Mobility as a Service

Indications of the societal impact of Mobility as a Service

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Preface

Dear reader,

This report reflects the explorative research I conducted on the concept of Mobility as a Service (MaaS) and its societal impact. The research was part of my internship, aiming for more insights in mobility developments and experiencing daily practices within the field of mobility. The Dutch network organization Connekt provided me this internship position. Connekt focuses on smart, sustainable and social mobility and aims to develop and implement innovative solutions for improving society.

At this moment I am a graduate student Civil Engineering at Delft University of Technology, following the specialization on Transport & Planning. This internship is also part of the Civil Engineering curriculum. My motivation for the topic of MaaS is the paradigm shift towards a holistic view on mobility. I believe this perspective provides new opportunities for improving mobility.

This report is written for all people interested in the developments on future mobility. For those who are unfamiliar with MaaS, I tried to explain the concept, to provide views on how it would look like in practice and what determines the use of MaaS and its related user behavior. From this fundament, I indicated the potential impact of MaaS in both a qualitative and quantitative way. I hope these insights will inspire transport providers, public bodies and other actors in mobility to become ready for future mobility within the concept of MaaS.

I am thankful for all contributions helping me to write this report. I would like to thank Marije de Vreeze and Niels van Oort, for providing useful feedback and support during my internship. The interview sessions I held with experts were very helpful to get a better understanding of the MaaS concept. I acknowledge Hans Stevens, Marc Stemerding, Ron Bos, Sandra Nijenstein, Peter Krumm, Robert Scheerder and Robert Jan ter Kuile for providing me interesting insights. I am also very pleased with the support I got from all the colleagues of Connekt. I had a very good time!

Roy van Kuijk

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Definitions and Abbreviations

Geographical accessibility – the impairment to access a set of places of interest in terms of travel times and travel costs from a specific geographical area.

Service accessibility – the person-specific impairment for accessing and using a specific mobility service

Service or platform provider – provides Mobility as a Service to end-users, a platform-based mobility offering, based on multiple mobility services.

Mobility providers – provides mobility services, predominantly transportation services, to the service provider.

Mobility services – individual services providing the transport of people or services in support of the transport of people (such as parking and transfer possibilities).

Transportation resources – individual units representing a specific mode of transportation which can be allocated by the service provider to end-users.

AVs – Autonomous Vehicles

EVs – Electric Vehicles

GHG – Green House Gasses

LOS – Level of Service

PV – Potential Value

SLA – Service Level Agreement

VKT – Vehicle Kilometers Travelled

Summary

The research goal is to explore and clarify the concept of Mobility as a Service (MaaS) and to provide indications of its societal impact. The main research question is: Which indications can be given for the societal impact of Mobility as a Service? In the final chapter a quantitative assessment is conducted on its impact on mobility behavior. For this assessment, real data from the City of Amsterdam has been used.

Both a literature study and expert interviews are conducted in order to explore the concept of MaaS and to get a first understanding about its possible impacts. From there, this report defines MaaS as *a subscription-based service offering a wide range of combined transportation options in order to fulfill the major transportation need of its end-users within its service area, supported by a single digital interface (mobile application) which can provide full assistance during all trip phases (planning, booking, paying, ticketing, travelling, trip guidance and trip evaluation).* By this definition it combines two kinds of mobility integration: the first related to the accessibility to multiple mobility services ("one interface gives people access to all kinds of mobility options"), the second related to the integration of technical system aspects enabling smooth travelling (e.g. real-time trip information, automatic billing systems, etc.).

In order to make the concept of MaaS more tangible and to provide indications of the societal impact of MaaS, four scenario-specific MaaS offerings have been determined: (1) car-based, (2) active & collective, (3) robocars and (4) hybrid public transportation MaaS offering. For 1 and 3, the extent of governmental interventions is assumed to be limited, where for 3 and 4, automated vehicles are assumed to be available. In all these offerings, the mobility services shared car, taxi, shared taxi, public transportation, bike and walking are available. Each of these services has its own level of service (LOS) defined as its quality terms of travel times, costs and comfort. A MaaS subscription is likely be based on so-called Service Level Agreements (SLAs), in which users and service providers make arrangements together about process or output related requirements.

A next step is the determination of three conceptual models to support both the qualitative and quantitative assessment. The first conceptual model determines the number of MaaS users by means of a push- and pull model. Attitudinal, hedonistic and personal factors determine the willingness to use MaaS and push potential users towards MaaS. The earlier determined MaaS offerings pull these potential users by its combination of LOS and SLA.
The second conceptual model describes how modal choices within MaaS are determined. This is not

solely based on the SLA of choice and the LOS in terms of cost, travel time and comfort, but also on the allocative power of service providers and the distribution of mobility services to MaaS users; service providers can provide bonuses or incentives for people to make different modal choices. When service providers face difficulties to meet the mobility demand, they can upgrade or exclude users from specific services.

The third conceptual model describes the interdependencies between the mobility network and the organization and structure of the mobility system. Important aspects of this model are related to how the demand and supply of mobility services are determined.

The qualitative impact assessment is supported by means of the *5E framework*. The following impacts provide only a very brief overview of its results. Regarding *effective mobility*, MaaS is able to provide redundancy in case of delays or disruptions. However, this is the result of a trade-off between the reliability of individual mobility services vs. the robustness of the mobility system. Regarding *efficient cities*, different impact types are found depending on the considered MaaS offering. Related to *economy*, the improved robustness of the mobility system will likely enhance the geographical accessibility and secure travel times and reduce travel time losses. Regarding *environment*, apart from the different modal splits of each MaaS offering, its impact is likely to be positive as (car) fleets are more intensively used and therefore replaced faster which positively impacts the penetration rates of hybrid or electrical vehicles. Related to *equity*, mostly negative impacts are found, especially in relation to access and exclusion of mobility services and labor and work conditions. Determinants for these impacts are the risk of an uneven level playing field outcompeting labor-intensive mobility services and the use of personal data which can enhance discriminatory behavior.

The most important results from the quantitative assessment are the following: the use of (shared) cars decreases for the AC and HPT offering, where it remains similar for the car-based CB and RC offering. The use of (shared) taxi services rises tremendously for the CB and RC offering. Opposite modal share changes are found for the active modes. Average trip lengths are getting shorter for shared cars, where these are becoming larger for (shared) taxi services. For the CB and RC offering, people are generally travelling longer distances by public transportation. When only the behavioral change of MaaS users is considered, it is found that they are going to use more shared car and (shared) taxi services. It is assumed this is the result of the improved LOS for these services and the improved service accessibility to shared car and (shared) taxi services by people who first did not have access to a car.

1 Introduction

Mobility as a Service (MaaS) is a concept that is connected to the modern trend of servitization: the provision of added value to conventional mobility by offering user-centered combinations of goods, services, support, self-service and knowledge. (Van der Merwe & Rada, 1988) It goes far beyond existing servitization concepts in mobility, such as lease cars and mobility cards. Because MaaS is a relatively new concept in the field of mobility, there is a need for a detailed description of the concept of MaaS and its context.

MaaS can be considered as the distribution of mobility services over a digital platform. This implicates a significant paradigm shift. For travelers, mobility will focus on the trip itself instead of the transport resources enabling travelling. For researchers and policy makers, segregated views on different modes of transportation are replaced by an integrated view on the accessibility of areas and the mobility of people. Historically, transportation planning is about predict & provide, where future mobility is about the optimal allocation of transport resources and efficient use of infrastructure. It is MaaS that breaks through the world of conventional mobility.

Many problems of today are connected to the traditional organization of mobility. Car-based mobility is related to severe congestion, intensive land use impacts and environmental burden. Especially in urban areas the quality of life is at stake of car usage; it limits possibilities for housing and recreational development and does not contribute to less polluted cities.

For the city of Amsterdam, the development of MaaS is of high interest. Pieter Litjens, deputy major of Amsterdam; “People want to go as fast and smart as possible from A to B. Current transport options do not always fit to this. By means of MaaS, we can allow for individual preferences and travel behavior, whether people bike, drive or walk.” (Connekt, 2016)

There are already some views on the impacts of MaaS, but at this moment it is still unclear what the concrete impact of MaaS on society could be. This report explores the MaaS concept in more detail and will determine the most important impact factors. It will provide first insights of the added value of MaaS and its potential side effects.

This report aims to provide a better understanding of the MaaS concept and its impact on society. It is written to give mobility practitioners, scientists, policy makers and politicians more insights in what MaaS could bring. The report has a general perspective as it does not focus on a specific area. However, the scenario-specific MaaS offerings (section 3.2) and the quantitative impact assessment (chapter 6) are based on (the mobility demand of) the urban areas of Amsterdam.

1.1 Research goal and research questions

The research goal is to explore and clarify the concept of Mobility as a Service and to provide indications of its societal impact. The main research question is: Which indications can be given for the societal impact of Mobility as a Service?

This question is divided into the following sub-research questions:

- How looks the MaaS concept according to academics and experts?
- What determines the societal impacts of MaaS?
- Which impacts can be expected by implementing MaaS?
- What will be the modal split and user behavior when MaaS is fully operational?

1.2 Research demarciation

The report focuses on the societal (macroscopic) impact of MaaS by means of describing the individual behavior of people (micro-level). For this explanatory study, MaaS is considered as a well-structured and well-defined mobility concept. Therefore all considerations on the concept of MaaS are eventually scoped to the given definition (see section 2.3.1)

As data about MaaS in practice is only available to a limited extent, the report does not only aim for providing evidence regarding its impacts, but also focuses on the interpretation of the MaaS concept and its impact. Data for the quantitative assessment is based on the urban areas of Amsterdam.

Both the qualitative and quantitative analysis focus on full-operational impact of MaaS. Therefore, the analyses does not focus on the transition towards full-operational MaaS.

The report does not aim to provide solutions for specific mobility-related issues. Therefore, normative statements regarding the deployment and development of MaaS are avoided. This means that prescribing recommendations regarding the technical specifications, business model and governance structure are not given.

1.3 Research methodology and report structure

In this report, the four research sub-questions are successively answered in four parts. This section elaborates on the supportive report structure and applied methodology. The methodological approach is set out in detail in table 1, by providing goals, means and proposed results (or deliverables) of each research step.

Part I – Exploration of MaaS – How looks the MaaS concept according to scientists and experts?
In chapter 2, literature study and expert interviews create a fundamental basis for further research in this report. The literature study (section 2.1) focusses specifically on how academics describe and perceive MaaS, where the expert interviews (section 2.2) have an additional focus on the manifestation of MaaS in practice. In the interpretive synthesis part (section 2.3) the outcomes of the literature study and expert interviews are compared and translated to a fundamental basis, in terms of a MaaS definition and conceptualization, for further research. The used methodology in this section is predominantly meta-ethnography, which is able to synthesize qualitative data.

Part II – Description of MaaS and its impact – What determines the societal impacts of MaaS?
In chapter 3, inductive reasoning and intuitive scenario development are used to come up with 4 scenario-specific MaaS offerings. This chapter builds on insights from chapter 2 and results in the determination of 4 scenario-specific MaaS offerings. The basis of MaaS offerings (section 3.1) is derived by reasoning which elements are necessary for service provision within MaaS. Scenario-specific MaaS offerings (section 3.2) are developed by questioning how scenario variables could influence mobility propositions to customers.

In chapter 4, several conceptual models and the assessment framework are presented in order to come up with an theoretical framework for the impact assessment of MaaS. A conceptual model for the number of MaaS users (section 4.1) is deduced from the theory of planned behavior (Ajzen, 2005). The conceptual model for the use of mobility services (section 4.2) is deduced from the theory of utility maximization and the MaaS conceptualization. The conceptual model for the mobility system (section 4.3) is developed by means of identification of the impact factors and describing its interdependencies. For each conceptual model, a section elaborates on how the conceptual model is applied in the research of this report. The proposed assessment framework (section 4.4) sets out the 5E framework for the qualitative assessment and quantitative indicators for the analytical model.

Part III – Description of the qualitative impacts – Which impacts can be expected by implementing MaaS?
In chapter 5, the partial qualitative assessments regarding the system characteristics (section 5.1), system effectiveness (section 5.2) and system efficiency (section 5.3) are set out. The assessments

are supported by the conceptual model for the use of mobility services. The conceptual model for the mobility system provides additional support for the system characteristics assessment. The full qualitative impact assessment (section 5.4), which consists of the prior partial qualitative assessments, is structured by means of the 5E framework.

Part IV – Prediction of the qualitative impacts – What will be the modal split and user behavior when MaaS is fully operational?

In chapter 6, an analytical Excel model is used to provide the quantitative assessment. Before presenting the results of this assessment, the conceptualization (section 6.1), specification (section 6.2) and validation (section 6.3) of the analytical model are briefly described. Hereafter, the results of the quantitative assessment are given along the defined quantitative indicators from section 4.4.

The last chapters of the report consist of a conclusion and discussion. The conclusion section provides brief and concise answers on the stated research question. The discussion section elaborates on the conclusion of this report. This section reflects on the methodological approach, research results and provides an interpretation of these results. This brings up the research limitations and recommendations for further research.

Table 1: overview on the methodological approach

Goal	Means	Result / deliverable
Part I – Exploration of MaaS – How looks the MaaS concept according to academics and experts?		
Chapter 2 – Exploration of the MaaS concept		
Exploration of the MaaS concept and its context	Literature study	Section 2.1 Literature study
Exploration of the MaaS concept and its context; exploration of the operationalized MaaS concept and its potential impacts	Expert interviews	Section 2.2 Expert interviews
Determination of a fundamental basis for further research in terms of definition and conceptualization.	Meta-etnography (Britten et al., 2002)	Section 2.3 Interpretive synthesis
Part II – Description of MaaS and its impact – What determines the societal impacts of MaaS?		
Chapter 3 – MaaS offerings		
Exploration of possible MaaS offerings in reality	Inductive reasoning	Section 3.1 The basis of MaaS offerings
Determination of possible MaaS offerings in reality	Intuitive scenario development	Section 3.2 Scenario-specific MaaS offerings
Chapter 4 – Theoretical framework for impact assessment of MaaS		
Explicitation of a conceptual model for the number of MaaS users	Deductive reasoning; theory of planned behavior (Atjzen, 2005)	Section 4.1 Conceptual modal for the number of MaaS users
Explicitation of a conceptual model for the use of mobility services	Inductive reasoning, utility maximization and the MaaS conceptualization.	Section 4.2 Conceptual model for the use of mobility services
Explicitation of a conceptual model for the identification of impact factors and its interdependencies within the mobility system	Inductive reasoning	Section 4.3 Conceptual model for the mobility system

Providing a framework / indicators for qualitative and quantitative assessment	Literature study	Section 4.4 Assessment framework
Part III – Description of the qualitative impacts – Which impacts can be expected by implementing MaaS?		
Chapter 5 – Qualitative impact of MaaS		
Providing qualitative indications on the impact of MaaS related to the system characteristics	Inductive reasoning	Section 5.1 System characteristics
Providing qualitative indications on the impact of MaaS related to the system effectiveness	Describing changes in costs, travel times and comfort for all modes of transportation in each MaaS offering	Section 5.2 System effectiveness
Providing qualitative indications on the impact of MaaS related to the system efficiency	Deductive reasoning	Section 5.3 System efficiency
Providing qualitative indications on the impact of MaaS	Integration of qualitative assessment	Section 5.4 Results
Part IV – Prediction of the qualitative impacts – What will be the modal split and user behavior when MaaS is fully operational?		
Chapter 6 – Quantitative impact of MaaS		
Providing a concept for the development of a model for quantitative analysis	Nested Logit Modelling	Section 6.1 Model conceptualization
Providing a specified model for quantitative analysis	Nested Logit Modelling in Excel	Section 6.2 Model specification
Providing indications of the validity of the specified model for quantitative analysis	Comparison of model results with actual data	Section 6.3 Model validation
Providing qualitative indications of the impact of MaaS	Nested Logit Modelling in Excel	Section 6.4 Model results

2 Exploration of the MaaS concept

In this chapter, the concept of MaaS is explored in order to provide a fundamental basis for further research in terms of definition and conceptualization.

The exploration of the MaaS concept is approached in two ways. At first, a literature study (section 2.1) is conducted in order to explore the views of academics on the concept of MaaS. Thereafter, an elaboration on expert interviews (section 2.2) is given in order to reflect on the literature study and provide an additional focus on the manifestation of MaaS in practice. Both approaches come together in the interpretive synthesis part (section 2.3). By means of meta-ethnography (Britten et al., 2002) the outcomes of the literature study and expert interviews are compared and translated to a fundamental basis, in terms of a MaaS definition and conceptualization, for further research.

2.1 Literature study

This section sets out the literature study as part of the exploration of the MaaS concept. This section is divided in three parts. Consecutively, an elaboration is given on respectively the MaaS context (section 2.1.1) and the MaaS concept (section 2.1.2).

2.1.1 MaaS Context

In this section, the mobility context in which MaaS will be developed is explored. In the context of mobility, a distinction can be made between changing mobility patterns and travel preferences and the changing characteristics of transportation resources and its related innovations. Regarding the first, urbanization and changing lifestyles and mobility patterns are important trends. One of its important implications is the rise of sharing. Concerning transportation resources, vehicle innovations and automated driving are important determinants in future mobility. (Deloitte, 2015; McKinsey, 2016; RAC Foundation, 2016) An elaboration these context elements is given in this section.

Urbanization and changing lifestyles and mobility patterns

Worldwide population is expected to increasingly live in urban areas. By 2050, 66 percent of the world population will live in urban areas, where nowadays 54 percent of the world population lives in urban areas. (United Nations, 2014) Also the Netherlands will further urbanize; in 2030, the population of the four largest Dutch cities is expected to grow with about 10% (CBS/PBL, 2016). Simultaneously, population growth will stagnate, population numbers will stabilize and ageing will further take place, according to future European projections. (EEA, 2011) The city of Amsterdam recognizes these trends in its scenarios. (Gemeente Amsterdam, 2016)

Lifestyles are also about to change. Especially from the group of people born between 1979 and 2000, by many referred as millennials. In general, millennials have different attitudes in life compared to older generations; they are more driven by cost and convenience instead of status and ownership. On the field of mobility, they travel less, own fewer cars and have lower driver's licensure rates. Instead of car usage, alternative modes of transportation are used more by millennials, including the use of shared resources. (Sakaria N. & Stehfest N., 2013, Garikapati et al., 2016) For millenials the importance of ICT and social media increases, resulting in a higher virtualization of life and work (Optimism, 2013).

The rise of sharing

Sharing is the use of transport resources, either simultaneously or sequentially, by different users. The owners of these transport resources can be individuals, organized groups (e.g. groups of residents, people with same interests, etc.), public organizations or private companies. By sharing, either the owner can have a direct agreement with co-users or an intermediary party (or platform) can facilitate the sharing agreement. Transport resources such as cars and bikes are increasingly shared with others. In figure 1 an overview of car sharing concepts is provided.

Different kinds of car sharing concepts

- Round trip (classical) car sharing
  Company/organization-owned, pick-up and drop-off are at the same location.
- One-way car sharing (floating car service)
  Different to classical car sharing as pick-up and drop-off can differ.
- Private car sharing
  Sharing of cars with family, friends, etc.
- Peer-2-peer car sharing
  Car shared by individuals within a (online) community.
- Business car sharing
  Car sharing by a company for company-related trips.

Source: CROW/KpVV (2016)

Figure 1: Overview on different kinds of car sharing concepts

The concept of sharing and its definition are controversial. Academics discuss which mobility services should be considered part of the sharing economy (Eckhardt & Bardhi, 2015). However, it is undisputed among transportation agencies and planners that innovative mobility services fall under the umbrella term of shared mobility. (Shaheen et al, 2016) The distinction between the sharing economy and shared mobility is important as the first emphasizes the social benefits of sharing, where the second includes shared use as a new business opportunity.

In the begin of 2016 there were about 25.000 shared cars in the Netherlands, with peer-2-peer shared cars being the most prevalent. (CROW/KpVV, 2016) At the end of 2014, the number of people using car sharing was about 110.000. (Spark, 2016) They mostly use classical car sharing and a great proportion only uses it less than 6 times a year. Car share users are predominantly higher educated and have high incomes. They are mostly younger than 40 year. Important user groups are singles, parents with young children and older people without children. Car sharing is mostly used for the transport of heavy or odd-sized goods, visiting family and relatives and shopping. (KIM, 2015)

Replacement of trips by car sharing

Nijland et al. (2017) found out that most users of car sharing disposed a second or third car. They drive considerably less and, as a result, they emit 13-18% less CO^2. According to this research original car trips are replaced by the following modes of transportation.

Mode of transport	Kilometers in %
Car	34
Train	41
Bus, Tram, Metro	4
Bike	3
Car passenger	1
Other	2
Not travelled	15

Figure 2: trip replacement by car sharing from Nijland et al. (2017)

A great part of the shared car users only use it incidentally (< 6 days per year): 58% for classical car sharing and 78% for peer-2-peer car sharing. Together, shared cars are responsible for 0,02% of the VKT in the Netherlands. The size of the future potential user group is estimated to be 800.000 people. This could lead to 0,5-1 percent lower VKT in Dutch traffic in 2020. (KIM, 2015) According to Nijland et al. (2017), car sharing users will have a lower car-VKT and will make different mode choices, see figure 2.

The sharing of bikes in the Netherlands is popular. In 2015, 200.000 people made 1,9 million trips with the so-called OV-fiets. (Verkeersnet, 2016) At this moment, especially in Amsterdam, many shared bike initiatives are taken. (Volkskrant, 2016) Van Heijningen (2016) found that 25 percent of the Dutch populations is willing to use a shared bike, while only 12 percent believes it brings added value to their commuter or business trip.

Vehicle innovations and automated driving

Developments in vehicle technology are evolving. This is predominantly related to the vehicle's powertrain, the use of light-weight materials and the introduction of automation.

Instead of conventional fuel cars, car manufacturers introduce electric vehicles (EVs) and speeding up its development. of electric vehicles (EVs). Currently, for many vehicle model types there are plugin-hybrid (PHEV) and full-electric versions available. Tesla is challenging conventional car manufactures with their EVs. Daimler, manufacturer of i.a. Smart and Mercedes cars, will only sell Smart cars with an electric powertrain and options all Mercedes model types as EV. (Reuters, 2017)

At this moment 1,1 percent of all person cars are electrified. For shared cars this is 4,5 percent. (CROW/KpVV, 2016). According to Ecofys (2016), EVs will become economically interesting for many people to buy. Therefore it is likely that EVs will become widely spread in the next decade.

Cars are also getting less heavy, mostly driven by full-efficiency rules. (NY Times, 2012) Together with the electrification of vehicles, car-based mobility becomes more environment-friendly.

Many activity is going towards the development of autonomous vehicles (AVs). These vehicles are able to sense its environment and navigate without human interaction. The extent of vehicle automation is defined by the level automation (SAE International, 2014). At this moment only lower levels of automation are available to the public. Pilot studies and trials worldwide show that automated vehicles of all levels will be available in the not so far way future. (Alessandrini et al. 2015). For the next couple of years, several AV-pilots will take place in the Netherlands. For the Rotterdam-The Hague metropolitan area alone, 7 pilots are in planning (Rijkswaterstaat, 2016). The introduction of fully automated vehicles (level 5) is likely to be in 2025, based on expert statements. (Driverless Future, 2017) This does not mean that these vehicles will become widespread on short term. It can take more than a decade for significant numbers and usage of AVs. (Litman, 2017)

The deployment of AVs instead of conventional vehicles could potentially mean that cars will be used by multiple users sequentially: a sort-like taxi service. This could mean that new user groups will use AVs, such as elderly and people without a driver's license. AVs will impact fleet numbers and the VKT, which affects traffic flows and thus travel times. Multiple studies for AVs deployed for taxi services are conducted. The replacement ratio of AVs to privately owned cars could be anywhere between 1:2 and 1:13 – where any ratio of 1:1.2 or greater could be transformative in reducing congestion. (Canada and Automated Vehicles, 2015). Fagnant et al. (2015) found that each AV would be able to replace 11 conventional vehicles, but could induce 10% higher mileage due to empty trips. An OECD (2015) study shows a replacement ratio of 1:10. The VKT would increase with 6% and in absence of high-capacity public transportation it would nearly dubble. Ecofys (2016) states that a scenario of AVs with scenario can lead up to a 50% decrease of the car fleet in the Netherlands.

It is likely that the introduction of AVs will impact the value of travel time (VOT) for its "drivers". The VOT for car-drivers already decreased with 19% for commuter and business purposes between 1997 and 2010 (KIM, 2013). Possible explanation can be the introduction of cell phones. This explanation is punctuated by the VOT of car passenger which is 80% of the car driver. (KIM, 2013). From this perspecitive it is likely that the VOT will further decrease, resulting in a higher attractiveness of longer trips. Parallel findings from Dutch Railways (NS) confirm this. Warffemius et al. (2016) shows that train traveller's VOT lower with 29% (social-leisure) up to 50% (business) when they can sped travel time in a useful way as planned before entering the train.

AVs are at this moment far more expensive than conventional vehicles. For example, the spinning laser instrument (LIDAR) enabling Google's AV to drive autonomously costs currently 80,000 US dollars. IHS (2014) estimates the initial premium costs for AVs to be between 7,000 and 10,000 US dollars. It is clear that operational costs for collective transportation by AVs will be significantly cheaper. Operational cost savings are estimated to be 50%, for reasons of reduced labor costs, more quality by flexibility and full-day operations. (Rijkswaterstaat, 2016)

2.1.2 MaaS Concept

In this section, the concept of Mobility as a Service (MaaS) is explored. MaaS is a widely used term but is not well defined and can be interpreted in multiple ways. In addition, MaaS has a time and person specific component. In this section, a definition will be derived starting from a broader view on MaaS from the definition of Sampo Hietanen (2014) and is scoped by recent input of other academics.

A broader view on MaaS

Sampo Hietanen is one of the founding fathers of the MaaS concept. He defines MaaS as 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, 2014).

The definition of mobility – the ability to move or be moved freely and easily (Oxford Dictionaries, 2017) – doesn't focus on the means allowing people to move themselves, but on the potential to move or be moved. The latter emphasizes that people can both move themselves – and by means they own themselves – or can be moved by means of others, i.e. people they know (family, relatives, etc.), by publically available means (public transport) or means acquired on commercial markets (taxi's, planes, etc.) Note that this also means the freedom to not move; by replacement of activities, for example by on-line shopping as an alternative to grocery shopping.

According to Hietanen (2014) the distribution of a mobility via MaaS faces three criteria: it should meet the customer's major transportation need, the distribution takes place via one interface and the mobility is offered by a service provider. These three criteria are discussed below.

Customer's major transportation needs

Different people have different transportation needs. This is dependent on e.g. the place they live and work, their household composition, their income, etc. This implicates that not all MaaS propositions can be considered as mobility as a service to all people. People living in areas far away from bus stops and train stations will probably not use a MaaS concept which focusses on the provision of mobility by public transportation. A MaaS concept which relies on exclusive cars and VIP services, and thus high prices, will not meet the transportation needs of lower income groups. But these MaaS concepts do not have to be static in itself. When prices lower as a result of economies of scale or accessibility improves as networks become more hybrid, MaaS concepts can become attractive to more people.

Single interface

To many people, a single interface is seen by means of a digital platform, whether this can be retrieved via a smartphone application, by phone or by internet. When facing the single interface criterion man could argue that a digital platform is not necessary when the MaaS concept focusses on a single mode which can be used exclusively by its subscriber, like lease bikes and lease cars. To state it differently: single interfaces can be established for both single-mode or multi-modal mobility concepts.

The MaaS concept of Whim (MaaS Global, 2017) is a good example of a multi-modal mobility concept; where via a single application public transportation, bikes, taxi's, rental cars can be used. All stage of making a trip – planning, booking, paying, ticketing and traveling (Giesecke et al., 2016) – are taken care off via the Whim application. Single-mode mobility concepts do even exist longer, for example: Greenwheels (round-trip car rental), Car2Go (one-way car rental), and Swapfiets (lease bikes) and many car manufactures provide private lease cars. Some of these single-mode mobility concepts make use of an application to book and retrieve mobility resources. Some of them provide you private and direct access – as you have your own key - but can be contacted by phone or internet when needed help or assistance (e.g. for malfunction or maintenance questions).

The single interface criterion as described above, poses conflicts with those who consider the platform-based structure as necessary for developing MaaS. This will be reflected in further sections.

Service provider

A (mobility) service provider does not provide the ownership of transport resources (e.g. by selling cars), but provides access to transport services. As this company aims to provide “mobility” instead of “transportation” this implicates that a service provider is a different company than the provider of transport services, but this does not necessarily has to be. Especially for multi-modal concepts it is likely that service providers are intermediary parties which have the function of hatchers or brokers bringing transport services and transport demand together.

Conceptually, the need for intermediary parties to provide services is not crucial when the transport provider possesses sufficient resources to provide transport services to customers directly. This can be the case for car-manufactures as Daimler and Volvo, but also for the NS Business Card concept, where the Dutch Railways (NS) horizontally integrates traditional train transportation with other transportation options such as bikes and cars.

Detailed focus on MaaS

Many consider MaaS in relation to the integration of transport options. This section elaborates on the integration of transportation option by means of MaaS.

Heikkilä (2014) describes MaaS as a system, in which a comprehensive range of mobility services are provided to customers by service providers. Heikkilä came up with the concept as shown in figure 3. When considering the lower part of the framework some possibilities for integration become visible. Service providers work together with transport operators, fleet operators and infrastructure operators in order to provide transport services to the users. The exchange of (real-time) data is essential in order to enable and/or optimize this collaboration.

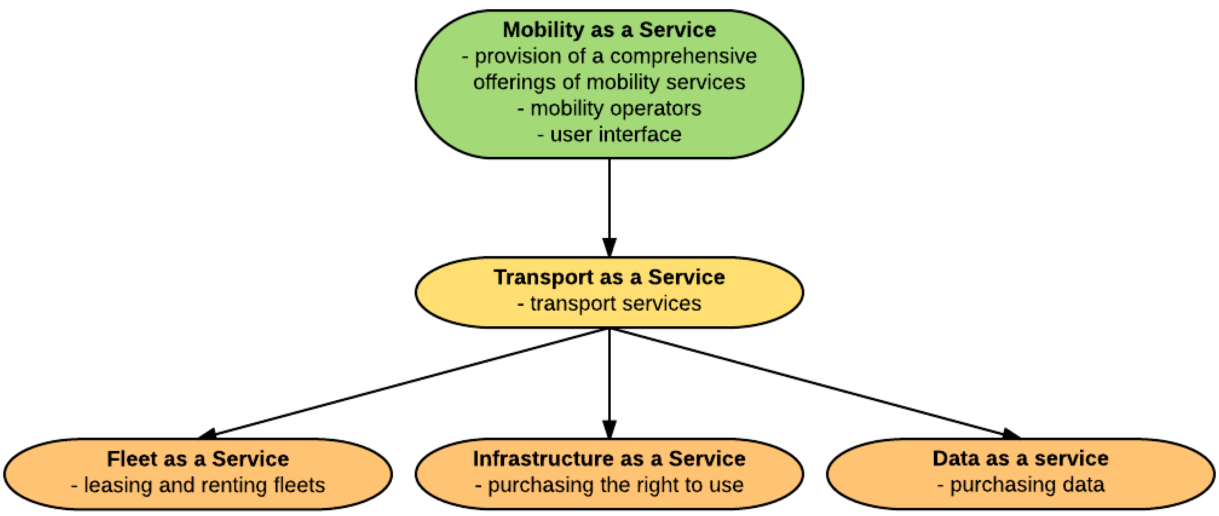

Figure 3: Service provision within MaaS, an interpretation from Heikkilä, 2014

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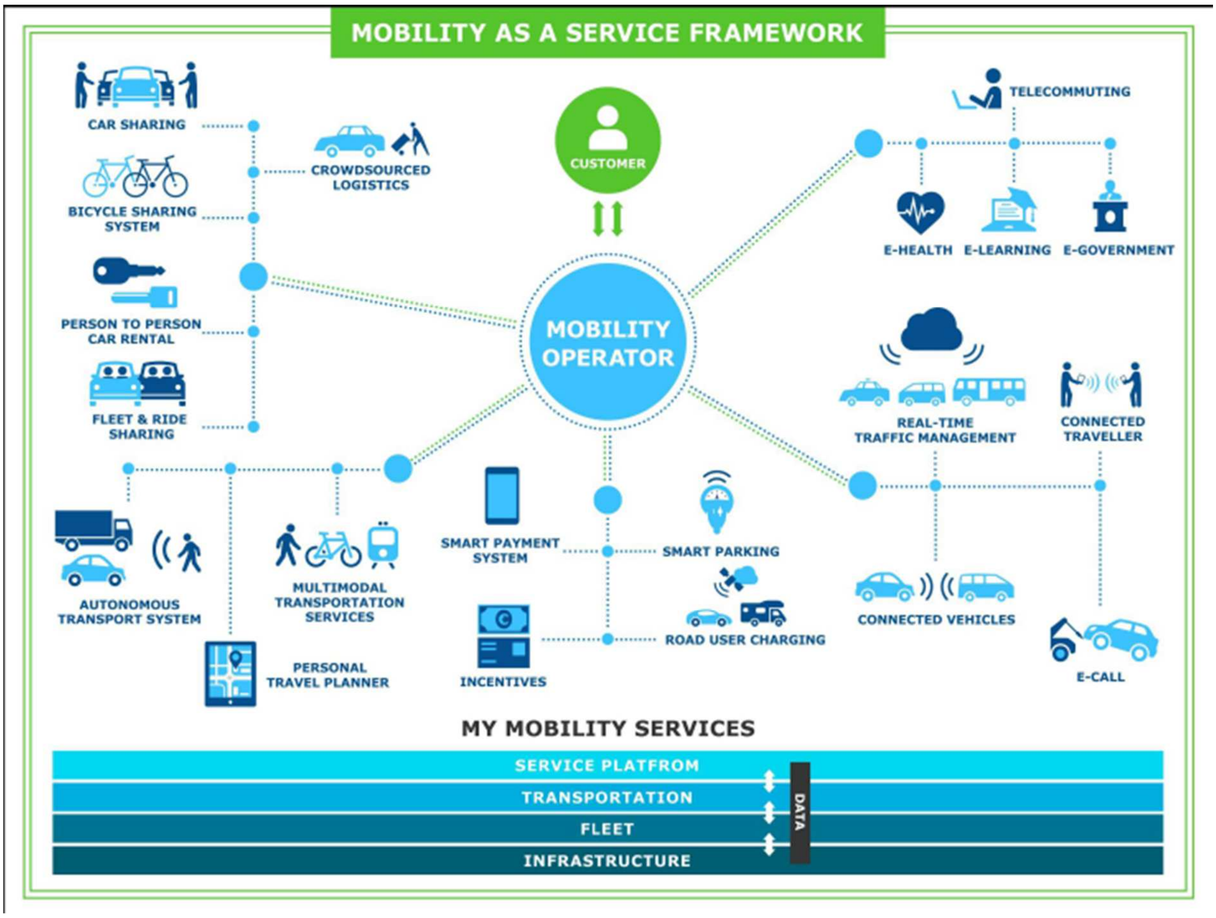

Figure 4: an elaborate overview on the MaaS framework (ITS UK Review, 2016)

A follow- up on that concept came up by the more elaborate MaaS framework as seen in figure 4. The previous concept focusses on the vertical collaboration of service providers, where this framework focusses on the horizontal integration of related services. Not only basis transport services can be provided via MaaS, but also complementary services as the provision of parking spaces and possibilities for mobility replacement such as tele-commuting, and online consults of public services and medical care.

Kamargianni et al. (2016) states that integrated and seamless mobility is the idea behind MaaS. According to Kamargianni et al. (2016) MaaS is based on four main elements (ticket integration, payment integration, ICT integration, integration of mobility packages) that in combination with each other enable seamless intermodal travel for users.

Holmberg et al. (2016) has a similar approach, where different types of MaaS concepts are ranked based on their level of integration. Holmberg et al. (2016) comes up with a different term: combined mobility services (CMS) with examples like UbiGo and Whim. It is defined as a service provided by a neutral third-party that offers a wide range of combined mobility options and is offered to users based on subscription and unified invoicing, the support of some form of digital interface for the customer (app, web based service, etc.) and possibly also with some form of repackaging of the included services. He defines CMS as an important subset of MaaS, as others argument that extended travel planners are also part of MaaS.

The aspect of integration is something Hietanen (2014) already mentioned when he provided his first definition. He visions the whole transport sector as a co-operative, interconnected ecosystem, providing services reflecting the needs of customers. Therefore, the boundaries between different transport modes are blurred or disappear completely. Its ecosystem will consists of transport infrastructure, transportation services, the inter- and exchange of information and payment services.

2.2 Expert interviews

This section provides an elaboration on the conducted expert interviews as part of the exploration of the MaaS concept. This section elaborates on the different aspects of the expert interviews: the definition of MaaS (section 2.2.1), the drivers of MaaS (section 2.2.2), mobility services and the mobility network (section 2.2.3), MaaS adoption and user behavior (section 2.2.4) and market failure and public interventions (section 2.2.5).

The group of experts which have been interviewed are:

- Ron Bos – Urban trend watcher and urban planner for the Municipality of ’s-Hertogenbosch;
- Hans Stevens – Program manager Mobility Management at the Verkeersonderneming (a public-private partnership to address mobility issues in the greater Rotterdam area);
- Sandra Nijenstein – Product manager Market Research and Transport Development at HTM (public transportation operator of The Hague);
- Peter Krumm – Head of Strategy and Innovation at Transdev / Connexxion;
- Robert Jan ter Kuile – Strategy Consultant at GVB (public transportation of Amsterdam);
- Robert Scheerder – Transition manager / entrepreneur;
- Marc Stemerding – Program manager Mobility Services at Goudappel Coffeng

The experts have given input how MaaS and the mobility system will look like, who will use MaaS and how they will use MaaS. In addition, they have been asked about their perception on the implications of MaaS on the mobility system and its societal impacts. Appendix I sets out the related questions. Appendix II sets out the reports of all expert interviews.

2.2.1 Definition of MaaS

The definitions of MaaS from the experts showed lots of similarities. However, many experts found it difficult to provide a strict definition and room was given for different interpretations or complementary remarks.

There is a broad consensus about that MaaS is about the integration of modes of transportation, and all trip-related aspects. Ter Kuile emphasizes the integration of the three components of transportation means: payments, information and physical elements (transport means and supportive infrastructure). Scheerder, Krumm, Stevens and Nijenstein speak about the user-centered organization and integration of all trip aspects (planning, booking, travelling, (disruption) support and payment).

All experts state that user centrality is a part of the definition of MaaS. In addition, Stemerding states that user centrality is essential for MaaS to become a full alternative for car usage. Krumm emphasizes that the needs of users are person-specific. This underlines there will be no one-size-fits-all MaaS concept.

All experts state that MaaS integration takes place on a digital platform, or denominate the exchange of data and development of data interfaces as means for integration within MaaS.

Some experts reflected on the definition of MaaS in a more holistic way. Ter Kuile states that MaaS is a container concept. Stemerding adumbrates a broad spectrum of possible MaaS concepts, which can be considered as the completion of MaaS as a container concept. Stemerding names the two options on both ends of the MaaS spectrum. At one hand, the organization of seamless chain mobility (comparable to the current NS Business Card concept). On the other hand, a platform-based solution to provide a full alternative to car ownership.

2.2.2 Drivers of MaaS

All participants refer to the importance of technology for MaaS and many state that customer and commercial interests can be better served by enabling technologies. Krumm states that technology innovations enable better mobility services. According to him, accessibility and environmental goals are no primary drivers, but they determine the constraints within the MaaS ecosystem.
Stemerding and Nijenstein focus on the improved user centrality and the improvements for fulfilling their mobility needs. Stemerding emphasizes that MaaS is driven by the possibilities for redistribution and more efficient allocation of public mobility funding.
Nijenstein adds that MaaS is also driven by the need for improvement of the attractiveness of chain mobility. She states that commercial interest is an additional driver as MaaS enables new business models. MaaS can make current mobility services can rise and give room for new services to develop. Not for the least reason, it activates latent mobility demand so more business possibilities can be developed. Ter Kuile states that MaaS is based on enabling technology driven by the need for better mobility services and the attraction of new user groups.

There is a big consensus that MaaS will be commercialized and supply and demand will determine the future MaaS concept together. Stemerding says that market actors determine MaaS with only a limited role of the government: "MaaS can only be successful when market needs are met sufficiently." Bos agrees on the dominance of commercial actors. He states that – in parallel with the mobile telecom market – several platforms and many mobility providers will develop.

Apart from commercial and user-related drivers, also other drivers have been recalled. Bos states that accessibility, environment and innovation can be important drivers of MaaS. These drivers can also depend on the spatial context; for rural areas there can be different drivers than for urban areas. Scheerder states that environmental issues, accessibility and the increasing scarcity of urban space also drive the development of MaaS. In the context of urbanization and scarcity on the (urban) housing market, there is a need for cities to plan for extra housing and safeguard the urban quality of life. Nijenstein adds that when municipalities would tender a MaaS concept, this would most likely be driven by perspectives on improved accessibility or a more efficient modal shift.

2.2.3 Mobility services and mobility network

All experts include all modes of transportation from the "traditional public transportation", such as train, bus, tram and subway, and shared concepts of transportation resources such as cars, bikes, e-bikes and motorized bikes in future MaaS offerings. Also taxi and other demand-responsive services will be included within MaaS.

The function and role of public transportation is likely to change. According to Ter Kuile, the core of MaaS in urban environments will be based on important public transportation services (subway and tram). Bikes and floating-car services, such as Car2Go, will become strong competitors of public transportation. In the end, people will choose the service which serves them the best. Ter Kuile doesn't consider this as a threat for public transportation, he says: "By giving people the freedom to choose, it is easier to bound them to the platform and thus also public transportation".
Nijenstein argues that new modes of transportation bring more value to public transportation and to the mobility system as a whole. Shared bikes and demand responsive transportation are complementary to public transport and will impact service and accessibility levels. Within MaaS this results in a full alternative to car ownership.
Ter Kuile states that the Amsterdam tram network can be further expanded to fulfill the need for high-capacity public transportation. By replacing over-crowded bus services for tram services and by eliminating missing links in the tram network.

All experts state that important public transport services, with a high demand and high speeds and frequencies, will further develop their services and demand levels. This is considered as a selfenforcing effect. This predominantly concerns tram and subway services. Nijenstein and Stemerding add that inter-stop distances will become bigger. This enables further enhancement of speeds and frequencies. It will also give more importance to first- and last-mile solutions. Opposed to these services, public transportation services with low demand and low service levels will further degrade and most likely disappear in the end.

Several expert recall the increased importance of (transfer) hubs. According to Stemerding, the government will focus more on the development of hubs and stops. Instead of providing more infrastructure capacity and investments in (expensive) line infrastructure, the government will focus on different street designs and configurations. Ter Kuile states that park and ride facilities will become more important; its number and the connectivity of these facilities will be further increased. Stemerding adds that transfer hubs next to the freeway can become important: from there it will be easy to transfer to higher and lower level networks. Future platooning will be an important driver for this specific development.

Sharing concepts and taxi services will have an important role within MaaS. Krumm underlines this and points out current developments in sharing concepts. Market parties believe they can make money out of these systems. According to Ter Kuile the availability and reliability of mobility services is very important to users. Therefore sharing concepts will rise so people can move themselves, independently of transportation services supplied by transport providers.
The same goes for taxi services, says Ter Kuile. These will have an important role within the MaaS ecosystem as they can provide fast and direct transportation. Stemerding places a critical side note: a mobility platform which significantly relies on taxi services will be difficult to deploy: "Taxi services are likely to face a lot of difficulties, viewing Uber at target of several scandals and the troubled situation in the (Amsterdam) taxi market."
According to Scheerder active modes (walking and biking) will become more important within MaaS. It is very cheap, so service providers will encourage and incentivize the use of active modes.

Local and society-focused mobility services can play an important role within MaaS. According to Stevens, by offering tailored services for specific mobility needs, e.g. related to day care activities or care giving, MaaS can bring added-value to its users. By asking specifically what people and society want, services are centered on these specific needs, instead centered on available modes of transportation. This can be an effort of co-creation between population and interest groups, private and public organizations. Note there is a different approach compared to general mobility services. Local and society-focused mobility services aim for adding "mobility happiness" to society, where general mobility services aim for improving current mobility and decrease deficiencies in mobility

("mobility poverty"). Stevens states that an integral approach on social mobility can also improve the affiliation with general mobility services and could legitimate reconsidering the social function of public transportation; society-focused mobility services can be able to substitute or complement this social function.

The importance of employers' participation is stated by several experts. Scheerder states that employers have interest in accessibility improvements and are i.a. willing to look for lease car alternatives. They are and will be critical towards the costs and benefits of these alternatives: "Currently it is seen that employers hardly contribute financially to the development of MaaS."
Bos adds that the use of MaaS will increase when also employers incentivize their employees to make different choices. This is likely from an idealistic perspective (environment, social, health) or direct interest (improved accessibility, lower mobility costs).

The impact of future autonomous vehicles (AVs) is unclear. According to Krumm is it difficult to forecast the impact of autonomous vehicles: "It is uncertain on which term AVs will be used by a significant group of people". It is clear to Krumm that AVs enable a smarter mobility system, which results in a more efficient mobility system. It will also result that more people will move (semi-)directly, potentially impact the importance of chain mobility.
Nijenstein states that the perception of people on alternative travel time expenditure in AVs will be important for determination of the impacts of AVs.
Scheerder refers to the potential increase of car traffic when AVs are introduced. MaaS will be necessary to control this trends, as it improves the possibilities for ride sharing.

2.2.4 MaaS adoption and user behavior

The potential first user group consist of young urban people. First adopters are likely to be found in urban areas, where high mobility demand levels enable a diverse set of mobility services. Young people (age 20-35) and young urban professionals are denominated multiple times by the experts. Scheerder states that young urban people already possess less cars and have less driver's licenses than previous generations. Many recall a different mindset: compared to other generations, young people value sharing over ownership and they are more acquainted with the use of smartphones. Other first adopters groups consist of people acquainted with and interested in technology developments. Also the belief in the (potential) added value of MaaS is a determinant for MaaS adoption.

The business segment will be an important target group. "It will be easier for platform and mobility providers to earn money from business mobility, as these users have a higher willingness to pay", says Ter Kuile. The initial MaaS proposition will be deployed around this target group. By providing additional service, e.g. the creation of lounges, VIP car-services, and rewarding via tiers and status miles, the number of business users can be boosted.

A diverse set of user groups were denominated as potential early adopter groups. Nijenstein refers to incidental users of public transportation. Ter Kuile refers to tourists as they are not stuck into specific mobility patterns. He also believes that disabled people and the visual/hearing impaired can be potential MaaS adopters, although this likely needs additional public interventions.

Most important factors for MaaS adoption are considered to be costs, travel time, comfort and the ease of travelling. Stemerding states that mobility costs will be a great determinant. He emphasizes research findings that most people only use their cars during a very limited period of time and pay hundreds of euros for only limited mileage.
The ease of travel is also mentioned several times, specified as a high level of support and automatic compensation for dissatisfying travel (e.g. delays, disruptions). Stemerding underlines the need for guaranteed mobility, the ability to get anywhere and anytime. He says: “many people view car ownership as an insurance for full mobility at any time. When MaaS is able to provide the same accessibility, this will attract many new customers.”
Nijenstein emphasizes the ease of travel. She says that MaaS needs to provide people a safe feeling, so that they have trust they will be helped out at all times. The related criterion of dummy-proofness will be important for the acceptance of MaaS and its adoption.

Most experts recall the effect of life changing events, such as: start of career life, getting a child, etc. In these cases, people have to reconsider their mobility anyway, so they are more open to alternatives for their current travel pattern. Following this reasoning, it is likely that households with multiple cars will replace one of their cars with mobility via MaaS.

Participants have also been asked about the affect values of MaaS. Krumm states that the affect value is low when compared to the affect value of having a car. Nijenstein has a different view on affect: “MaaS enables the possibility to try something different and change when certain mobility services do not satisfy. MaaS can also give people a secure and comfortable feeling, when they believe their mobility is guaranteed and their trips are supported”.

Most experts agree on changes in travel behavior. Krumm argues that mobility services will be provided in a very flexible way. Similar to mobile telecom providers, users can easily subscribe or unsubscribe for extra services. This will result in the level of service which is adjusted to people’s need. Ter Kuile adds to that the tuning of mobility services with the available modes is very important. In the end, the quality of the mobility services determines the usage and success of MaaS.

Scheerder mentions that the quality of transport services is determined by the negotiation of mobility providers with transport providers.

2.2.5 Market failure and public interventions

The presence of negative externalities are stated frequently. Depending on the MaaS operationalization and user behavior, negative impacts on accessibility, environment, and urban space can still manifest. In defense to that, Scheerder states: "Society and business interests can be more in line than one would think; walking and biking are sustainable ways of mobility and simultaneously cheap for mobility providers."

The increased availability of public transportation can push people from active modes to public transportation. Similar movements can currently be seen from Car2Go users which predominantly substitute former active mode trips. According to Scheerder governmental interventions will be important for how the modal split will look like.

Access and exclusion effects are mentioned several times. Bos states that it is not unlikely that car-based services are predominantly available to higher income groups. Many state the need for governmental funding to guarantee the accessibility of rural areas. Low demand levels are making it difficult to deploy profitable mobility services.

The market organization within MaaS can pose certain impacts. Krumm denominates possible bankruptcies of mobility and service providers, although he does not believe this will be a significant problem. There will be lots of mobility and service providers, such that people can easily switch to other mobility services. Ter Kuile states that high market shares can create market power and counter act the integration of transport services.

Some experts state that governments have the power to boost MaaS developments. Ter Kuile denominates the provision of parking space in favor of electrical vehicles instead of conventional vehicles and for shared cars instead of privately-owned cars. Bos also mentions the intermediary role of the government to facilitate social mobility initiatives on the MaaS platform.

From the interviews, several measures were recalled that municipalities could take in order to control mobility and the availability and the use of mobility services.

Focus on major public transportation services

Several experts of the interviews recall that public transportation will focus on the major services. Municipalities can alter the current concessions, such that frequencies of services with a high demand are further increased. Optionally, operational speeds are further increased by removing some of the stops. Most likely, this would be combined with the degradation of services with a lower demand. Potentially these services are left out future concessions.

Withdraw (partially) from subsidizing public transportation
This will make public transportation providers more dependent on user fares. As a result, public transportation providers will yield non-profitable services and provide opportunities for other service providers to serve the affected users in a better and more profitable way. Fare differentiation for different people and day periods could provide additional income. Ter Kuile states this is an option for public service providers, but would only be limited when the surpluses are invested in mobility.

Have an intermediary role between local and society-focused initiatives and service providers
Bos and Stevens state that public bodies can help with the deployment of mobility services which will not be created by market parties. These mobility services can be tendered or operated by volunteers.

Municipalities have instruments to limit the number of cars
They can introduce cordon charges or adjust the issuing of parking permits. It is possible to differentiate these measures to e.g. the number of vehicle occupants and the powertrain of the vehicle.

Regulation of taxi services
The quality of taxi services and the access towards these services can be guaranteed by licensing and (additional) service standards.

2.3 Synthesis

This section combines the findings from the literature study and the expert interviews in order to come up with a fundamental basis, in terms of a MaaS definition and interpretative synthesis for further research. First, the definition of MaaS which will be used in this report (section 2.3.1) is made explicit. Thereafter, the interpretative synthesis (section 2.3.2) and its reflection is given (section 2.3.3).

2.3.1 Definition of MaaS in this report

For the purpose of this report, MaaS is defined as follows:

A subscription-based service offering a wide range of combined transportation options in order to fulfill the major transportation need of its end-users within its service area, supported by a single digital interface (mobile application) which can provide full assistance during all trip phases (planning, booking, paying, ticketing, travelling, trip guidance and trip evaluation).

This definition is most directly linked to the definitions of Combined Mobility Service (CMS) and Integrated Public Transport (IPT). The first part of the definition is linked to the concept of CMS, which can be perceived as the bundled accessibility to multiple mobility services. The second part of the definition is linked to IPT, which represents the technical system aspects enabling smooth travelling and the use of multiple modes of transportation. (Holmberg et al.; 2016)

The combination of these two aspects may result in a different definition than others have about MaaS. Some perceive both CMS and IPT as important subsets of MaaS, where in this report only its combination is considered as MaaS. From that perspective, only the subscription-based accessibility to multiple mobility services, which is currently mainly represented by the provision of mobility cards, is not considered to be MaaS. Similarly, solely the integration of technical system, which is most tangible in the presence of extended travel planners, is also not considered to be MaaS.

Mind that some elements of the CMS definition (see p. 16) are left out the MaaS definition. The provision of MaaS via a neutral third-party is not necessary, as this report does not consider normative statements regarding the governance of mobility via MaaS. Also the repackaging of included services and unified invoicing are left out. Although this is likely to happen from a commercial point of view, MaaS will manifest in all kinds of propositions (pay-as-you-go, subscription-based with all kinds of service level agreements). By simplifying the MaaS concept and the use of marginal costs of transportation services the specific MaaS offerings can be left out of scope. In the end, travel behavior is determined by the full range of transportation services including its costs and level of service. By not considering the repackaging of included services and unified invoicing as prerequisites for MaaS, the societal impact of MaaS can also be linked to these aspects.

For the IPT part of the MaaS definition, the trip phases – planning, booking, ticketing, travel and payment – are distilled from Kamargianni (2016). In order to fulfill all possible customer needs the trip phases "trip guidance" and "trip evaluation" have also been included. The first is similar to trip planning, but is different as it takes place during trip instead prior travelling. It implicates that people can retrieve alternative advises in case of disruptions or delays. Users can also get location-based information about where a successive stop or shared car can be found. With trip evaluation is meant the follow-up on the trip, for example for financial compensation of delays.

In order to make to make the MaaS concept more comprehensible, the supportive digital interface will be via a mobile application. By doing so, MaaS can be perceived with regards to current developments in mobility; see the applications of Whim, UbiGo and Turnn.

In this report, service providers and mobility providers have different meanings and refer to different actors. Service (or platform) providers provide Mobility as a Service to end-users, which is the platform-based mobility offering, based on multiple mobility services. Mobility providers provide the individual mobility services offered within MaaS, predominantly transportation services, to the service provider. An overview on the definition of these and other MaaS-related elements are provided in the definitions and abbreviations section in order to provide a clear overview and understanding of MaaS.

By taking one step back and considering MaaS via the definition of Hietanen (2014) – a mobility distribution model in which a customer's major transportation needs are met over one interface and are offered by a service provider – the differences between CMS and IPT become even more visible. Table 2 sets out some of the currently available mobility services with a single interface with regards to trip phases and customer needs. Mind that customer needs are inherently subjective and depend from person to person. Therefore the stated perceptions on the customer needs deficiencies do not represent the quality of these mobility services, but show the personal and temporal component in the MaaS definition; a service which fulfills someone's transportation needs right now, will not necessary do that tomorrow.

Most evident from table 2 is that there are clear differences between the already provided services on the left and the platform-based services on the right. Lease cars and lease bikes offerings can be perceived as "solely" mobility services as its fleets would perfectly fit within the MaaS framework of Heikkilä (2014) in figure 3. Mobility card services already integrate more trip phases, but these services only enable the accessibility towards mobility services. They focus predominantly on the servicing-payment relation between the service provider and the customer over several modes of transportation, but hardly consider additional customer needs. The platform-based services on the right consider the full set of trip phases, such that it approaches mobility as a fully integrated concept: Mobility as a Service.

Table 2: the integration of trip phases and the fulfillment of customer needs of mobility concepts

Provider	NS	Mobimixx	Multiple Providers	Swapfiets	Verkeers-onderneming	MaaS Global
Service	Business Card	Mobility Card	Lease Car	Lease Bike	Turnn	Whim
			Trip phases			
Planning					X	X
Booking					X	X
Ticketing	X	X			X	X
Travel	X	X	X	X	X	X
"Guidance during trip"			X		X	X
Payment	X	X	X	X	(X)	X
Evaluation / "After-Sales"			X	X	(X)	X
			Customer needs (possible perceived deficiencies)			
Accessibility	"Too little car coverage"		"Innercities are too difficult to access"	"No bike when I am somewhere else"		
Speed	"Too low train frequenci es"					
Comfort			"I cannot work in my car"			
Convenience		"No transport information provided"				
Flexibility			"I am bound to a car"	"I am bound to a bike"		
Costs						

2.3.2 Interpretative synthesis

This section provides the comparison of the findings from the literature study and expert interviews and their translation towards a synthesized interpretation. This is done by a technique called meta-ethnography (Britten et al., 2002). The findings of this interpretative synthesis are grouped on the sources they are derived from. In appendix III, an elaboration on meta-ethnography is given and the translation steps towards the interpretative synthesis are specified.

Hietanen (2014) – Mobility as a Service – the new transport model?

Advances in technology enable MaaS and the entrance of new mobility providers will likely change the mobility value chain. This is encouraged by different needs of users and increasing expectations. Users will spend their transportation budget on mobility services which serve them the best and they will use the service providers which give them the best access to those services.

MaaS is a revolutionary mobility distribution model, which can only develop when all mobility actors encompass open minds. This open mind set can be defined as the presence of open data and interface, organization within mobility alliances, standardized data formats and changes in subsidy policies and tax legislation.

Governments provide less resources for new transport systems and want to increase the efficient use of their investments on mobility. MaaS can improve the (willingness to) use the public transportation system, when it is able to bring public transportation in improved conjunction with other mobility services. From that perspective, governments do not have to invest in improved public transportation, but can focus on the societal interests of public transportation; e.g. the mobility of people who would otherwise have no access to mobility.

In other words, MaaS can make chain mobility more attractive, but it will also lead to rebound effects by people choosing other mobility services that public transportation. To which extent this will happen is unknown. It will likely implicate that low demand public transportation services are the first to disappear; these services are most easily to replace by other kind of mobility services.

Yet, there is no hard evidence for future user behavior within MaaS, but tailoring mobility services will likely increase the use of MaaS. It is therefore likely that MaaS offerings towards specific user groups will develop; e.g. business people, young urban professionals, disabled people. From a commercial perspective, service providers will first focus on user groups from which they expect to profit the most.

Giesecke et al. (2016) – Conceptualizing Mobility as a Service. A User Centric View on Key Issues of Mobility Services

There is a wide spread "believe" that MaaS will adopted by the many and that its resulting changes in travel behavior will make the mobility system more effective and efficient. Whether this will be true or not, it is currently visible that new parties (e.g. Uber and Car2Go) enter the market and cities, such as Amsterdam, are providing opportunities for them to operate (e.g. by giving them parking licenses). This indicates that (new) actors in mobility are actually working towards a revolution in mobility. Nevertheless, the current mobility market is fragmented and mobility providers hardly cooperate with each other.

The impact of MaaS is related to how mobility demand and supply come together. This is therefore a chicken-egg dilemma. On the short term, it will require courage and trust for actors in mobility to cooperate. On the long term however, it is possible that these collaborating actors will harvest their efforts, resulting in a more effective and efficient mobility system and a higher business profitability.

Heikkilä (2014) – Mobility as a Service. A proposal for action for the public administration. Case Helsinki

For MaaS deployment, cooperation is key and needs to result in full disclosure and exchange of operational data of all involved actors. Excessive market powers should be avoided, otherwise service and mobility providers have the ability to operate on an individual basis.

Rebound effects are likely to occur, and the interdependencies between factors are quite complex with regards to the expected initial decrease of mobility costs, the withdrawal of private cars and the (temporal) decrease of traffic intensities and congestion. This suggests that positive externalities potentially need to be harvest by governmental regulation as otherwise more elaborate rebound effects can occur. This is different than stating that governmental regulation is necessary, because it could also affect the attractiveness and willingness to use MaaS in such way that its positive externalities could not flourish anymore.

Kamargianni (2016) – A critical review of new mobility services for urban transport

Mobility packaging will enlarge the use of its included mobility services. This can be an incentive for current mobility providers to make arrangements for lower fares and wages in order to maintain or enlarge their current position on the mobility market. For public transportation (PT) operators this would be food for thought; their services with low profitability could potentially be substituted by other services or will need additional subsidies. This would strengthen the position of PT operators in a commercial MaaS eco-system. It will automatically lead to a more user-centered fit of the remaining mobility services.

Holmberg et al. (2016) – Mobility as a Service (MaaS). Describing the framework

It can be argued that public transportation operators have the benefit to provide a better stability of mobility services, but they have not the same flexibility as private parties. When commercial actors become dominant within MaaS, it is possible that PT operators repel their profitable services to these commercial actors or exploit these in a more commercial way. The latter refers to the exploitation of these services beyond the original boundaries of standardized fares, time tables and quality standards. These possibilities can be viewed as renewed opportunities for traditional PT operators. It is likely that public actors will keep track on potential negative externalities or even set hard constraints in order to prevent these. When PT operators focus on these renewed opportunities, this would impose that the flexibility of profitable services can be improved, while the stability for "niche" mobility services by PT operators, e.g. in low demand areas or for specific user groups, can be guaranteed. The latter whether or not with financial support of public bodies.

The interests of MaaS service providers and governments can be similar with regards to the reduction of privately owned cars. Service providers ideally want to facilitate as much mobility demand as possible which can be achieved by attracting private car users. Here also lies a role for co-created mobility services, in conjunction with local people, organizations and governments; traveling via MaaS implies a dependency on service providers, and it will be difficult for these providers to provide fully guaranteed mobility at any time and any place. Their sub-optimal offerings can be complemented by these co-created services and can provide resilience when MaaS is not able to meet the mobility demand. Example of these co-created services could be taxi services by volunteers, ride sharing, or shared cars owned by multiple neighbors.

When rebound effects cause that MaaS users increase their (individual) use of cars, similar or worse impacts on accessibility, environment and urban space can occur. This implies that environmental sustainability can only be guaranteed when travelers are grouped together in the same vehicle, whether this is by public transportation or by shared taxi services.

2.3.3 Reflection

This section reflects on the main outcomes from the interpretative synthesis (section 2.3.2). The characteristics of platform-based mobility via MaaS has implications on how the mobility eco-system will look like. Based on the drivers of MaaS, an elaboration on the most evident MaaS characteristics are given. This section therefore elaborates on the improved service accessibility (related to the user centrality within MaaS), the importance of data (related to the need for effective and efficient mobility) and the importance of critical mass (related to commercial interests).

Improved service accessibility

MaaS enables improved accessibility to transportatioin ervices. This means that current, and new, mobility services will become better available to the public.

By means of a coordinated, planned and integrated proposition of several transportation services, an attractive and credible alternative to car ownership can be developed. This involves the physical perspective (a coordinated network planning, the incorporation of stations and urban planning, and the algorithmic optimization of fleets) and the information perspective (a one-stop-shop for personal mobility assistance offering information, booking and ticketing. (UITP, 2017)

Karlsson et al. (2016) emphasize the improved availability of service attributes. They compare MaaS to the concept of a *transportation smörgásbord*, acknowledging the similarities of the typical Swedish buffet (see figure 5) with the broad availability of mobility services. MaaS improves the mobility of people as MaaS users can metaphorically eat everything they want, as much as they want.

Figure 5: smorgasbord reflecting the availability of mobility services in MaaS (Tripadvisor, 2017)

In traditional mobility, users focus on modes of transportation. There are only a limited amounts of modes available and all these modes have specific characteristics. This implicates that these modes of transportation meet specific mobility needs, as depicted in figure 6. For illustrative reasons, this figure differentiate between on the one hand cheap mobility options (walking and biking) vs. the generally faster mobility options (public transportation, car mobility), keeping in mind this differentiation will not be the same for each location and time. From figure 6 it becomes clear that in a traditional mobility system there is a significant unsatisfied – or at least sub-optimally satisfied –

mobility demand as can be seen on the "white spots" where no sufficient mobility services are available. The relative positions of the modes of transportation results in sub-optimal mobility from both a user and society point of view. The lock-in towards specific transportation services or car-ownership further limits the choice for optimal mobility.

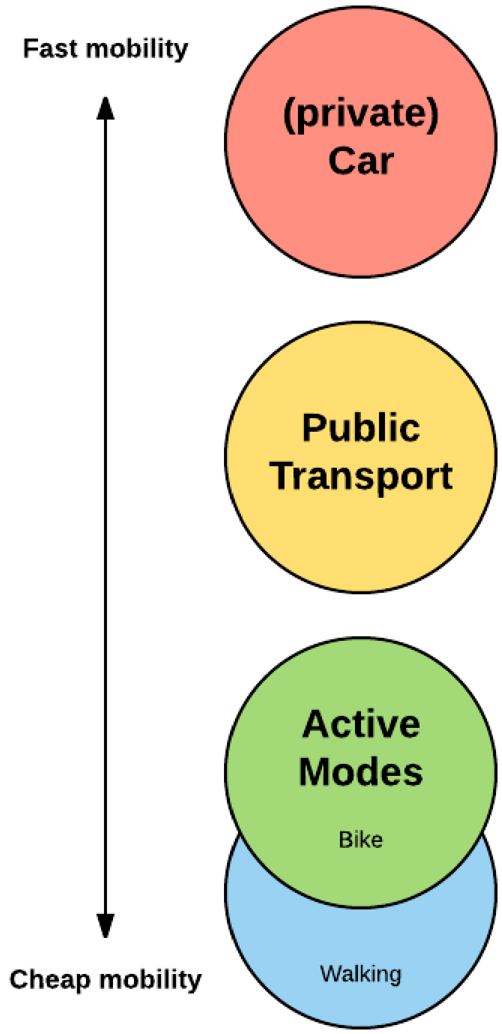

Figure 6: the relative positions of mobility services in a traditional mobility system

Importance of data

Enabling technologies such as smart cards, GPS location services, smartphones, wirelesss connectivity via 4G and WiFi provide data (exchange) within MaaS. By these means, platform and service providers exchange information about mobility demand and available mobility services. Primarily, to bring mobility services to the specific demand of individual MaaS users. At the same time, it provides opportunities for platform and service providers to analyze and assess usage and demand patterns, potentially resulting in enabling better and more efficient mobility services. (Deloitte, 2017) This means that MaaS is not only a platform to allocate mobility services to users, but also improves the fit of these services towards the requirements of users and the business interests of service providers.

Effects of critical mass

It is important for MaaS platforms to obtain a critical mass, to ensure a viable business model and guarantee better mobility to its users. Enabling open interfaces and the availability of appealing mobility services will be necessary to attract many people to platform providers. (Rutuu et al., 2017) When enough users are obtained, platform providers will have improved power to negotiate lower prices and better service with mobility providers. There will be a dynamic where service providers aim for higher (resource) efficiency and therefore lower prices.

On the other hand, the access to a significant group of users creates a potential market for new and innovative mobility services. Simultaneously, this creates possibilities for public actors to intervene in mobility patterns. Currently, mobility patterns are predominantly characterized by habitual mobility behavior, where MaaS users are likely to show more flexible travel behavior as they will choose mobility services which fit them the beset. Public actors can encourage and discourage the use of certain mobility services in direct interaction with service providers, instead introducing measurements aiming for behavioral change.

3 MaaS offerings

In this chapter, possible MaaS offerings are described in order to provide insights in the appearance of MaaS in reality and the identification of specific MaaS offerings for further impact assessment. This chapter builds on insights from the previous chapter and results in the determination of 4 scenario-specific MaaS offerings.

At first, the basis of MaaS offerings (section 3.1) is derived by reasoning which elements are necessary for the provision of MaaS offerings. Consecutively, scenario-specific MaaS offerings (section 3.2) are developed by questioning how uncertain context variables could influence mobility propositions to customers.

3.1 The basis of MaaS offerings

In this section the basis of MaaS offerings is set out, by exploring possibilities for MaaS offerings in reality. This is done by inductive reasoning and regards the availability of mobility services and import network determinants.

According the statements from the expert interviews, this report will consider the following mobility services to be available within MaaS:

- Public transportation (PT; train, bus, tram, subway);
- Active modes of transportation (bike, walking);
- Taxi;
- Shared taxi services;
- One-way car (floating) services;
- One-way (floating) bike.

The level of service (LOS) is defined as the quality of mobility services in terms of travel times, costs and comfort and is specified for specific user groups and can be dependent on space and time. These items can be further operationalized in process-related terms such as request times, vehicles occupancy levels and detour factors or output-related terms such as agreements on accessibility (e.g. all destinations within 50 kilometers can be reached within an hour).

The subscription of users for MaaS is likely to be based on so-called Service Level Agreements (SLA's). Users and service providers make arrangements together about process or output related requirements, based on the terms as noted above. As mobility is a complex concept, it can be argued that SLA's are essential to keep customers satisfied. Similar arrangements are common, mostly in

B2B markets. Examples can be found in call centers ("how many calls should be answered within 10 seconds") and cleaning ("how many times should paper bins be emptied each week").

For reasons of simplification, the existence of privately-owned transportation resources is left out of scope. This means that within MaaS all resources are shared with others (shared or simultaneously). In this report the latter three services are characterized as follows: taxi services have their pick-up and drop-off in the direct area of the origin and destination with a certain waiting time between ride hailing and pick-up. The user does not have to drive. Shared taxi's are different in that way that they combine other passengers with similar or different origins and destinations during the same ride. For simplicity, car and bike sharing services are only available in a one-way (floating) concept. Users of these services face a certain access and egress time.

A few other modes of transportation are likely to be available, but are let out of scope for simplicity. This concerns i.a. mopeds and scooters. Although, e-bikes and speed pedelecs are emerging in transportation and have specific features such as more speed and comfort (compared to conventional bikes), it is assumed that these benefits are limited in urban traffic as continuous stretches of road (without traffic lights, speed bumps, etc.) are not widely available. Therefore these bike types are grouped together with conventional bikes.

Scenario-specific characteristics of MaaS offerings consist of the following items and are further explained in the next section:

- Cost drivers: such as public transportation and parking costs;
- Network characteristics: average speeds, (stop) density of the public transportation network, available parking space;
- Service characteristics: such as ride-hailing times, access and egress times;

3.2 Scenario-specific MaaS offerings

This section determines possible MaaS offerings in reality, resulting in four scenario-specific MaaS offerings. The determination of MaaS offerings can be considered as the development of intuitive scenarios. This means that the MaaS offerings relate to important determinants of future mobility systems, without providing evidence confirming that these MaaS offerings are a direct result of these determinants.

In the reflection on literature and expert interviews, sharing, automation and public interventions are considered to be important determinants for the future mobility system and the characteristics of mobility services. Sharing and automation potentially have a great impact, however their acceptation and deployment rates for 2025 are questionable. Public governance will have an impact on the functioning of MaaS and the mobility system. By considering different levels of public interventions this impact becomes explicit. Together with the availability or absence of automated vehicles, it determines future mobility scenarios.

The future mobility scenarios, which determine the future mobility system and MaaS concept in Amsterdam are set out in table 3.

When there is no automated driving, in the **active & collective (AC) scenario** car-based mobility is limited by governmental intervention, such that the extensive PT network and active modes will play a significant role. The opposed scenario is therefore called **car-based (CB)**, as little restrictions are posed to car-based mobility.

When automated driving is available, governmental interventions let the extensive PT network synergize with the rise of driverless (shared) taxi services. Therefore this scenario is called **hybrid PT (HPT)**, where the provision of collective mobility is based on time- and location-based demand. When the interventions of the government are limited, direct transportation by means of autonomous vehicles will rise. Therefore this scenario is called **robocars (RC)**.

Table 3: the four defined scenarios for the mobility system and MaaS

Mobility Systems	No automated driving	Automated driving
Many governmental interventions	**Active & Collective**	**Hybrid PT**
	- Extensive PT network - Significant PT subsidy - Limited cars available - Taxi licenses - Technology costs motorized transportation remain similar	- Extensive PT network - Significant PT subsidy - Limited cars available - Taxi licenses - Lower technology costs motorized transportation
Limited governmental interventions	**Car-based**	**Robocars**
	- Limited PT network - Little PT subsidy - No car limitation - Deregulated taxi market - Technology costs motorized transportation remain similar	- Limited PT network - Little PT subsidy - No car limitation - Deregulated taxi market - Lower technology costs motorized transportation

Figure 7: impression of a car-based mobility system (Charged, 2017)

Figure 8: impression of an active & collective mobility system (Marker Nieuws, 2016)

Figure 9: impression of a hybrid public transportation mobility system (OV Magazine, 2017)

Figure 10: impression of a robocars mobility system (Autoblog, 2016)

A possible visualization of the relative positions of the modes of transportation in future mobility scenarios are set out in figure 11. From this figure it can be seen on the left that in case automated driving is inexistent, there are multiple modes of transportation and these modes have a slight overlap with each other. A possible grouping of these modes would consist of car-based transportation, public transportation and active modes. For the car-based and active & collective scenario logically the mobility system focuses on respectively the upper part and lower part of this conceptualization.

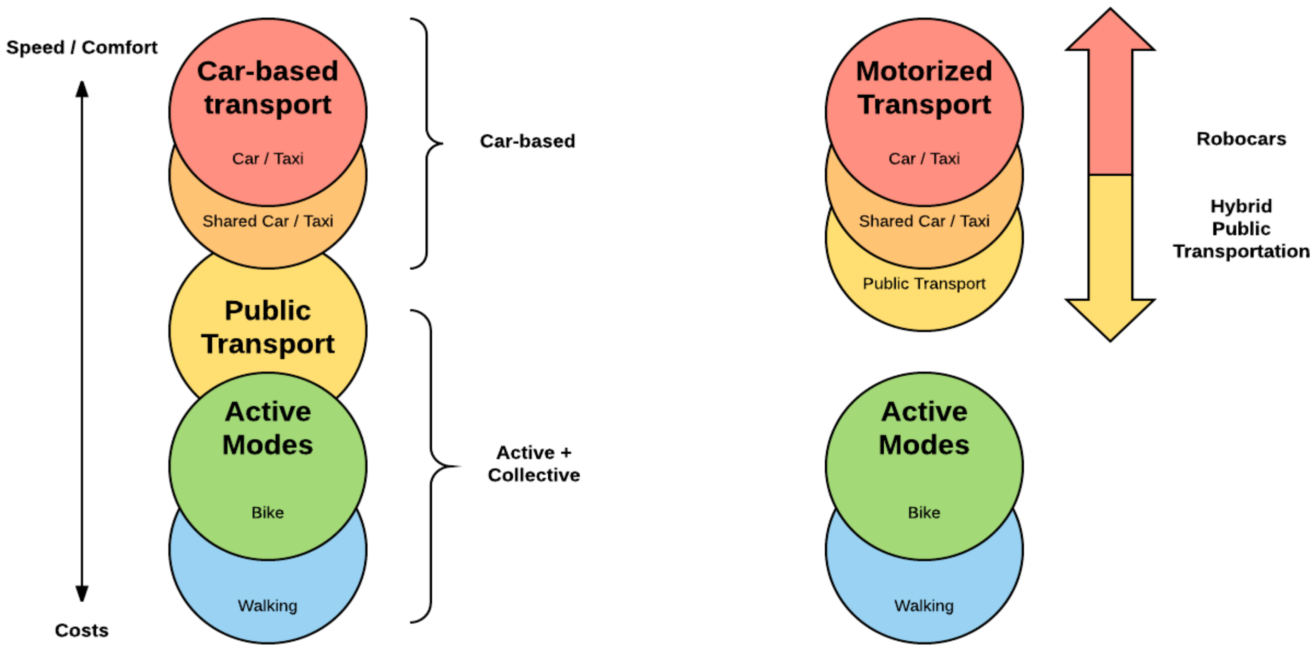

Figure 11: the relative positions of mobility services in a renewed mobility system via MaaS

In case there is automated driving the public transportation group is likely to be absorbed by the motorized transportation group, predominantly driven by the demand-responsive character of public transportation in these scenarios. Therefore, in figure 11 on the right side two separate groups of modes of transportation are formed: motorized transportation and the active modes. For the robocars and hybrid public transportation scenario there are only minor differences. The robocars scenario focusses on smaller-scale and individual direct transportation where the hybrid public transportation scenario is focusing on larger-scale and collective semi-direct transportation. This implicates that especially in the latter scenario there is a more significant role for the active modes, predominantly for travelling in the first and last mile.

The four future mobility scenarios are used for conceptualizing the future mobility systems and the related MaaS offerings. The conceptualization and quantification of these mobility systems and MaaS offerings is set out in Appendix IV.

4 Theoretical framework for impact assessment of MaaS

In this chapter, a theoretical framework is developed in order to enable both the qualitative and quantitative impact assessment of MaaS. This chapter continues on insights from chapter 2, but its resulting framework is used together with the 4 determined scenario-specific MaaS offerings from chapter 3 to conduct the impact assessment.

The theoretical framework for determination of the societal impact of MaaS consists of several parts. This is clarified in figure 12. On the one hand, the societal impact of MaaS is determined by the extent in which MaaS is used; reflected by the number of MaaS users. On the other hand, the impact relates to how mobility services within MaaS are used and how elements of the mobility system and its impact factors relate to each other. This is reflected by the three conceptual models which are introduced in the beginning of this chapter: the conceptual models related to the number of MaaS users (section 4.1), the use of mobility services (section 4.2) and the mobility system (section 4.3). The first is deduced from the theory of planned behavior (Ajzen, 1991), the second is deduced from conditional logit analysis of qualitative choice behavior (McFadden, 1973) and the MaaS conceptualization, where the latter is the product of inductive reasoning.

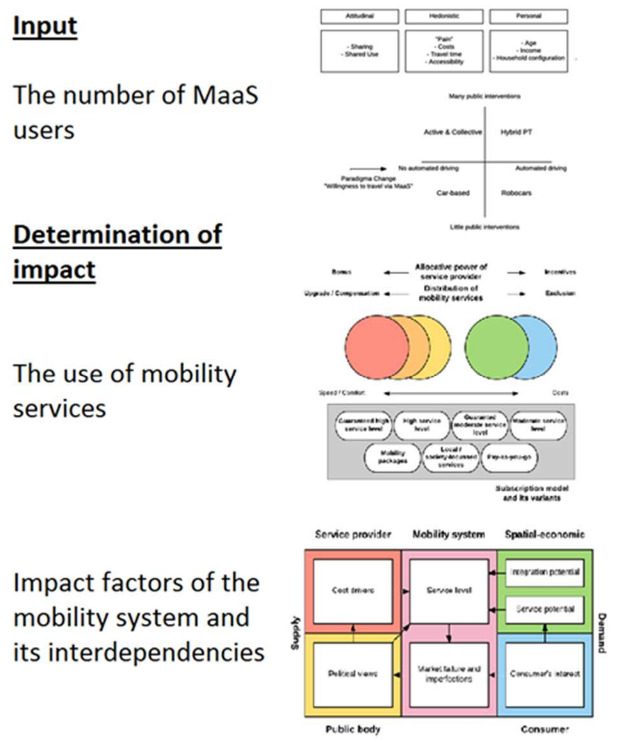

Figure 12: introduction of the different conceptual models for impact assessment

People make individual choices regarding if and how they use MaaS. In order to deal with this individual behavior wisely in terms of research time and complexity, the relation between personal characteristics and mobility behavior is taken into account in the first conceptual model. This enables the grouping of similar person types. The abovementioned parts of the theoretical framework, together with the assessment framework (section 4.4), enable both the qualitative and quantitative assessment.

4.1 Conceptual model for the number of MaaS users

This section aims to make the conceptual model for the number of MaaS users explicit. First, this conceptual model is introduced in section 4.1.1. Thereafter, an elaboration on its application in research is given in section 4.1.2.

4.1.1 Introduction of the conceptual model

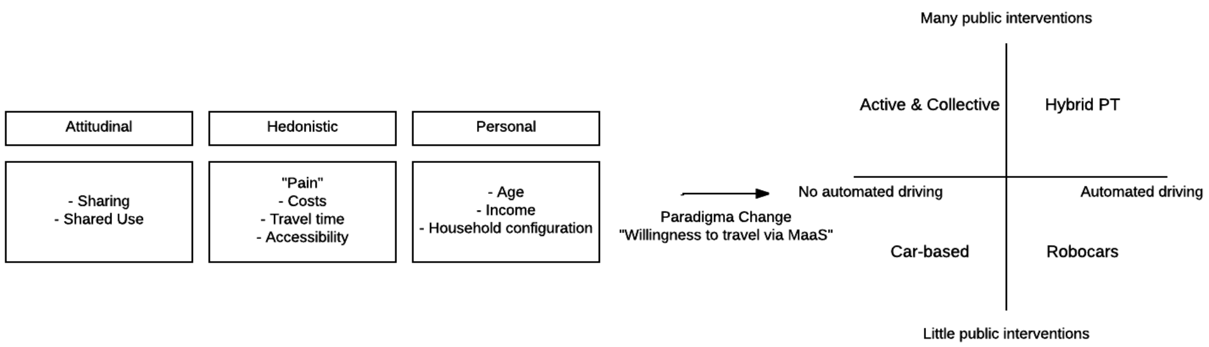

Figure 13: the conceptual model for the number of MaaS users

The conceptual model is a product of deductive reasoning from the theory of planned behavior (Ajzen, 1991). The conceptual model for determination of the number of MaaS users is based on a push- and pull model and is set out in figure 12. The push-factors represent the people travelling in a traditional way. The pull towards MaaS is determined by the available MaaS offerings. According to Ploeger en Van der Waard (1997) and the statements from the expert interviews (see appendix II), the following person-specific characteristics will be most relevant for the push towards MaaS:

- Attitudinal factors such as the acceptance of sharing and shared use in comparison with attitudes towards ownership and individual use.
- Hedonistic factors, which can be aggregated in a factor called "mobility pain". It represents the dissatisfaction with traditional mobility in terms of costs, travel times and comfort. Affective values towards traditional mobility (status of car ownership, feeling of freedom, etc.) are also important hedonistic aspects.
- Personal factors, such as age, income and the household size and type.

The pull towards MaaS is mainly determined by the MaaS offerings. However, travelling via MaaS can be considered as a paradigm change, as the nature of travelling will be different. Therefore, platform-specific effects should be taken in to account.

Via the platform, different routes and (combinations of) modes become available and users are better informed about these alternatives. Users of MaaS are no longer locked-in to transportation resources ownership (e.g. car ownership), predominantly caused by sunk costs such as redemption and insurance costs. Therefore, MaaS users are better able to choose mobility services they would not have considered otherwise. This can result in a higher satisfaction in mobility. In addition, travelling gets more reliable as these alternatives provide redundancy in case of congestion or disruptions.

Negative platform effects are related to the way mobility services are distributed to users. MaaS users no longer rely on own resources, so they have to trust in the availability of mobility services. This implicates MaaS users need to overcome perceptions on service uncertainty. In addition, servitization implicates the dependency on others for mobility fulfillment. Especially public bodies will have more power as they can directly control mobility via mobility providers instead of targeting mobility behavior. This can people give to feeling to be out of control of their own mobility.

4.1.2 Application in research

This conceptual model is used for the quantitative assessment. The potential users of MaaS within are grouped based on their mobility preferences. These groups are deducted from prior research which has been conducted on so-called mobility lifestyles. Beemster (2016) has given an overview of these studies. These studies present from 3 to 7 different lifestyles; Anable (2011) identified seven mobility lifestyles: status seekers, devoted drivers, reluctant pragmatics, practical travelers, active car owners, car contemplators and car free choosers. For simplicity's sake, these 7 different mobility lifestyles are grouped in three behavior groups: strong preference for car transport, strong preference for public transportation and active modes, or hybrid preferences towards transportation means.

According Beemster (2016), the distribution of behavior groups within the Amsterdam urban area can be considered as follows: 24% car-based, 40% hybrid and 36% PT-based (36%) of the total population. In order to simplify the study, this distribution of behavior groups is assumed to be uniform within the Amsterdam urban area.

The number of MaaS users is determined by considering the disutility of using MaaS versus the disutility of conventional mobility. In this research, this is primarily based on hedonistic factors; what are the impedances for both alternatives in terms of costs, travel time and discomfort. Additional (perceived) disutility, by considering attitudinal and personal factors, is not explicitly taken into account. For that reason, the MaaS fine is introduced. The MaaS fine is used as a proxy for this additional disutility. For the sake of simplicity, these MaaS fines are set similar for each behavior group, but are varied within the study to show the impact of differences in this additional disutility.

What is known, when considering current mobility behavior, attitudes play a significant role for all groups. These attitudes can be based on cognition or affect. Cognitive attitudes are related to the thoughts and beliefs. Affective attitudes are based on the judgement about the pleasantness or unpleasantness of performing certain behavior. (Breckler & Wiggins, 1989; Crites et al., 1994; Trafimow & Sheeran, 1998). In figure 14 an elaboration on these attitudes can be read.

Affective attitudes

In the study of Anable (2011) positive affective attitudes are predominantly related to car use. A preference for car transport can simply be there because some people simply like to drive a car. More specific affective attitudes positive to car transport can be the belief that driving a car means status or success in life or the belief that it is a good way to express your own identity. Negative affective attitudes can be the belief that car driving enhances unhealthy lifestyles and reduces the quality of life of many people.

Cognition-based attitudes

This affective attitudes are an important determinant of people's behavior type. On the other hand people's preference can also be determined on cognition-based attitudes. People will prefer the car when they cannot reach relevant places without exceeding a certain amount of time or money. This can both be based on reality or perception. When both car transport as pubic transport are considered to be serious alternatives, people will predominantly choose their means of transportation by choosing the most optimal

Figure 14: elaboration on affective and cognition-based attitudes

The number of MaaS users is determined by calculating the probability someone chooses to use MaaS. This is done by means of logit modelling. The probability is eventually translated over the total population within the Amsterdam urban area. The respective equation is shown in equation 1.

$$Pr(MaaS|\{MaaS, non-MaaS\}) = \frac{e^{V_{MaaS}}}{e^{V_{MaaS}}+e^{V_{non-MaaS}}} \quad \text{where:} \quad (1)$$

$Pr(MaaS|\{MaaS, non-MaaS\})$ *reflects the probability that someone chooses to use MaaS, considering the alternative for not using MaaS;*

V_{MaaS} , $V_{non-Maas}$ *reflect the disutility of (not) using MaaS.*

The scale parameter, which describes the sensitivity for differences in disutility, is set to one and could therefore left out of the equation. An elaboration on the calculation of the disutilities is given in Appendix VI.

4.2 Conceptual model for the use of mobility services

This section aims to make the conceptual model for the use of mobility services explicit. First, this conceptual model is introduced in section 4.2.1. Thereafter, an elaboration on its application in research is given in section 4.2.2.

4.2.1 Introduction of the conceptual model

This conceptual model is the product of inductive reasoning based on the previous chapters. For quantitative impact assessment it is modelled along the principles behind conditional logit analysis of qualitative choice behavior. (McFadden, 1973) The conceptual model is figure 15 describes the use of mobility services. The use of mobility services is not limited to short-term user behavior ("Will I take a car or the bus today?"), but is also determined by subscription plans (strategic, longer-term user behavior), the allocative power of service providers and the distribution of mobility services to users.

By only considering short-term user behavior, mobility services are chosen on the perceived mobility fulfillment (e.g. based on costs, travel time, comfort, etc.) at that moment. It is more likely that users will first choose a specific subscription plan, based on a service level and additional services. These subscription plans are also chosen on the perceived mobility fulfillment, which are predominantly based on service availability and geographic accessibility. This will make mobility cheaper as people will only choose a service subscription they will actually use. It is likely there will be variants available for peak- and non-peak hour usage, specific areas, etc.

Service providers have interest in low mobility costs and high user satisfaction rates. By influencing the choice for mobility services they can secure these interests. However, it is unknown how big this allocative power will be. Service providers can incentivize certain mobility services in order to shift the use of services, for example by upgrading future trips or financial rewards. On the other hand, service providers can give bonuses to users in order to keep them satisfied.

Service providers aim to fulfill all service level agreements. However, there can be situations where there is a lack of sufficient mobility services. In these cases, service providers can upgrade users to other mobility services or compensate them for service downgrading or exclusion. As this affects user satisfaction rates, service providers will aim for preventing this to happen. This can be possible by providing subscription plans where the service level is not always guaranteed. In exchange for cheaper mobility, service providers can exclude users in order to maintain the general level of service.

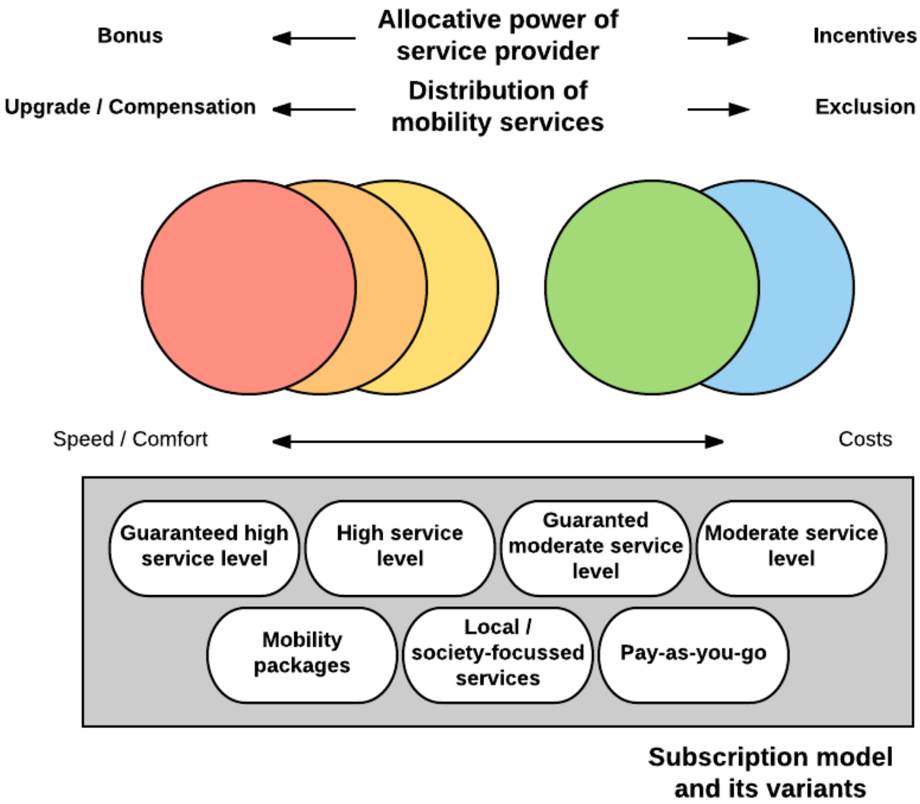

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Figure 15: conceptual model for the use of mobility services

As figure 15 shows, the choice for mobility services is bound by the subscription plan, the allocative power of service providers and the distribution of mobility services to users. The characteristics of mobility services will be traded-off by MaaS users. The SWOT analyses (see table 4-7) of shared cars, (shared) taxi services, public transportation and bikes provide the most important characteristics of these services. An elaboration on these trade-offs are given in appendix V.

Table 4: SWOT analysis for shared car

Shared car

Strengths	Weaknesses
• High comfort • High accessibility, especially to sub-urban and rural areas • Becomes cheaper when used by more people	• Expensive • Parking difficulties in urban areas • Low speeds in urban areas
Opportunities	**Threats**
• Autonomous vehicles will make it cheaper and more comfortable • Platforms make sharing more available and interesting	• Societal trends such as individualization and trust in society can affect acceptance of sharing • Further discouragement of (shared) cars in urban areas

Table 5: SWOT analysis for (shared) taxi

(Shared) taxi

Strengths	Weaknesses
• Cheaper than non-shared cars • Enables social interaction • High comfort • High accessibility, especially to sub-urban and rural areas	• Slower compared to cars • Less privacy compared to cars
Opportunities	**Threats**
• Can potentially be a good substitution for public transport with lower capacities.	• Regulation can maintain high prices for (shared) taxi services • Selection effects can exclude people in low demand areas

Table 6: SWOT analysis for public transportation

Public Transportation

Strengths	Weaknesses
• Cheaper than car-based mobility • Potentially fast on important corridors	• Limited service and service area (schedule and line bound) • First- and last mile dependency • Becomes more expensive when used by more people
Opportunities	**Threats**
• Future hybrid services can be more flexible in terms of routing, scheduling	• Less subsidy from governmental bodies

Table 7: SWOT analysis for active modes

Active modes

Strengths	Weaknesses
• Cheapest form of mobility • Positive health effects • Fast within dense areas and short areas, • Suitable for first- and last mile	• Less comfortable than motorized mobility • Physically intensive • Subject to weather influences
Opportunities	**Threats**
• Proliferation of e-bikes will enhance average speeds • Improvement of bike and walk infrastructure	• Increased regulation (bike parking, helmets and cell phones) can discourage bike usage

4.2.2 Application in research

For the qualitative assessment, this conceptual model is only used to have an improved understanding of MaaS offerings can affect the use of mobility services within MaaS. Regarding the quantitative assessment, only the 4 scenario-specific MaaS offerings from chapter 3 are used to determine the choice of mobility services. For simplicity's sake, no further differentiation in service levels is made within these scenario-specific MaaS offerings. The allocative power of service providers and the distribution of mobility services within MaaS is left out of the scope of the quantitative assessment. The specification and quantification of the scenario-specific MaaS offerings is set out in appendix IV.

MaaS users choose for a specific mode of transportation with respect to for example its related travel time and costs. Also additional preferences towards these modes of transportation play a role. For each of the three behavior groups, as specified in the previous section, different preferences are assumed. This is expressed in the so-called alternative specific constants for each mobility service. An elaboration on the ASCs is given in appendix VI. For the Amsterdam case according the determined ASCs, it can be said that for equal travel times and costs, walking is the most preferred and car transportation is the least preferred mode of transportation. It is reasonable to assume this is related to the hassle people experience from using a specific mode of transportation.

4.3 Conceptual model for the mobility system

This section aims to make the conceptual model for the mobility system, its impact factors and related interdependencies explicit. First, this conceptual model is introduced in section 4.3.1. Thereafter, an elaboration on its application in research is given in section 4.3.2.

4.3.1 Introduction of the conceptual model

This conceptual model is the product of inductive reasoning based on the previous chapters.

In the previous chapters it is made clear that the number of users and the user behavior are the most important determinants for the societal impact of MaaS. Also, mobility networks and the organization of the mobility system – which can change as a result of MaaS – have an impact on society. The conceptual model in figure 16 visualizes the interdependencies within the mobility system. It ensures that potential impact factors on the mobility system are identified.

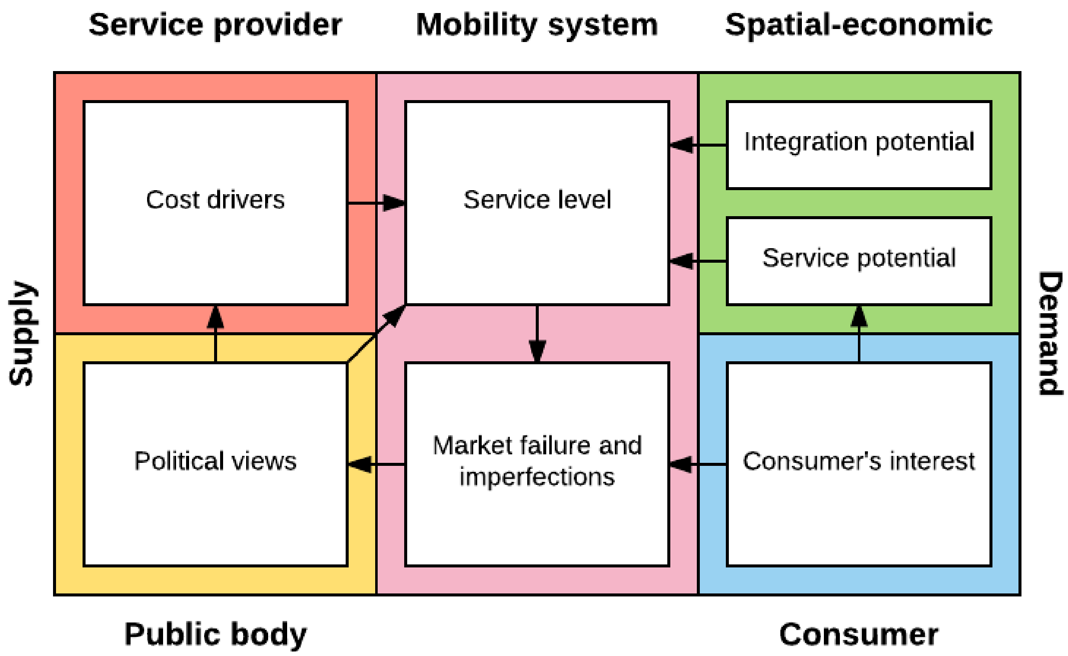

Figure 16: conceptual model describing the interdependencies within the mobility system

On the right side in this conceptual model, two blocks determine the demand of mobility services: the blue consumer block with its consumer's interest and the spatial-economic block represented by the potential value (PV), subdivided in the service potential and integration potential. The PV is defined as the attractiveness for mobility providers to deploy mobility services within a specific area, and it determines to which extent economies of scale can be reached. In general it can be said that the bigger the PV, the more service providers will deploy services in that area. A further elaboration on the PV is given in figure 17.

On the left side in this conceptual model public bodies and service providers, determine the supply of mobility services. Mobility cost drivers determine the pricing of mobility services, having a direct impact on the service level. Public bodies can influence these cost drivers with all kinds of measures (such as parking costs, licensing, etc.). They can also directly provide mobility services themselves (or indirectly via tendering or facilitating co-creation initiatives)

Together, supply and demand determine the level of service (LOS). The LOS is dependent of location and time and can be defined as the service standard provided to users in terms of travel times, costs and comfort. Sub-optimal situations can occur; it is named market failure when externalities are not sufficiently taken into account (such as environmental or equity impacts). Market imperfections occur when optimal supply and pricing cannot be reached. Both of them can be reason for public bodies to intervene as described above.

Potential Value

The Potential Value (PV) is the attractiveness for mobility providers to deploy mobility services within a specific area, and it determines to which extent economies of scale can be reached. The following spatial-economic aspects of an area determine the PV:

Area density is the most relevant determinant of PV. For very low density levels, certain business models will not be profitable anymore.

The *area population* is also an important determinant; when the population can be translated to the target audience of a specific mobility service, it becomes more interesting to deploy this service in that area. Therefore, this is related to person-specific characteristics (e.g. attitudes towards their current mobility behavior and future mobility services).

The *area functionality, centrality and distance to other areas* determine the mobility demand and thus the PV. For example, commuting distances, the in- and outflow of people in an area and the dominance of certain connections.

Figure 17: determinants for the Potential Value of areas

4.3.2 Application in research

This conceptual model is predominantly used for the qualitative assessment of the system characteristics. The model enables to make statements regarding the impact MaaS has on the structure and organization of the mobility system. This concerns the direct service provision within MaaS reflected in the reliability (of mobility services) and the robustness (of the mobility system) and the access and exclusion of MaaS users towards mobility services. Also other aspects can be evaluated by means of this conceptual model, concerning the labor and work conditions, environmental sustainability, spatial service structure and the legitimacy of MaaS.

4.4 Assessment framework

This section sets out the assessment framework for both the qualitative and quantitative assessment. First, it sets out the 5E framework (section 4.4.1) as means for the qualitative assessment. In addition, quantitative indicators (section 4.4.2) are determined in order to quantitative assess the outcomes of the model study.

4.4.1 5E framework

This section elaborates on the 5E framework in order to provide an assessment framework for the qualitative assessment. The 5 E framework is a recently developed framework to assess the impacts of public transportation. Its added value compared to an assessment over costs and transport value is that it also considers different areas of impact. The 5 E framework (see figure 18) is developed by Van der Bijl et al. (2016) and it consists of the following elements:

Effective mobility deals with the performance of the transport of people. This goes further than standard transport performance numbers; it also deals with the value of reliability, robustness and comfort.

Efficient city is related to the use of urban space. Transportation impacts the structure and the quality of urban space. As a result, it can enable attractive and compact cities and enhance the urban business climate.

Economy deals with the financial impacts, such as the increase of property values and the rise of retail revenues.

Environment deals with the consumption of energy, the emissions of noise and GHG and noise emissions and land use impacts. As the latter is also corresponding to efficient cities, it is chosen to assess land use impacts only under the element of efficient cities.

Equity deals with, but is not limited to, the equal distribution of impacts over population groups. It is also linked to social improvements by means of a better transportation system such as improved accessibility to work and public health.

Figure 18: qualitative assesment via the 5 E framework (Van der Bijl et al., 2016)

4.4.2 Quantitative indicators

This section sets out the quantitative indicators in order to quantitatively assess the outcomes of the model study. The quantitative indicators need to relate to the sub-research question: what will be the modal split of full-operational MaaS? This leads to the following quantitative indicators which relate to the modal split or are a derivative of this modal split.

1 Number of MaaS users

The number of MaaS users is an important outcome which can result in changes in the modal split in future mobility systems. The number of MaaS users is specified as the percentage of the total population of the Amsterdam urban area using MaaS.

2 **Modal split in the future mobility system**

The modal split concerns the transport performance of a specific mode of transportation as a percentage over all available modes of transportation. The transport performance is measured in respectively the number of trips and the number of passenger-kilometers.

2 Trip length changes in future mobility systems

This is a derivative of the modal share of each mode of transportation. It is defined as the index number concerning the ratio between the number of passenger-kilometers and the number of trips for each mode of transportation. This index number reflects whether trips become shorter or larger within the future mobility system.

4 Current individual travel behavior vs. future individual travel behavior within MaaS

This concerns the relative difference of the future individual travel behavior within MaaS from the current individual travel behavior. By calculating the relative changes of each modal share it becomes clear how behavior changes when someone starts using MaaS.

5 Future individual travel behavior without MaaS vs. future individual travel behavior within MaaS

This concerns the relative difference of the future individual travel behavior within MaaS from future individual travel behavior without MaaS. By calculating the relative changes of each modal share it becomes clear how future travel behavior differs for people who use MaaS in respect to people who do not use MaaS.

5 Qualitative impact assessment of MaaS

This chapter elaborates on the conducted qualitative impact assessment. This assessment is conducted in order to provide broad and multi-aspect indications on the societal impact of MaaS.

This chapter sets out the qualitative assessment of MaaS in relation to the system characteristics (section 5.1), system effectiveness (section 5.2) and the system efficiency (section 5.3). The assessment of the system characteristics is conducted by means of inductive reasoning. For the system effectiveness, the changes in costs, travel times and comfort are described for all modes of transportation in each MaaS offering. The assessment of the system efficiency is conducted by means of deductive reasoning from conditional logit analysis of qualitative choice behavior (McFadden, 1973). This chapter concludes with its results (section 5.4) by combing the outputs of the conducted qualitative assessments in relation to the 5E framework.

5.1 System characteristics

The section provides the qualitative assessment of MaaS in relation to the system characteristics. The system characteristics do not only concern the modes of transportation and their availability. They also concern in what way the distribution of mobility services is organized and the structure of the mobility system. It can be subdivided in the following impact factors, which are discussed in the next sections: system reliability and robustness (section 5.1.1), labor and working conditions (section 5.1.2), environmental sustainability (section 5.1.3), access and exclusion (section 5.1.4), market organization (section 5.1.5) and legitimacy (section 5.1.6).

These impact factors are described independently from any MaaS offering. As all these impact factors tend to be quite complex, only the most basic impacts are considered. Research in more detail is needed to gain more specific insights in the impacts derived from the system characteristics. An overview on the impact factors regarding system characteristics is given in table 8.

Table 8: overview on the impact factors regarding system characteristics

System characteristics		
Effective mobility		
Reliability / Robustness	+ +	Mobility system as a whole becomes more robust
Access and exclusion	+	Data can improve service accessibility
Legitimacy	+/–	MaaS improves the service accessibility, but could yield the use of private ownership. Control of mobility services could negatively impact the LOS
Economy		
Reliability / Robustness	+ +	Costs of travel time losses decrease as system becomes more robust
Labor and work conditions	–	Number of jobs and wages at risk by automation, time-based and piece-rated labor
Access and exclusion	+	Shift from locations to activity types can enable cheaper mobility
Environment		
Environmental sustainability	+	Modern fleets will produce less emissions (noise, GHG)
Equity		
Reliability / Robustness	–	Reliability of specific mobility services can be affected to maintain the system's robustness.
Labor and work conditions	– –	New work arrangements potentially affects the level playing field between mobility services
Access and exclusion	– –	User data and profiling can have discriminatory effects on the accessibility of mobility services.
Spatial service structure	–	Around service area boundries LOS could lower. MaaS can have a big impact on the LOS distribution.
Legitimacy	+	Empowerment of local communities

5.1.1 Reliability and robustness

Reliability can be defined as the deviation of operations from its original planning. (Van Oort, 2016) Robustness can be defined as the ability of a system to sustain fluctuations or shocks of internal or external factors (disturbances) targeting its functioning. (Cats, 2016)

The origins of disturbances affecting robustness are likely to change. They can be related to physical infrastructure degradation, technical and mechanical failures, traffic incidents, natural hazards, intentional attacks, unusual events and demand, crew strikes, planned construction and maintenance, severe propagation of service perturbations. (Cats, 2016) Within MaaS, unusual events and demand will become more important factors. Trips within MaaS are made in accordance to SLAs, where traditional mobility is based on predetermined networks, schedules and routes. This implicates that mobility patterns within MaaS are more in line with the actual mobility demand. This poses more uncertainty of passenger flows to mobility providers, for example in case of incidental events sand excessive weather conditions.

The determination of reliability will shift, from schedule-based to user-based indicators. Within MaaS, as there is more (real-time) data regarding the mobility demand available, mobility services are likely to become more demand responsive. In conventional public transportation reliability can be based on delay ("a train arrives 5 minutes after its scheduled arrival time"). The demand responsive character of MaaS implicates that future reliability will be determined on other indicators which are directly related to its users. For example the direct availability of vehicles and bikes can be considered ("at this moment 10% of the shared cars can directly be used") or the actual ride-hailing time for (shared) taxi services.

The interdependencies between mobility providers are likely to impact reliability and robustness ambiguously. The possibility to control and mitigate perturbations (resilience) will be different within MaaS. The shift towards servitization, implies that control measures are less bound to the characteristics of predetermined networks, schedules and routes. Instead, service providers will *control by allocation*: by allocating users to different mobility resources and services the reliability and robustness of the mobility system can be guaranteed. In section 4.2 an elaboration on these allocation means (incentives, bonuses, upgrading, compensation, exclusion) is given. This also includes the redistribution of transportation resources and services. Illustrative are taxi services picking up extra passengers and the distribution of more bikes to a high demand area.

Considering this information, it is likely that by reallocation the system robustness can be guaranteed, but at cost of lower availability and accessibility of specific mobility services. This could affect lower incomes, as people with a higher willingness to pay will be served earlier. Also people living in areas *with a lower PV can be affected. In the latter case there will be less alternative services available. More research should be conducted to indicate which, and to which extent, mobility services are prone to lower reliability.*

5.1.2 Labor and work conditions

General societal questions are related to how future people will earn money and how capital is distributed over society. Newspaper headlines such as "Robots make people unnecessary" (Trouw, 2014) and "Robots threat thousands of jobs" (RTL Nieuws, 2017) unambiguously show the immense impacts of automation.

General labor-related issues are also prevalent in the mobility system. Related to mobility, there are no doubts there will be autonomous cars, busses and trains in the future. Also the emergence of time-based and piece-rated labor takes place in mobility. An example of this is Uber's surge pricing, the dynamic adjustments of pricing and piece-rates.
It leads to more competition between workers, as the entrance barriers for labor supply are lower. Employees have no fixed working agreement and can work besides other jobs or during free-time. This means employees can only set working conditions to a very limited extent, as they can easily be substituted by other employees. This could lead to outcompeting employees, lower incomes and longer working times. (Hill, 2015)

In relation to time-based and piece-rated labor, the presence of a level playing field needs to be assessed. Mobility providers with low labor costs, for example by means of time-based and piece-rated labor, can yield the business viability of mobility providers with traditional labor arrangements.

There is a risk that user groups who rely on human support and interaction, such as children and disabled people, will be affected by labor-related impacts. Labor intensive mobility services could be outcompeted by cheaper mobility services, potentially impoverish service availability for these user groups. It is recommendable to gain more insights in these effects and how they can be prevented or mitigated.

5.1.3 Environmental sustainability

Environmental sustainability refers to the contribution to and the conservation of a diverse and livable planet (Wikipedia, 2017). Within this report, it is limited to the use of energy and the emission of noise, GHG and particulate matter (PM10). It is also related to land use aspects, but these are assessed separately under system efficiency.

Environmental sustainability is much related to the modal split and the VKT of specific mobility services. This is related to system efficiency, but also to the penetration rate of powertrain innovations. It is likely that fleets of new mobility services are more modern than privately-owned fleets, possibly in combination with an increased number of EVs. This will result in lower emissions of noise and GHG.

5.1.4 Access and exclusion

Access and exclusion can relate to both the geographical accessibility of areas by means of mobility services and the access to mobility services (service accessibility) from a user perspective. This section sets out the impact factors based on the latter category. Impact factors related to geographical accessibility are discussed under system effectiveness.

Businesses tend to have a homogeneous target group. This is cheaper as they do not have to make additional investments to serve different needs within the target group. Mobility demand is heterogeneous; not only in its origins and destinations, but also concerning additional requirements. For example requirements towards disabled people, the visual and hearing impaired and the elderly. It can be an option for service providers to (inexplicitly) exclude these people, in order to acquire product and process standardization. For example, aids to support disabled people to enter a vehicle cost extra money; longer boarding times for older people can lead to longer running and cycle times and thus higher operational costs.

MaaS is a data-driven business model for mobility servitization enabling user profiling. Based on this data, platform and service providers can group individuals based on e.g. residential area, working locations, and mobility preferences. Together with operational data (e.g. related to vandalism, waiting and boarding times) this will create a powerful source for platform and service providers to optimize their operations. This can be positive, for example when users are transported faster (higher LOS) and mobility resources are used more often (higher system efficiency). Negative effects can occur when service providers provide lower LOS or even exclude certain users in order to optimize their operations. A similar trend is seen at Google and Facebook, where user data is used to optimize search results and sponsored content. However, it can also have opposite effects. It can self-enforce user's choices of mobility services, the so-called *filter bubble*. (Mediawijsheid, 2017) People with a preference for car mobility could get less offerings for other types of mobility, potentially leading to sub-optimal choices from both a consumer and system point of view.

The data-driven business model of MaaS enables information provision of mobility services. Before taxi-hailing, users can see where taxis are and who are driving them. Simultaneously, mobility providers (and/or their subcontractors) can see information about users asking for mobility. This provides people feelings of trust and safety, improving the attractiveness of MaaS.
However, sharing of personal information is also having downsides in practice. Ethnic minorities are

more often refused and face longer waiting times with Uber (Smart Meetings, 2017). African-Americans are less likely to be accepted for Airbnb rentals. (Edelman et al., 2016) Thus, there are indications personal information on platforms is used for servicing related on other characteristics than service-related aspects. Apart from the undesirability of discriminatory behavior, discrimination at large scale would pose serious risks for exclusion of minority groups. This impact factor needs special attention, especially when MaaS offerings are significantly relying on social ratings and personal information.

There can be a shift from locations to activity types as destinations for travel. Platforms could introduce alternative ways to request mobility services. Users do not enter a specific location, but ask for mobility to a certain activity type, such as shopping or entertainment. It is likely that platform providers will push users to locations which are the most profitable for them. This can be the nearest activity, but this can also be sponsored locations. In that case (activity) locations pay money to the platform provider, so they will make these locations more interesting to travel to. There can be more attention for these travel options ("they are on the top of the list") or these locations will be reduced priced. A similar phenomenon are individual-specific discount deals at grocery stores based on historical purchase behavior.

Considering this information, it is plausible that mobility providers will meet the additional requirements of certain user groups (elderly, disable people etc.) insufficiently and that the use of data will have negative side effects towards minority groups. Off course, there are possibilities for setting up a legal framework to prevent this to happen, but it is questionable if this is a favorable thing to do. Extensive legislation and service constraints could limit the introduction of new mobility services. Therefore, a trade-off should be made between the effectiveness of general mobility against the equity-related effects towards specific user groups. Considering this, it is recommendable to discuss these possible impacts with these user groups, in order to find an acceptable strategy to cope with these impacts.

5.1.5 Spatial service structure

This section deals with the way mobility services are organized and structured over a larger area. This is related to the centrality and boundaries of service area of mobility services and the distribution of LOS over a larger area.

Many transport services of today focus on specific, centrally located, areas and have specific service areas; local public transportation services are mostly focused on the central station and the transfer possibilities at the central station. Shared bike systems have their bike terminals at central places such as shopping malls, bus stops, etc.

One of the ideas behind MaaS – an integrated mobility concept – would blur those centralities and service area boundaries. Users will use services which best fit their mobility needs, so mobility services will be (dynamically) arranged around their actual mobility demand. Still, mobility providers will most likely maintain the concept of service areas, presumably for (financial) operational reasons. When one-way bikes can be parked everywhere, some of them will be parked at remote places, such that they are not likely to be used on short term. Taxi services can transport people over long distances, but the provider's interest is to have its return trip (partly) covered so its profitability can be guaranteed. Especially when the MaaS development will be incremental and follow a bottom-up approach. Local entrepreneurs will provide local services and it could take a long time for these services to become fully interoperable.

On the long term, it is possible that mobility services to be interoperable to a high extent and their service areas will overlap such that certain people (living near province or country borders) are not faced with sub-optimal LOS for living near (former) service area boundaries. However, on the short term all trip phases – planning, booking, ticketing, payment, guidance and evaluation - are standardized and at ease of use, except for the travelling itself. That is still bound to the limitations of the available service provider. This can result in longer travel times (detours), higher costs (cheaper services are not available), and potentially results in lower acceptance rates for MaaS use.

MaaS has a big impact on the distribution of the Level of Service (LOS) and thus the accessibility of areas. The distribution of the level of service (LOS) over areas with different PVs could develop towards the following extreme situations:

- Standardization - LOS are similar for areas with a high PV and areas with a low PV;
- Differentiation - LOS are significantly higher in areas with a high PV compared to areas with a low PV.

For the scenario of LOS differentiation it is likely this will reinforce the spatial concentration of people and activities. Mobility in rural areas will be more expensive, so urbanization will be further driven. It can also lead to hard distinctions between urban and suburban areas. Higher income groups can afford expensive urban housing and will spend only little money on mobility. Lower income groups can only afford cheaper sub-urban housing and will have difficulties paying for higher mobility prices. For the latter group, If financial resources are there, it is most likely these will be spend on mobility within the own neighborhood. Simultaneously, for many facilities like retail and businesses it is most interesting to locate in urban areas as there are more people living and people have more to spend. This can drives the inequity of rich urban areas and poor suburban areas.

On the other hand, when the LOS is uniformly distributed over both areas with low and high PVs, this will contribute to the attractiveness of poorer suburban areas. The geographical distance to the city center remains similar, but MaaS does not weaken the geographical accessibility further in these areas. Its inhabitants will face similar ride hailing times for (shared) taxi services and will not pay disproportional costs for longer travel times.

What eventually will be the case is still uncertain. A driver for the standardized LOS could be the importance of trips of people living in high PV areas to lower PV areas. When it is difficult to make such trips and it consequently affects the acceptance of MaaS for the bigger crowd, service providers need to standardize the LOS in order to provide high acceptance levels for MaaS. Differentiation of LOS could especially occur when service providers will focus on market penetration for local trips in urban areas by lower priced services with high quality standards.

Considering this information, it is questionable if MaaS is the ultimate form of mobility integration. In the first place, MaaS is a platform integrating the access to all kinds of mobility services, approaching ultimate mobility integration. Mobility providers will consider their businesses from the perspective of profitability and target groups. The concept of ultimate mobility integration will only be achieved in dense urban areas. In more rural areas, especially around service area boundaries mobility will be less effective. By means of MaaS it is possible to uniform the service accessibility, when service providers let users in urban areas pay for the accessibility in rural areas or when the government intervenes in a different way towards mobility services in urban and rural areas.

5.1.6 Legitimacy

This section questions the fairness of this mobility system. This relates to concepts in the previous sections such as the freedom of choice and exclusion. Instead of a socio-technical focus on these items, this section has a more philosophical and ethical perspective on this matter. There are two main considerations when reviewing the legitimacy of MaaS:

- MaaS: a window of opportunity vs. the yield of private ownership
- MaaS: the empowerment of local communities vs. a decrease in level of service

MaaS can be considered as – literally – a window of opportunity, improving service accessibility and encouraging rationalized decision making. MaaS is the integration platform for accessing all kinds of mobility services. According to the MaaS concept it is likely, but not necessary, that redistribution of mobility services can be facilitated via the platform. When leaving this redistribution out of scope, MaaS is simply a window of opportunity for using (new) mobility services. It enhances rationalized decision making, as within MaaS people are more aware of the available mobility services.

MaaS can be considered as much more than a paradigm change as it could yield private ownership of transportation resources. High MaaS penetration rates could impose that infrastructure is developed and facilitated such that it is no longer available for privately-owned mobility resources. The desirability of this situation can be discussed. When people have to rely fully on the availability of mobility services, service exclusion would severely affect their lives; people will not be able to participate in any kind of activity. In current mobility, ownership of transportation resources implies a certain guarantee of individual mobility. An important question is how certain mobility can be guaranteed and how this can be established within MaaS.

MaaS can empower local communities, as mobility control can be specified for specific times and areas. When there is a sufficient amount of users on the platform, the government can control mobility more easily by direct control on the mobility services. From there, the control can be different for specific areas, bringing possibilities for balancing interests in a different way. This provides people more say in how their direct, local environment looks like.

MaaS can significantly lower the threshold for mobility control measures which could impose counter effects. It will be possible to control mobility services in real-time. This would require immediate action, posing a risk of not sufficiently balancing all interests. In addition, extra risks come up when MaaS will be over-controlled. This is the case when policy-makers aim for optimal outcomes on both system and individual level at any time. By doing so, any problem awareness could be masked under the apparent perception of effective mobility. It could leave more structural problems out of scope from policy makers.

Considering the aforementioned statements in this section, it is clear that mobility governance and mobility in itself are likely to change significantly by means of MaaS; it will bring many new opportunities for improving mobility and society as a whole. However, public bodies have to reconsider how they will deploy all these control opportunities. The number of users is important for the societal impact of MaaS. From this point of view, the government should enable the growth and development of MaaS. When there are enough users of MaaS, public bodies should have a clear view on what they would like to achieve via MaaS.

5.2 System effectiveness

The section provides the qualitative assessment of MaaS in relation to the system effectiveness. The system effectiveness relates to the extent to which the system facilitates the mobility of all people. The system effectiveness relates to costs (section 5.2.1), travel times (section 5.2.2) and comfort (section 5.2.3) of mobility services. Accessibility is not taken as a separate impact factor, but can be considered as the sum of costs, travel times and comfort.

Table 9 shows an overview on accessibility. It is derived by giving costs and travel times a double weight and comfort a single weight. From this overview it becomes clear that compared to the current situation, all MaaS offerings provide better accessibility than current mobility options. Except for public transportation (*-marked), which is likely to become less effective in suburban areas. For the car-based and robocars offerings, accessibility by car-based services increases significantly. For the active & collective offering all mobility services improve, leaving taxi services behind. Hybrid public transportation improves the accessibility of all services, especially collectively-used services.

Table 9: overview on the impact factors regarding system effectiveness

	Car-based	Active & Collective	Robocars	Hybrid PT
Shared Car	++	+	++	+
PT	+/–*	+	+/–*	++
Taxi	++	+/–	++	+
Shared Taxi	++	+	++	++

Assessment is conducted on a 5-point scale varying from ++ great improvement (dark green), + moderate improvement (light green), +/– no improvement or deterioration (yellow), - moderate deterioration (orange) and - - great deterioration (red) compared to current mobility.

5.2.1 Costs

Table 10 provides an overview on the costs of mobility services. This is directly derived from the quantification of MaaS offerings in section 3.2. For the car-based scenario the costs of car-based services will improve, where public transportation becomes more expensive. For the active & collective scenario costs remain similar. For the robocars scenario relative differences in costs between services are smaller than for the car-based scenario. For hybrid public transportation collectively-used services will become cheaper.

Table 10: overview on the cost-related impact factors

	Car-based	Active + Collective	Robocars	Hybrid PT
Shared car	+	+/–	+	+/–
PT	– –	+/–	+/–	++
Taxi	++	–	++	+/–
Shared Taxi	++	+/–	++	++

Lowered costs are indicated as an improvement. Assessment is conducted on a 5-point scale varying from ++ great improvement (dark green), + moderate improvement (light green), +/– no improvement or deterioration (yellow), - moderate deterioration (orange) and - - great deterioration (red) compared to current mobility.

5.2.2 Travel times

Table 11 provides an overview on the travel times of mobility services. This is directly derived from the quantification of MaaS offerings in section 3.2. In general, travel times of all mobility services slightly improve compared to the current situation. However, it is assumed that little public interventions result in great differences in travel times by public transportation; they will strongly improve in high density areas, where other areas will face a significant decline. Based on travel time, taxi services will become more attractive for the robocars scenario.

Table 11: overview of the travel time for mobility services within each MaaS offering

	Car-based	Active+Collective	Robocars	Hybrid PT
Shared car	+	+/–	+	+
PT	++ /– – *	+	++ /– – *	+
Taxi	+	+	+	+
Shared Taxi	+	+	++	+

Lowered travel times are indicated as an improvement. Assessment is conducted on a 5-point scale varying from ++ great improvement (dark green), + moderate improvement (light green), +/– no improvement or deterioration (yellow), - moderate deterioration (orange) and - - great deterioration (red) compared to current mobility.

5.2.3 Comfort

Table 12 provides an overview on the comfort of mobility services. It is seen that except for shared car services, the comfort of all services remains similar, as the modes of transportation in itself will not be different compared to the current situation. However, for shared cars there is increased comfort as the alternative – private car ownership – is related to extra hassle such as car maintenance and cleaning.

Table 12: overview on comfort-related impact factors

	Car-based	Active+Collective	Robocars	Hybrid PT
Shared Car	+	+	+	+
Public Transport	+/–	+/–	+/–	+/–
Taxi	+/–	+/–	+/–	+/–
Shared Taxi	+/–	+/–	+/–	+/–

Higher comfort values are indicated as an improvement. Assessment is conducted on a 5-point scale varying from ++ great improvement (dark green), + moderate improvement (light green), +/– no improvement or deterioration (yellow), - moderate deterioration (orange) and - - great deterioration (red) compared to current mobility.

5.3 System efficiency

The section provides the qualitative assessment of MaaS in relation to the system efficiency. The system efficiency relates to the extent to which the system is optimized regarding the use and scarcity of transportation resources. This relates to the availability of mobility services (section 5.3.1), utilization rates of transportation resources (section 5.3.2) and VKT of both car-based services and public transportation (section 5.3.3).

Table 13 shows an overview on the system efficiency. It is derived by using the scenario-specific accessibility of mobility services (see section 5.2) to estimate future use of mobility services and resources. The most important finding is that there is a trade-off between the utilization rate of transportation resources and the VKT, affected by the extent of public interventions. The car-VKT increases, and is thus assessed lower, when automated vehicles are available.

On the next page, table 14 provides detailed insights on the factors impacting system efficiency.

Table 13: overview on the impact factors regarding system efficiency

Impact factor	Desired change	Car-based	Active & collective	Robocars	Hybrid PT
Availability	Increase	+/–	+	+/–	+
Utilization	Increase	++	+	++	+
VKT (car)	Decrease	+/–	+	–	+/–
VKT (PT)	Decrease	++	+/–	++	+/–

Assessment is conducted on a 5-point scale varying from ++ great improvement (dark green), + moderate improvement (light green), +/– no improvement or deterioration (yellow), - moderate deterioration (orange) and - - great deterioration (red) compared to current mobility.

Table 14: assessment of system efficiency via the 5 E framework

Car-based	**Efficient cities**	**Environment**	**Equity**
In urban areas many services are available. In sub-urban areas services are less available, especially public transportation. A high number of car-based services is allowed. Mobility providers will differentiate prices to acquire high utilization rates.	Limited availability of mobility services can result in sub-optimal choices from an efficiency point of view. High utilization rates of car-based services. Especially during non-peak hour potentially outcompeting public transportation, result in high car VKT.	Unequal distribution of environmental effects; relatively more car-based transportation in suburbs. High utilization rates of car-based services require little parking space. High car VKT can result in environmental burden.	Unequal spatial distribution of mobility services; substitution of higher priced car-based mobility instead of public transportation in suburbs. In addition, higher share of car-based services in suburbs result in unequal environmental impacts.
Active & Collective	**Efficient cities**	**Environment**	**Equity**
Throughout the city many services are available. The number of car-based services is limited. Mobility providers will differentiate prices only to a limited extent.	Availability of more mobility services enable efficient choices. Higher utilization rates of car-based services compared to privately-owned cars. No extra car VKT as discount pricing for car-based services will not exist.	Availability of more mobility services enables sustainable mobility services to grow. Compared to privately-owned cars less parking space is required. Moderate car VKT can result in lower environmental burden.	Equal spatial distribution of mobility services. In addition, environmental impacts are likely to be equally distributed.
Robocars	**Efficient cities**	**Environment**	**Equity**
In urban areas many services are available In sub-urban areas services are less available, especially public transportation. A high number of car-based services is allowed. Mobility providers will differentiate prices to acquire high utilization rates. Automation imposes “empty rides”	Limited availability of mobility services can result in sub-optimal choices from an efficiency point of view. High utilization rates of car-based services. Especially during non-peak hour potentially outcompeting public transportation, result in high car VKT. Car services are less efficient as also empty rides will occur.	Unequal distribution of environmental effects; relatively more car-based transportation in suburbs. High utilization rates of car-based services require little parking space. High car VKT can result in environmental burden. Empty rides will result in additional environmental burden.	Unequal spatial distribution of mobility services; substitution of higher priced car-based mobility instead of public transportation in suburbs. In addition, higher share of car-based services in suburbs result in unequal environmental impacts. Empty rides are more likely to take place in suburbs as demand are lower and it will generally take longer to access people.
Hybrid PT	**Efficient cities**	**Environment**	**Equity**
Throughout the city many services are available. The number of car-based services is limited. Mobility providers will differentiate prices only to a limited extent. Automation imposes “empty rides”	Availability of more mobility services enable efficient choices. Higher utilization rates of car-based services compared to privately-owned cars. No extra car VKT as discount pricing for car-based services will not exist. Car services are less efficient as also empty rides will occur.	Availability of more mobility services enables sustainable mobility services to grow. Compared to privately-owned cars less parking space is required. Moderate car VKT can result in lower environmental burden. Empty rides will result in additional environmental burden.	Equal spatial distribution of mobility services. In addition, environmental impacts are likely to be equally distributed. Empty rides are more likely to take place in suburbs as demand are lower and it will generally take longer to access people.

5.3.1 Availability of mobility services

The availability of mobility services determines the freedom of choice people have to move around. From a consumer's perspective a more diverse mix of mobility services is appreciated, as it is more likely to find a better mobility fit. This is related to efficient cities as services with a lower fit can be substituted to services with a better fit. On the contrary, environmental effects can occur when sustainable services can be replaced by less sustainable services.

Table 15 provides an overview on the availability of mobility services for each MaaS offering. Public interventions ensure a better mobility fit as public transportation will also be available in lower demand (sub-urban) areas. However, the rise of autonomous vehicles will make car-based services cheaper and can make these services an alternative to public transportation. Public interventions will not increase the efficiency of public transportation, as services with a low demand will still be in service.

Table 15: overview on the impact factors related to the availability of mobility services

	Car-based	Active & collective	Robocars	Hybrid PT
Availability	+/–	+	+/–	+
Urban	+	+	+	+
Sub-urban	–	+/–	–	+/–

Assessment is conducted on a 5-point scale varying from ++ great improvement (dark green), + moderate improvement (light green), +/– no improvement or deterioration (yellow), - moderate deterioration (orange) and - - great deterioration (red) compared to current mobility.

5.3.2 Utilization rates of transport resources

Utilization rates are related to the use of transport resources over time. Less resources are needed when they are used more frequently, which predominantly impacts the use of public space. In general it can be said that resources will be utilized more often as MaaS is about enabling greater availability of mobility services and resources.

Table 16 provides an overview on the utilization rates for each MaaS offering. Public interventions result in moderate utilization rates of transport resources. In these scenarios there will be no price differentiation in space and time for car-based services (e.g. taxi services at knockdown prices when there is little demand). This will result in a significant number of transportation resources unused during off-peak periods. When public interventions are pulled back, mobility providers want to acquire as much revenue as possible, especially when marginal costs for autonomous cars are low. This will result in almost full utilization of vehicles. These effects are likely to be similar amongst different areas.

Table 16: overview on the impact factors related to utilization rates

	Car-based	Active & collective	Robocars	Hybrid PT
Utilization	++	+	++	+
Price differentiation	++	+	++	+

Assessment is conducted on a 5-point scale varying from ++ great improvement (dark green), + moderate improvement (light green), +/– no improvement or deterioration (yellow), - moderate deterioration (orange) and - - great deterioration (red) compared to current mobility.

5.3.3 Vehicle Kilometers Travelled

The vehicle kilometers travelled (VKT) is related to the number of available transport resources and its utilization rates. For public transportation, this is related to the number of scheduled services. where for other services this is predominately based on demand.

Respectively table 17 and table 18 show the VKT for both car-based services and public transportation for each MaaS offering. By means of public interventions, the relative transport value (based on costs, travel time and comfort) of these services will not change significantly and thus not result in big differences in the VKT for car-based services and public transportation. The pull-back of public interventions will result in a lower VMT for public transportation as these services will wither away. Simultaneously, the VKT for car-based services increases, as it substitutes public transportation. Price differentiation will lead to knock-down prices for car-based transportation during off-peak hours and thus leading to additional VKT. Automated vehicles lead to addition VKT, as there will be more “empty rides” between successive taxi rides.

Table 17: overview on the impact factors related to the car-VKT

	Car-based	Active & collective	Robocars	Hybrid PT
VKT (car)	+/–	+	–	+/–
Number of cars	+/–	+	+/–	+
Price differentiation	– –	+/–	– –	+/–
Automation	+/–	+/–	–	–

Assessment is conducted on a 5-point scale varying from ++ great improvement (dark green), + moderate improvement (light green), +/– no improvement or deterioration (yellow), - moderate deterioration (orange) and - - great deterioration (red) compared to current mobility.

Table 18: overview on the impact factors related to the PT-VKT

	Car-based	Active & collective	Robocars	Hybrid PT
VKT (PT)	++	+/–	++	+/–
Provided services	++	+/–	++	+/–

Assessment is conducted on a 5-point scale varying from ++ great improvement (dark green), + moderate improvement (light green), +/– no improvement or deterioration (yellow), - moderate deterioration (orange) and - - great deterioration (red) compared to current mobility.

5.4 Results

This section combines the outcomes of the previous qualitative assessments. Its result is reflected in Table 19. An elaboration on this table is given on the next page.

Table 19: assessment of the full impact of all MaaS offerings via the 5 E framework

System effectiveness		Car-based	A&C	Robocars	Hybrid PT
Effective mobility					
Shared Car	Cost	+	+/–	+	+/–
	Travel Time	+	+/–	+	+
	Comfort	+	+	+	+
Public Transportation	Cost	– –	+/–	+/–	++
	Travel Time	+/– *	+	+/– *	+
	Comfort	+/–	+/–	+/–	+/–
Taxi	Cost	++	–	++	+/–
	Travel Time	+	+	+	+
	Comfort	+/–	+/–	+/–	+/–
Shared Taxi	Cost	++	+/–	++	++
	Travel Time	+	+	++	+
	Comfort	+/–	+/–	+/–	+/–
System efficiency		**Car-based**	**A&C**	**Robocars**	**Hybrid PT**
Efficient cities					
Availability of mobility services		+/–	+	+/–	+
Utilization rates of transport. resources		++	+	++	+
VKT car-based services		+/–	+	–	+/–
VKT public transportation		++	+/–	++	+/–
Environment					
VKT Car-based services		+/–	+	–	+/–
VKT public transportation		++	+/–	++	+/–
Equity					
Availability of mobility services		–	+/–	–	+/–
Utilization rates of transport. resources		+/–	+/–	+/–	+/–
VKT Car		–	+/–	–	+/–
VKT public transportation		+	+/–	+	+/–
System characteristics		**Car-based**	**A&C**	**Robocars**	**Hybrid PT**
Effective mobility					
Reliability / Robustness	++				
Access and exclusion	+				
Legitimacy	+/–				
Economy					
Reliability / Robustness	++				
Labor and working cond.	–				
Access and exclusion	+				
Environment					
Environmental sustain.	+				
Equity					
Reliability / Robustness	–				
Labor and working cond.	– –				
Access and exclusion	– –				
Spatial service structure	–				
Legitimacy	+				

Assessment is conducted on a 5-point scale varying from ++ great improvement (dark green), + moderate improvement (light green), +/– no improvement or deterioration (yellow), - moderate deterioration (orange) and - - great deterioration (red) compared to current mobility.

Table 19 successively deals with the system effectiveness, system efficiency and system characteristics. The system effectiveness and efficiency are specified for each scenario-specific MaaS offering, as the combination of mobility services and their LOS, determine in what way they are used and consequently their impact on society. Regarding the system characteristics, this relates to the distribution of mobility services and the organization and structure of the mobility system. As this is assumed to be more generic for mobility provision via MaaS, its impact is not specified for the scenario-specific MaaS offerings.

For each of these impact areas, the relevant items from the 5E framework are evaluated.
For system effectiveness this only refers to "effective mobility", as the mobility services within each scenario-specific MaaS offering determine the ease or impendences of travelling in terms of travel time, cost and comfort.
However, for system efficiency, more items from the 5E framework become relevant. This concerns the items of efficient cities, environment and equity. The efficiency of the future mobility system determines whether the city in itself can function efficiently (in terms of land use and business climate), the extent to which environmental burden is limited or mitigated and how the supplied mobility services are distributed amongst the population.
For system characteristics the 5E framework items effective mobility, economy, environment and equity are considered. The organization and structure of the mobility system directly impacts to the extend people can move themselves and can boost or retain economy-, environment and equity-related interests.

Table 19 should be interpreted by taking the current mobility system as a reference. Improvements of future MaaS offerings compared to the current mobility system are indicated in green and with a +-sign. An elaboration on the items of the 5E framework is given below.

Effective mobility
Regarding effective mobility, the mobility system becomes more robust as there are multiple mobility services available providing redundancy in case of delays or disruptions. The service accessibility improves by means of data-exchange as it will generally become more easy to use the different mobility services within MaaS. With respect to legitimacy-related impacts, MaaS could yield the use of privately-owned resources, potentially affecting the freedom to move and making people more dependent on the available mobility services. The improved (governmental) control of mobility services could negatively impact the LOS of mobility services.

When considering the different modes of transportation, the following impacts on effective mobility can be seen.

Regarding **shared cars**, the comfort of using a shared car instead of a private car is likely to increase. Users will not experience the hassle related to the ownership of a car, such as car maintenance, parking licensing, etc. With respect to costs and travel time, the use of shared cars will likely be more appealing in the car-based and robocars offerings. It is assumed that the supply of shared cars will increase in these offerings, as there will be no or limited governmental regulation on the exploitation of shared cars. Therefore, the increased use of shared cars and improved economies of scale will lead to lowered costs and shorter access times.

The attractiveness of future **public transportation** will be comparable with the current situation. Its costs will be higher in the car-based offering, by assumption that public funding will be (partially) withdrawn thus increasing the need for higher patronage revenues. Automation will decrease the costs of public transportation, especially for the hybrid PT offering. Regarding travel time, it is expected that the travel time distribution will be different for urban and sub-urban areas in the car-based and robocars offerings. In these offerings, public transportation services with lower demand, which are predominantly manifest in sub-urban areas, will disappear (partially).

Regarding **taxi services**, travel times become shorter by the increased availability of taxi services resulting in shorter ride-hailing (access) times. Generally, taxi services become cheaper by means of deregulation and economies of scale. However, for the active & collective and hybrid PT offering this impact will be limited or even non-existent as a result of increased governmental control. For shared taxi services, the impacts will be even stronger than for conventional taxi services. When the demand for shared taxi services increases it becomes easier to combine trips leading to even lower costs. For the active & collective offering decreased costs for shared taxi services are not expected, by means of increased governmental control. The presence of autonomous vehicles will lead to further improvements regarding the travel time of shared taxi services in the robocars offering.

When considering the scenario-specific MaaS offerings, the following impacts on effective mobility can be seen.

For the **car-based offering**, car-based services (shared cars, taxi and shared taxi services) become more attractive, leaving public transportation behind, especially in terms of costs and travel times in sub-urban areas. The absence of (extensive) governmental control and public transportation funding, creates opportunities and thus economies of scale for car-based services and stems the viability of public transportation services with a lower demand.

For the **active & collective offering**, only small changes in the attractiveness of the different mobility services become manifest. The travel times of both public transportation and (shared) taxi services will decrease, while the travel time of shared cars will remain similar as it is assumed that governmental interventions will limit the dispersion of shared cars throughout the city. These interventions will also lead to increased costs for taxi services.

In the **robocars offering**, car-based services and especially shared taxi services will become more appealing to MaaS users. Automation lowers the costs of these services and limited governmental control will provide many opportunities for these services to rise. It is expected that the number of vehicles (shared cars of taxis) will rise significantly, resulting in lower access and/or ride-hailing times.

The **hybrid PT offering** shows similar impacts on the attractiveness of mobility services in comparison to the robocars offering. However, the increased governmental control leads to a shift in costs enabling cheaper mobility via collectively-used services such as shared taxis and public transportation.

Efficient cities

Impacts related to efficient cities are mainly related to efficient modal choices. This concerns the availability of mobility services, where a higher number of available mobility services can impose better or worse choices in terms of utilization rates and VKT. It also concerns the (spatial-temporal) pricing of mobility services which could invoke the supply of more mobility services than necessary from an efficiency point of view. Also the number of "empty rides" of autonomous vehicles affect efficient cities, as these vehicles provide no personal mobility when they have served a customer and are moving towards a successive customer.

In general it can be said that a higher availability of mobility services will lead to lower utilization and a lower VKT of these services as they are competing for serving the same mobility demand. When considering the scenario-specific MaaS offerings, the following impacts on efficient cities can be seen.

For the **car-based offering**, the limited availability of public transportation will push the demand for car-based services. Both the remaining PT services and car-based services will face high utilization rates. During non-peak hours, lower priced car-based services could outcompete public transportation, leading to sub-optimal modal choices; users are more likely to use these services where they previously would be satisfied by the provision of PT services. The VKT of PT services will therefore be limited, but leaving the VKT of car-based services at a similar level as in today's situation.

For the **active & collective offering**, a limited number of vehicles will lead to higher utilization rates of car-based services. The presence of extensive public transportation results in a higher VKT for these services. The availability of mobility services increases, and both the utilization of transportation resources and the VKT of car-based services improve.

For both the robocars offering and the hybrid PT offering, the VKT of car-based services increases in comparison to their counterparts. For the **robocars offering**, in comparison to the car-based offering, the VKT of car-based services increases and is therefore assessed worse, as there will also be “empty rides”. Autonomous vehicles will be able to facilitate cheap direct transportation, but will be unoccupied when these vehicles travel from a served client to the next requesting client. The **hybrid PT offering**, also leads to an increase of the VKT of car-based services in comparison to the active & collective offering. Car-based services and individual demand-responsive transportation will become better available and lower priced, leading to increased mileage for these services.

Economy

Related to economy, only impacts related to the system characteristics are derived. It is plausible that improved robustness of the mobility network via MaaS will enhance the accessibility of areas and secure travel times. This leads to less travel time losses and positively impact property values by means of improved accessibility.

Regarding labor and work conditions, the number of jobs can be at risk by (vehicle) automation. The proliferation of time-based and piece-rated labor could negatively impact working conditions, as laborers can experience less job security and difficulties in earning a sufficient income.

With respect to access and exclusion, service providers will be able to (partially) shift location-based mobility towards activity-based mobility. In that case, users will be able to choose transportation towards a desired activity, instead of a given location. For mobility providers this means that they can make these trips more efficient and provide interesting activity-based offerings to users, leading to cheaper mobility.

Environment

Impacts related to environment are predominantly related to the vehicle kilometers travelled (VKT), which is considered to be a proxy for the emission of GHG, noise nuisance, etc. These impacts, which are specified for each MaaS offering, are in parallel with those which are found with respect to system effectiveness. The system characteristics of MaaS will likely impose positive environmental impacts. Fleets of mobility providers will be intensively used, are replaced faster and will generally be more modern. This will probably lead to a higher penetration rate of fuel-efficient vehicles and EVs in comparison to privately-owned car fleets, leading to a lower environmental burden.

Equity

Both system characteristics and system efficiency impacts are related to equity. With regards to system characteristics, equity is likely to be affected negatively, especially in relation to access and exclusion and labor and work conditions. The level playing field can be affected when labor and working conditions differ between mobility providers. This implicates that difference employment regulations can oppress mobility services which are more expensive to facilitate, which potentially lowers the LOS for specific areas or user groups. The use of data can enhance discriminatory behavior within MaaS and can lead in the worst case to the (partial) exclusion of specific users.

The reliability of specific mobility services is at stake in order to maintain the robustness of the mobility system. For example, disturbances of e.g. PT services can be mitigated by the redistribution of shared car fleets. Regarding the spatial service structure, it is not unlikely that the LOS will be lower around service area boundaries as not all mobility services will be operational at larger scale levels. The spatial service structure can also be positively impacted by MaaS as it has the ability to equal the distribution of the LOS over different areas.

Local communities can be empowered via MaaS, as transportation related measures can be taken for specific mobility services, neighborhoods and periods of time, creating windows of opportunity for local developments.

With regards to system efficiency, for the **car-based and robocars offering** negative equity related impacts will occur as public transportation services will be withdrawn in areas with a lower mobility demand, lowering the availability of mobility services in these areas. It is likely that the VKT for car-based mobility will relatively increase more in these areas, as car-based services can substitute for public transportation. As a positive consequence, the VKT of public transportation in these areas will lower, resulting in less nuisance in these areas.

For the **active & collective and hybrid PT offering** public transportation will be more widely available, such that impacts related to the availability of mobility services and the VKT of public transportation and car-based mobility will be comparable with today’s situation.

6 Quantitative impact assessment of MaaS

This chapter elaborates on the conducted quantitative impact assessment. This assessment is conducted in order to provide more tangible indications on the transport performance in case of full-operational MaaS. The quantitative impact assessment is conducted using future transport demand and infrastructure for the city (center) of Amsterdam.

This chapter starts with setting out the conceptual model (section 6.1), the model specification (section 6.2) and the model validation (section 6.3). This results in a concrete Excel model which is used for the actual quantitative impact assessment. The chapter concludes with its results (section 6.4) in relation to the quantitative indicators.

6.1 Conceptual model

This section elaborates on the first step of the model development, by describing its underlying conceptual model.

In section 4.1 the conceptual model regarding the willingness to use MaaS and the user behavior within MaaS is given. The conceptual modal stated in figure 19 shows how the use of MaaS and the user behavior within MaaS or for traditional mobility is modelled.

Travel behavior within the system itself (whether this is based on traditional characteristics or on the Mobility as a Service approach), is determined by the scenario-specific mobility network and the related MaaS offering.

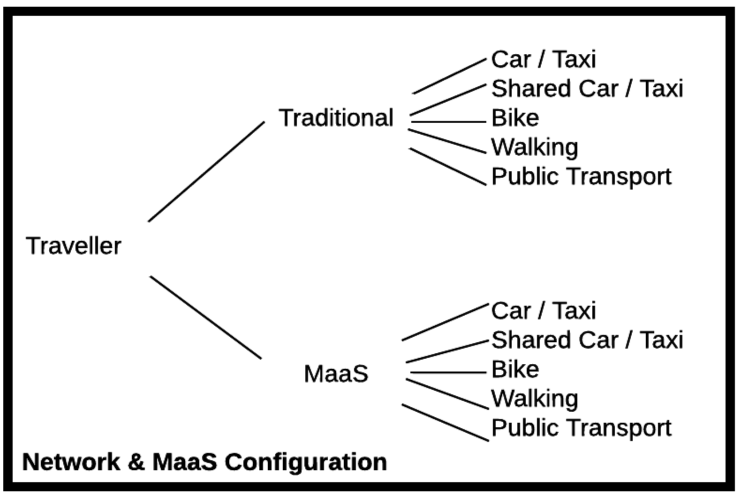

Figure 19: conceptual model for calculating the quantitative impact

First, the traveler decides whether he will use MaaS. Several person-specific factors influence the willingness to use MaaS and thus its penetration rate. These factors consist of attitudinal and hedonistic perceptions and personal characteristics such as age, gender and income.

A quantitative approach on the impact of these factors on the penetration rate is out of scope of this study. Therefore, a range of these impacts are considered via the so-called "MaaS fine". This fine is the perception of the additional disutility of travelling via MaaS, but then monetarized. In this analysis the fines vary from 0 to 250 euro.

After choosing for travelling in a traditional way or traveling via MaaS the user chooses one of the available modes of transportation, mainly based on travel costs, travel time and specific perceptions.

It should be noted there is a mutual relationship between the willingness to travel via MaaS and the network and MaaS specifications. However, this study does not take the impact of the willingness to travel via MaaS on the MaaS offering into account. The MaaS offerings are assumed to be indifferent to the number of users.

6.2 Model specification

This section elaborates in the next step of the model development, by providing the specifications of the model. An overview on the model input, process data and model output is set out in figure 20. A more detailed model specification is given in appendix VI.

The model is specified in order to predict the trip redistribution for several MaaS offerings in 2025. Input data is obtained from the VMA, the urban traffic model of the city of Amsterdam. For simplicity and validity issues, only morning peak-hour traffic is considered for trips both departing and arriving within the city center of Amsterdam. This is defined as the area within the freeway ring A10. Therefore the Amsterdam areas ("stadsdelen") Noord, Westpoort, Nieuw-West and Zuid-Oost are excluded from the model. From the original data, trips by car, public transportation (PT), bike and walking are taken into account for redistribution. The distribution of behavior groups in Amsterdam is assumed to be similar as in Beemster (2016). The preferences of these behavior groups is also set out in appendix VI.

The input data from the VMA is based on future calculations for the year 2025 in combination with the Amsterdam Realistic scenario is been used. Zonal data is aggregated to 58 zones, the so-called "buurtcombinaties", in order to obtain a less complex model.

The production and attraction of traffic in and between zones is the same as in the original data, except for the distribution over the different modes of transport. For all so-called origin-destination pairs the car-distance are determined. These are used for all modes of transportation, except public transport.

For PT the known travel times and travel costs are used. PT travel times can be adjusted in the model for specifically important and non-important lines. Important PT lines are defined by means of the VF ratio: when the travel time of a PT connection takes less than 150% of the car travel time, the PT connection is considered to be an important one.

Table 20: overview on the specified model elements

Input
OD matrix
Distances
Travel times PT
Travel costs PT
Important lines PT
Coefficients
Correction factor distance
Population characteristics
Alternative Specific Constants
Parameters
Speeds non-PT
Speed factor PT
MaaS fine
Trip purpose (VoT)
Kilometer price non-PT
Price factor PT
Outputs
Generalized trip costs
Disutilities
Number of trips
Number of passenger kilometers
Modal split
Nested disutility non-MaaS / MaaS
Penetration rates MaaS

Correction factors for distances can make connections shorter for specific modes of transportation. Only walking trips are shortened, 60% of the car trip distance. Underlying assumption is that pedestrians move more directly to their destinations. For each scenario and the related MaaS offering speeds, value of time and pricing are specified in appendix VI. The MaaS fine, used for conceptualizing the willingness to travel differently, is person-specific and its distribution is unknown. Therefore, the model uses several MaaS fines to provide more insight in the impact of this willingness.

The model produces via the generalized trip costs (the combination of travel costs and weighted travel time) and trip disutility functions, the number of trips, kilometers travelled, modal splits, and penetration rates for MaaS.

6.3 Model validation

This section elaborates on the third step of the model development, by describing the model validity and the related validation process.

For model validation, in order to fit the model to the original data given the speeds of car travel and walking are adjusted. The number of trips and passenger kilometers of car-based transportation, public transportation, biking and walking predicted by the model are compared to the original data. From the model validation is concluded that a car speed of 26 kilometer/hour and a walking speed of 6 kilometer/hour provide the best fit to the model. As the modes of transport car, taxi and shared taxi are aggregated, it is plausible that the demand distribution over these modes is less accurate. In appendix VI, an elaboration on the model validation is given.

6.4 Model results

This section sets out the results of the model study in Excel. It provides the quantitative assessment in relation to the set quantitative indicators. the literature study as part of the exploration of the MaaS concept. This section deals consecutively with the modal split in future mobility systems (section 6.4.1), trip length changes in future mobility systems (section 6.4.2), behavioral change by MaaS (section 6.4.3), user behavior in MaaS in relation to trip purpose (section 6.4.4) and the number of MaaS users (section 6.4.5).

6.4.1 Modal Split in future mobility systems

This section sets out the expected manifest modal split in future mobility systems. This is the total modal split, combining both MaaS and non-MaaS users. In figure 20 and 21 the modal splits are visualized.

Considering the modal split in relation to person kilometers (figure 20), the use of (shared) cars decreases for the AC and HPT offering. It remains similar for the CB and RC offering. It is reasonable to assume that for the AC and HPT offering car-based mobility becomes less attractive for trips which are originally dominated by car-based mobility. Higher costs and access/egress times for car-based mobility seem to be an important factor for this. For the CB and RC offering the relative LOS for both car-based and non-car-based mobility does not change significantly, remaining car-based mobility at a similar level.

The use of (shared) taxi services rises tremendously for the CB and RC offering. It is likely that improved LOS, in comparison to current pricing and access/egress times of (shared) taxi services, and improved service accessibility are the main drivers for this outcome. For the AC and HPT offering, this effect is not manifest for conventional taxi services; its modal share remains at a similar level. However, the use of shared taxi services rises for these offerings. Possible explanation is that shared taxi services provide improved mobility; although people face longer travel times in comparison to conventional taxi services, shared taxi services provide direct transportation but at lower costs.

Biking and walking usage remains similar for the AC and HPT offerings. For the CB, and especially the RC, offerings, the use of active modes decreases significantly. The latter implies that motorized transportation becomes a more interesting alternative for trips on short and medium-range distances. Considering the modal shares of the other modes of transportation, (shared) taxi services seem to be responsible for the decreased use of active modes.

For the modal split in relation to the number of trips (figure 21), similar outcomes can be seen. However, the modal share of walking is higher in general, at costs of the other modes of transportation. This makes sense as by the nature of walking, walking trips are shorter than trips by bike or motorized transportation.

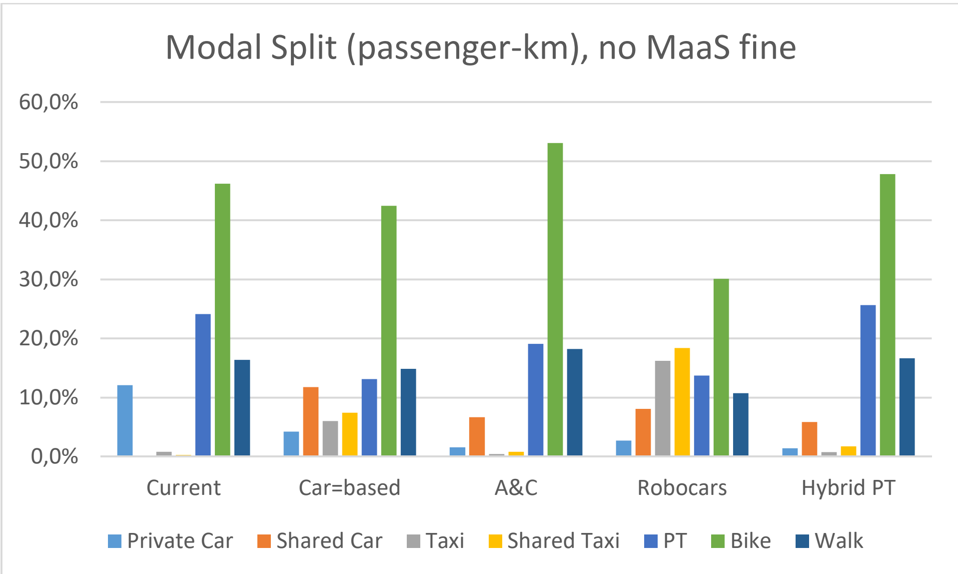

Figure 20: modal split in person-km for all future mobility systems and no MaaS fine

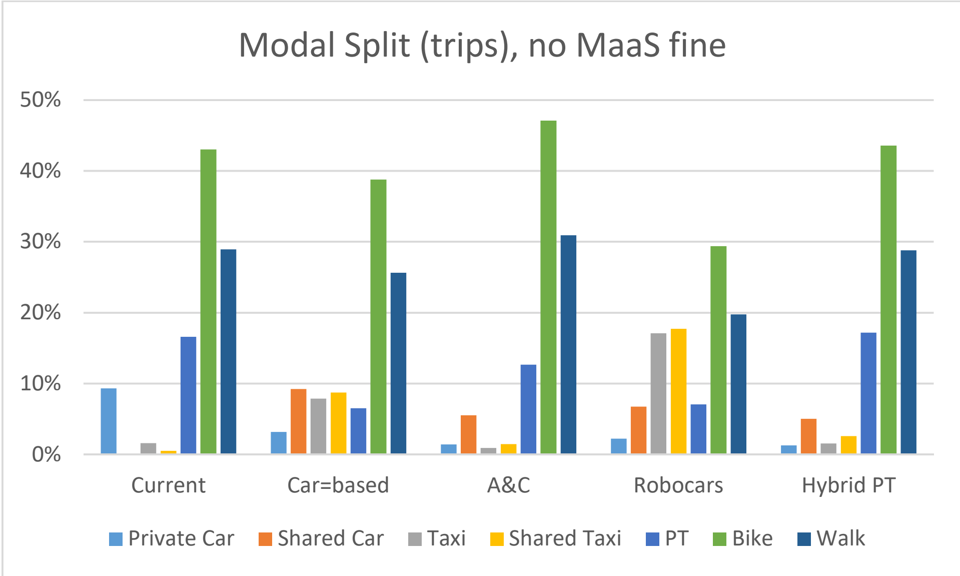

Figure 21: modal split in number of trips for all future mobility systems and no MaaS fine

6.4.2 Trip length changes in future mobility systems

This section sets out the expected trip length changes in future mobility systems. Table 21 provides an overview of the trip length changes.

These changes provide an indication about the renewed choices people make for their mode of transportation. The expected trip length are calculated as indices by taking the ratios of the modal split in person-km over the modal split in the number of trips.

Table 21: overview on the trip length changes in future mobility systems

	Trip Length Proxy (current)	Car-based	A&C	Robocars	Hybrid PT
(Shared) Car	2,22	99,1%	91,7%	92,5%	88,7%
Taxi	0,51	150,6%	88,7%	186,5%	101,1%
Shared Taxi	0,57	150,0%	102,6%	182,4%	120,7%
PT	1,45	138,2%	103,9%	133,5%	102,7%
Bike	1,07	101,9%	105,1%	95,4%	102,2%
Walk	0,57	102,5%	103,8%	96,1%	102,0%

In table 21, the trip length proxies on the far left, reflect the trip lengths in the current situation. On the right, the ratios of the modal split in person-km over the modal split in the number of trips, reflect the changes in trip length for the 4 MaaS offerings. From this table, it becomes clear that car trips are on average by far the longest. Trips by bike and public transportation on average medium trip lengths. Trips by (shared) taxi and on foot are on average quite short.

In general, average trip length indices for shared cars trip are getting lower, while the average trip length indices for taxi and shared taxi service increase significantly. It is likely that in future mobility systems, former (shared) car users are going to use (shared) taxi services.

Car-based mobility and biking are substituted by public transportation. Public transportation trips are getting longer for the CB and RC offerings. In these systems, it is likely that public transportation will be a substitute for trips by car. For the RC offering, it is likely that the longer bike and walking trips are replaced by motorized services.

6.4.3 Behavioral change by MaaS

This section sets out the behavioral change of MaaS users for all MaaS offerings. Table 22 provides an overview of the behavioral changes of MaaS users compared to the current mobility system. The left, blue indicated column indicates the modal split in the current mobility system. Table 23 provides an overview on behavioral differences between non-MaaS users and MaaS users for the 4 MaaS offerings. Note that for both tables future shared car use by MaaS users is compared with current private car use.

Table 22: overview on behavioral changes for MaaS users compared to the current mobility system

	Current (trips)	Current (km)	Car-based (trips)	Car-based (km)	A&C (trips)	A&C (km)	Robocars (trips)	Robocars (km)	Hybrid PT (trips)	Hybrid PT (km)
(Shd) Car	9,3%	12,1%	89,5%	86,0%	14,9 %	6,7 %	39,1%	28,2%	4,5%	-6,3%
Taxi	1,6%	0,8%	368,2%	592,7%	-42,7 %	-49,6 %	917,8%	1774,9 %	-5,6%	-5,3%
Shd. Taxi	0,5%	0,3%	1484,2 %	2231,4 %	171,3%	175,8%	3137,4 %	5731,1 %	380,8%	475,2%
PT	16,6%	24,2%	-62,7%	-49,0%	-26,5 %	-24,4 %	-58,8%	-45,3%	0,3%	2,3%
Bike	43,0%	46,2%	-15,7%	-16,0%	4,9%	9,0 %	-35,0%	-38,7%	-2,6%	-1,3%
Walk	28,9%	16,4%	-17,0%	-16,7%	2,4%	5,1 %	-34,9%	-38,2%	-4,4%	-3,4%

From table 22 it becomes clear that when MaaS is fully available, (shared) cars are far more used by MaaS users. Except for the car VKT in the HPT offering, this impact is clearly visible. It is reasonable to assume that this is mainly caused by the improved service accessibility to shared car services by people who first did not have access to a car.

For all MaaS offerings, shared taxi services are far more used by MaaS users than its use in the current mobility system. An explanation for this is twofold: first of all, the current modal share of shared taxi services is very low, such that even minor usage increase results in tremendous behavioral changes. On the other hand, improved LOS in terms of costs and travel times (shorter access/egress times) and improved service accessibility enable significant increase of shared taxi services.

The use of taxi services increases for the CB and RC offerings, while taxi services are less used in the AC and HPT offerings. It is likely this is caused by the price differences between these offerings. In the AC and HPT offerings, taxi services are relatively high priced, such that people are choosing alternative modes of transportation.

MaaS users are generally less using public transportation, biking and walking within MaaS. For all MaaS offerings, except the HPT offering, the use of public transportation is significantly declining. Within the HPT offering, the use of public transportation remains stable. Regarding the active modes, decreased use is visible for the CB and RC offering. For the AC and HPT offering, walking and biking respectively slightly increases and decreases. It is likely that this is caused by the increased competence with shared cars and (shared) taxi services. Especially for the CB and RC offerings, it is likely that users prefer other modes of transportation, as they are cheaper or provide faster transportation.

Table 23: overview on the behavioral changes of MaaS users compared to non-MaaS users

	Car-based (trips)	**Car-based (km)**	**A&C (trips)**	**A&C (km)**	**Robocars (trips)**	**Robocars (km)**	**Hybrid PT (trips)**	**Hybrid PT (km)**
(Shared) Car	162,6%	153,5%	267,4%	290,2%	177,1%	173,1%	267,3%	289,6%
Taxi	-9,0%	-12,3%	-5,0%	-6,6%	-8,2%	-10,4%	-5,0%	-6,4%
Shared Taxi	-9,1%	-12,6%	-4,9%	-6,6%	-8,0%	-10,2%	-4,9%	-6,5%
PT	-10,3%	-12,1%	-7,0%	-9,0%	-6,6%	-7,3%	-6,1%	-7,4%
Bike	-12,6%	-16,3%	-8,2%	-10,2%	-9,4%	-11,6%	-7,5%	-9,2%
Walk	-12,4%	-15,9%	-8,5%	-10,4%	-9,5%	-11,6%	-7,9%	-9,6%

In table 23, for each MaaS offering the percentages indicate the increased or decreased use of all modes of transportation by MaaS users in comparison to those who not use MaaS in the same mobility system.

From table 23 it can be clearly seen that MaaS users make significantly more use of (shared) cars than non-MaaS users. All other mobility services are less used by MaaS users in comparison to non-MaaS users.

The increased use of (shared) cars can be explained as it is more easy to access a shared car over a privately-owned car, as there is less hassle with finding and parking a car, which is reflected in lowered access/egress times. In addition, a significant part of the non-MaaS users doesn’t has access to a own car, where within MaaS car-based mobility is more accessible.

The decrease in the use of (shared) taxi services is limited for the AC and HPT offerings. For these and the RC offerings, the same holds for the use of public transportation. For the other MaaS offerings this decreased use of (shared) taxi services and public transportation is slightly higher. This is related to the relative differences in LOS between these mobility services and (shared) car services. The added value of (shared) taxi services and public transportation is limited for those offerings where (shared) cars can offer a sufficient contribution in cheaper and faster mobility; this is especially the case for the CB offering where shared cars are relatively cheap.

MaaS especially affects the use of walking and biking of MaaS users in the CB offering. Also here it is likely that the increased service accessibility and the relative low prices of (shared) cars are a substitute for these active modes.

6.4.4 User behavior in MaaS in relation to trip purpose

This section sets out the user behavior within MaaS users for different trip purposes. Figures 22-25 provide the user behavior for all MaaS offerings for each trip purpose. The commuter purpose, which is used for all previous results, is used for reference to show the impact of the trip purpose. In the model specification, the impact of trip purpose is only reflected in the value of time (see section 6.2). This means that when the relative differences in travel time become larger between mobility services, there will be larger differences in the modal split for the different trip purposes.

For the car-based offering, business travelers make significantly more use of car-based services. Especially, the relative changes for (shared) taxi services are big. All other services are less used by business travelers, especially the active modes. For social-recreative purposes car-based services are slightly less used. Public transportation and biking are slightly more used. Especially walking is rising for social-recreative purposes.

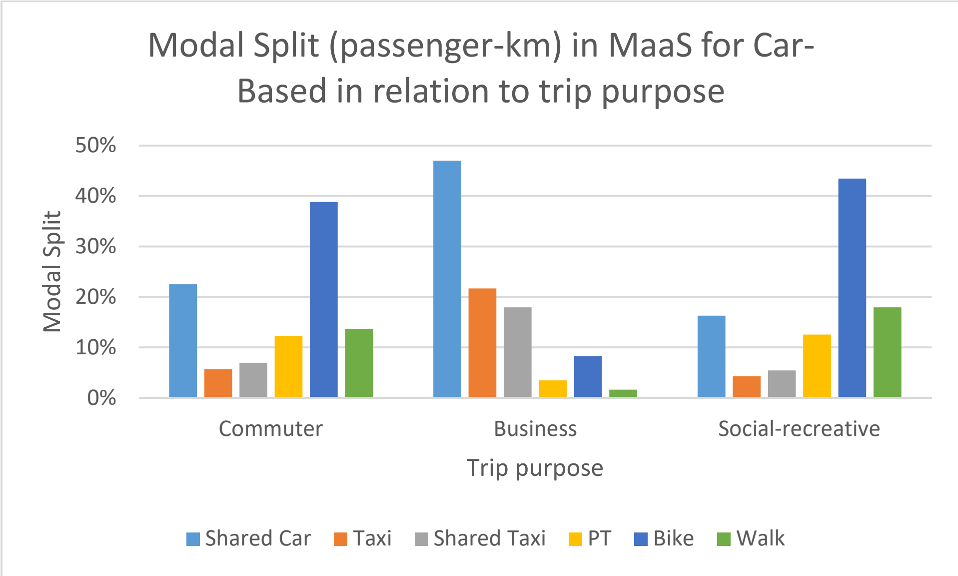

Figure 22: modal split in passenger-km for the car-based offering in relation to trip purpose

For the active & collective offering, business users make far more use of shared cars. The use of (shared) taxi services is rising, but still represents a small part of the business trips. Public transportation and active modes are less used by business travelers. Especially the use of public transportation and walking is much lower for business travelers. For social-recreative purposes, biking and walking are significantly more used. Car-based services, and especially shared cars, are less used by this user group.

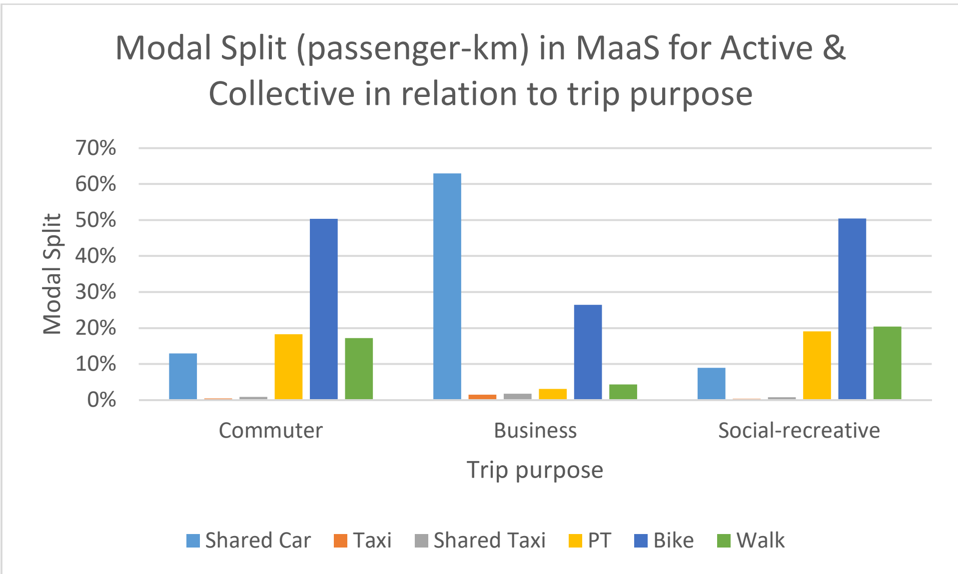

Figure 23: modal split in passenger-km for the active & col. offering in relation to trip purpose

For the robocars offering, (shared) taxi services are far more used by business travelers. The use of shared cars is slightly increasing, while all other services are significantly less used. For social-recreative purposes, the active modes are becoming more used while car-based service become less used. The use of public transportation for social-recreational purposes remains similar.

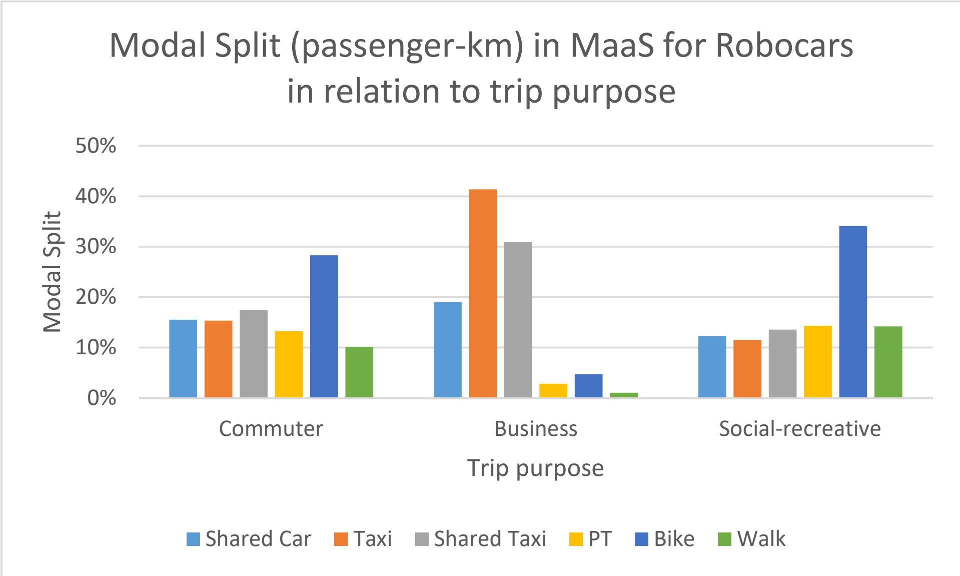

Figure 24: modal split in passenger-km for the robocars offering in relation to trip purpose

For the hybrid public transportation offering, business travelers predominantly use shared cars, albeit the use of (shared) taxi services is also increasing. Especially public transportation is less used by business travelers. The use of mobility services for social-recreative purposes, is comparable to commuter purposes with only a minor shift from car-based services towards active modes.

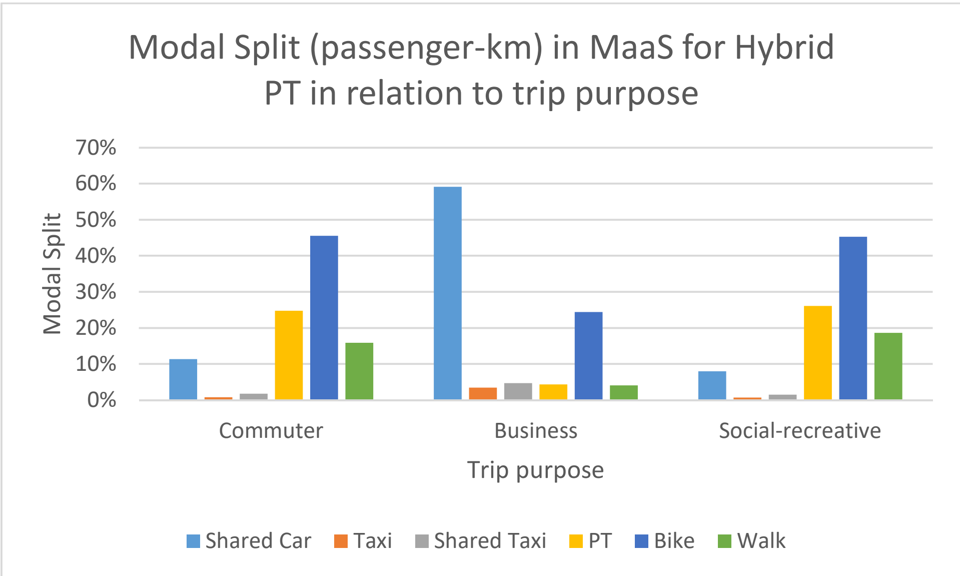

Figure 25: modal split in passenger-km for the hybrid PT offering in relation to trip purpose

6.4.5 Number of MaaS users

This section sets out the number of MaaS users for the considered MaaS fines. Figure 26 shows the related penetration rates – the percentage of MaaS users in the general population.

In order to provide a clear overview, no differentiation is made between the penetration rates for the different MaaS offerings. The weighted perceived (dis)utility for both MaaS and non-MaaS users does not differ significantly for each MaaS offering, leading to almost similar penetration rates for each considered MaaS fine.

When people do not perceive any disutility for using MaaS, the penetration rate gets slightly over 50 percent. This means that MaaS is generally considered to have a small benefit in comparison to convention mobility. When the perceived disutility of MaaS is monetarized as 100 euro, the penetration rates drop to around 15 percent. For higher perceived disutilities only a small minor of the population is willing to use MaaS.

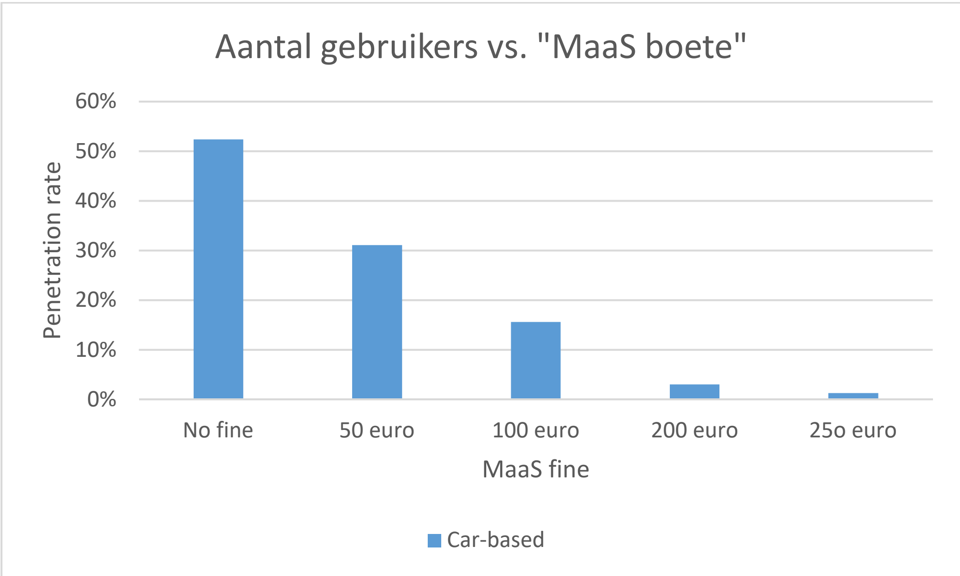

Figure 26: penetration rates for all MaaS offerings for each MaaS fine

Conclusion

Indications of the societal impact of Mobility as a Service are given are stated along the posed research questions.

- How looks the MaaS concept according to academics and experts?
- What determines the societal impacts of MaaS?
- Which impacts can be expected by implementing MaaS?
- What will be the modal split and user behavior when MaaS is fully operational?

How looks the MaaS concept according to scientist and experts?
At this moment, no clear definition and conceptualization of Mobility as a Service is present. After reviewing both literature and the conduct of expert interviews, MaaS is defined as follows:

A subscription-based service offering a wide range of combined transportation options in order to fulfill the major transportation need of its end-users within its service area, supported by a single digital interface (mobile application) which can provide full assistance during all trip phases (planning, booking, paying, ticketing, travelling, trip guidance and trip evaluation).

This definition is most directly related to the distinction Holmberg et al. (2016) makes between so-called Combined Mobility Service (CMS) and Integrated Public Transport (IPT). The first referring to the bundled accessibility to multiple mobility services, the latter referring to the technical system aspects enabling smooth travelling and the use of multiple modes of transportation. Following the abovementioned definition, MaaS concerns both the service accessibility and technical integration of multiple mobility services.

Combining and reflecting on the literature review and expert interviews the most relevant aspects of future mobility via MaaS are:

- The improved accessibility of mobility services, such that its users have more freedom of choice in the way they move themselves. MaaS makes chain mobility more attractive as it will be easier for users to plan multi-modal trips and access different modes of transportation.
- A more flexible allocation of mobility services and improved access by users to multiple mobility services, which likely results that the traditional distinctions between these services blur. This means that mobility services are increasingly interchangeable, providing opportunities for system optimization and user satisfaction.

- The distribution of mobility over a platform, which can only fully develop when all actors involved encompass open minds, most importantly by the development of open and standardized data and interfaces.
- The collective purchase of mobility services by service providers, which potentially leads to lower prices and higher service levels. By means of data, the efficiency of mobility services can be increased. The (re-)packaging of mobility services by service providers will increase the use of the included services. This can have a positive impact on the use of public transportation, when mobility providers are willing to include these services within their packages.
- The introduction of new actors in mobility and new mobility services. There are indications that new actors in mobility, for example but certainly not limited to Uber and Car2Go, will have a prominent role within MaaS. Mobility services which are hardly present today, such as one-way bike sharing and shared taxi services, can become better available via MaaS.
- Co-created services (e.g. with help from local people and non-profit organizations) such as taxi services by volunteers can complement other mobility services within MaaS and lead to a better mobility fulfillment of its users.

What determines the societal impact of MaaS?

The societal impact of MaaS is defined by the available modes of transportation and the way the mobility system is structured and organized. This determines how mobility services are used and how these mobility services can impact society.

Regarding the first, the level of service (LOS) is most important. The LOS is defined as the quality of mobility services in terms of travel times, costs and comfort and is specified for specific user groups and can be dependent on space and time. Regarding the organization of service provision via service providers the concept of service level agreements is important (SLAs). They can be considered as the arrangements between users and service providers about mobility provision in terms of process or output related requirements. This can be based on travel times and costs, but can also be operationalized in process-related terms such as request times and vehicles occupancy levels or output-related terms such as geographical accessibility.

Also the general organization of mobility via MaaS and its structure impacts society. Cost drivers and mobility demand are important determinants for the LOS, but governmental control can intervene in the LOS, which is most likely to happen when otherwise market failure and –imperfections would occur. Specific attributes of mobility services, such as for example the physical accessibility of transportation means and supported operations by real-time personal data can also lead to societal impacts.

The determination of the societal impact of MaaS is related to three different aspects, which in this report are reflected by three conceptual models. Changing demand and supply of mobility services is a result of:

- People willing to use MaaS, which is conceptualized by a push-model where attitudinal (e.g. acceptance of sharing), hedonistic (e.g. dissatisfaction of traditional mobility in terms of costs and travel times) and personal factors (e.g. age and income).
- The use of mobility services within MaaS, which is conceptualized by the presence of mobility services and their LOS, the SLA of choice, the allocative power of service providers (i.e. the ability of service providers to incentive certain behavior or rewarding users) and the distribution of mobility services (i.e. the provision of upgrades or compensation when SLAs cannot be fulfilled or the exclusion of users in order to fulfill the SLAs of others).
- The interdependencies of actors and elements of the mobility system, mainly described by the above-mentioned LOS, SLAs and governmental control. Also the demand side, including the potential value for mobility providers to deploy services in a specific area plays an important role. The latter is determined by i.a. the area density, area population, area functionality, area centrality and the distance to other areas.

Which impacts can be expected by implementing MaaS?

This question relations to the qualitative assessment of 4 possible future MaaS offerings. The assessment is conducted along the 5 items of the 5E framework.

Regarding *effective mobility*, MaaS provides redundancy in case of delays or disruptions. However, there is a trade-off between the reliability of individual mobility services vs. the robustness of the mobility system as a whole. The exchange of data improves the accessibility of mobility services. Potentially negative are the legitimacy related impacts to those who are dependent on mobility via MaaS; governmental control of mobility services can negatively impact the LOS of mobility services.

Regarding *efficient cities*, generally a bigger supply of mobility services will lead to lower utilization rates and a lower VKT of individual services for reasons of increased competition. Considering the different MaaS offerings, an extensive network of public transportation (PT) services can lower the VKT of car-based services but will simultaneously lead to generally less efficient PT as some of its services will be limitedly used (“empty busses and trains”). Price differentiation of car-based services can outcompete PT services during off-peak periods; when these services are provided at knockdown prices this would raise the VKT of car-based services. It is likely that vehicle automation will result in additional car VKT as the number of “empty rides” will increase.

Regarding *economy*, the improved robustness of the mobility system will likely enhance the geographical accessibility and secure travel times. Consequently, this leads to less travel time losses and raising property values. The number of jobs can be at risk by (vehicle) automation, while the proliferation of time-based and piece-rated labor could negatively impact working conditions, such as lowered job security and difficulties in earning a sufficient income. The shift of location-based mobility towards activity-based mobility could lead to more efficient and thus cheaper mobility.

Regarding *environment*, these impacts are predominantly related to the VKT, which is considered to be a proxy for the emission of GHG, noise nuisance, etc. This is similar to the findings in relation to efficient cities where the presence of an extensive PT network (hybrid PT offering) and the absence of vehicle automation (active & collective offering) will lead to lowered car-based VKT than their direct counterparts. Generally, MaaS will likely impose positive environmental impacts. As (car) fleets of mobility providers will be intensively used, these are replaced faster and will therefore be more modern. This probably lead to higher penetration rates of fuel-efficient vehicles and EVs in comparison to privately-owned car fleets.

Regarding *equity*, the impacts especially in relation to access and exclusion and labor and work conditions tend to be negative. The level playing field can be affected when labor and working conditions differ between mobility providers, which could outcompete disadvantaged mobility services, potentially lowering the LOS for specific areas or user groups. The use of data can enhance discriminatory behavior within MaaS and can lead in the worst case to the (partial) exclusion of specific users. Unequal distribution of mobility services can be reinforced when the robustness of the mobility system is secured by changing the operations of individual mobility services. The presence of service area boundaries of individual mobility services can affect the LOS negatively around these boundaries. The spatial service structure can also be positively impacted, as MaaS has the ability to equal the distribution of the LOS over different areas. In addition, local communities can be empowered via MaaS, as transportation related measures can be taken for specific mobility services, neighborhoods and periods of time, creating new windows for local opportunities.

What will be the modal split and user behavior when MaaS is fully operational?

Although this research question is approach by means of a quantitative assessment, it is answered by describing the quantitative results and their respective changes. This is done as the found results can only be interpreted as a first indication of the future mobility behavior by MaaS. The numbers itself can be found in the report.

Regarding *the modal split in future mobility systems* (in person kilometers), the use of (shared) cars decreases for the active & collective (AC) and hybrid public transportation (HPT) offering, where it remains similar for the car-based (CB) and robocars (RC) offering. Where the current modal split for (shared) taxi services is very small, it rises tremendously for the CB and RC offering. For the other offerings the increase is limited. In contract to the use of (shared) cars, the use of biking and walking remains similar for the AC and HPT offerings. For the CB - and especially the RC - offerings, the use of active modes decreases significantly. Future modal splits in relation to the number of trips show similar outcomes. However, because of the (short distance) nature of walking trips, the modal share of walking is higher at costs of the other modes of transportation.

Regarding *the trip length changes in future mobility systems*, average trip lengths by (shared) cars are getting shorter, while the average trip length by (shared) taxi services increase significantly. The average trip lengths by public transportation are getting longer for the CB and RC offerings, where it remains constant for the AC and HPT offerings. No significantly average trip length changes are noticed for trips by bike or on foot.

Regarding *the behavioral change by MaaS* by taking current mobility behavior as a reference it becomes clear that shared car and shared taxi services are far more used by MaaS users. Except for the (shared) car VKT in the HPT offering, this impact is clearly visible. It is assumed this is the result of the improved service accessibility to shared car and shared taxi services by people who first did not have access to a car. Also the improved LOS in terms of costs and travel times (shorter access/egress times) for shared taxi services is an important determinant for this change. For non-shared taxi services a more mixed picture is visible: its use increases for the CB and RC offerings, while taxi services are less used in the AC and HPT offerings. The relatively high prices of taxi services make people choosing alternative modes of transportation. MaaS users are generally less using public transportation, biking and walking within MaaS. Except for the HPT offering, the use of public transportation is significantly declining. Regarding the active modes, decreased use is visible for the CB and RC offering, while for the AC and HPT offering, walking and biking respectively slightly increase and decrease. Most plausible for this behavioral change is the increased competition with shared cars and (shared) taxi services.

Regarding *the behavioral differences between MaaS and non-MaaS users* in future mobility systems, users of MaaS make significantly more use of (shared) cars than non-MaaS users. All other mobility services are less used by MaaS users in comparison to non-MaaS users. The increased use of (shared) cars can be explained as it is more easy to access a shared car over a privately-owned car, as there is less hassle with finding and parking a car, which is reflected in lowered access/egress times. In addition, a significant part of the non-MaaS users doesn't has access to a own car, where within MaaS car-based mobility is more accessible. Specifically in the CB offering, MaaS users travel far less by public transportation and active modes. It is most likely that there is only limited added value of these mobility services in comparison to shared car services, as the latter can provide cheap and fast mobility.

Regarding *the user behavior in MaaS in relation to trip purpose*, by taking the commuter trip purpose as a reference, business travelers make significantly more use of car-based services. For the CB and RC offerings this is mainly visible in the increase of (shared) taxi use. For the AC and HPT offerings, business travelers use predominantly shared cars. The use of public transportation and active modes decreases significantly for this group, while in contrast, the use of these services increases for people with a social-recreative trip purpose.

Regarding *the number of MaaS users*, the penetration rate of MaaS gets slightly over 50 percent when no general disutility to the use of MaaS is perceived. This means that MaaS is generally considered to have a small benefit in comparison to convention mobility when only the LOS of its mobility services is considered. When the perceived disutility of MaaS is monetarized as 100 euro, the penetration rates drop to around 15 percent. For higher perceived disutilities only a small minor of the population is willing to use MaaS.

Discussion

In this section an elaboration is given on the conclusion of this report. This section reflects on the methodological approach, research results and provides an interpretation of these results. This brings up the research limitations and recommendations for further research.

In general, considering the limited amount of time and preliminary knowledge about MaaS, the conducted research answered the research questions in an indicative manner. This is in line with the purpose of this research. Albeit, further research is needed in order to sharpen the understanding of MaaS. This research can be useful as a starting point for this research as it reveals knowledge gaps and possible approaches for future research. In this section, the report chapters and its related research questions are discussed sequentially including these knowledge gaps and recommendable research approaches.

Regarding the research demarcation, the research was scoped down to the impacts of full-operational MaaS and the quantitative assessment was limited to the urban areas of Amsterdam. The choice for scoping down to full-operational MaaS generally implied that only long term impacts were considered. Consequently, the transition period towards full-operational MaaS was not taken into consideration. This transition period can have specific societal impacts, which can determine the positions and attitudes of relevant actors regarding the development of MaaS. Additionally, this transition period can be valuable on the longer term as learning effects can appear. The so-called “lessons learned” during this period can lead to adjusted societal outcomes on the longer term. This means that societal impacts on the longer term are more uncertain.

Limiting the quantitative assessment to the urban areas of Amsterdam has even bigger implications on the future societal impacts of MaaS. However, this demarcation is justifiable considering the limited time available and the provision of insights without considering tremendous amounts of data. Apart from different demographic compositions between urban and sub-urban or rural areas, the dynamics and characteristics of intra-urban mobility and urban-rural mobility are expected to be different. In order for MaaS to be attractive on a broader spatial level, these dynamics and characteristics need to be taken in to account. Otherwise, MaaS cannot provide a full alternative for conventional mobility for those with a mobility demand which is not limited to urban areas. Or stating it differently: when urban-rural mobility is not sufficiently met by MaaS, these users will less likely use MaaS which consequently affects mobility outcomes.

Chapter 2 explored the concept of MaaS. This chapter was therefore directly related to the research question: How looks the MaaS concept according to academics and experts? The expert interviews provided interesting insights and additional value on what is stated in existing literature. In that sense, the set-up and conduct of these expert interviews was very useful for this report. The set-up of a literature review in combination with the consultation of experts, leaded to a clear overview of MaaS and the different perspectives which currently exists. However, there was room for improvement regarding the conduct of the expert interviews. A structured interview plan was already available, but this plan could be handled more strictly during the interview sessions itself. This would have eased the deduction of the most important results and would have saved the scarce time of the interviewed experts. The first interviewed experts could have been questioned more thoroughly (by asking questions such as: “why do think this?”, “can you give an example of this?”, etc.) in order to get more concrete insights in the concept of MaaS.

In chapter 3 several MaaS offerings were specified. This can be considered as an elaboration on the MaaS exploration. This chapter provided insights in this broad spectrum of possible MaaS offerings. However, these insights provided only a shallow, general overview on how MaaS can be offered to users. Its added value is that the defined MaaS offerings provide a more tangible MaaS concept for the reader. In addition, the defined MaaS offerings provided the fundamentals for both the qualitative and quantitative assessment.

One of the most important remarks regarding this chapter is that it is still unclear what the future MaaS offerings will be. The method of intuitive scenario development can be considered in parallel to the current thoughts of experts and mobility practitioners about future MaaS offerings. Hard evidence is lacking, but many experts have their own thoughts about it. In order to guarantee the model validity of future impact studies it is recommendable to gain a better understanding in these MaaS offerings and taking more of its characteristics into account. Contribution from other academic fields, such as business and public administration, could especially be valuable regarding these characteristics, such as the dynamics of pricing (over time, space and between transportation services) and governmental constraints (e.g. service tendering and permits, parking regulations, etc.).

The MaaS offerings were developed along the most important scenario factors (the availability of automated driving and the extent of governmental interventions). However, it is not clear if these factors determine MaaS offerings, or that the development of MaaS drives increased automation and governmental interventions. Valid arguments on this chicken-egg dilemma are available on both perceptions. However the willingness to share was not taken as a specific scenario factor – it was considered to influence the number of MaaS users in the theoretical framework – it should be noted that sharing can also drive MaaS or vice versa. Information on these factors in relation to MaaS is valuable for scoping future research. This research can either focus on the investigation of full-operational impacts (in extension of this research) or can provide analytics on the need and/or critical mass to drive sharing, automation and governmental interventions.

Chapter 4 provided a theoretical framework for the impact assessment of MaaS. This framework consisted of three conceptual model regarding the number of MaaS users, the use of mobility services and the mobility system itself. Respectively, these conceptual models related to the three important questions which need to be answered in order to assess the impact of MaaS; (1) who is going to use MaaS?, (2) what is their preferred service level agreement (SLA)? and (3) what will be the availability of mobility services?. By providing this framework, it became clear how the societal impact of MaaS can be determined. The impact assessment focused on the first and third questions as these are the most tangible to approach. The second question needs additional research, as the outcomes regarding the preferred SLA are very important for the impact assessment of MaaS. Users tend to choose a SLA which serves their mobility needs the best with regards to its costs. For the current assessment, users had unlimited access to all kinds of mobility services at fixed costs. It is likely this does not represent the future reality of service provision via MaaS.

The conceptual model related to the number of MaaS users (section 4.1) was grounded thoroughly on existing insights regarding human behavior, and more specifically mobility behavior. It considered background variables such as personal characteristics, attitudinal and hedonistic factors, allowing people to use MaaS (with its specifications) within a context of normative beliefs and perceived effectiveness of MaaS to meet someone's mobility needs. The resulting (dis)utility from these normative beliefs and perceived effectiveness was monetarized in the so-called "MaaS fine". It is recommendable to conduct future research on improved understanding on the motivation and considerations of people for using MaaS and the choice of a specific MaaS offering and mobility services (the latter are discussed in the next section). Information is needed on which factors are most relevant. Apart from personal or household attributes, such as age, gender and income, this can be attitudinal or hedonistic factors. Even other – less tangible – factors, such as the mobility demand, the volatility in mobility demand and special needs (work-related mobility, transportation of children and pets) could be important for using MaaS. Regarding attitudes, it is important to find out what its determinants are and how these can be controlled. By gaining these insights, there will be no need for the use of an abstract "MaaS fine" as a proxy for the perceptions of (potential) users.

The conceptual model regarding the use of mobility services (section 4.2) described thoroughly what the choice of MaaS users for specific mobility services determines. This conceptual model connects with the findings from the MaaS exploration in chapter 2. As stated before, this conceptual model was used limitedly for both the qualitative and quantitative assessment. Future research should focus on how the person-specific SLA of choice can be implemented in transportation models. This requires more detailed and specialized MaaS offerings, for example offerings for specific groups (e.g. students or business travelers) and preference groups (requiring unlimited car-based transportation or unlimited public transportation). The development of more elaborate analytical models could support this research. By changing the availability and pricing of mobility services and all relevant user parameters in this model, a broader perspective on how MaaS will be used can be provided. Specifically the following items should be included into these analytical models: the spatial-temporal dynamic LOS for each mobility service, the incentives and bonuses which can be provided by service providers to its users and the possible upgrades and exclusion of mobility services. Specifically these forenamed characteristics distinguish the MaaS concept from conventional mobility and are likely to determine the MaaS specific mobility performance. When such an analytical model is developed, the structure and organization of the mobility market should be taken into account. For example the presence or absence of a level playing field (between mobility providers) could potentially have a significant effect on how mobility services are distributed towards MaaS users.

The conceptual model regarding the supply of mobility services (section 4.3) described the interdependencies within the mobility system. It described how the LOS for each mobility service is determined. The model was predominantly used to support findings from the qualitative assessment. Albeit its scientific validity can be discussed, the added value of the conceptual model lies in the contributing approach towards a better understanding on how elements of the mobility system are linked with each other. The conceptualized relationships only reflected the first-order impact of MaaS on the mobility system. Second-order impacts, e.g. changes in geographical accessibility or consumer's interest, were therefore not taken in to account. It is likely that these play a significant role in how the supply of mobility services within MaaS, and thus its impact, will develop over time. Therefore, in future research these second-order impacts should be taken into further consideration. However, as these second-order impacts tend to be complex alternative research methods should be considered, for example by means of a Land Use and Transport Interaction (LUTI) model. Depending the scope of research, relationships between intermediary factors can be better determined. In the current conceptual model, the direction of these relationships was defined but not the correlation of its connecting factors with each other. As there are also feed-back loops present in the conceptual model, the required time for impact to occur (time delay) needs to be addressed. This conceptual model can be used for quantitative studies when these correlations and time delays are defined. For the qualitative assessment, the recently proposed 5E framework was used. This framework is very helpful for the conduct of such an assessment because it does not limit mobility-related impact to traditional measures in terms of traffic and transport performance. Therefore, other impact types could be made more explicit. The 5E framework does not prescribe how the assessment of the different impact types needs to be conducted. This was not considered to be a problem, but it can complicate addressing the validity of the actual assessment via this framework.

Chapter 5 provided the qualitative impact assessment of MaaS. Many of the found impacts were deducted from the proposed conceptual models. In addition, some of the found impacts were induced from empirical findings of related developments – concerning the virtualization and digitalization of life by means of social media and interactive digital platforms - such as Uber and AirBnB. The qualitative impact assessment can be further improved by a better integration of the impact factors to the characteristics of MaaS. This especially concerns the importance of data and the impacts related to the (non-)organization of a level playing field. This would require more in-depth literature research and more extensive expert interviews in order to have an improved understanding of these impacts.

The qualitative assessment results were predominantly based on the 4 scenario-specific MaaS offerings. These offerings were only specified to a limited extent and it is unclear whether these offerings will be realistic for future MaaS development. Therefore, the found impacts related to these offerings have mainly an indicative value.

In addition to this qualitative assessment it is recommendable to get a better understanding about the likelihood of these impacts to happen and their respective impact sizes. By conducting a so-called risk assessment it becomes clear which impacts are the most urgent and require the most attention. Future research needs also to be concentrated around the development of best practices. As several MaaS pilots are currently being conducted, the experiences from MaaS users, service and mobility providers and other relevant stakeholders need to be described. From there, it needs to become clear which problems arise when MaaS is deployed. In addition, their perceptions on future MaaS developments and their proposed actions should be derived.

From the qualitative assessment, indications for negative equity-related impacts were given. Specifically these impacts should be taken into further consideration along developing, introducing and operating MaaS. More research should be conducted towards this topic as many equity-related impacts are still unclear and they could manifest in many different ways. What is clear, is that a significant part of the population could be affected. This makes that these impacts cannot simply be neglected.

Chapter 6 provided the quantitative impact assessment of MaaS. Most important to address is the validity of the developed assessment model. The validity needs to be considered in relation to the purpose of the model which was to produce indicative numbers instead of very accurate and precise predictions of future mobility behavior via MaaS. As there is no data about mobility behavior via MaaS available and time was limited, the model was only checked whether it produced a similar modal split in the current mobility network. This was only done by changing the operational speeds of the modes of transportation. For future work this can also be done by changing respectively the alternative specific constants of each mode of transportation and the scalar parameters for the nested logit structure. However, this requires data about individual discrete modal choices which for this study were not available. The application of the value of time (VOT) seemed to be valid, as the VOT numbers were derived from recent studies.

The model results itself were in line with the reasoning prior to the development of the model; the model indicated the increased attractiveness and use of car-based services within MaaS and provided the need for more extensive models, where trip purposes and subscription packages are taken explicitly into account.

As stated in earlier sections, so-called "MaaS fines" were used to monetarize the resulting (dis)utility from the normative beliefs and perceived effectiveness of MaaS. For this study only positive MaaS fines were used. This represented a generally perceived disutility for each MaaS offering, where negative MaaS fines would have represented a generally perceived utility of the MaaS offerings. Thie latter can be the case when the general public is aware and convinced that MaaS brings added value in comparison to conventional mobility. It was assumed that the limited awareness of MaaS and risk-avoiding behavior in larger parts of society will initially not result in negative MaaS fines. However, for future research it is recommendable to take the perceived added value of MaaS into account. In addition, these MaaS fines are person specific and also depend on the available MaaS offerings. Future research can be improved by taking a distribution of this MaaS fine for the considered population instead of a fixed fine. Survey-based statistical research, for example by means of conjunct analysis representing possible MaaS offerings, could reveal data about the (dis)utility people expect from MaaS and its distribution.

As the developed model was only very basic, no attention was given to the dynamics of pricing over space and time. It is plausible that this will happen within MaaS. A more accurate quantitative model would therefore take these dynamics into account.

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Appendix I Expert interview structure and questions

- Introduction
  - What is the definition of MaaS?
- MaaS development
  - Who and what determines who MaaS will look like?
  - What are the drivers for MaaS development?
- MaaS concept
  - Which modes of transportation are available within MaaS?
  - What will be the level of service within MaaS?
  - If so, how will governmental intervention on MaaS look like?
- Adoption of MaaS
  - Who will be the early adopters of MaaS, and why?
  - What will determine the willingness to use of MaaS? (service adoption)
  - Will MaaS in the end be used by the majority of people?
- Travel behavior of MaaS users
  - What will determine the behavior of users within MaaS?
- Market failure and imperfection
  - What are possible market failures and imperfections?
  - Who will this affect?
  - How can be dealt with these market failures?

Interview Ron Bos

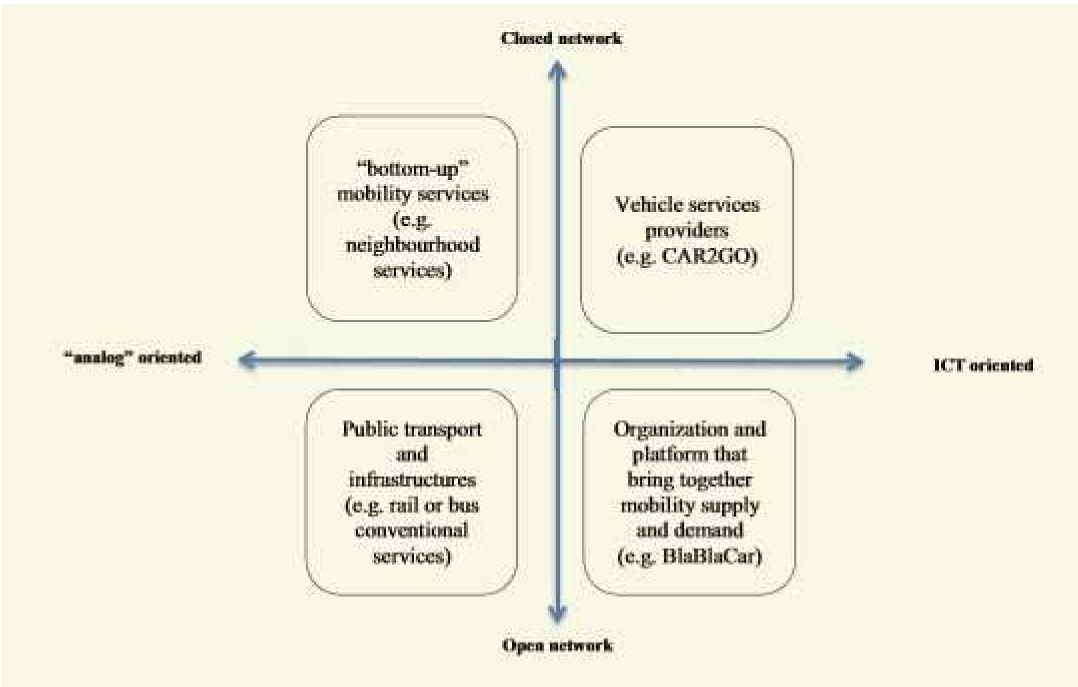
's-Hertogenbosch, maandag 9 januari 2017

Ron Bos en Roy van Kuijk

Introductie
Ron stelt zich voor. Hij werkt sinds circa een half jaar bij de gemeente 's-Hertogenbosch en is naast planoloog ook trendwatcher op het gebied van toekomstige mobiliteit. Vanwege zijn opleiding en huidige functie heeft hij vooral een verkeerskundige en ruimtelijke kijk op MaaS.

Definitie
MaaS is een digitaal platform waarbij iedereen die mobiliteit aanbiedt kan aansluiten. Het gaat daarbij niet om "of, of, of", maar om "en, en, en". MaaS biedt daarbij zowel multi-modaal als synchro-modaal vervoer aan. MaaS is geen vervoermiddel, maar maakt dat grenzen tussen vervoermiddelen gaan vervagen. In MaaS is daarbij zowel aandacht voor "smart, shared en social", waarbij het dan respectievelijk gaat om het efficiënter inzetten van vevoermiddelen, het delen van vervoermiddelen, en het beoordelen en uitwisselen van ervaringen tussen gebruikers (aanbieders en vragers).

Conceptualisatie
Om structuur te geven aan MaaS gebruikt Ron onderstaand schema dat weergeeft welke organisatievormen voor mobiliteit er bestaan.



Het kwadrantenmodel geeft aan waar mogelijke spelers binnen het ecosysteem te vinden zijn. Elk kwadrant heeft specifieke spelers en gebruikersgroepen. De belangrijkste vraag is waar MaaS start en of een grote speler van binnen of buiten het speelveld afkomstig zal zijn. Mede gelet op het "innovatiedilemma" is het te verwachten dat innovaties ontstaan vanuit nieuwe partijen die eerst nichemarkten gaan aanboren. De vraag is in hoeverre een bedrijf in staat is om vanuit zijn huidige positie alle gebruikersgroepen tevreden te kunnen stellen.

Belangrijk daarbij is dat het huidige OV concessiemodel erg star is, al komt er langzaamaan wat meer experimenteerruimte beschikbaar.

MaaS zal op termijn door de markt gedragen worden, waarbij er nauwelijks sprake van subsidies zal zijn. De overheid zal zich terughoudend opstellen, maar gaat mogelijk restricties opleggen om negatieve effecten te voorkomen en heeft een regierol om sociale mobiliteitsinitiatieven te vermarkten die anders niet kunnen ontstaan vanuit de markt, bijvoorbeeld op het platteland (die functie heeft OV nu ook al).Er zullen – zoals in de mobiele telecom – meerdere platforms en aantal grote aanbieders ontstaan.

Drivers
Ron ziet hoofdzakelijk congestie/bereikbaarheid als belangrijke drijfveer. Duurzaamheid (zowel milieu als sociaal) zijn samen met het stimuleren van innovatie andere relevante drijfveren. Op dit moment worden de mogelijkheden verkend om voor het Paleiskwartier de bereikbaarheid te verbeteren door een MaaS oplossing. Ron merkt op dat voor kleine kernen er heel andere drivers zijn. Het gaat dan vooral om leefbaarheid en sociale duurzaamheid.

Gebruikers
Specifiek voor de casus in het Paleiskwartier zijn het studenten en forenzen die in het gebied werken of naar school gaan. Kijk je meer algemeen dan verwacht hij dat aan de 'voor- en achterkant' juist de gebruikersgroepen voor MaaS zullen ontstaan:jongeren en de gepensioneerden. Juist deze groepen zijn afhankelijker van andere vervoerwijzen dan hun eigen auto.

Gebruik zal in het algemeen verder ontwikkelen als werkgevers hun medewerkers andere keuzes laten maken. Dit kan dan gedreven worden vanuit een idealistische insteek (milieu, sociaal, gezondheid), maar kan ook om de eigen bereikbaarheid te verbeteren of om kosten te sparen.

Ron benoemt dat een goede implementatie wel erg belangrijk, waarbij hij de introductie van de OV-chipkaart ziet als een voorbeeld zoals het niet moet. Early adopters kunnen dienen als bèta testers die het product eerst verder kunnen verbeteren, waarna het grootschalig kan worden aangeboden.

Marktfalen en –imperfecties
Vooral op het platteland zal geld nodig zijn om een goede bereikbaarheid te waarborgen omdat hier te weinig dichtheid bestaat voor de markt (vraag en aanbod). Kijk je binnen de stad dan zullen er vooral planologisch marktfalen zijn doordat de kans bestaat dat er juist teveel voertuigen komen. Nog steeds zal de behoefte bestaan om negatieve externaliteiten te beheersen. Daarnaast dient het gebruik van een (gedeelde) auto niet enkel iets te worden voor hogere inkomensgroepen (zie AirBnB).

Most likely outcome
Ron vergelijkt de marktstructuur met de longtail. Een belangrijk deel van de markt zal door enkele grotere spelers worden verzorgd. Er zullen daarnaast vele kleine partijen ontstaan die zich richten op een specifieke niche.

Interview Hans Stevens

Delft, donderdag 15 december 2016

Hans Stevens en Roy van Kuijk

Introductie
Nadat ik mezelf kort heb voorgesteld, stelt Hans zich voor. Hij is mobiliteitsmanager bij de Verkeersonderneming (VO). De VO bestaat nu 8 jaar en is ontstaan vanuit het havenbedrijf en de gemeente Rotterdam. Daar haakten het ministerie van I&M en de toenmalige stadsregio bij aan. Vanuit deze samenwerking is de VO als brede uitvoeringsorganisatie aan de slag gegaan.

Als eerste wapenfeit is spitsmijden/spitsbelonen ontstaan. Mensen krijgen tijdelijk betaald om uit de spits te blijven. Regelmatig werd daarbij met overheid/bedrijven gesproken welke problemen zij zagen m.b.t. havenmobiliteit en welke prioriteit zij hier aan gaven. In de praktijk blijkt dat de overheid vaak een langere termijnvisie heeft dan het bedrijfsleven. Het spitsmijden was een eerste vorm van samenwerking met de markt, waarbij er sprake was van een prestatieafspraak bij de winnende marktpartij.

Marktplaatsbenadering
Er zijn inmiddels 3 aanbestedingsrondes geweest voor projecten die leiden tot duurzame gedragsverandering. Spitsbelonen is daar de aanjager in geweest. Dit blijkt effectief te zijn, maar een duurzaam effect (dus maximaal 6 maanden financiële compensatie) is vereist. In de 3 aanbestedingsrondes ging het daarom over nieuwe mobiliteitsdiensten. De VO financiert maximaal 50% van duurzame business cases. Twee belangrijke criteria voor de projecten zijn dan ook dat ze na een bepaalde aanloopperiode geheel zelfstandig (zonder subsidiegeld) moeten kunnen zijn en dat er een daadwerkelijk spitsmijdend effect is.

Myjini is een goed voorbeeld van een dergelijk project, waarbij gebruikers credits kunnen verdienen met “goed gedrag”. De focus zal voor de komende periode komen te liggen op grotere projecten die gedragen zullen worden door consortia voor meer impact. Hierbij wordt een stap gezet op weg naar Mobility as a Service, of liever: ontzorging van de reiziger van deur tot deur.

Mobility as a Service
Hans geeft onderdelen van een definitie: MaaS omvat een platform waarbij alle aspecten van reizen (plannen, boeken, reizen, ondersteuning, aanpassingen bij verstoringen, betalen) worden gefaciliteerd en de focus op de eindgebruiker ligt. De eindgebruiker heeft dan 1 aanspreekpunt voor al zijn reizen. Op termijn horen daar abonnementsvormen bij.

Hans stelt me gelijk op de hoogte dat er een dezer dagen een persbericht uitkomt dat Rotterdam met één portal voor alle vervoermiddelen gaat werken. Daarmee komt MaaS al iets dichterbij.

Dat platform gaat zich focussen op 4 gebieden: BAR-gemeenten, Drechtsteden, Voorne-Putten en haven en Schiedam-Vlaardingen. Het idee m.b.t. MaaS is dat er maatwerk komt voor de inwoners en bedrijven van deze gebieden. Daarmee ontstaat een mooie aanvulling op het “standaard aanbod” binnen MaaS.

Hans denkt voor maatwerk te kunnen zorgen door niet vanuit een negatieve focus mobiliteit aan te vliegen (“mobiliteitsarmoede”), maar door te spreken op een positieve manier: mobiliteitsgeluk! En daarbij de vraag te stellen wat mensen nodig hebben, zodat ze meer mobiliteitsgeluk kunnen genieten. En dan daar MaaS aan te koppelen. MaaS gaat dus niet alleen over files oplossen, maar ook over de sociale kant van mobiliteit.

Hans geeft als voorbeeld dat jaarlijks veel geld gaat richting het reguliere openbaar vervoer. Een klantgerichte MaaS-aanpak kan er wellicht aan bijdragen dat beter enefficiënter kan worden aangesloten op dit reguliere openbaar vervoer, en kan wellicht zelfs onderdelen vervangen.

Interview Sandra Nijenstein

Den Haag, donderdag 19 januari 2017

Sandra Nijenstein en Roy van Kuijk

MaaS Definitie
MaaS is de integrator waardoor de grenzen tussen modaliteiten vager worden. MaaS is tweeledig en omvat (1) het ontstaan van een dienst middels het vrijgeven van data en de API's en (2) het ontzorgen van de gebruiker door de volledige keten te organiseren (van reisadvies en reservering tot betaling). MaaS is daarmee een spreekwoordelijke paraplu die alle modaliteiten afdekt.

MaaS Partijen
Het zal de gebruiker/reiziger zijn die bepaalt hoe MaaS eruit gaat zien, omdat MaaS vanuit marktpartijen zal komen. Voor de traditionele vervoerpartijen zal het erg zoeken zijn. Een kwalitatief MaaS concept is waarschijnlijk makkelijker te ontwerpen wanneer je niet vanuit bestaande structuren (waaronder concessies) denkt, maar als partij los van dergelijke structuren staat. Dat MaaS ontstaat vanuit "nieuwe" marktpartijen is daarom het meest waarschijnlijk.

MaaS Concept
Binnen MaaS ontstaat een aaneenschakeling van modaliteiten. Oorspronkelijk kan het traditioneel OV en privaat vervoer (auto/taxi) onderscheiden worden. Door de aanvuling met deel concepten (auto en fiets), vraagafhankelijk vervoer en gedeelde taxi's ontstaat de aaneenschakeling van modaliteiten en wordt deze verder verdicht. HTM wil graag wat meer in die tussenruimte gaan doen omdat deze steeds belangrijker gaat worden en nodig zullen gaan zijn voor een totaal mobiliteitssysteem. Gedeelde modaliteiten kunnen het OV versterken en zorgen voor een beter alternatief voor de auto. Zie bijvoorbeeld de reeds bestaande initiatieven: Breng Flex (regio Arnhem-Nijmegen) en Abel (Amsterdam). Breng Flex is OV en wordt door sommigen gezien (en roept daarom ook weerstand op) als vervanging voor traditioneel OV. Abel daarentegen wil complementair zijn aan andere modaliteiten en heeft daarom ook een andere prijsstelling (geen standaard OV-tarief).

Kenmerkend voor HTM is dat ze verbonden zijn aan de overheid. De concessie is niet alleen verleend door de overheid, de overheid is tevens aandeelhouder. Dat maakt dat HTM niet zomaar nevenactiviteiten kan ontplooien, maar op zijn minst politieke goedkeuring moet krijgen. Daarin verschilt HTM met bijvoorbeeld Transdev die meer vrijheid hebben over hun eigen kapitaal.

Modaliteiten en Level of Service
Modaliteiten bestaan (in ieder geval) uit: deelfiets, -auto en –taxi (vraagafhankelijk vervoer), parkeer- en rijdfaciliteiten, stallingen en parkeerplaatsen, auto, taxi, fietsen/wandelen en uiteraard ook het OV.

Een aantal trends zijn waar te nemen. We gaan naar grotere halteafstanden. Dat is mede afhankelijk van het soort OV (tram vs. Randstadrail) en de functie die het OV heeft. Automatisch vervoer zal ervoor zorgen dat "bestuurders" hun reistijd anders kunnen gaan besteden. De rol van OV en automatisch vervoer wordt met name bepaald door de behoefte aan doorwerken in het voertuig, de onzekerheid van automobiliteit (files, parkeermoeilijkheden, kosten), maar uiteraard ook de kosten van toekomstig OV en automatische vervoer.

Daarnaast zien we dat halte-inrichtingen steeds geavanceerder worden met bijvoorbeeld digitale real-time reisinformatie.

Ten aanzien van het OV-netwerk in de stad is waar te nemen dat de grote lijnen steeds dikker worden en in gebieden waar de vraag steeds diffuser wordt dienstregelingen worden uitgedund. Deze tendens zal aanhouden, vanwege het zelfversterkend effect dat plaatsvindt.

MaaS Drivers
Door het ontsluiten van verschillende modaliteiten wordt ketenmobiliteit bevordert en tevens een latente vraag geactiveerd. Dat verbetert verdienmodellen in de mobiliteit. Daarnaast kan de overheid een aanbesteding doen voor een MaaS platform. In dat geval zijn het bevorderen van OV gebuik of het verbeteren van de bereikbaarheid belangrijke drijfveren.

MaaS gebruikers
De eerste gebruikersgroep bestaat uit mensen die een smartphone hebben. Sluit grotendeels aan bij de huidige OV gebruikersgroep, al is het gebruik van smartphones door een belangrijke OV-gebruikersgroep, 65+-ers, veelal beperkt. Het kan ook een uitkomst bieden voor mensen die infrequent reizen en daarmee gemakkelijker hun reis kunnen voorbereiden. MaaS kan interessant zijn voor auto-gebruikers als het ook is toegespitst op autogebruik (zoals bijvoorbeeld reistijdvoorspellingen en parkeervoorzieningen).

MaaS moet uiteraard dummy-proof zijn wil het door het grote publiek worden gebruikt. Belangrijkste factoren voor MaaS-gebruik zijn de snelheid/reistijd, het comfort voor de gebruiker en de mate waarin de reiziger ontzorgd wordt. Wanneer MaaS er in slaagt de onzekerheid (vertragingen, gemiste overstappen, etc.) die samenhangen met ketenmobiliteit weg te nemen, kan MaaS een flinke stimulans geven aan ketenmobiliteit.

Wanneer het de affectwaarde van MaaS betreft, zit dit voor MaaS vooral in de marketing en de positionering van het product. Affectwaarde wordt ook gecreëerd doordat reizigers andere mobiliteitskeuzes kunnen uitproberen en eenvoudig kunnen veranderen wanneer bepaalde keuzes niet bevallen. Daarnaast kan MaaS gezien worden als een TomTom, wat mensen een prettig gevoel geeft omdat ze weten hoe zij zich kunnen verplaatsen.

Als je kijkt naar het gedrag van mensen dan zie je vooral dat ze op belangrijke “life changing moments” hun mobiliteitskeuzes gaan heroverwegen. Grote gedragsveranderingen in MaaS zullen lastig te voorspellen blijven. Mensen zijn gewoontedieren, dus de gedragsverandering zal waarschijnlijk niet al te groot zijn op de middellange termijn.

Marktfalen
In principe heb je maar 1 kans om MaaS goed weg te zetten, als reizigers geen vertrouwen krijgen in het systeem zullen ze het daarna niet meer gaan gebruiken. De algoritmes voor MaaS worden erg ingewikkeld, zodat de snelheid voor het oproepen van reisadviezen kan afnemen. Daarnaast is de neutraliteit van de MaaS-keten relevant. Het kan zijn dat een service provider bepaalde modaliteiten of vervoersopties uitsluit. Dat kan dan geld opleveren voor de service provider, maar kan zorgen voor een slechtere maatschappelijke uitkomst.

Interview Peter Krumm

Hilversum, vrijdag 20 januari 2016

Peter Krumm en Roy van Kuijk

MaaS Definitie
MaaS behelst de integratie van de gehele reisketen (van plannen tot en met betalen). MaaS heeft daarbij als doel de gebruiker te ontzorgen. Verschillende reizigers hebben verschillende behoeftes. Zij zullen dan ook op verschillende manieren ontzorgd worden. Er is daarom niet zo iets als een one size fits all propositie voor MaaS.

MaaS Concept
In de praktijk zul je gaan zien dat reizigers eenvoudig bepaalde opties kunt in- of uitschakelen naar gelang behoefte. Dat is in analogie met de telefoniemarkt waar dit al gebruikelijk is. Uiteindelijk is het hoofdzakelijk vraag en aanbod dat bepaalt hoe MaaS er uit gaat zien. De rol van de overheid is erg beperkt. Zij zullen hoogstens faciliteren. Een alleenrecht voor een specifiek MaaS product zal er niet komen, dat is veel te beknellend voor de gebruikers.

MaaS zal dus door de markt worden opgepakt. Marktpartijen kunnen al aan de slag met de reeds beschikbare OV informatie. Het lastigste onderdeel voor MaaS zal het verzorgen van betalingen zijn.

MaaS omvat alle modaliteiten, dus zowel het eigen vervoer (auto, fiets, lopen), als het openbaar vervoer en allerlei deelconcepten.

Mensen zullen meer gaan kijken naar alternatieven. De rol van het OV zal zich gaan toespitsen op de grote lijnen en stromen (spoorwegen, metro en belangrijke bus- en tramverbindingen) en ligt vooral in dichtbevolkte gebieden. Wat autonome voertuigen voor invloed gaan hebben is lastig. Het is namelijk nog onduidelijk wanneer deze hun intrede gaan doen. Wat experts zeggen hierover loopt namelijk sterk uiteen. De verwachting is dat het voorlopig blijft bij een aantal pilots. Op de lange termijn maken autonome en adaptieve voertuigen het mobiliteitsnetwerk slimmer zodat het veel efficiënter gaat werken. Mensen zullen dan veel directer gaan reizen, in plaats van in ketens.

Ten aanzien van deelsystemen zullen er steeds meer partijen die daar geld in zien en zullen deze systemen dus gaan aanbieden. Deze tendens is momenteel al volop gaande. Ten aanzien van de auto zal te zien zijn dat mensen zich in drukke steden liever per fiets verplaatsen, hoofdzakelijk vanwege de snelheid. Buiten de stad zullen mensen grotendeels gebruik maken van auto's, omdat er minder beperkingen voor de auto zijn en afstanden al snel te groot worden voor de fiets.

Ten aanzien van de sociale component zal de politiek moeten beslissen of zij subsidies voor mobiliteit in landelijke gebieden gaat verstrekken. Dat valt of staat uiteindelijk met een goed product, wil het gebruikt gaan worden.

De level of service zal voor iedereen dus verschillen. Het gaat met andere woorden om fitness for use. Je zal op lange termijn dus (semi-)direct naar je bestemming kunnen. Grote concentraties van vervoersstromen zullen blijven. In dunbevolkte gebieden zal meer planmatig te werk moeten worden gegaan. Daar moet dan geld bij. Uiteraard kan de overheid bepaalde mobiliteitsvormen meer of minder belasten zodat ze middels de prijs mobiliteit kunnen sturen. Eigen initiatieven kunnen daarbij op lokaal niveau erg effectief zijn.

MaaS Drivers
Technische ontwikkelingen maken dat nieuwe mobiliteitsproducten en –diensten mogelijk zijn.

Bedrijven kunnen een beter product ontwikkelen en dus meer toegevoegde waarde creëren. Dat geeft hen een verdienmodel in handen. Bereikbaarheid en duurzaamheid zijn belangrijk, maar zullen geen grote drijvende krachten zijn voor MaaS zijn. Het bepaalt wel de context van MaaS, bijvoorbeeld doordat de overheid regels stelt over brandstofgebruik en emissies.

MaaS Gebruikers

De groep mensen die verstand heeft van de techniek en weet wat er mee mogelijk is, zal sneller openstaan voor een nieuw concept als MaaS. De eerste gebruikers zullen vooral in grootstedelijk gebied te vinden zijn, omdat daar veel verschillende mobiliteitskeuzes/-ketens mogelijk zijn. De groep millenials zullen ook gebruikers gaan worden, vooral omdat zij gewend zijn al veel met de smartphone te doen. De potentiële groep is groot, omdat veel mensen al over een smartphone beschikken en deze niet meer is weg te denken uit de maatschappij.

Er is momenteel weinig inzicht in de kosten van een auto. De pricing van de MaaS propositie zal erg belangrijk gaan worden. Er zullen verschillende mogelijkheden moeten komen zoals een prepaid variant en verschillende abonnementsvormen. Het expliciet maken van kosten kan voor veel mensen een trigger zijn om andere mobiliteitsvormen te gaan gebruiken. Daarbij is de vraag of een product/dienst duur is erg afhankelijk van de persoon aan wie je het vraagt. Mensen die nu gevoelsmatig veel betalen voor mobiliteit zullen eerder geneigd zijn om op een andere manier te gaan reizen.

De belangrijkste factoren voor mobiliteitskeuzes zijn verder het gemak dat mensen ervaren en de reistijd. De gevoelswaarde van MaaS zal voor veel mensen laag zijn wanneer je dit vergelijkt met andere vormen van mobiliteit (eigen autogebruik).

Marktfalen

Marktpartijen kunnen failliet gaan, maar er zullen genoeg partijen zijn die de rol van een failliet partij kunnen oppakken. Verschraling van het OV kan, zeker in dunbevolkte gebieden, optreden, maar het is uiteindelijk aan de overheid om daar wat te vinden en in te grijpen. Het Zweedse model kan daarbij als voorbeeld dienen. Eerst worden marktpartijen uitgenodigd een aanbod te doen voor diensten. Daarna gaat de overheid concessies uitgeven voor die delen van de markt waar geen marktvraag voor is

Interview Robert Jan ter Kuile

Amsterdam, vrijdag 20 januari 2016

Robert Jan ter Kuile en Roy van Kuijk

MaaS Definitie
MaaS is een containerbegrip. MaaS behelst dat het gebruiksgemak voor de reiziger toeneemt. MaaS omvat feitelijk 3 interfaces. Dat zijn als het ware de onderdelen die aan elkaar zijn geknoopt: betalen, informatie en de fysieke elementen.

MaaS Concept
MaaS moet als concept een meerwaarde hebben t.o.v. het bezit van een auto. Die meerwaarde is persoonsafhankelijk. Uit de oorspronkelijke plaatjes wordt de service (bovenste laag) onderscheiden van de modaliteiten (midden laag) en de infrastructuur (onderste laag). De interactie en afstemming tussen de bovenste twee lagen is belangrijk voor het gebruik en succes van MaaS.

Belangrijk voor gebruikers is de betrouwbaarheid en beschikbaarheid van de dienstverlening. Gebruikers willen het gevoel hebben dat ze altijd kunnen rekenen op MaaS en dat ze kunnen vertrekken op ieder gewenst tijdstip. Concepten als Car2Go, Uber, Snappcar, Abel en Hellobike dragen daar aan bij.

De kern van MaaS wordt gevormd door het OV. Metro en tram verbindingen zullen aan belangrijkheid toenemen, terwijl de positie van de bus verzwakt. De fiets en Car2Go zullen concurrenten worden voor het OV in de stad. Die producten zullen worden gekozen als het OV product onvoldoende is. Dat is in principe niet erg, want dat maakt wel blijere, meer tevreden reizigers. Door minder star aan een gewenste modaliteit vast te houden, kun je reizigers juist aan je binden.

Het tramnetwerk van GVB is al behoorlijk extensief. Desondanks zal het tramnetwerk wel worden uitgbreid. Er zijn een aantal buslijnen die op basis van hun passagiersaantallen zouden moeten worden vertramd. Daarnaast kunnen missende schakels worden aangepakt.

Ten aanzien van parkeren zal er meer aandacht komen voor P+R faciliteiten. Er zullen meer van dergelijke faciliteiten komen en de overstap gaat eenvoudig zijn. Dat kan in potentie het aantal auto's van buitenaf in de stad doen afnemen. Een toekomst met zelfrijdende autos kan een verdere afname van het aantal auto's in de stad betekenen.

De gemeente heeft de mogelijkheid om mobiliteit te sturen met bijvoorbeeld het parkeerbeleid. Zo krijgen elektrische auto's sneller een parkeervergunning en zijn er 350 plekken beschikbaar gesteld voor Car2Go. Totaal zijn er 700 plekken beschikbaar voor deelinitiatieven, omdat de gemeente niet wil dat er een partij komt die het alleenrecht hierop heeft.

Partijen
Er gebeurt op dit moment binnen Nederland niet zoveel met MaaS. Het business model lijkt matig. De vraag is daarbij of het wel zo makkelijk is om aan alle data te komen. De kosten voor een overkoepelend platform zullen hoog zijn, maar de vraag is of dat geld wel terug te verdienen is. Een vergelijking met een zakelijke mobiliteitspas volgt. Het bedrijfsleven is 5 euro p.p.p.m. bereid te betalen met het oog op de eenvoudige afwikkeling van brandstof- en OV declaraties. Voor consumenten is dit nog maar de vraag. Daarnaast zullen er heel veel kosten opgaan in de marketing van het product.

De ontwikkeling van een MaaS platform komt van de grond door ofwel (1) een grote partij, dan wel (2) een vervoerder in samenwerking met andere partijen, dan wel (3) middels een aanbesteding. Het overleg voor optie 2 zal intensiever moeten om een MaaS platform van de grond te krijgen. Een MaaS platform via een aanbesteding kan, maar dan moet de overheid dit wel kunnen verantwoorden binnen maatschappelijke doelstellingen.

Een MaaS platform van een vervoer in samenwerking met andere partijen lijkt het meest waarschijnlijk. Op de langere termijn zal een oligopolie ontstaan met daarnaast een aantal specifieke platforms.

MaaS Drivers
De kwaliteit van het OV zal beter worden, terwijl de kwaliteit van automobiliteit afneemt. In het spectrum van gebruikers met aan de ene kant de “die-hard automobilist” en aan de andere kant de “fanatieke OV gebruiker” wordt de tussengroep steeds groter. Deze groep maakt afwisselend gebruik van auto en OV en komt vooral van de groep oorspronkelijke automobilisten vandaan.

Het gegeven dat de techniek er is: de ICT en smartphone beschikbaarheid maakt dat een nieuw product/dienst kan worden gelanceerd. Daarnaast zijn er meer modaliteiten en mobiliteits(deel)concepten die beter tot hun recht komen als ze ontsloten worden. Kanttekening kan geplaatst worden bij de rekencapaciteit die benodigd is om ketenmodaliteit mogelijk te maken. Al is de verwachting dat de kwantumcomputer hiervoor beter geschikt zal zijn dan de huidige computers.

De (potentiële) baten van MaaS moeten groot genoeg zijn wil MaaS worden gelanceerd. Daarnaast moet de pijn groot genoeg zijn om mensen hun huidige manier mobiliteitspatroon aan te passen.

MaaS Gebruikers
De moeilijkste doelgroep zijn gezinnen met jonge kinderen. De kinderen moeten namelijk geregeld worden weggebracht en in auto’s zijn kinderzitjes bijvoorbeeld nodig.

Yuppen zijn een makkelijke doelgroep. Veel van hen zijn in staat om op dit moment al zonder auto te komen waar zij willen.

Ook de zakelijke markt is een belangrijke eerste gebruikersgroep. Door status aan mobiliteit toe te voegen zullen zij eerder van MaaS gebruik gaan maken. Denk daarbij aan het aanbieden van lounges, tiers, status miles en de mogelijkheid voor limousine vervoer of afwisselende (dure) auto’s.

Het gebruik zal vanuit de zakelijke markt richting de consumenten markt gaan. De basispropositie zal namelijk op de zakelijke markt zijn afgestemd. Daarnaast zijn de verdienmogelijkheden voor de zakelijke markt groter, omdat hier een betere willingness to pay is. Het privé gebruik van MaaS is vooral afhankelijk van de reisfrequentie en de locatie waar een persoon woont. Met name de “jong zakelijke markt” zal een interessante eerste gebruikersgroep worden.

Een andere belangrijke eerste gebruikersgroep zal bestaan uit toeristen en dagjesmensen. Deze mensen hebben namelijk geen vast mobiliteitspatroon binnen de stad, er is de behoefte om ze niet met de auto de binnenstad in te laten rijden en er zijn interessante commerciële mogelijkheden, zoals toeristische advertenties.

Ook zijn er mogelijkheden dat specifieke doelgroepen, zoals slechtzienden en gehandicapten, al vroegtijdig van MaaS gebruik gaan maken. Daar zal dan wel meer overheidsinmenging voor nodig zijn. Daarnaast zijn mensen die bewust leven (reizen, geld uitgeven, etc.) een relevante eerste gebruikersgroep.

Het gebruik zal verder toenemen als de volgende factoren worden verbeterd: snelheid en betrouwbaar, gemak en comfort en flexibiliteit. Ook duurzaamheid zal een relevante factor zijn.

MaaS zal op termijn een volwaardig alternatief voor de huidige automobiliteit zijn en kan daarmee de concurrentiestrijd aangaan.

Marktfalen
Op de verschillende MaaS proposities is directe sturing vanuit de overheid lastig. Wanneer een te grote marktmacht ontstaat kan dit de integratie van modaliteiten belemmeren. Binnen het GVB is prijsdifferentiatie niet ondenkbaar als blijkt dat voor sommige gebruikers de willingness to pay hoger is. Prijsdifferentiatie zou in tegenstelling tot Uber (surge pricing) vanuit een maatschappelijk oogpunt enkel te rechtvaardigen zijn als de winsten weer terug naar de burger/gebruiker gaan.

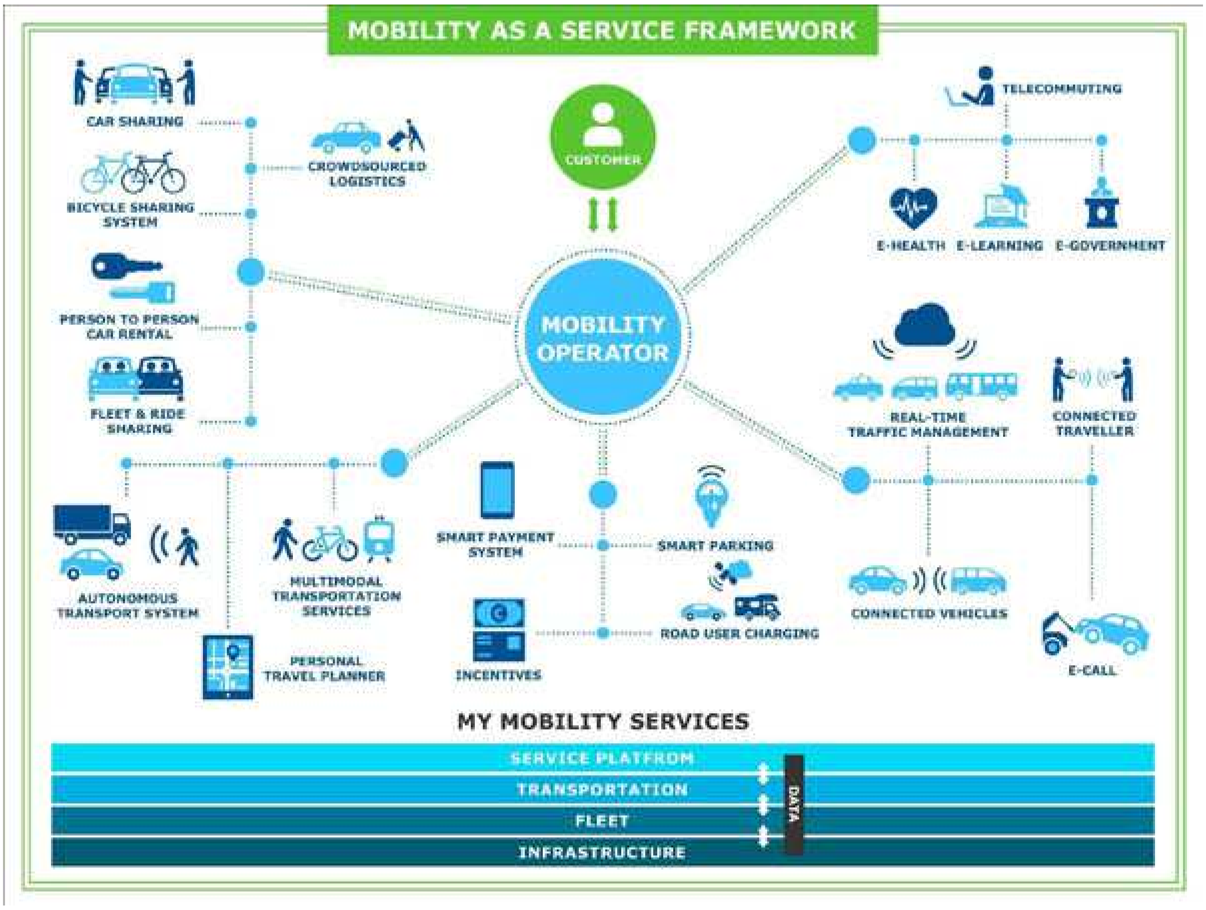
Interview Robert Scheerder

Amsterdam, vrijdag 20 januari 2016

Robert Scheerder en Roy van Kuijk

MaaS Definitie

Robert hanteert de definitie van MaaS zoals die door MaaS Global die formuleert(zie hieronder). MaaS streeft uiteindelijk naar de ultieme integratie van alle reisaspecten. Het is gericht op de gebruiker die daardoor verschillende vervoersmogelijkheden kan benutten. De data in MaaS kan gebruikt worden voor het verbeteren van individuele mobiliteit maar ook voor het mobiliteitssysteem als geheel.



MaaS Partijen

In zijn presentatie op de eerste MaaS Meetup van Amsterdam Economic Board schetste Robert drie mogelijke manieren van marktrevolutieNamelijk, (1) een initiatief vanuit de huidige OV markt, (2) een winner takes-all (bv. Google) of (3) een roaming/open MaaS komt waarbij vele partijen samenwerken.

Op de langere termijn kunnen verschillende MaaS vormen naast elkaar bestaan. Als we in NL op het huidige niveau van samenwerken blijven steken (focus op marktgedreven standalone initiatieven) dan verwacht Robert dat een winner takes-it-all MaaS als eerste gaat introduceren in NL. De OV-bedrijven hebben wel MaaS-ambities, maar Robert acht dat scenario niet kansrijk. Onder meer omdat NS door Den Haag steeds meer op zijn eigen postzegel terug geduwd wordt en GVB aangeeft dat zij andere prioriteiten hebben dan MaaS-provider worden. Daarnaast wordt de OV-sector substantieel gesubsidieerd vanuit de overheid en zou dit waarschijnlijk een dure, deels publiek gefinancierde oplossing opleveren. Werkgevers willen wel verbetering van bereikbaarheid en zoeken ook naar alternatieven voor de lease-auto. Ze kijken echter heel kritisch wat een alternatief hen kost c.q. oplevert. Bijdragen aan MaaS-ontwikkelkosten ligt lastig bij werkgevers, blijkt uit praktijkvoorbeelden.

De overheid heeft nu een belangrijke rol, met name in OV- mobiliteit. Door de komst van MaaS zal die rol zeker veranderen. Het is denkbaar dat die rol veel kleiner wordt, doordat vraag en aanbod veel dynamischer en door de markt gematcht gaan worden. worden herbezien.

Nieuwe partijen die zich met MaaS gaan bezighouden doen dat enerzijds vanuit een intrinsieke roeping (bv.: “het kan ook anders”, “we kunnen met MaaS de wereld beter maken”, etc.), maar bovenal de potentiële verdienmogelijkheden. OV-bedrijven zullen waarschijnlijk defensief handelen omdat hun business case mogelijk in gevaar komt.

MaaS Concept
Naar verluid heeft MaaS Global tijdens de Connekt-MaaS-reis (nov 2016) aangegeven dat hun businessmodel alleen uit kan als lopen en fietsen veel gebruikte modaliteiten zijn. De gemeente kan met quota voor bijvoorbeeld het aantal parkeerplekken en mogelijkheden voor deelconcepten als Car2Go de markt sturen. Er lijkt momentum te ontstaan in de regio Amsterdam om op een hoger niveau met MaaS aan de slag te gaan.

Een zekere “pijn” in de huidige manier van mobiliteit zal noodzakelijk zijn om tot betere vormen van (deel)mobiliteit te komen. Om MaaS op te schalen is het noodzakelijk om marktvraag te bundelen, zodat daarmee na de startfase nieuwe concepten voldoende rendabel worden.

In het OV verwacht men dat de sterke lijnen alleen maar sterker worden. De overheid zal zich de vraag moeten stellen wat ze moet doen om mensen te ondersteunen. Deelconcepten spelen nu nog een bescheiden rol, maar deze rol zal groter worden.

Een goede customer experience zal noodzakelijk zijn om mensen bereidwillig te laten zijn om gebruik van MaaS te gaan maken. Het zullen de serviceproviders zijn die transportdiensten zullen inkopen en eisen zullen stellen aan de dienstverlening.

MaaS Drivers
Voor Amsterdam zijn de 3 belangrijke maatschappelijke uitdagingen (in relatie tot MaaS, in willekeurige volgorde): luchtverontreiniging, schaarste van de openbare ruimte en bereikbaarheid. Er wordt sowieso een flinke autonome toename in het autovervoer verwacht. Ook gewenste woningbouw om de groei van de stad op te vangen, brengt uitdagingen met zich mee omdat er simpelweg geen ruimte meer is om de bijbehorende groei aan autoverkeer op te vangen. Daarbovenop is de verwachting dat de komst van zelfrijdend vervoer een exponentiële extra groei aan autovervoer gaat opleveren. Om ritdeling te stimuleren en daarmee de groei (en dus de consquenties voor bereikbaarheid, luchtkwaliteit en ruimtegebruik) behapbaar te houden zal een vergaande vorm van MaaS noodzakelijk zijn.

MaaS Gebruikers
MaaS zal grootschalig worden gebruikt als de customer experience van de gebruiker veel beter is dan die van zijn huidige mobiliteit (lees: auto voor de deur). De customer experience reikt veel verder dan de app, het gaat ook om de uitvoering, nazorg en service bij verstoring van de geplande reis. Zo zou je bijvoorbeeld automatisch geld terug moeten krijgen bij treinvertragingen, waar je nu zelf actie moet ondernemen.

Onder de eerste gebruikers zullen waarschijnlijk de jongere generaties woonachtig in steden zijn. Je ziet bij hen dat ze al minder auto's bezitten en zelfs minder rijbewijzen hebben dan de voorgaande generaties op die leeftijd. Daarnaast zal MaaS ook voor recent afgestudeerden die net een baan hebben interessant zijn. Zij groeien over het algemeen al veel meer op met gebruik in plaats van bezit, delen via apps en intensief gebruik van de smartphone.

Het gebruik zal groeien als de reistijd en de nazorg van reizen op orde zijn. Uiteindelijk willen gebruikers zekerheid hebben dat ze op tijd op hun bestemming zullen komen. Inspelen op de gevoelswaarde van MaaS is belangrijk voor een toename van het aantal gebruikers.

De gewoontes van mensen worden steeds sterker over de tijd. Idealiter sluipen dergelijke gewoontes bij jongere generaties er niet in, omdat ze binnen MaaS minder star vast zitten aan een specifieke modaliteit. Belangrijke factoren voor het gebruik maken van MaaS is de manier van eigenaarschap (bezit of lease) en de kosten van automobiliteit.

Marktfalen
MaaS zou kunnen zorgen voor een verergering van de huidige situatie (slechtere bereikbaarheid, meer vervuiling) in het geval er wordt gestuurd op "verkeerde keuzes". Hier ligt een rol voor de overheid, de vraag is hoe zij deze effectief en efficiënt kan vormgeven. Overigens zou het maatschappelijke belang deels parallel kunnen lopen met het zakelijke belang van MaaS-serviceproviders, zie de eerdere opmerking van MaaS Global dat lopen en fietsen belangrijke modaliteiten zouden zijn om de businesscase rendabel te krijgen. Daarnaast kan de betere beschikbaarheid van modaliteiten er voor zorgen dat mensen bijvoorbeeld van de fiets in het OV terecht komen. In het geval van Car2Go zie je dat er een verschuiving is van lopen en fietsen naar Car2Go. Doordat busvervoer in dunbevolkte gebieden steeds onrendabeler wordt, is er een tendens dat busvervoer in de buitengebieden verschraalt. De vraag is hoe MaaS, eventueel i.c.m. zelfrijdend vervoer ook daarin een oplossing zou kunnen bieden.

Interview Marc Stemerding

Delft, donderdag 22 december 2016

Marc Stemerding en Roy van Kuijk

MaaS Definitie
MaaS kan op vele manieren worden gedefinieerd. Enerzijds kan het worden gezien als de organisatie van ketenmobiliteit (vergelijkbaar met NS Businesscard concept). In het andere uiterste kan het gezien worden als een aanval op autobezit, omdat het een totaaloplossing biedt voor het bezit van een auto. De eindgebruiker moet daarvoor centraal staan, omdat het anders geen volwaardig alternatief wordt.

MaaS Conceptualisatie
MaaS wordt uiteindelijk gevormd door de markt (vraag en aanbod), waarbij de overheid een marginale rol zal spelen. Wil MaaS succesvol zijn, dan moet het vanuit de maatschappij zelf komen. Dat kan anders zijn wanneer er een "economische agenda" aan ten grondslag ligt, maar dit is voor Nederland niet aan de orde.

Hoe gaat het er uitzien?
De (deel)auto, de (deel)fiets, OV en taxi's zullen een rol spelen binnen MaaS. Contracten met veel partijen zal lastig zijn, maar je hebt idealiter de onafhankelijkheid van verschillende modaliteiten. Een MaaS platform dat zich focust op automated vehicles zal het erg lastig krijgen. Er hangt veel negativiteit rondom Uber (taxiwetgeving en de chauffeurs). Het geld wordt verdiend in het OV vanwege schaalvoordelen die samenhangen met de "normale reizen". OV zal naar verwachting een belangrijke rol krijgen.

Dat betekent dat in stedelijke gebieden de level of service hoog is met hoge snelheden en frequenties. Voor plattelandsgebieden zal het heel anders worden, omdat het huidig OV daar erg onrendabel is. Ook hier geldt dat de grote stromen verzorgd dienen te worden, dus OV haltes komen hoofdzakelijk in de grote kernen. Hierdoor komt geld vrij om voor hetzelfde geld hogere frequenties waar te maken. Dat betekent dat er op het platteland wel een grotere rol komt voor het voor- en natransport.

De rol van de overheid zal vooral zitten in de inrichting van de openbare ruimte. Er komt een focus op knopen in plaats van lijnen.

Wat zijn de drivers?
De driver wordt dat de consument dit wil. De consument ziet meerwaarde in MaaS en is dus bereid om daar geld aan te besteden. Gemeenten hebben een marginale rol en het huidige budget voor plattelands OV zou gebruikt kunnen worden voor MaaS. Daar ligt tevens een belangrijke politieke afweging.

Wie zijn de gebruikers?
Dat zullen allereerst gebruikers zijn die nog niet vast zitten in "vastgeroeste patronen". Dat is vooral de leeftijdscategorie 25-35 jaar. Daarnaast mensen die belangrijke levensveranderingen doormaken: mensen die met pensioen gaan of van baan veranderen. Huishoudens met 2 auto's zouden hun eerste auto weg kunnen doen. Leaserijders worden erg gestuurd door de bedrijven waarvoor ze werken. Als het voor hen bedrijfseconomisch interessanter om een MaaS abonnement af te sluiten, dan zullen zij dit doen.

MaaS zal eerst voor woon-werkverkeer worden ingericht, omdat hier de grootste stromen te vinden zijn. In een later stadium zal ook op de “vreemde, moeilijke ritten” worden gefocust.

Zal er sprake zijn van marktfalen en -imperfecties?
De aandacht gaat naar knopen, om het overstappen hier zo makkelijk mogelijk te kunnen maken. Mogelijk ontstaan hier problemen met het voor- en natransport, zodat minima of maxima van het aantal auto’s dienen te worden gesteld.

De eerdere beschreven situatie op het platteland kan voor de mensen daar negatief uitpakken. Wellicht komt er een focus op knopen langs de snelweg, waar makkelijk kan worden overgestapt op het stedelijke netwerk en mogelijkheden voor platooning kunnen worden ontgonnen.

Kan MaaS zorgen voor een gedragsverandering?
MaaS wordt succesvol als je overal heen kunt met het systeem. Huurauto’s en taxi’s zullen dan essentieel onderdeel vormen van het systeem. De auto als mobiliteitsverzekering is erg duur. Finse getallen wijzen op 500-600 euro per maand voor 3 ritjes van gemiddeld 7 kilometer. Dat kan gebruikt worden als prikkel om slimmer met mobiliteit om te gaan.

Het affect in het OV verbeteren kan slechts in beperkte mate. Wellicht kunnen de knopen wat prettiger worden ingericht of kunnen relevante functies aan de knopen worden toegevoegd. Er zal nauwelijks nieuwe lijninfrastructuur ontstaan omdat dit veel te duur is. Affectiewaarde kan bereikt worden door hetgeen wat niet bereikbaar is, bereikbaar te maken. Mensen kunnen bijvoorbeeld een paar keer jaar weg met een Tesla of kunnen gebruik maken van een Hyperloop.

Appendix III Interpretative Synthesis

Meta-ethnography (Britten et al., 2002) considers the combination of multiple qualitative studies. By combining the key concepts of these studies and identifying the relationships between these studies, new knowledge and insights can be deducted.

The methodology commences with the selection of appropriate studies in order to come up with the resulting interpretative synthesis. It is important that the relevance of these studies and the focus for the interpretative synthesis is clear.

After reading the studies, the key concepts are identified. All concepts which are relevant within the focus of the interpretative synthesis and recur multiple times in the different studies are concerned to be a key concept. After this identification process, the descriptions of these key concepts are listed for each study. When a study elaborates on this concept, the elaboration is stated between parenthesis. A review of the key concepts for this study is given in Table 24.

Consecutively, for each study the second-order interpretations are given. These concern the (induced) statements from the study authors. They are called second-order interpretations, as they are deducted from the (first-order) observations and analysis within the study. The already identified key concepts can be considered as these first-order observations. Based on the found second-order interpretations it can be seen whether the studies confirm each other, they are reciprocal to each other, or they contradict each other.

As a final step, by taking one (or multiple) second-order interpretations and combining these with relevant key concepts new, third-order interpretations can be derived. As the key concepts can be defined in several ways or are approached from different perspectives, these can lead to renewed insights on what was originally found in the studies. These third-order interpretations can be extended to narratives when they are perceived in parallel with the found relationships between the studies. For the interpretative synthesis on the concept of Maas, the methodology of meta-ethnography is applied as follows:

Scope interpretative synthesis

- The definition of MaaS is left out of scope, as MaaS is already defined in section 2.3.1;
- The identified core concepts are solely derived from the expert interviews and are grouped on the four relevant focus areas for the interpretative synthesis (MaaS drivers, mobility services and network, MaaS adoption and user behavior, market failure and public interventions);
- The importance of (transfer) hubs was not discussed in the 5 most relevant studies and is therefore left out of scope;
- The second-order interpretations are solely derived from the 5 most relevant studies from the literature study in order to secure the scientific value of the interpretative synthesis.

Key concepts and second-order interpretations

All concepts from the selected sources are stated in table 24. When an elaboration on these concepts was given, this is indicated by putting this elaboration between parenthesis. The second-order interpretation are briefly stated. When this concerns literally a quotation from the source, this indicated by putting the quotation between quotation marks.

Table 24: overview of key concepts and second-order interpret. for the interpretative synthesis

Key concepts	Hietanen	Giesecke	Heikilla	Kamargiani	Holmberg	Expert interviews
Drivers						
Commer-cial interest			Development of technology, possible business opportunities and export		Monetize excess or idle inventory, attraction of new user groups	New business opportunities, activation of latent mobility demand
Added value	Needs and expectations of users become more demanding and fragmented	User centric and seamless travel	Differing appreciations and increasing expectations	Integrating different transport modes and providing seamless door-to-door mobility; "mobility services (..) by (..) one platform and single payment		Improved user centrality and improved mobility needs fulfillment
Effective + efficient mobility	Less resources for developing transport systems	Increased mobility	Pressure for increase in efficiency, Urbanization and immigration	Growing pressure on urban passenger transport systems	Urbanization, climate change & sharing economy	Improved attractiveness chain mobility, accessibility, environment, and scarcity of urban space
Mobility services and network						
Position of PT network	(Having mobility operators makes it easier to use public transportation)		(The current organization of the PT provision does not sufficiently support individual and flexible multimodal mobility)			Core of MaaS offerings and becomes more attractive by the presence of other mobility services, high demand PT services will further develop
Position of car-based services	(Automated vehicles will provide the convenience of a private vehicle, without the physical ownership)					Shared car and taxi services will develop, so users experience more freedom in mobility.
Commer-cial basis of mobility services	(Profitable markets for new transporation services, renewed opportunities for the traditional		(Stakeholder collaborate and their roles might switch)			Commerical actors are possibly dominant within MaaS

	transporation sector)					
Impor-tance of local/ society focused services						Mobility services within MaaS can also be a result of co-creation
MaaS adoption and user behavior						
Impor-tant target groups					Millenials	Young urban people, business segment, Incidental PT users, tourists, disabled people,
Impor-tant factors for adoption		"comfort, flexibility, accessibility, ease of use, financial arrangements"	Service accessibility	Ticket & payment integration, mobility packaging, ICT integration		Costs, travel time, comfort, ease of travelling
Changes in travel behavior		"suggestion that tailoring MaaS offerings is a key success factor in travel behavioral change"			(From private car use to MaaS, or from PT to other mobility services within MaaS)	Users are less bound to specific modes of transportation
Market failure + public interventions						
Negative external -ities		Less environmental cars and low standard work conditions in Uber/Lyft	Uncertainty of market profitability, equity, safety, quality of service, pricing and rebound effects		Negative environmental effects, rebound effects	Not clear; potentially on accessibility, environment, urban space
Push away from PT						Car2Go users previously use active modes
Market power						Potentially a lot service providers available, high market shares of service providers could impede the integration of transportation services.
Public interven-tions		Standardization and inclusion of interfaces to open data	(A new organization framework, encompassing open minds, open data and alliances; standardized data formats and open interfaces)		Changes in subsidy policy, improving open data standards, tax-legislation,	Participation/subsidizing PT, give way to car-sharing services, regulation of private cars and taxi services

Appendix IV Quantification of MaaS offerings on the mobility system

This section sets out the quantification of MaaS offerings. Characteristics of the mobility system and mobility services are determined by the scenario outcomes and the expected future autonomous developments.

The availability of parking spaces of shared cars will increase, making it easier for people (lower search, access and egress times) to find a shared car.

Shared cars and private cars are competing for the same public space. Therefore the increase of parking space for shared cars will make it more difficult to park private vehicles. Therefore people will face more difficulties with parking private vehicles (longer search, access and egress times).

Shared taxi services are already available but are still in their initial development phase. It is expected that these services will further develop and are able to ensure shorter access times (time between hailing the ride and the service use).

In table 25 the expected effects of these future autonomous developments on access and egress times are quantified.

Table 25: autonomous developments on access and egress times

Autonomous increase	Access/egress time
Private	40%
Shared Car	-25%
Taxi	0%
Shared Taxi	-50%
PT	0%
Bike	0%
Walk	0%

Table 26 shows the expected impacts on costs for public intervention based scenarios. For limited public interventions, prices of public transportation are likely to rise. In the same case, pricing for shared cars, taxis and shared taxis are likely to drop as economies of scale develop. When there are many public interventions, the pricing of taxi services is likely to rise in order to fulfill additional (quality) requirements. Also the costs for private car use will increase, as municipalities will discourage car transportation.

Table 26: expected impact on costs for public intervention scenarios

Impact factor on costs	MOT	Limited interventions	Many interventions
PT subsidy	PT	40%	0%
Car limitation	Private car	0%	40%
	Shared Car	-20%	0%
	Taxi	-40%	0%
	Shared Taxi	-40%	0%
Taxi regulation	Taxi	0	20%

Table 27 shows the expected impacts on costs for automated driving based scenarios. When automated driving is available, costs for (shared) taxi services and public transportation are likely to drop as significantly less labor is needed. It is assumed that the costs of private cars and shared cars will remain the same as travel time savings by means of higher comfort are levelled out by the additional costs for automation technology.

Table 27: expected impact on costs for automation scenarios

Impact factor on costs	MOT	No automation	High automation
Technology costs	Private car	0%	0%
	Shared car	0%	0%
	Taxi	0%	-20%
	Shared taxi	0%	-20%
	PT	0%	-40%

Table 28 shows the expected impacts on travel times. Travel times for car-based mobility are likely to show a slight decrease for scenarios with extensive public interventions and the availability of automated driving. Respectively in these situations, the number of cars will be limited resulting in less congestion or roads will be used more efficiently as vehicle automation provides capacity-related benefits.

Table 28: expected impact on travel times for all scenarios

Impact factor on travel times	MOT	Many interventions	Limited interventions	No automation	High automation
PT network	PT	0%	-40% / 40%	No impact	No impact
Car limitation	Private car	10%	0%	0%	10%
	Shared Car	10%	0%	0%	10%
	Taxi	10%	0%	0%	10%
	Shared Taxi	10%	0%	0%	10%

Table 29 shows the impacts on access / egress times. It is assumed that public interventions will provide less parking space to private vehicles and shared cars, such that it will take a longer time to find and reach these vehicles. Taxi and shared taxi services will further develop in case there is little public intervention, such that the time between ride hailing and vehicle boarding will be smaller.

Table 29: expected impact on access and egress times for all scenarios

Impact factor on access / egress time	MOT	Many interventions	Limited interventions	No automation	High automation
Car limitation	Private Car	20%	0%	no impact	no impact
	Shared Car	33%	0%	no impact	no impact
	Taxi	0%	-50%	no impact	no impact
	Shared Taxi	0%	-50%	no impact	no impact

Appendix V User trade-offs between mobility services

In this appendix the trade-offs between mobility services are visualized. In the blue box the most important determinants for the use of the specific service is set out. For the specific trade-off the characteristics are given who determine the likelihood for choosing a specific mobility service.

Car	**(Shared) Taxi**
Comfort, direct	Directness
• Costs / urban road pricing • Ease of parking	• Request time • Detour ratio

Car	**Public Transport**
Comfort, direct	Fast to important places (CBD, train stations, etc.)
• Costs / urban road pricing • Ease of parking	• Frequencies • Speeds • Importance of first / last mile transport

Car	**Bike**
Comfort, direct	Fast, direct, healthy and social
• Costs / urban road pricing • Ease of parking	• Bike infrastructure • Weather conditions

(Shared) Taxi	**Public Transport**
Directness	Fast to important places (CBD, train stations, etc.)
• Costs • Request time • Detour ratio	• Frequencies • Speed • Importance of first / last mile transport

(Shared) Taxi	**Bike**
Directness	Fast, direct, healthy and social
• Costs • Request time • Detour factor	• Bike infrastructure • Weather conditions

Public Transport	**Bike**
Fast to important places (CBD, train stations, etc.)	Fast, direct, healthy and social
• Frequency • Speed • Importance of first / last mile transport	• Bike infrastructure • Weather conditions

Appendix VI Model Specification and Validation

The model produces via the generalized trip costs (the combination of travel costs and weighted travel time) and trip disutilities the number of trips, kilometers travelled, modal splits, and penetration rates for MaaS.

Introduction

The specified model is a so-called nested logit model. Therefore we can calculate the use mobility options within MaaS apart from conventional transportation. This means that the attractiveness of the "two nest" (non-MaaS and MaaS) can be calculated and thus their related penetration rates. Between the non-MaaS and MaaS nests there are no interdependencies. Therefore, two modal splits (for non-MaaS and MaaS) are calculated and can be combined to retrieve the manifest modal split.

Important for the determination of the attractiveness of modes of transportation and the nests are generalized trip costs, which consists of the combination of travel costs and weighted travel time. Travel times are weighted by means of the Value of Time (VoT). The higher the VOT, the higher the willingness to pay for travel time savings.

The costs for mobility services are based on the indices in table 30. The travel times of mobility services are based on the indices in table 31.

Table 30: indices for the costs of mobility services

	Current	Car-based	Active + Collective	Robocars	Hybrid PT
Car	100	80	100	80	100
Public Transport	100	140	100	100	60
Taxi	100	60	120	40	100
Shared Car	100	60	100	40	60

Table 31: indices for the travel times of mobility services

	Current	Car-based	Active+Collective	Robocars	Hybrid PT
Car	100	90	100	80	90
Public Transport	100	60-140	80	60-140	80
Taxi	100	80	90	80	90
Shared Car	100	90	90	60	80

Speeds and distances

In table 32 the speed and distance factors are specified. The speeds for car and bike transportation are tuned in order to provide a valid model. Later on in this appendix, an elaboration on this is given. The distance for (shared) taxis and bikes are not corrected. This means that trip lengths of these modes are similar to car trip lengths. However, the walking distance is corrected with -40% to 60% of the car driving distance for two reasons. First, pedestrians move more directly to their destinations. Additional benefit is that for longer distances the model's underestimation of the number of walking trips is corrected. Because the aggregation of inter-zonal distances together with the strong competition with other modes of transport, would not sufficiently take walking trips between zones located close to each other into account.

Table 32: specification of speed and distance factors

Speed car	
Current situation	26
Car based	23,4
Active & Collective	26
Robocars	20,8
Hybrid	23,4
Speed Bike	13,5
Speed Walk	6
Correction factor Taxi/Share	1
Correction factor Bike	1
Correction factor Walk	0,6

Pricing and access/egress times

The pricing and access and egress times as stated in table 33 are based on the conceptualization from the introduction of this appendix. The PT speed factors adjust the travel time with public transport. These can be adjusted in the model for specifically important and non-important lines. Important PT lines are defined by means of the VF ratio: when the travel time of a PT connection takes less than 150% of the car travel time, the PT connection is considered to be an important one.

Table 33: specification of pricing and access/egress times

Km price	Current	Car based	A+C	Robocars	Hybrid
Private	0,5	0,5	0,7	0,5	0,7
Car	0,6	0,48	0,6	0,48	0,6
Taxi	1,85	1,11	2,22	0,74	1,85
Share	1,6	0,96	1,6	0,64	1,28
PT	Defined on current PT pricing and PT price factor				
Bike	0,08	0,08	0,08	0,08	0,08
Walk	0	0	0	0	0
Access / egress time (min)	**Current**	**Car based**	**A+C**	**Robocars**	**Hybrid**
Private	8	10	12	10	12
Car	8	6	8	6	8
Taxi	4	2	4	2	4
Share	15	4	8	4	8
Core PT speed factor	0,8	0,48	0,8	0,48	0,8
Other PT speed factor	0,8	1,12	0,8	1,12	0,8
PT price factor	1	1,4	1	1	0,6

Population types

The model makes use of three population types: car-based (24%), hybrid (40%) and PT-based (36%) types. The distribution of these population times ide derived from Beemster (2016) and further elaboration is given in section 5.3. These population types are assumed to have different preference towards modes of transportation. This is operationalized by means of the alternative specific constant (ASC) as shown in table 34. This is in addition on the generalized travel time and is thus expressed in minutes. For this study, a ASC of zero mean that people don't perceive any disutility towards a specific mode of transportation other than its travel time and travel costs; in this case walking trips are assumed not to have any other perceived disutility.

The most significant ASC's are seen for private vehicle / car usage. People who do not use MaaS have a perceived disutility of 30 or 45 minutes for the first two population groups. This is assumed as people likely perceive many hassle for example the difficulties of finding the car or a vacant parking space, uncertainties in traffic due to congestion and road works, etc. The "hybrid group" has a higher ASC as they are assumed to only use a car when the need is high: the car should provide a big improvement on generalized travel cost in order to use it.

As said, walking is considered to have no additional perceived disutility. For other modes of transportation more actions need to be taken, such as: check the bus schedule, call for a taxi, grab a bike, etc. As for taxi services the trip itself is completely taken care of, the ASC is assumed to be low. For collective modes and biking the perceived disutility from other travelers and physical activity is taken into account. It is assumed that this perception differs over the population with the "PT group" having the lowest ASC's as they are most acquainted with these disutilities.

Table 34: overview on the ASCs for non-MaaS and MaaS users

Non MaaS	1. Car	2. Hybrid	3. PT
ASC - private	30	45	10000
ASC - car	10000	10000	10000
ASC - taxi	2	2	2
ASC - share	4	3	2
ASC - PT	4	3	2
ASC - bike	4	3	2
ASC - walk	0	0	0
MaaS	1. Car	2. Hybrid	3. PT
ASC - car	24	27	30
ASC - taxi	1	1	1
ASC - share	2	1,5	1
ASC - PT	2	1,5	1
ASC - bike	3	2,25	0
ASC - walk	0	0	0

It is assumed there are difference in the value of time between the population groups. The used VoT are determined from KIM (2013) and are set out in table 35.

Table 35: value of time for the three population groups

VoT	1. Car	2. Hybrid	3. PT
Business	26,25	22,75	19
Commuter	9,25	8,5	7,75
Other	7,5	6,75	6

Validation

Validation of the model results is conducted by checking the results different scenarios of car speed and bike speed. The validation aimed on the distribution of the number of trips and the passenger kilometers for 4 categories of transportation (car, PT, bike, walk). This means that the modes private vehicle, shared car, taxi and shared taxi were combined for validation purposes. From these differences between the model and VMA the sum of squares (SS) was calculated. A lower SS means a better approximation of the original results.

Originally, the bike speed was set at 14 km/h and the car speed at 26 km/h. Thus a start was given for the scenarios with bike speeds [13, 14, 15] and car speeds [22, 24, 26]. The lower speed area appeared to provide better results and extra results within this area have been considered more closely. From the extra validation numbers it is concluded that the scenario [22;13,5] had the best fit for modal split (trips) and the scenario [26;13,5] had the best fit for modal split (passenger kilometers). As the performance based on passenger kilometers is considered to be the most important, the [26;13,5] scenario is chosen for use in the model.

In figure 36 the sums of squares from the validation analysis are set out. In table 37 and 38 the modal splits and the differences with the VMA are set out for respectively the number of trips and the number of passenger kilometers.

Table 36: calculated sum of squares for model validation

Car speed (column) vs. bike speed (row)	22 km/h	24 km/h	26 km/h	30 km/h
13 km/h	11.45 – 13.91	12,75 – 13,98	13,86 – 14,19	15,65 – 14,77
13,5 km/h	10,61 – 6,07	11.56 – 5,30	12,41 – 4,92	13,86 – 5,02
14 km/h	14,69 – 9,12	15,07 – 7,99	15,46 – 7,11	16,22 – 5,98
15 km/h	26,54 – 25,81	28,42 – 25,05	26,37 – 24,43	26,35 – 23,52

Table 37: relative differences modal split in model with the VMA

Number of trips	Car	PT	Bike	Walk
Excel	12,16%	11,99%	45,52%	30,33%
VMA	11,13%	12,76%	44,23%	31,88%
Difference	9,25%	-6,01%	2,92%	-4,88%

Table 38: absolute VKT differences in model with the VMA

Passenger km	Car	PT	Bike	Walk
Excel	91138	109840	313861	109671
VMA	91582	108583	321984	105418
Difference	-0,48%	1,16%	-2,52%	4,03%

Appendix VII Model results

For all fines (0, 50, 100, 200, 250 euro) the model results are given in this appendix. Mind that for the same concepts the fine difference doesn't affect the modal splits within the non-MaaS or MaaS nest. It only affects the attractiveness of these nests and thus the penetration rate. In the end, it is this penetration rate which affects the manifest modal split.

Table 39: model result no MaaS fine

Car-based	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	6,72%	0,00%	3,2%			Private Car	8,9%	0,0%	4,2%			47,6%	52,4%
	Shared Car	0,00%	17,66%	9,2%	162,6%	85,2%	Shared Car	0,0%	22,5%	11,8%	153,5%	80,4%		
	Taxi	8,29%	7,54%	7,9%	-9,0%	-4,7%	Taxi	6,5%	5,7%	6,1%	-12,3%	-6,4%		
	Shared Taxi	9,17%	8,33%	8,7%	-9,1%	-4,8%	Shared Taxi	8,0%	7,0%	7,4%	-12,6%	-6,6%		
	PT	6,90%	6,19%	6,5%	-10,3%	-5,4%	PT	14,0%	12,3%	13,1%	-12,1%	-6,4%		
	Bike	41,53%	36,28%	38,8%	-12,6%	-6,6%	Bike	46,4%	38,8%	42,4%	-16,3%	-8,5%		
	Walk	27,38%	24,00%	25,6%	-12,4%	-6,5%	Walk	16,2%	13,7%	14,9%	-15,9%	-8,3%		
A&C	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	2,9%	0,0%	1,4%			Private Car	3,3%	0,0%	1,6%			48,2%	51,8%
	Shared Car	0,0%	10,7%	5,6%	267,4%	138,6%	Shared Car	0,0%	12,9%	6,7%	290,2%	150,5%		
	Taxi	1,0%	0,9%	0,9%	-5,0%	-2,6%	Taxi	0,4%	0,4%	0,4%	-6,6%	-3,4%		
	Shared Taxi	1,5%	1,4%	1,5%	-4,9%	-2,5%	Shared Taxi	0,9%	0,8%	0,9%	-6,6%	-3,4%		
	PT	13,1%	12,2%	12,7%	-7,0%	-3,6%	PT	20,1%	18,3%	19,1%	-9,0%	-4,6%		
	Bike	49,1%	45,1%	47,1%	-8,2%	-4,2%	Bike	56,1%	50,3%	53,1%	-10,2%	-5,3%		
	Walk	32,3%	29,6%	30,9%	-8,5%	-4,4%	Walk	19,2%	17,2%	18,2%	-10,4%	-5,4%		
Robo-cars	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	4,7%	0,0%	2,2%			Private Car	5,7%	0,0%	2,7%			48,0%	52,0%
	Shared Car	0,0%	13,0%	6,7%	177,1%	92,1%	Shared Car	0,0%	15,5%	8,1%	173,1%	90,1%		
	Taxi	17,8%	16,4%	17,1%	-8,2%	-4,2%	Taxi	17,1%	15,4%	16,2%	-10,4%	-5,4%		
	Shared Taxi	18,5%	17,0%	17,7%	-8,0%	-4,1%	Shared Taxi	19,4%	17,4%	18,4%	-10,2%	-5,3%		
	PT	7,3%	6,8%	7,1%	-6,6%	-3,5%	PT	14,3%	13,2%	13,7%	-7,3%	-3,8%		
	Bike	30,9%	28,0%	29,4%	-9,4%	-4,9%	Bike	32,0%	28,3%	30,1%	-11,6%	-6,0%		
	Walk	20,8%	18,8%	19,8%	-9,5%	-4,9%	Walk	11,5%	10,1%	10,8%	-11,6%	-6,0%		
Hybrid PT	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	2,7%	0,0%	1,3%			Private Car	2,9%	0,0%	1,4%			48,3%	51,7%
	Shared Car	0,0%	9,7%	5,0%	267,3%	138,3%	Shared Car	0,0%	11,4%	5,9%	289,6%	149,9%		
	Taxi	1,6%	1,5%	1,6%	-5,0%	-2,6%	Taxi	0,8%	0,8%	0,8%	-6,4%	-3,3%		
	Shared Taxi	2,7%	2,5%	2,6%	-4,9%	-2,5%	Shared Taxi	1,8%	1,7%	1,8%	-6,5%	-3,4%		
	PT	17,8%	16,7%	17,2%	-6,1%	-3,2%	PT	26,7%	24,7%	25,7%	-7,4%	-3,9%		
	Bike	45,3%	41,9%	43,5%	-7,5%	-3,9%	Bike	50,2%	45,6%	47,8%	-9,2%	-4,7%		
	Walk	30,0%	27,6%	28,8%	-7,9%	-4,1%	Walk	17,5%	15,9%	16,7%	-9,6%	-5,0%		

Table 40: model results MaaS fine 50 euro

Car-based	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	6,72%	0,00%	4,6%			Private Car	8,9%	0,0%	6,1%			68,9%	31,1%
	Shared Car	0,00%	17,66%	5,5%	162,6%	50,5%	Shared Car	0,0%	22,5%	7,0%	153,5%	47,7%		
	Taxi	8,29%	7,54%	8,1%	-9,0%	-2,8%	Taxi	6,5%	5,7%	6,2%	-12,3%	-3,8%		
	Shared Taxi	9,17%	8,33%	8,9%	-9,1%	-2,8%	Shared Taxi	8,0%	7,0%	7,7%	-12,6%	-3,9%		
	PT	6,90%	6,19%	6,7%	-10,3%	-3,2%	PT	14,0%	12,3%	13,5%	-12,1%	-3,8%		
	Bike	41,53%	36,28%	39,9%	-12,6%	-3,9%	Bike	46,4%	38,8%	44,0%	-16,3%	-5,1%		
	Walk	27,38%	24,00%	26,3%	-12,4%	-3,8%	Walk	16,2%	13,7%	15,4%	-15,9%	-4,9%		
A&C	**Ritten**	**Niet-MaaS**	**MaaS**	**Systeem**	**Gedrag**	**Maats**	**KM**	**Niet-MaaS**	**MaaS**	**Systeem**	**Gedrag**	**Maats**	**Niet-MaaS**	**MaaS**
	Private Car	2,9%	0,0%	2,0%			Private Car	3,3%	0,0%	2,3%			69,4%	30,6%
	Shared Car	0,0%	10,7%	3,3%	267,4%	81,9%	Shared Car	0,0%	12,9%	4,0%	290,2%	88,9%		
	Taxi	1,0%	0,9%	1,0%	-5,0%	-1,5%	Taxi	0,4%	0,4%	0,4%	-6,6%	-2,0%		
	Shared Taxi	1,5%	1,4%	1,5%	-4,9%	-1,5%	Shared Taxi	0,9%	0,8%	0,9%	-6,6%	-2,0%		
	PT	13,1%	12,2%	12,8%	-7,0%	-2,2%	PT	20,1%	18,3%	19,5%	-9,0%	-2,7%		
	Bike	49,1%	45,1%	47,9%	-8,2%	-2,5%	Bike	56,1%	50,3%	54,3%	-10,2%	-3,1%		
	Walk	32,3%	29,6%	31,5%	-8,5%	-2,6%	Walk	19,2%	17,2%	18,6%	-10,4%	-3,2%		
Robo-cars	**Ritten**	**Niet-MaaS**	**MaaS**	**Systeem**	**Gedrag**	**Maats**	**KM**	**Niet-MaaS**	**MaaS**	**Systeem**	**Gedrag**	**Maats**	**Niet-MaaS**	**MaaS**
	Private Car	4,7%	0,0%	3,2%			Private Car	5,7%	0,0%	3,9%			69,2%	30,8%
	Shared Car	0,0%	13,0%	4,0%	177,1%	54,5%	Shared Car	0,0%	15,5%	4,8%	173,1%	53,3%		
	Taxi	17,8%	16,4%	17,4%	-8,2%	-2,5%	Taxi	17,1%	15,4%	16,6%	-10,4%	-3,2%		
	Shared Taxi	18,5%	17,0%	18,0%	-8,0%	-2,5%	Shared Taxi	19,4%	17,4%	18,8%	-10,2%	-3,1%		
	PT	7,3%	6,8%	7,2%	-6,6%	-2,0%	PT	14,3%	13,2%	13,9%	-7,3%	-2,2%		
	Bike	30,9%	28,0%	30,0%	-9,4%	-2,9%	Bike	32,0%	28,3%	30,9%	-11,6%	-3,6%		
	Walk	20,8%	18,8%	20,2%	-9,5%	-2,9%	Walk	11,5%	10,1%	11,1%	-11,6%	-3,6%		
Hybrid PT	**Ritten**	**Niet-MaaS**	**MaaS**	**Systeem**	**Gedrag**	**Maats**	**KM**	**Niet-MaaS**	**MaaS**	**Systeem**	**Gedrag**	**Maats**	**Niet-MaaS**	**MaaS**
	Private Car	2,7%	0,0%	1,8%			Private Car	2,9%	0,0%	2,0%			69,5%	30,5%
	Shared Car	0,0%	9,7%	3,0%	267,3%	81,6%	Shared Car	0,0%	11,4%	3,5%	289,6%	88,5%		
	Taxi	1,6%	1,5%	1,6%	-5,0%	-1,5%	Taxi	0,8%	0,8%	0,8%	-6,4%	-2,0%		
	Shared Taxi	2,7%	2,5%	2,6%	-4,9%	-1,5%	Shared Taxi	1,8%	1,7%	1,8%	-6,5%	-2,0%		
	PT	17,8%	16,7%	17,4%	-6,1%	-1,9%	PT	26,7%	24,7%	26,1%	-7,4%	-2,3%		
	Bike	45,3%	41,9%	44,3%	-7,5%	-2,3%	Bike	50,2%	45,6%	48,8%	-9,2%	-2,8%		
	Walk	30,0%	27,6%	29,3%	-7,9%	-2,4%	Walk	17,5%	15,9%	17,0%	-9,6%	-2,9%		

Table 41: model results MaaS fine 100 euro

Car-based	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	6,72%	0,00%	5,7%			Private Car	8,9%	0,0%	7,5%			84,4%	15,6%
	Shared Car	0,00%	17,66%	2,8%	162,6%	25,4%	Shared Car	0,0%	22,5%	3,5%	153,5%	24,0%		
	Taxi	8,29%	7,54%	8,2%	-9,0%	-1,4%	Taxi	6,5%	5,7%	6,3%	-12,3%	-1,9%		
	Shared Taxi	9,17%	8,33%	9,0%	-9,1%	-1,4%	Shared Taxi	8,0%	7,0%	7,8%	-12,6%	-2,0%		
	PT	6,90%	6,19%	6,8%	-10,3%	-1,6%	PT	14,0%	12,3%	13,8%	-12,1%	-1,9%		
	Bike	41,53%	36,28%	40,7%	-12,6%	-2,0%	Bike	46,4%	38,8%	45,2%	-16,3%	-2,5%		
	Walk	27,38%	24,00%	26,9%	-12,4%	-1,9%	Walk	16,2%	13,7%	15,8%	-15,9%	-2,5%		
A&C	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	2,9%	0,0%	2,5%			Private Car	3,3%	0,0%	2,8%			84,7%	15,3%
	Shared Car	0,0%	10,7%	1,6%	267,4%	41,0%	Shared Car	0,0%	12,9%	2,0%	290,2%	44,5%		
	Taxi	1,0%	0,9%	1,0%	-5,0%	-0,8%	Taxi	0,4%	0,4%	0,4%	-6,6%	-1,0%		
	Shared Taxi	1,5%	1,4%	1,5%	-4,9%	-0,7%	Shared Taxi	0,9%	0,8%	0,9%	-6,6%	-1,0%		
	PT	13,1%	12,2%	13,0%	-7,0%	-1,1%	PT	20,1%	18,3%	19,8%	-9,0%	-1,4%		
	Bike	49,1%	45,1%	48,5%	-8,2%	-1,2%	Bike	56,1%	50,3%	55,2%	-10,2%	-1,6%		
	Walk	32,3%	29,6%	31,9%	-8,5%	-1,3%	Walk	19,2%	17,2%	18,9%	-10,4%	-1,6%		
Robo-cars	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	4,7%	0,0%	4,0%			Private Car	5,7%	0,0%	4,8%			84,6%	15,4%
	Shared Car	0,0%	13,0%	2,0%	177,1%	27,3%	Shared Car	0,0%	15,5%	2,4%	173,1%	26,7%		
	Taxi	17,8%	16,4%	17,6%	-8,2%	-1,3%	Taxi	17,1%	15,4%	16,9%	-10,4%	-1,6%		
	Shared Taxi	18,5%	17,0%	18,3%	-8,0%	-1,2%	Shared Taxi	19,4%	17,4%	19,1%	-10,2%	-1,6%		
	PT	7,3%	6,8%	7,2%	-6,6%	-1,0%	PT	14,3%	13,2%	14,1%	-7,3%	-1,1%		
	Bike	30,9%	28,0%	30,4%	-9,4%	-1,4%	Bike	32,0%	28,3%	31,5%	-11,6%	-1,8%		
	Walk	20,8%	18,8%	20,5%	-9,5%	-1,5%	Walk	11,5%	10,1%	11,3%	-11,6%	-1,8%		
Hybrid PT	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	2,7%	0,0%	2,2%			Private Car	2,9%	0,0%	2,5%			84,7%	15,3%
	Shared Car	0,0%	9,7%	1,5%	267,3%	40,8%	Shared Car	0,0%	11,4%	1,7%	289,6%	44,3%		
	Taxi	1,6%	1,5%	1,6%	-5,0%	-0,8%	Taxi	0,8%	0,8%	0,8%	-6,4%	-1,0%		
	Shared Taxi	2,7%	2,5%	2,6%	-4,9%	-0,7%	Shared Taxi	1,8%	1,7%	1,8%	-6,5%	-1,0%		
	PT	17,8%	16,7%	17,6%	-6,1%	-0,9%	PT	26,7%	24,7%	26,4%	-7,4%	-1,1%		
	Bike	45,3%	41,9%	44,8%	-7,5%	-1,1%	Bike	50,2%	45,6%	49,5%	-9,2%	-1,4%		
	Walk	30,0%	27,6%	29,7%	-7,9%	-1,2%	Walk	17,5%	15,9%	17,3%	-9,6%	-1,5%		

Table 42: model results MaaS fine 200 euro

Car-based	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	6,72%	0,00%	6,5%			Private Car	8,9%	0,0%	8,6%			97,0%	3,0%
	Shared Car	0,00%	17,66%	0,5%	162,6%	4,9%	Shared Car	0,0%	22,5%	0,7%	153,5%	4,7%		
	Taxi	8,29%	7,54%	8,3%	-9,0%	-0,3%	Taxi	6,5%	5,7%	6,4%	-12,3%	-0,4%		
	Shared Taxi	9,17%	8,33%	9,1%	-9,1%	-0,3%	Shared Taxi	8,0%	7,0%	7,9%	-12,6%	-0,4%		
	PT	6,90%	6,19%	6,9%	-10,3%	-0,3%	PT	14,0%	12,3%	14,0%	-12,1%	-0,4%		
	Bike	41,53%	36,28%	41,4%	-12,6%	-0,4%	Bike	46,4%	38,8%	46,2%	-16,3%	-0,5%		
	Walk	27,38%	24,00%	27,3%	-12,4%	-0,4%	Walk	16,2%	13,7%	16,2%	-15,9%	-0,5%		
A&C	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	2,9%	0,0%	2,8%			Private Car	3,3%	0,0%	3,2%			97,1%	2,9%
	Shared Car	0,0%	10,7%	0,3%	267,4%	7,9%	Shared Car	0,0%	12,9%	0,4%	290,2%	8,6%		
	Taxi	1,0%	0,9%	1,0%	-5,0%	-0,1%	Taxi	0,4%	0,4%	0,4%	-6,6%	-0,2%		
	Shared Taxi	1,5%	1,4%	1,5%	-4,9%	-0,1%	Shared Taxi	0,9%	0,8%	0,9%	-6,6%	-0,2%		
	PT	13,1%	12,2%	13,1%	-7,0%	-0,2%	PT	20,1%	18,3%	20,0%	-9,0%	-0,3%		
	Bike	49,1%	45,1%	49,0%	-8,2%	-0,2%	Bike	56,1%	50,3%	55,9%	-10,2%	-0,3%		
	Walk	32,3%	29,6%	32,3%	-8,5%	-0,2%	Walk	19,2%	17,2%	19,2%	-10,4%	-0,3%		
Robo-cars	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	4,7%	0,0%	4,5%			Private Car	5,7%	0,0%	5,5%			97,0%	3,0%
	Shared Car	0,0%	13,0%	0,4%	177,1%	5,3%	Shared Car	0,0%	15,5%	0,5%	173,1%	5,2%		
	Taxi	17,8%	16,4%	17,8%	-8,2%	-0,2%	Taxi	17,1%	15,4%	17,1%	-10,4%	-0,3%		
	Shared Taxi	18,5%	17,0%	18,5%	-8,0%	-0,2%	Shared Taxi	19,4%	17,4%	19,4%	-10,2%	-0,3%		
	PT	7,3%	6,8%	7,3%	-6,6%	-0,2%	PT	14,3%	13,2%	14,2%	-7,3%	-0,2%		
	Bike	30,9%	28,0%	30,8%	-9,4%	-0,3%	Bike	32,0%	28,3%	31,9%	-11,6%	-0,3%		
	Walk	20,8%	18,8%	20,7%	-9,5%	-0,3%	Walk	11,5%	10,1%	11,4%	-11,6%	-0,3%		
Hybrid PT	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	2,7%	0,0%	2,6%			Private Car	2,9%	0,0%	2,8%			97,1%	2,9%
	Shared Car	0,0%	9,7%	0,3%	267,3%	7,9%	Shared Car	0,0%	11,4%	0,3%	289,6%	8,6%		
	Taxi	1,6%	1,5%	1,6%	-5,0%	-0,1%	Taxi	0,8%	0,8%	0,8%	-6,4%	-0,2%		
	Shared Taxi	2,7%	2,5%	2,7%	-4,9%	-0,1%	Shared Taxi	1,8%	1,7%	1,8%	-6,5%	-0,2%		
	PT	17,8%	16,7%	17,7%	-6,1%	-0,2%	PT	26,7%	24,7%	26,6%	-7,4%	-0,2%		
	Bike	45,3%	41,9%	45,2%	-7,5%	-0,2%	Bike	50,2%	45,6%	50,0%	-9,2%	-0,3%		
	Walk	30,0%	27,6%	30,0%	-7,9%	-0,2%	Walk	17,5%	15,9%	17,5%	-9,6%	-0,3%		

Table 43: model results MaaS fine 250 euro

Car-based	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	6,72%	0,00%	6,6%			Private Car	8,9%	0,0%	8,8%			98,7%	1,3%
	Shared Car	0,00%	17,66%	0,2%	162,6%	2,1%	Shared Car	0,0%	22,5%	0,3%	153,5%	2,0%		
	Taxi	8,29%	7,54%	8,3%	-9,0%	-0,1%	Taxi	6,5%	5,7%	6,5%	-12,3%	-0,2%		
	Shared Taxi	9,17%	8,33%	9,2%	-9,1%	-0,1%	Shared Taxi	8,0%	7,0%	8,0%	-12,6%	-0,2%		
	PT	6,90%	6,19%	6,9%	-10,3%	-0,1%	PT	14,0%	12,3%	14,0%	-12,1%	-0,2%		
	Bike	41,53%	36,28%	41,5%	-12,6%	-0,2%	Bike	46,4%	38,8%	46,3%	-16,3%	-0,2%		
	Walk	27,38%	24,00%	27,3%	-12,4%	-0,2%	Walk	16,2%	13,7%	16,2%	-15,9%	-0,2%		
A&C	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	2,9%	0,0%	2,9%			Private Car	3,3%	0,0%	3,3%			98,8%	1,2%
	Shared Car	0,0%	10,7%	0,1%	267,4%	3,3%	Shared Car	0,0%	12,9%	0,2%	290,2%	3,6%		
	Taxi	1,0%	0,9%	1,0%	-5,0%	-0,1%	Taxi	0,4%	0,4%	0,4%	-6,6%	-0,1%		
	Shared Taxi	1,5%	1,4%	1,5%	-4,9%	-0,1%	Shared Taxi	0,9%	0,8%	0,9%	-6,6%	-0,1%		
	PT	13,1%	12,2%	13,1%	-7,0%	-0,1%	PT	20,1%	18,3%	20,0%	-9,0%	-0,1%		
	Bike	49,1%	45,1%	49,1%	-8,2%	-0,1%	Bike	56,1%	50,3%	56,0%	-10,2%	-0,1%		
	Walk	32,3%	29,6%	32,3%	-8,5%	-0,1%	Walk	19,2%	17,2%	19,2%	-10,4%	-0,1%		
Robo-cars	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	4,7%	0,0%	4,6%			Private Car	5,7%	0,0%	5,6%			98,8%	1,2%
	Shared Car	0,0%	13,0%	0,2%	177,1%	2,2%	Shared Car	0,0%	15,5%	0,2%	173,1%	2,2%		
	Taxi	17,8%	16,4%	17,8%	-8,2%	-0,1%	Taxi	17,1%	15,4%	17,1%	-10,4%	-0,1%		
	Shared Taxi	18,5%	17,0%	18,5%	-8,0%	-0,1%	Shared Taxi	19,4%	17,4%	19,4%	-10,2%	-0,1%		
	PT	7,3%	6,8%	7,3%	-6,6%	-0,1%	PT	14,3%	13,2%	14,3%	-7,3%	-0,1%		
	Bike	30,9%	28,0%	30,8%	-9,4%	-0,1%	Bike	32,0%	28,3%	32,0%	-11,6%	-0,1%		
	Walk	20,8%	18,8%	20,8%	-9,5%	-0,1%	Walk	11,5%	10,1%	11,4%	-11,6%	-0,1%		
Hybrid PT	Ritten	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	KM	Niet-MaaS	MaaS	Systeem	Gedrag	Maats	Niet-MaaS	MaaS
	Private Car	2,7%	0,0%	2,6%			Private Car	2,9%	0,0%	2,9%			98,8%	1,2%
	Shared Car	0,0%	9,7%	0,1%	267,3%	3,3%	Shared Car	0,0%	11,4%	0,1%	289,6%	3,6%		
	Taxi	1,6%	1,5%	1,6%	-5,0%	-0,1%	Taxi	0,8%	0,8%	0,8%	-6,4%	-0,1%		
	Shared Taxi	2,7%	2,5%	2,7%	-4,9%	-0,1%	Shared Taxi	1,8%	1,7%	1,8%	-6,5%	-0,1%		
	PT	17,8%	16,7%	17,7%	-6,1%	-0,1%	PT	26,7%	24,7%	26,7%	-7,4%	-0,1%		
	Bike	45,3%	41,9%	45,3%	-7,5%	-0,1%	Bike	50,2%	45,6%	50,1%	-9,2%	-0,1%		
	Walk	30,0%	27,6%	30,0%	-7,9%	-0,1%	Walk	17,5%	15,9%	17,5%	-9,6%	-0,1%		