not an option, thus the focus was on sharing the streets and expanding the soft mode infrastructure. San Francisco, on the other hand, was built from the start after the industrial revolution, hence it was decentralized by default and cars are dominant, though not accessible to all.

Being a relatively new city, Singapore has a higher acceptance of innovation. It was easier for the city to plan its urban travel from the beginning as a smart plan and being very dense promoted a faster deployment of innovative projects. Vienna, on the other hand, is an older city and digitizing a running system is challenging and slows down the promotion of innovation. This has limited it to pilot schemes so far rather than mainstream projects. San Francisco is car dominant and thus upgrading the existing basic infrastructure is a bigger challenge. But due to the involvement of the private sector and being part of Silicon Valley, the acceptance of innovation is high and it was easier for the city to promote and test various innovative projects.

In the absence of the public funds needed to upgrade the PT network in San Francisco, the city, which has an active role, involved the private sector to support it. Both public and private apps and platforms were thus developed to serve the city's needs. In Singapore, the city is also active, but unlike in San Francisco, the presence of the private sector is limited. The city provides an integrated public transport network displayed on a public platform which includes mass, collaborative and soft modes. In Vienna, where the city is also active, the public platform is an integrated one for PT services and a white label for private modes, and providers retain their users. A private platform exists too but only as a white label. Soft Modes are popular in all three cities, but while it is advanced in Singapore, it is developed in Vienna and emerging in San Francisco due to the lack of the necessary physical infrastructure.

After concluding the assessments, these cities can incorporate the highlighted needs and potential solutions to develop their mobility concept - mostly projected on one platform or more. Locally the modes, providers, platforms and additional services will vary. In Singapore, a lot of attention is given to the senior citizen in terms of their mobility (e.g., hailing an AVs shuttle), accessibility and re-employment as they form about 50% of the population. In San Francisco, the focus is more on securing accessibility for the less privileged citizens, who have no access to cars or nearby public transit by connecting them to single-occupant car commuters to fill the empty seats, and organizing carpool services to PT stations. In Vienna, the general public is eco-friendly, thus the focus is on expanding and displaying soft mode services and infrastructure.

Comparing the approaches and scores of the three cities demonstrates both the MDT's functionality and flexible utility. In terms of the evaluation, based on the outcome of the research, certain factors impact mobility concepts more than others and thus, these factors are weighted more. For example, implementing the most advanced technological concepts, upgrading the transport system, digitizing the infrastructure, seeking possibilities of sharing user's data and integrating the services, will not add value, be used, or reach the intended goal if these ideas do not align with the user's needs, acceptance and readiness. The users' satisfaction is crucial so this factor is ranked the highest. Likewise, having a suitable transport network is essential for moving people, goods and services and without it, an important element will be missing. Having the right policies and knowledgeable authorities in place makes it easier not only to plan, but also to execute the desired concept. In an area where the infrastructure (physical and digital) has not been upgraded yet or data sharing schemes have not been developed/accepted (yet), one tends to find substitutes and alternatives to compensate for these factors, i.e., the area's current readiness status is not an obstacle. Such areas should not drop the idea altogether, they will gain knowledge from the assessments about their status quo, milestones, pain points, what to change and thus how to move forward. The fact that Singapore scored the highest among the three cities comes as no surprise. Vienna follows, despite the fact that providers retain their users and data sharing concepts are not popular. San Francisco compensates for the missing PT network and infrastructure by sharing the assets to provide equity and accessibility. This in turn, shows how dynamic MaaS can be and how it can differ from one area to the other in terms of components, players, framework, target groups and needs. Some solutions are universal and needed in every smart city, but different approaches will be developed to implement them. For example, deploying autonomous vehicles in Singapore differs greatly from doing so in San Francisco or in Vienna on account of the differences in local urban structure, the role of the city, acceptance and readiness, etc.

In theory, using the MDT helps cities prepare systematically and within the same process for the journey and the scoring system provides a self-evaluation framework to start with. The focus needs to be on the need, not the race, and the resources will be allocated to serve the demand. Accordingly, cities will have the potential to avoid conflicts and dilemmas on the urban travel front, save costs, time, channel resources, impact the environment positively and improve the quality of life.

In practice, analyzing cities, towns and rural areas using the MDT can be used to answer the question of whether a city needs MaaS in the first place. If it does, then what type, and if not, which alternative is more suitable. The focus lies in the significance of the involvement of all the relevant factors and stakeholders whose cooperation and collaboration is crucial. This, in turn, sets the stage to explore various approaches for how to get them on board, for example, through the role of a mobility ambassador who will establish trust to keep them interested, and developing roadmaps in order to grow and expand together.

Although the MDT categorizes the areas into four groups in terms of the current ability to develop an MaaS concept, it emphasizes that every area can upgrade its system and offer a suitable and comprehensive plan based on its needs and resources. Likewise, even if the first group is highly likely to, and the second could develop MaaS, as it has most of the ingredients needed, it still might not invest in the concept because it may not align with the city's goals. Areas which need to put effort into developing MaaS can use the output of the MDT to plan their roadmap. Likewise, areas which cannot develop MaaS (yet), should not drop the idea altogether; they will gain knowledge about their pain points, milestones and what to change.

In general, to score even higher the three cities could consider multiple approaches such as promoting various mobility awareness campaigns/initiatives, designing mixed areas with eco-districts, developing easier and more effective ways to reach the user and understand their needs (such as the nature and frequency of the most commonly made trips, pain points, type of change needed, potential motive/s and willingness to change as well as openness to new ideas, for example, sharing/renting one's own vehicle, ... etc.). It is also important to consider winning new and enforcing existing collaboration with relevant partners to reach various target groups based on the concept of treading, i.e., what would an actor gain vs. demand, exploring and introducing the concept of the mediator/neutral facilitator/ambassador to support the approach. Involving the community in the decision making from an early stage is an essential thing to consider as well as developing effective ways to have a home office, supporting innovation and newcomers, utilizing and upgrading the existing platforms to accommodate diverse services (such as food/grocery/courier/post and online shopping delivery as well as car rental, car/bike/scooter/p2p parking services, ... etc.) and developing a (multifunctional) smart parking management system as well as promoting the hub concept to accommodate both digital and physical services together with an expansion of their infrastructure.

In particular, Vienna could focus on extending its infrastructure by involving the community in terms of carpooling services for commuters combined with special offers such as using the fast lane HOV (High Occupancy Vehicles) (WSDOT, 2021) at certain times to escape traffic when at least two passengers are in the car, getting a reserved train/bus seat when leaving the car at park and ride facilities, notifications with delays, etc. Alternative options to sharing a ride for certain trips could also be available on other channels, such as call-a-bus or via SMS. In terms of data sharing, additional services such as food and goods deliveries, post and courier could be added to the existing platforms, as well as co-working locations, the nearest hub, a smart map with relevant services such as bike lanes, e-charging stations, empty parking spaces, and community suggestions to fine tune ways to meet the users' needs. As an active city, Vienna needs to develop schemes to include all the relevant players in the decision-making process to guarantee reaching multiple target groups.

In order to compensate for the lack of the infrastructure needed San Francisco could utilize the existing resources by introducing multiple (easy) ways to hire out one's own car, promoting on-demand services such as shared vans, deploying private autonomous vans to cover the first-last miles as well as including multiple ways to connect those who lack a transport mode with solo commuters by offering incentives that make a difference such as pay-back points at certain services, using the fast lane HOV (High Occupancy Vehicles) (WSDOT, 2021) , and activating the waterways. The active city can also benefit from the users' acceptance of data sharing schemes to include the community in the various stages to detect the needs and accessibility challenges as well as to develop smart maps with multiple services such as existing soft modes infrastructure and services, hubs, co-working locations, notifications about safer routes, and community suggestions to adjust supply to the users' needs. Additionally, it could offer these services in parallel via lower tech-modes such as call-a-ride, or send an SMS to include those who are not knowledgeable about technology or do not own a smartphone. Collaboration with relevant stakeholders who share the same vision remains essential in order to develop/upgrade the required policies.

Singapore, where the city is an active player and a coordinator, could focus on developing schemes to include other relevant stakeholders in the decision-making process in order to tackle challenges such as congestion and pollution and include the communities to facilitate a better vision in terms of users' needs and readiness and thus, adjust and develop the policies needed. It could expand the open data platform to include other services needed to channel the overcrowded public transport network, display relevant infrastructures and services such as empty parking spaces, e-charging stations, next (autonomous) hub, deliveries and post/courier/drone services. It could also use the population's high-technology acceptance and knowledge to offer both variable remote working possibilities (especially for senior citizens), focus on developing mixed areas to reduce commuting to the minimum, and display various accessible modal systems for first/last-mile solutions and tailored information for the various target groups.

To sum up, when comparing the findings of the MDT vs. both the three cities' current mobility vision and those of other cities as shown in 2.5. by the good practices catalogue, and summarized in 4.1.5 by the takeaways from the good practices catalogue, the research identifies alignment of the approaches and the findings. For example, the different roles the cities of Vienna (Lichtenegger, 2017) and Helsinki (Hietanen, 2016) played, resulted among other factors in two different MaaS models. In the former city, (Lichtenegger, 2017) the providers retain their users' data and the MaaS platform provider is the public PT network provider, while in the latter (Hietanen, 2016), the MaaS provider owns all the data and sets the prices and is a private entity. When exploring (newer) decentralized cities like Columbus, Ohio (Friend, 2016) and St. Diego, California (Friend, 2016), one finds a similar approach to San Francisco's (Shaheen, 2016). They all depended on promoting shared mobility and on demand services as a solution to compensate for the lack of the PT offering through development of advanced technological services and toolkits. On the other hand, compact cities like New York (Simon, 2016), Singapore (Schwitalla, 2016), and Vienna (Lichtenegger, 2017) leaned more towards PT offerings, walkability and soft modes. Newer cities, which were built from the beginning on a smart grid such as in Malaysia (Schwitalla, 2016) and the UAE (Masdar, 2016), tend to focus on their technological advancement to provide various services. Likewise, other cities such as London (Macbeth, 2016), Stockholm (MOAI, 2018) and Berlin (Kellner, 2016) introduced, like Singapore, (Government of Singapore, 2021) a traffic tax at certain times and around urban areas to reduce traffic and generate funds to be used to boost the industry.

5-2 Research Gaps

Having an overview of all the relevant factors from the beginning reduces the danger of overlooking a crucial factor or ignoring an important player, and thus provides more precise analysis and results. The MDT includes and links all relevant factors in the assessment, and promotes a framework comprehensive enough to accommodate cities, towns and rural areas, but also specific enough to deliver convenient standardized methods for planning and implementing mobility concepts.

To avoid rebound effects, the MDT focuses on assessing the needs first, promoting a proactive and call-to-action concept in case certain measure have not yet been assessed, which would enable cities to design their solutions accordingly. Additionally, the MDT recommends suitable political frameworks, innovative schemes, which are regularly assessed to guarantee quality and provision, and easy-to-handle assessments after deployment (within the financial constraints) to guarantee long term provision and help discover any undesirable side effects earlier.

In terms of fallacies in the transport and mobility world, the MDT deals with this challenge on the one hand by providing a framework that helps collect the information needed to make informed decisions and, on the other hand, by building up layers logically and systematically to display the interconnections between the various factors and actors. This includes their interdependencies, both supply and demand, the possibility of having more than one pain point and hence the recommendation to develop a concept based on multiple solutions as well as emphasizing the importance of the collaborations among the various stakeholders, which will add rich and diverse insights that support logical results. It prevents cities from blindly following the mainstream by keeping their focus on their own specific goals.

As the MDT focuses on the phase before cities decide to implement a certain mobility concept, it complements the existing MaaS navigation tool sets, which focus on the phase after that. Together they complete the picture and enable the delivery of comprehensive and accurate results.
The MDT is designed to expand and accommodate, if needed, more details, branch out to cover new layers and factors and is adaptable to cities, towns and rural areas.

6 - Conclusion

This chapter answers the research questions, reflects on the research by highlighting the relevant implications and makes recommendations for actions and further research.

6-1 The Research Questions and Thesis

This research aimed to clarify which city needs MaaS and which does not and also to determine whether only cities that are prepared for MaaS can develop one and what factors impact the decision-making process. Based on the analysis conducted and the outcome, it became clearer what the different roles cities played were, as well as the impact of different city structures resulting in different mobility concepts. In consequence, it can be concluded that not all cities need (the same) MaaS (compare New York vs. the Bay area), not every MaaS-ready city needs MaaS (compare mobility in Vienna before MaaS) and not every MaaS-unready city (compare Dar) has to give up the idea of developing an alternative intermodal concept. Whether cities need MaaS or not stands independently and is not correlated to whether they are MaaS-ready or not. Local factors and city roles determine city structures, urban planning and transport systems. The developed MaaS type is a projection of this framework, but these factors are only subordinate tools, the determining factor for MaaS (if needed) to exist is the political will.

That is why it is crucial that cities prepare correctly, understand what they have and what they want to achieve in order to be able to make the right decision. For that, the right (short/long term) management approach is through a cross team, which prepares the agenda after considering all the relevant factors such as selected area, stakeholders, digitalization, modes available, user’s needs, obstacles, solutions, the ecosystem, etc. Following this, users' scenarios can be created and pilot projects developed. To achieve all that, by navigating the roadmap and building the ecosystem, the MDT is needed. This tool, which does not yet exist as such, complements and adds to the existing tools which either cover the phase of the MaaS journey after the decision is made or only certain aspects of it.

6-2 Practical Applications and Implications

6-2-1 The MaaS of Two Cities

Compact cities as seen by the good practices and the three selected cities, concentrate more on the transport offering (MaaS ecosystem) in terms of expanding the existing network and its infrastructure and adding new services among other things. The decentralized cities went for the sustainability of the cities in terms of upgrading the infrastructure, reusing the individual transport modes, road safety, walkability etc., regardless of their geographical location. Hence, MaaS needs to be adapted locally, cities separated by oceans can adopt the same system, while cities that share the same geographical boundaries could adopt different concepts. Moreover, policies, standards and rules have been developed historically and adapted in ways that are based on the culture and history of a particular nation. Accordingly, different concepts have emerged, for example, sharing-based behavior by MaaS vs. ownership-based consumption (as in "all-you-can-use") by MoD.

6-2-2 MaaS, no MaaS or a Different Type of MaaS, That is The Question

Based on the outcome of the study, the city structure suggests the type of mobility system and the role of the city may or may not enable that concept. Political decisions determine which mobility concept can develop in a city (e.g., Whim Helsinki vs. Whim Vienna). The legislation, tax policies, public vs. private stakeholders as well as the agility to adapt to change are also vital factors. With that in mind and for the political decision to be based on well-informed data, the various stakeholders in the ecosystem must contribute to keeping those in charge fully informed with all the relevant information. For those stakeholders to deliver the right data, all relevant local factors must be considered.

Thus, although not every city/town/rural area needs (the same) MaaS, every area needs a sustainable mobility system that long-term helps it to achieve its goal, whether it is for fully integrated services, partly integrated or not integrated. Accepting this fact moves the city from competing in the wrong race to the one that is more suited to its resources and enables it to exceed and contribute positively to both the quality of life and combatting climate change.

6-2-3 The Successful Mobility Equation

For an area to keep up long term in the mobility marathon, success accompanies those who see the whole picture and mix all the ingredients needed such as identifying what is missing and the needs of the users in terms of supply and demand regulations, exploring all relevant components to form the ecosystem (for example by identifying the backbone, which is the most functioning mode to lean on, and modes that could be replaced by the new system) and understanding the vision and how to approach the decision-makers to communicate the desired goal. Clear communication and transparency help to establish the trust needed to build a functioning ecosystem and avoid any misunderstanding. Perceiving the same concepts and following the same paths to the same goals makes it possible to reduce mistrust and strengthen team spirit, which automatically enables and facilitates a space for collaboration.

Transparency is also key when it comes to topics that often lead to dilemmas such as the data sharing schemes. Not only is it crucial to align with the vision of the area, but it might even help the users to understand what data is collected, for what purpose and what output they can expect in return, i.e., the added value. A significant success factor lies in offering the users a service which they need, and for that, it is essential to first understand the goal and purpose of their trips, how to reach them (the simpler the media are, the more effective the results are), why they would use the new service, whether it serves their needs and so forth. Having answered these questions, it is then possible to design and develop the service. The flexibility of the design needs to be built in from the beginning as one builds what the users need and not what the provider sees as suitable for them. Accordingly, the focus shifts gradually from general offerings based on demographic bundling to specific services based on needs. Needless to say, these steps go hand in hand with the crucial role of the authorities in terms of setting simple but effective rules and standards to achieve stability and create a shared vision of a common goal. Last but not least, emphasizing the importance of the engagement from all parties including the users, in terms of giving and receiving feedback, the governance, the various providers and third parties, is the bond that ties the ecosystem together and keeps it functioning and growing. Forming agreements and compromises makes it possible to reach the engagement level needed and thus establish stability, a common understanding, openness and following from this, trust.

6-3-4 Takeaways

MaaS is expected to cover all modes, personal, public, private, shared, on-demand, TNC, informal and AVs and goods delivery, post and services etc. The goal is to offer densified innovative mobility and transport solutions.

The major transport pathways/corridors will probably be covered by mass transit, complemented by collaborative modes whether autonomous or driven, on-demand or on route, informal or formal and active modes. Together they will cover the journey door-to-door and expand the transport coverage.

MaaS comes in different forms and shapes and when correctly implemented can solve the challenges cities are facing, offering consumers, providers, communities and cities great benefits and serve the general public regardless of age, disabilities, wealth, social class or digital/physical access. In other words, MaaS can offer physical and digital urban accessibility.

MaaS needs a backbone to rely on – this backbone represents the city's major transport mode. It is important to know what MaaS is replacing in terms of the second or third mode used in the city.

While some cities will agree on integrating all modes, others will integrate only some, or even none. Still others may develop hybrids and alternatives. Accordingly, the need will vary from a technological base to integrate the required features (web-based/app trip-planning systems, electronic fare systems and multi-trip ticketing, together with real-time schedules), to non-integrated services, SMS services, call-a-bus/van/AV services.

MaaS has enabled the rediscovery of informal PT crowd urbanism (crowdfunding and crowdsourcing), encouraged social responsibility and extended the benefits from the individual to the community.

When cities lead the disruption revolution, third parties will not blindly compete against PT and "cannibalize" them, they will complete each other. It is more likely that customers would prefer to be offered multimodal services in order to use mass and individual transit combined, than to be offered only PT services, which provide parallel but not integrated affordable individual transit services. The bottom line is that convenience is the key to covering the gaps and delivering a tailored service (Cole, 2018).

With the MDT, cities that are not yet ready for MaaS can start planning their strategy one step at a time. They can begin by assessing the status quo, exploring the pain points and testing possible supply options. Then they could mobilize all the stakeholders to fine tune the plan before presenting it to the politicians who will examine it, and if it aligns with the local goals and provides added value, they will support and facilitate the various project stages and thereafter deploy them.

City planning and mobility development need to go hand in hand to deliver a clear vision to the city politicians, who, in turn, are the main actors required to facilitate the project. It is crucial that they are well informed of the need, the existing offer, the gap, the potential partners and the added value of the project.

A comprehensive approach to the assessment and implementation of cities' mobility concepts, which is based on needs and takes into account all relevant factors and actors is required in order to guarantee long-term and effective provision. MaaS, unless correctly implemented, can backfire and cause more problems than it solves. In this regard, the MDT provides a solution in the form of a comprehensive roadmap navigator, an ecosystem planner and a decision tool. As such, it does not yet exist since existing tools either cover just the phase of the MaaS journey after the decision is made or only certain aspects of it.

6-3 Recommendations for Further Research

6-3-1 Who Can Benefit from This Research?

The MDT has the potential to help developed areas to systematically articulate and fine tune their concept, and underdeveloped areas to catch the mobility train, which may have already appeared to have left the station. Hence, the tool and research findings are not meant only for governments, policy/decision making actors, but also for local communities, research centers, providers (existing and potential), and other third parties, especially those who intend to explore new areas, who have not done any or only basic assessments of the current/future mobility vision/needs.

With time, the outcomes of the MDT can form a catalogue of best practices and a global database for cities, towns, and rural areas. A clear vision can help elevate the quality of life, save resources, and make it possible to achieve a more environmentally sustainable and less congested transport network.

Moreover, the MDT comes in handy outside the mobility world. It can help stakeholders to systematically develop a logical and easy way to assess complex topics which consist of multiple components and at the same time interact with each other on several levels.

6-3-2 More Research is Needed

The research process was not without difficulties. For example, it was not always easy to reach the right stakeholders to exchange views. Similarly, finding some accurate data to assess particular layers, such as the (clear) roles of the various stakeholders in the ecosystem, the users' needs assessments, policies that build trust and facilitate the collaboration, and (acceptance of) data sharing schemes. It would be of great assistance if volunteers in various locations and types of urban settings would agree to try out the MDT and share their feedback and outcomes. More research is needed to explore various scales and situations, and research the best approaches to introducing the tool to the relevant stakeholders. More research is also needed into combining urban planning with transport development, inviting relevant stakeholders on board, developing easier ways to assess city resources, including communities in the decision-making process, and ensuring that decision-makers are well informed from the early stages about the needs and problems. Regular fine tuning of the assessments based on the trials is also important to deliver more accurate and objective findings as well as developing before-and-after evaluation processes to assess the outcomes when using the tool vs. without it. The tool could then be upgraded accordingly. It is not clear whether alternative integrated mobility concepts such as MaaS and MoD can learn from the aviation sector, which has systems such as Amadeus, i.e., whether a solid global database which covers all legs of the journey with easy/public access will enhance mobility in the same way that Amadeus achieved this for aviation. Major differences need to be taken into account though; in aviation, there are more vertical corporations and the various stakeholders complete each other, whereas in the transport sector, there are more horizontal corporations competing for the same goal, which in turn tends to slow down the collaboration.

Further research is also needed to develop schemes to reduce or eliminate potential rebound effects and to reduce the impact of fallacies in the transport and mobility world. In addition, more research is needed to develop strategies on how to avoid them in the various phases as well as how to provide suitable solutions.

7 - Appendix

7-1 Interview questions

As mentioned in Chapter 3, the GT interviews take a more flexible form than normal interviews and the questions can branch out or change as needed. Thus, the interviewees were asked a mixture of general questions (list below) and particular questions depending on the interviewee's role, the development of the interview and the data needed.

What does MaaS mean to you?

What is the goal of MaaS?

What are the components of MaaS?

What are your experiences with MaaS?

What is your role in the context of MaaS?

What is your ideal MaaS platform?

What type of Platform do you have and how is the integration going to be?

Who owns the users' data?

Where is open data feasible and where is it not?

What is the ideal technical solution and user interface for the medium?

What are the biggest obstacles on the route towards the MaaS ecosystem and why?

Where do you see the most promising business model for MaaS? Is there any?

What does the user need?

What are the Good Practices of MaaS worldwide in terms of cooperation among the stakeholders, data exchange and usability?

What is the role of the city (various political bodies), PT and private sectors in terms of MaaS?

Who are the most important stakeholders promoting the idea of MaaS/the smart sustainable city?

What can we do to enhance people's willingness to cooperate?

What cooperation do you have with the other MaaS partners?

What is the disruptive nature of MaaS?

Does the US have a better chance to implement MaaS than Europe and why?

How do you estimate autonomous driving on MaaS?

What is coming up next?

7-2 Sensitizing questions used for the analytics

What

Who (function – position in the ecosystem), references

How/whereby (approach/ method)

Timeline/when/where

Why

Outcome/what for/consequence

Keywords

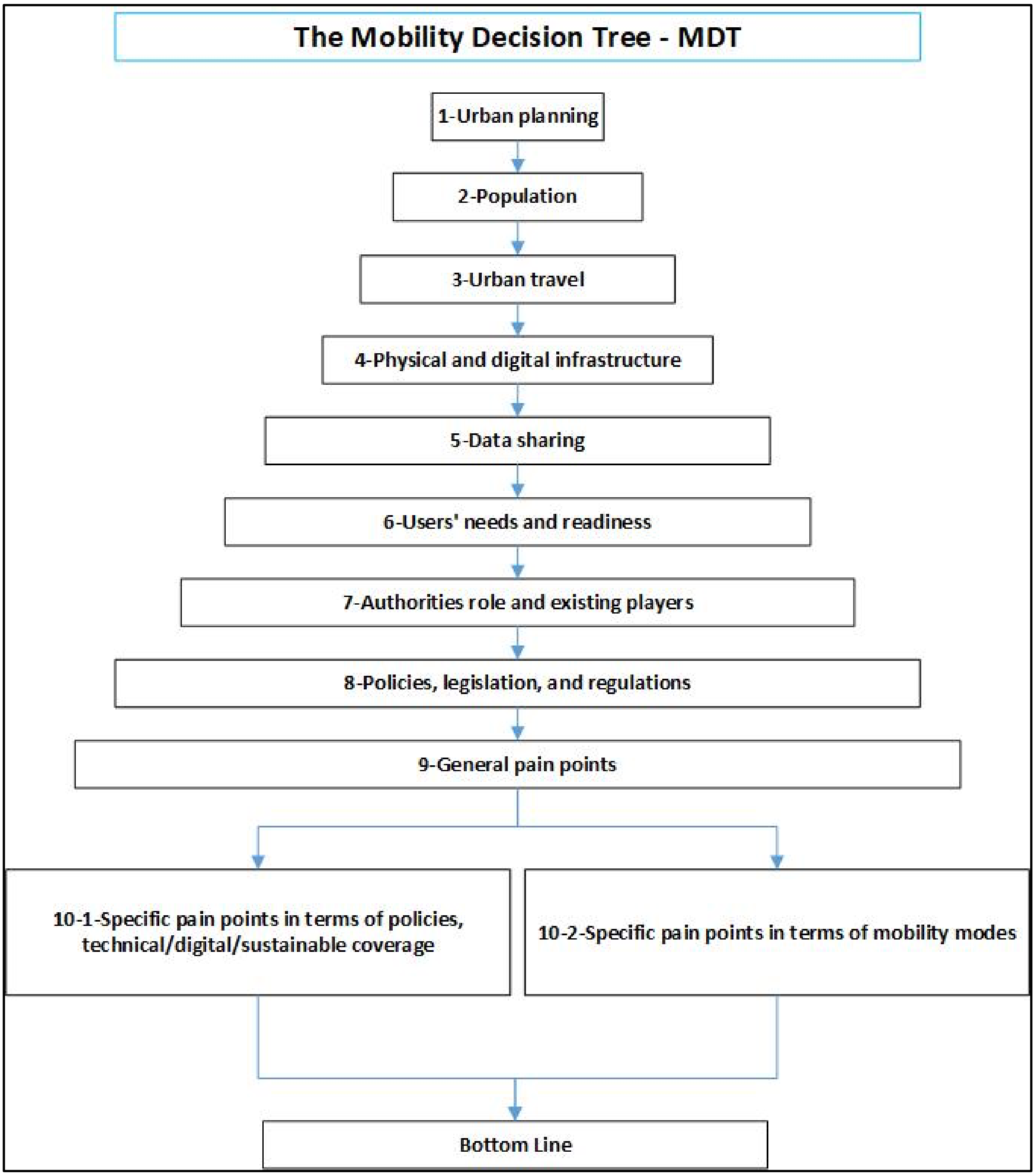
Citation

7-3 Codes used

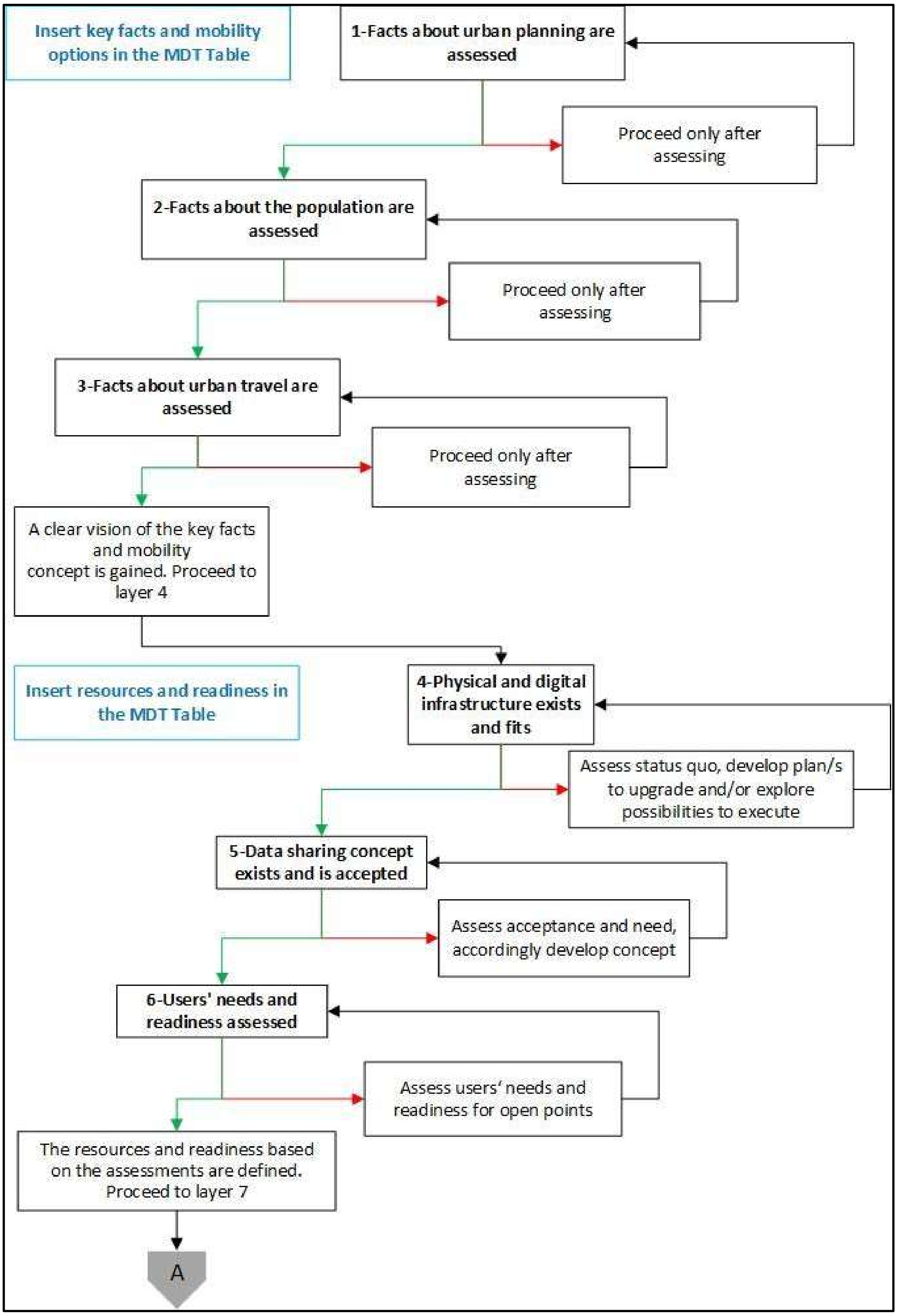
Accessibility, advertisement/market, active mode, antimotility, API, AV CC, Africa, Asia, Australia, Big Data, Bitcoins/Blockchain, business model, cars, (car) ownership vs sharing, get rid of car ownership, city, community sourcing, community capacity-building-city, (CO^2) emission Greenhouse effect, commuters, connectivity 4G & 5G, company, cross border multimodal exchange of info, cross team, culture, culture society, countryside/suburb, disruption, economics ecology, ecology/economy, ecosystem, e-Mobility, empowering citizens, enabler, EU, face to the consumer, financial aspect, first-last mile, future/present/past, good practices, Google, hybrid, informal transport, infrastructure role, innovation comes from inspiration, integration of services, ITS, legal aspect, low carbon, MaaS, MaaS platform, MaaS roadmap, mega city, mobility app, mobility hub, mobility solutions/developments, mobility tools, modes, mono/inter/multimodal, navigator, network, off grid, on Demand, one stop shop, open data, open source, park & ride, parking mobility services corporate/combined, peer2peer offers, physical integration, (pilot) project, policy, PPP, problem, PT Backbone of MaaS, Quandos/Scotty/info system, real-time, regulations, rollout requirement/project, sanft & leise mobility, self-sufficient, seamless mobility, service levels, service provider, shared economy, shared modes, sharing instead of owning, smart city, smart city solutions, SMILE, society, stakeholders, Startup, sustainable, street-city urban planning, tax, theory of the common, technical aspect, tip, ticket (reselling), tourism, TNC, transport planning, traveler/user info service, UBER, urban mobility, urban planning, US, USA vs EU, user, user data, user flexible and convenient offers, user's ecosystem, user interface, VAO (Verkehrsauskunft), vertical

7-4 Mobility Decision Tree

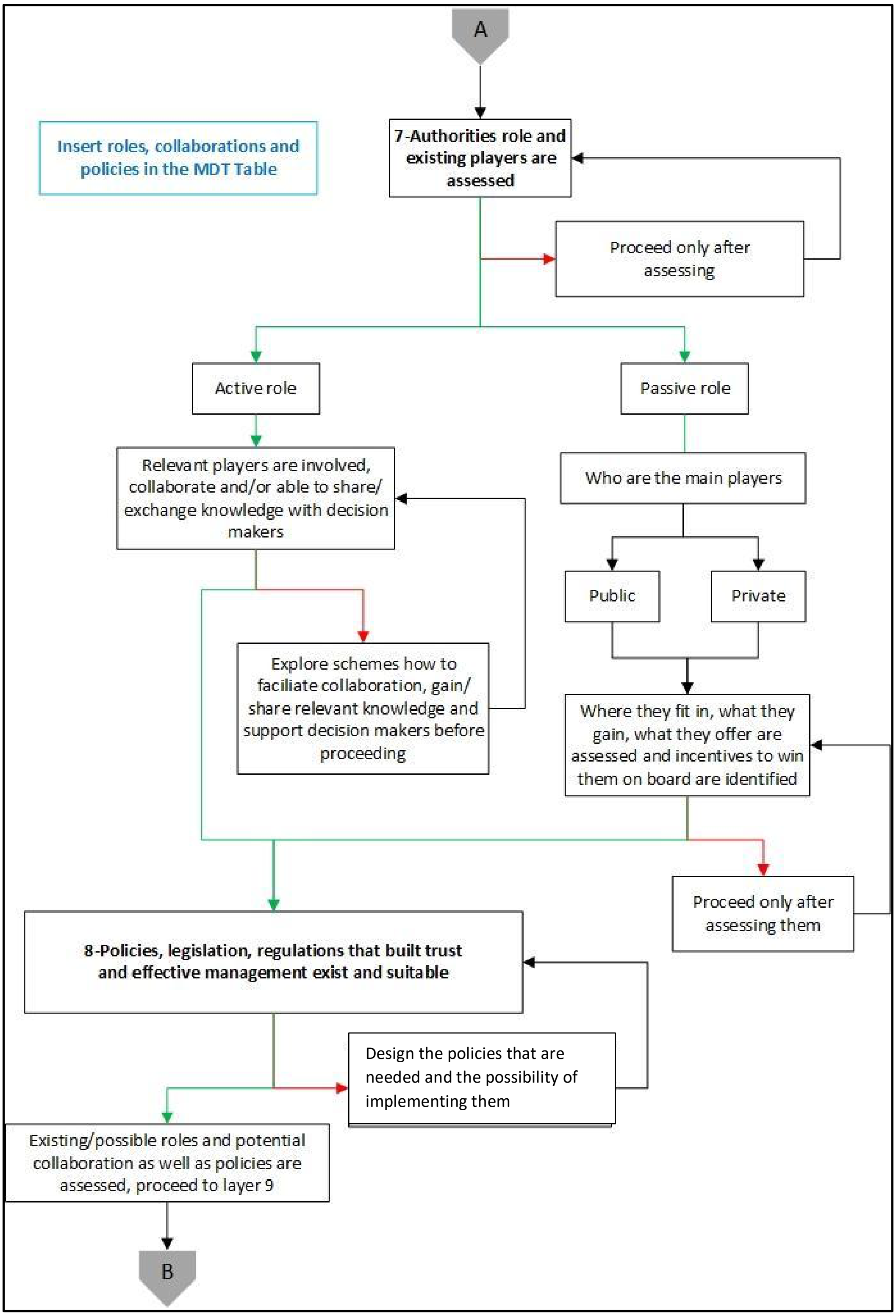
7-4-1 Figure 7-4-1 Overview, (own work)



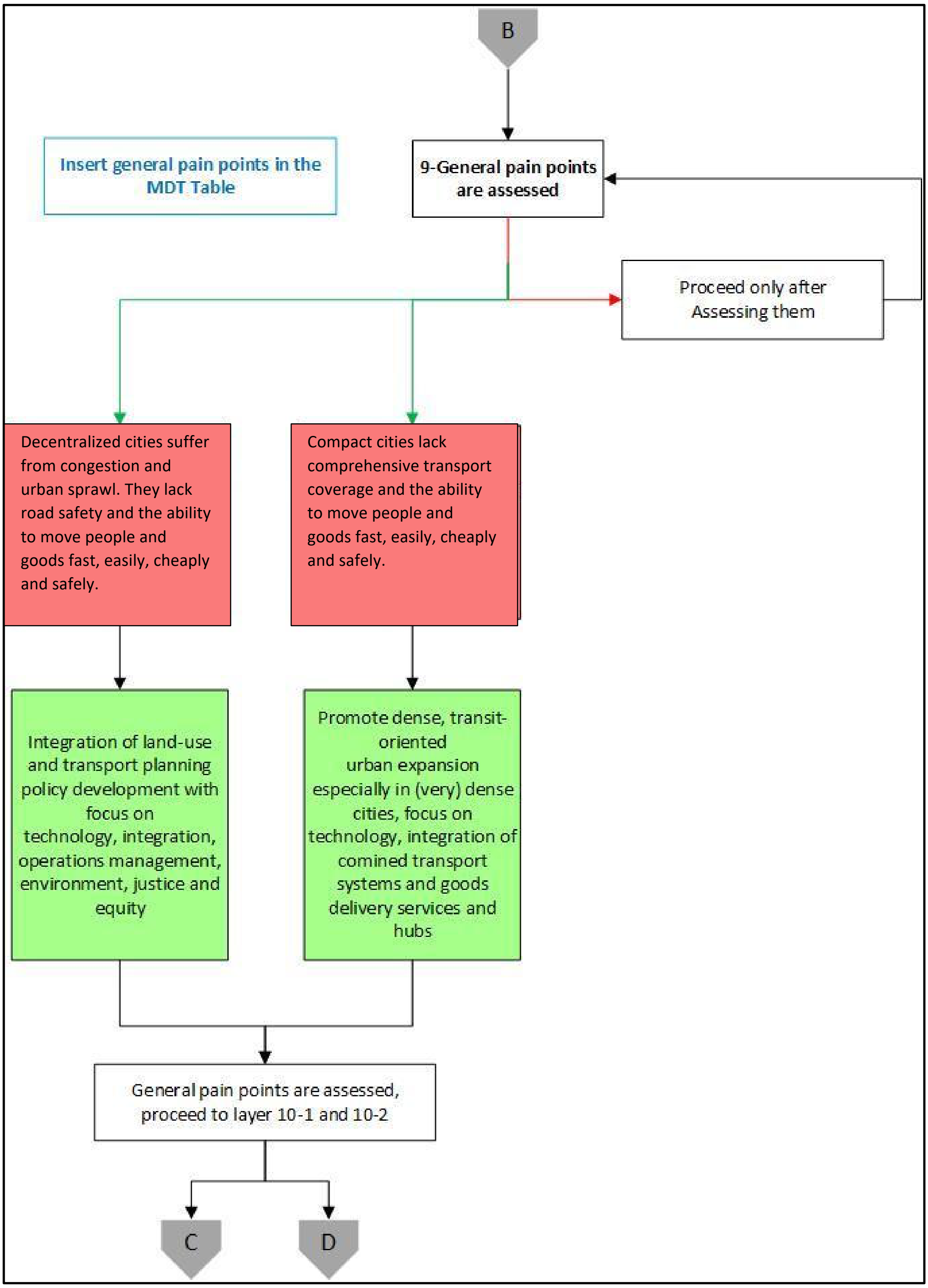
7-4-2 Figure 7-4-2 Layer 1-6, (own work)



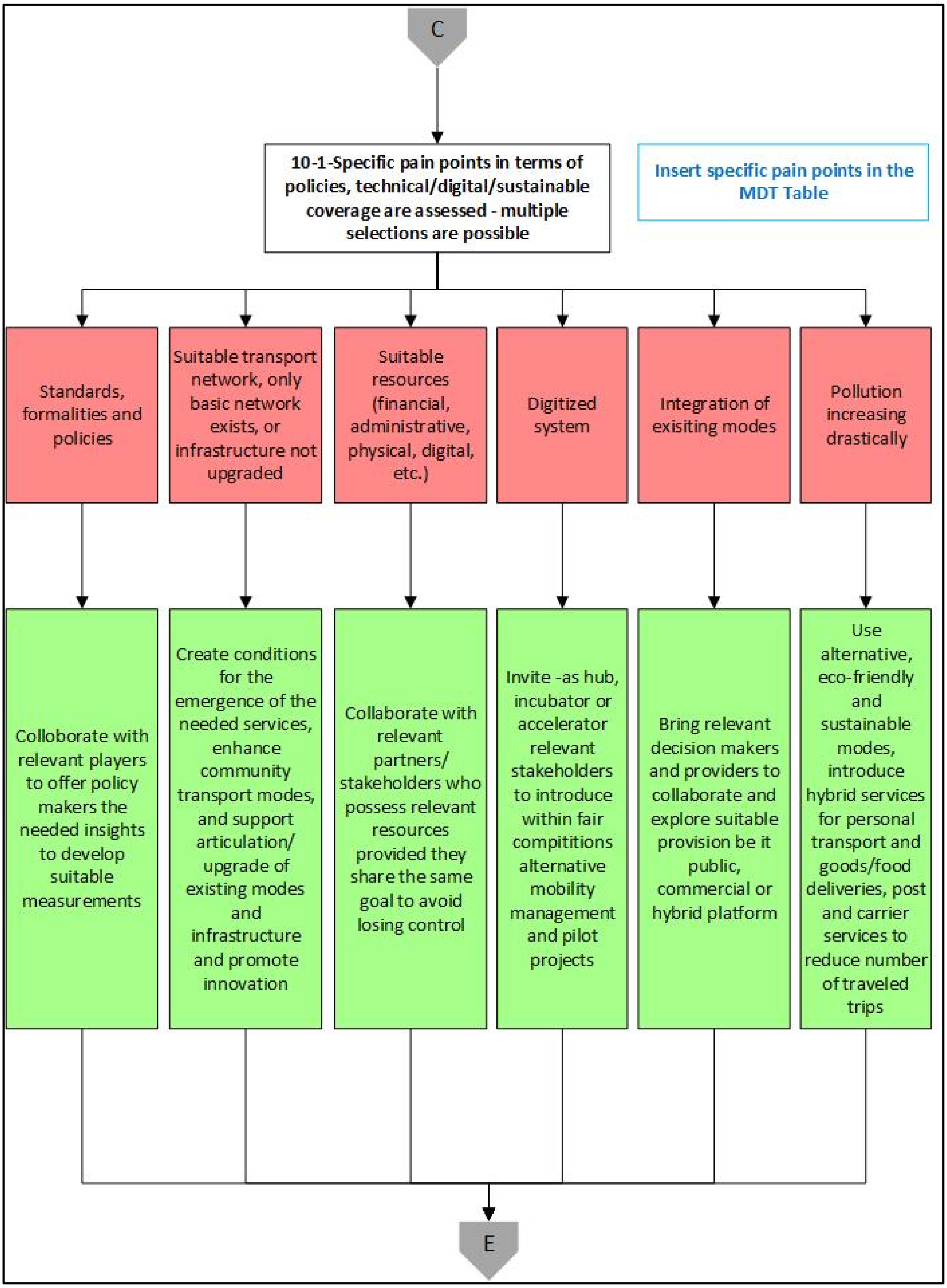
7-4-3 Figure 7-4-3 Layer 7-8, (own work)



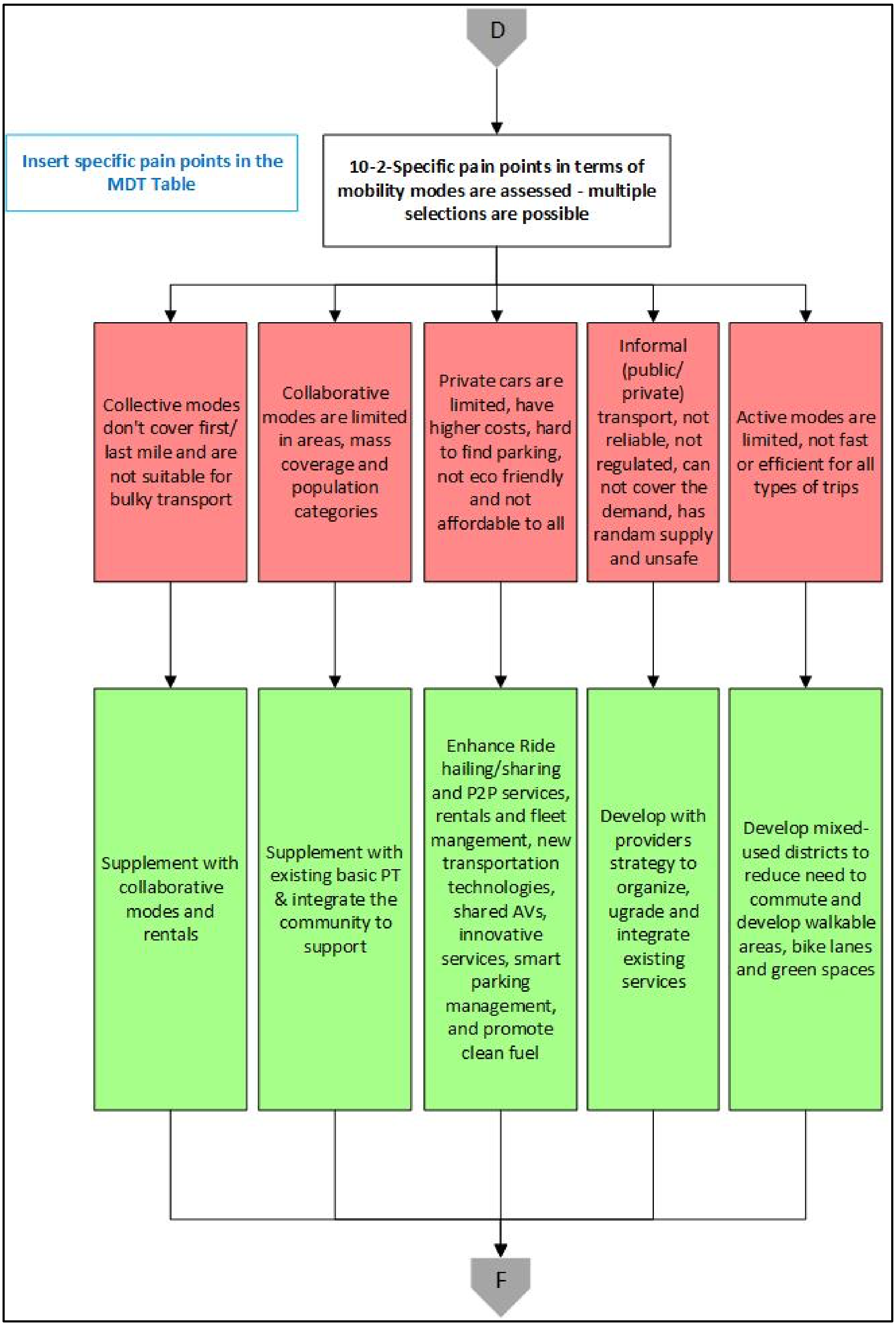
7-4-4 Figure 7-4-4 Layer 9, (own work)



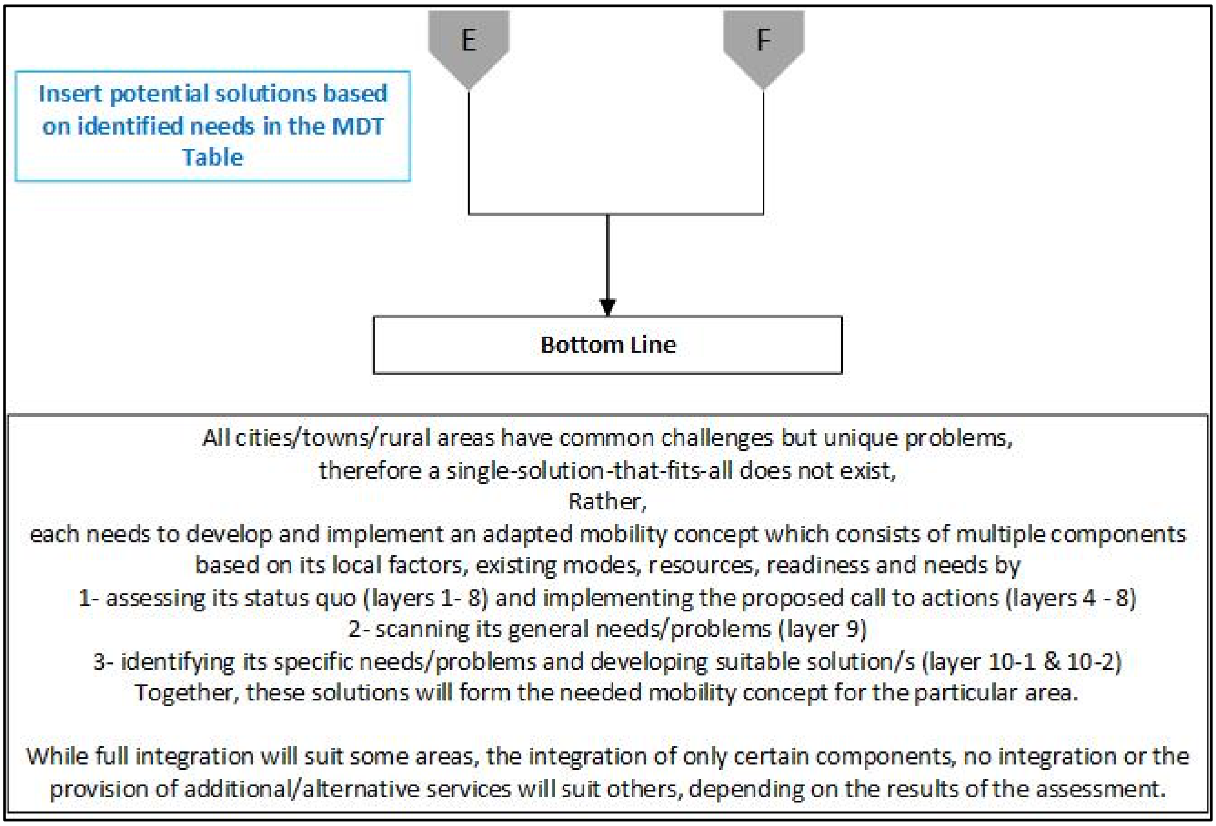
7-4-5 Figure 7-4-5 Layer 10-1, (own work)



7-4-6 Figure 7-4-6 Layer 10-2, (own work)



7-4-7 Figure 7-4-7 Bottom Line, (own work)



7-4-8 Table 7-4-8 MDT assessments table, (own work)

Assessments	**Area under study**
1- Urban planning – type of urbanization	
Degree of urbanization (City, town, rural area)	
Type of urban density (Compact, decentralized)	
Area	
Land use	

2- Populations	
Size of population	
Average income per capita	
3- Urban travel - mobility system (General: collective, collaborative, soft modes, individual, informal) and (Specific: subway, ram, bus, car/bike/rideshare, peer-to-peer, on demand, ride hail, etc.)	
3-1-Main used mode	
3-2-Second used mode	
3-3-Other used mode	
3-4-Less used mode	
3-5-Modal share	
3-6-Others	
3-7-Travel Time	
3-8-Motorization rate	
4- Physical and digital infrastructure	
Physical infrastructure	
Digital infrastructure	
5- Data sharing	

Concept exists	
Concept accepted	
6- Users' needs and readiness	
Users' needs	
Users' readiness	
7- Authorities role and relevant players	
Active – schemes to collaborate	
Passive – identify/win main players	**-**
8- Policies	
Legislations and regulations exist	
Plans to establish trust exist	
9- General needs	
If compact - generally compact cities lack comprehensive transport coverage and ability to move people and goods faster, more easily, cheaply and safely	
If decentralized - generally decentralized cities suffer from congestion, urban sprawl, lack road safety, sustainability and the ability to move people and goods fast, easily, cheaply and safely	
10-1 & 10-2- Specific needs	

Bottom line – potential solutions based on identified needs	
City structure	
City transport system	
City role	

7-4-9 Table 7-4-9 MDT evaluation table, (own work)

Assessment	**Ranking**	**Weight**	**Evaluation**				**Weight * Evaluation**
			Already exists	**There may be a solution**	**Don't know**	**No particular solution**	
Layer 1-Urban Planning – Type of Urbanization	Input	-	Input	Input	Input	Input	-
Layer 2-Populations	Input	-	Input	Input	Input	Input	-
Layer 3-Urban Travel - Mobility System	Should have	5	3	2	1	0	5* Evaluation
Layer 4-Physical and digital infrastructure	Not bad to have	2	3	2	1	0	2* Evaluation

Layer 5- Data sharing	Not a must have	1	3	2	1	0	1* Evaluation
Layer 6- Users' needs and readiness	Must have	6	3	2	1	0	6* Evaluation
Layer 7- Authorities role and relevant players	Needed	3	3	2	1	0	3* Evaluation
Layer 8- Policies	Good to have	4	3	2	1	0	4* Evaluation
Layer 9-General needs	Output	-	Output	Output	Output	Output	-
Layer 10 -1 & 10-2-Specific needs	Output	-	Output	Output	Output	Output	-
Bottom line – potential solutions based on identified needs	-	-	-	-	-	-	-
Total							

7-4-10 Table 7-4-10 MDT score index, (own work)

Score	Index
63-43	**Highly likely to develop MaaS**
42-22	**Could develop MaaS**
21-1	**Needs to make an effort to develop MaaS**
0	**Cannot develop MaaS**

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7-6 About the Author

Core Competencies

Mobility researcher with a background in architecture and urban planning

Extensive business experience in marketing, project management and coordination and EMBA

Short Profile

- PhD - MaaS, developing a Mobility Decision Tree to help Cities in their Decision-Making Process

- Co-project between TUW and Fluidetime Symposium, Vienna, "Mobility Ambassadors as Game Changer"

- EMBA – Quantic School of Business and Technology, Washington, DC

- Speaker, Fluidtime Symposium, VIE – "MaaS meets City – when seamless travel becomes reality"

- Progenium "AV Driving Index", Strategic user & market analysis - Berlin I Munich I London I Shanghai

Working Experiences

● Mobility Researcher – city roles, urban planning, city structures, transport systems, best practices, data analyses, new trends, MaaS, MoD, mobility ecosystems, collaboration, Mobility Decision Tools

● Project Manager/Coordinator – innovative service delivery, promote sustainable and socially responsible projects, communication, event planning (galleries, startup fairs), investment scout, social entrepreneurship events, international student exchange programs management

● Market Researcher – evaluate target market/groups, attract quality leads and enhance user experience, execute and process international orders and logistics, develop internal operation procedures, introduce new products, stakeholders' relationships, clients/suppliers' correspondence, photovoltaic system presales manager

● Architect and Urban Planner – R&D of future sustainable projects in conurbation, projection of city structures on urban travel, Smart Cities, designing plans, following up on site

Education

PhD, TU Vienna, Faculty of Architecture and Urban Planning

Executive Master of Business Administration (EMBA), Quantic Washington DC

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