Feasibility of the concept *Mobility as a Service* and its ability to support e-mobility in Germany

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M. Sc. Thesis: Fundamental study of “Mobility as a Service” and its relevance for e-mobility in Germany

Background and motivation of the thesis

“Mobility as a Service” (MaaS) is an innovative mobility concept which has the target to minimize the use of private cars by providing one mobility platform which merges all mobility services. The concept is therefore an opportunity to improve existing mobility systems and to design them more sustainable. As MaaS represents a significant change of the current mobility system, it provides new conditions to integrate electric vehicles.

Tentative Work Plan

The main target of the thesis is to develop a fundamental and interdisciplinary study about MaaS combined with e-mobility in Germany. The thesis analyzes the feasibility of MaaS and identifies existing obstacles when implementing the concept in Germany. Furthermore, it presents the potential of MaaS to integrate electric vehicles.

The steps of work are as follows:

1) Getting familiar with the concept of MaaS and analyzing related scientific literature
2) Evaluating potential benefits of MaaS for Germany
3) Developing a methodology to estimate the general feasibility of MaaS by considering various environmental conditions
4) Estimating the feasibility of MaaS in North Rhine-Westphalia (NRW) by
    a. Using the developed methodology
    b. Identifying core challenges while implementing MaaS in NRW/Germany
    c. Giving recommendations to improve the conditions to implement MaaS in NRW/Germany
5) Examining in how far the characteristics of MaaS provide positive conditions to boost the use of electric vehicles in Germany

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Abstract

The mobility sector in Germany is currently exposed to great challenges and chances. On the one hand trends like urbanization and a high degree of individual traffic lead to difficulties in reaching an efficient and sustainable mobility system which correspondents with national and international climate targets. On the other hand the current personal mobility system struggles to exploit the opportunities that are given by the trend of digitalization. Against this background, the examination of an alternative mobility system called *Mobility as a Service* is reasonable. Core elements of *Mobility as a Service* are multimodality, mobility services in a one shop principle and the minimization of individual traffic. Nevertheless the implementation of *Mobility as a Service* requires specific conditions which are basically defined by technology, politics, economy and infrastructure. Due to its core elements, *Mobility as a Service* leads to a highly efficient and modern transport system. At the same time *Mobility as a Service* can be the base for further developments in the field of e-mobility in Germany. The thesis finds out that there is a chance to implement the concept of *Mobility as a Service* in Germany and that provides good conditions to boost the use of electric vehicles.

In jüngster Zeit sieht sich der Mobilitätssektor in Deutschland enormen Risiken und Chancen ausgesetzt. Einerseits gefährden Trends wie Urbanisierung und der steigende Umfang motorisierten Individualverkehrs das Erreichen nationaler und internationaler Klimaziele. Andererseits bietet der Trend der Digitalisierung umfangreiche Möglichkeiten zur Umgestaltung des gegenwärtigen Mobilitätssystems. Bisher konnte diese Chance jedoch nicht in ausreichendem Maße genutzt werden. Den Verkehr in Deutschland effizient und nachhaltig zu gestalten stellt daher eine bedeutende Herausforderung dar. Vor diesem Hintergrund ist es sinnvoll, sich mit dem alternativen Mobilitätskonzept *Mobility as a Service* auseinanderzusetzen. Kernidee dieses Konzeptes ist es, multimodale Mobilität “aus einer Hand” anzubieten und damit den Individualverkehr zu reduzieren. Die Umsetzung des Konzepts *Mobility as a Service* erfordert jedoch geeignete technologische, politische, ökonomische und infrastrukturelle Rahmenbedingungen. *Mobility as a Service* stellt ein hocheffizientes und modernes Mobilitätssystem dar und könnte zugleich eine geeignete Grundlage für die Weiterentwicklung der Elektromobilität in Deutschland bieten. Die Arbeit zeigt auf, dass eine Umsetzung des Konzepts in Deutschland möglich ist, und dass *Mobility as a Service* gute Bedingungen bietet, um die Verbreitung von Elektrofahrzeugen in Deutschland zu erhöhen.

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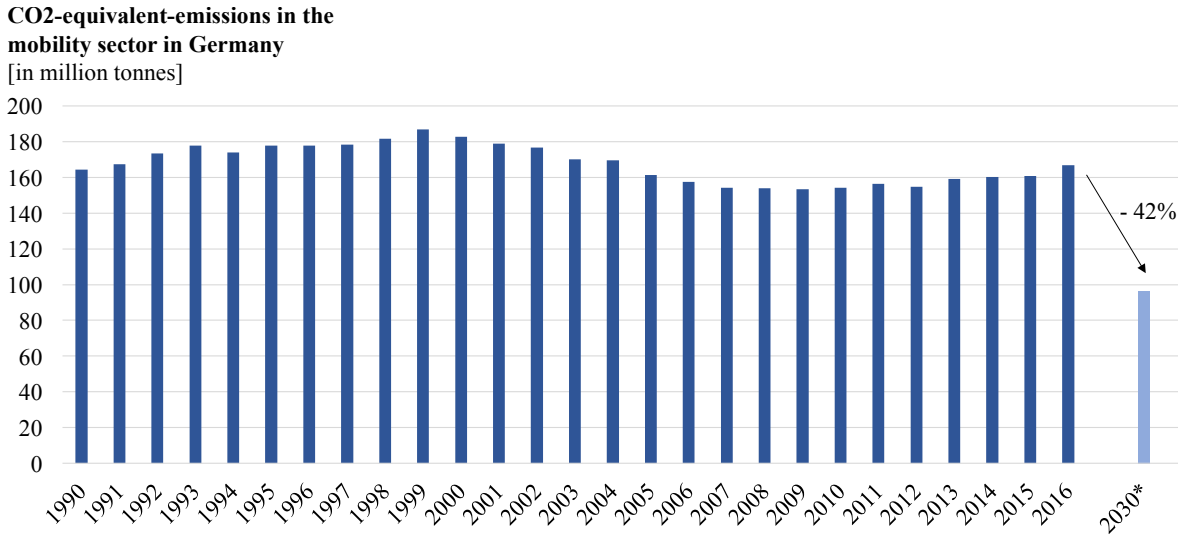
List of Abbreviations

ADAC	German automobile club (Allgemeiner Deutsche Automobil-Club e.V.)
CsgG	German car sharing law (Carsharinggesetz)
E-mobility	Electric mobility
GDPR	General Data Protection Regulation
MaaS	Mobility as a Service
NRW	North Rhine-Westphalia
PBefG	Passenger Transportation Law (Personenbeförderungsgesetz)
VDA	German association of the car industry (Verband der Automobilindustrie e. V.)
V2G	Vehicle-to-Grid

1 Introduction

The mobility sector in Germany is subject to comprehensive challenges and chances that are induced by global mega trends like digitalization, urbanization and climate change [3, p. 1], [58, p. 116], [9]. The trend of digitalization leads to the opportunity of using new tools and connectivity-based solutions like platforms and networks which can help to improve the efficiency of a system or an entire sector [3, p. 1], [8]. Against the background of the mega trend urbanization, this efficiency will be essential for the future of transport concepts in cities. Since 1970 the percentage of people who live in cities has increased from 30 percent up to 54 percent [58, p. 116]. In 2050, an estimated 66 percent of the world's population will live in cities [58, p. 116]. Therefore the mobility sector has to deal with the challenge of an increasing density of population in urban areas. At the same time climate targets deriving from rapid climate change in recent years, require the development of sustainable and efficient mobility systems. The European climate target defines a 40 percent reduction of greenhouse gas emission by 2030 compared to 1990 [55]. This initiative has its roots in the Paris Agreement which was adopted in 2015 by the United Nations and includes the effort to keep the global temperature grow "[...] to well below two degree Celsius above pre-industrial levels [...]" (*Paris Agreement, Article* $2\,1.$*(a)*). In addition to that, the article aims to reduce greenhouse gas emissions such as CO_2. Twelve percent of total CO_2-emission in the European Union are induced by cars [59, p. 1]. This high percentage shows that the mobility sector should be one of the key elements for international and national climate policy. It is not remarkable that Germany – as the biggest emitter within the European Union – has its own national climate target for the mobility sector: 42 percent reduction of CO_2-equivalent emissions between 2016 and 2030 caused by the mobility sector [17, p. 8]. In order to show the ambition of this target, Figure 1.0.1 depicts the development of the CO_2-equivalent emissions caused by mobility in Germany since 1990.



* Target-emission according to the C*limate Protection Plan 2050* of the German government

Figure 1.0.1: CO_2-equivalent emissions in Germany due to mobility since 1990 (own presentation, based on data from [57], [126], [17, p. 50])

The figure shows a wavelike development of the CO_2-equivalent emissions since 1990. Between 1990 and 1999 an increasing trend of emissions is shown. Afterwards the general tendency turns into a decrease until 2009. Between 2009 and 2016, the chart shows an increasing tendency which ends with 167 million tonnes of CO_2-equivalents. Taking into account the shown development, it is undeniable that strong efforts are necessary to reduce CO_2-emissions caused by mobility in Germany. The president of the German Environment Agency, Maria Krautzberger, clarifies that there has to be a change in the German mobility sector because otherwise the national climate targets will fail [125].

Apart from the outlined developments, additional challenges and chances in the mobility sector in Germany exist. The increasing volume of traffic leads to an all-time high of congestions in Germany with more than 1.4 million kilometers in 2017 [4]. An additional result caused by increasing traffic density is the pollution with toxic gases such as NO_2, which already exceeds European limits in some urban areas of Germany [83, p. 5], [89]. Inefficiencies caused by a high percentage of private and individual motorized transport exacerbate the described challenges [81]. On the other hand the inefficiency of today's mobility system provides opportunities for improvement. A growing sharing economy which no longer puts a high emphasis on owning a car could help to improve the efficiency in the mobility sector and to reduce individual and private traffic [122]. E-mobility is an additional chance for the future mobility sector: by using renewable energy and being more efficient, electric vehicles

provide the opportunity to reduce air pollution. Furthermore, electric vehicles show much higher efficiency compared to conventionally driven vehicles [5, p. 987]. Figure 1.0.2 pictures the described challenges and chances of the mobility sector. Furthermore it shows two options how to deal with the given conditions.

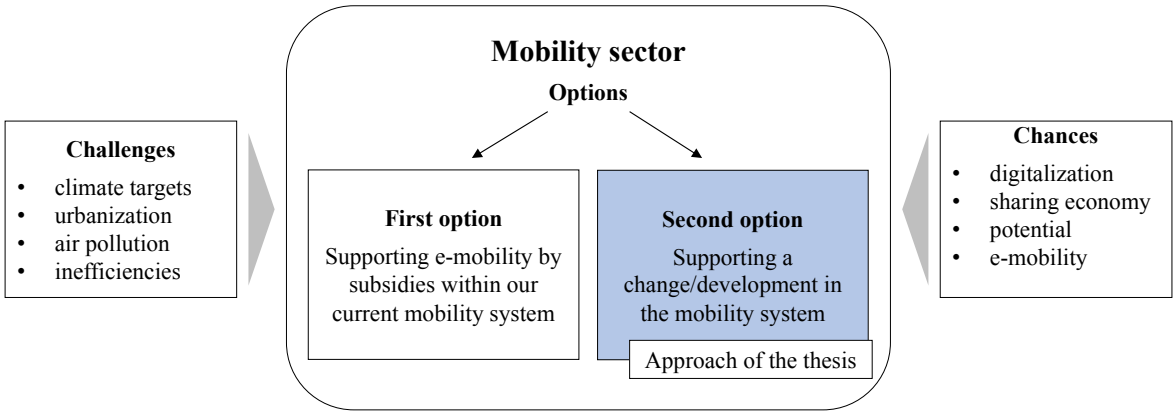


Figure 1.0.2: Current challenges, chances and opportunities of the mobility sector

On the one hand it is an option to keep the current mobility system and for example to accelerate the increasing number of electric vehicles by political interventions (e.g. subsidies for electric vehicles). This option focusses on specific parts of the entire system. On the other hand there is the second option of striving for a comprehensive development in the current mobility system and supporting totally new mobility concepts. Bringing together the presented mega trends of digitalization, urbanization and climate change, the study *Urban mobility at a tipping point* by *McKinsey* from 2015 comes to the conclusion that such a change in the mobility sector requires "bold, coordinated actions from the private and public sector" [15, p. 3]. The conclusion of the *McKinsey*-study underlines the approach of this thesis, which describes a totally new mobility system: *Mobility as a Service* (MaaS).

Future mobility is subject to a high number of scientific publications and multiple of these publications focus on the concept of MaaS, which is presented in this thesis. One of the first scientific works about MaaS was the master thesis *Mobility as a Service – A Proposal for Action for the Public Administration* for the case of Helsinki, which was written by Sonja Heikkilä in 2014 [65]. Since then, more and more researchers have dealt with the topic of MaaS from different perspectives. In [74] Maria Kamargianni and Melinda Matyas explore *The Business Ecosystem of Mobility-as-a-Service* and deal with fundamental definitions and actors of MaaS. Also Raphael Giesecke, Teemu Surakka and Marko Hakonen from the Aalto University in Finland deal with the conceptualization of MaaS [56]. Next to this holistic ap-

proaches, there are publications which focus on specific aspects of MaaS or other integrated mobility services. The conference papers *Evaluation of an Integrated Intermodal Travel Service* [12] and *Product Oriented Integration of Heterogeneous Mobility Services* [11] written by Markus C. Beutel et al. from the *RWTH Aachen University* deal with barriers on different levels that occur when implementing combined mobility services. By focussing on the availability of a critical mass for MaaS, in *Mobility as a Services (MaaS) – does it have critical mass?* Corinne Mulley deals with a specific challenge during the implementation phase of MaaS [95]. The dissertation *The Emergence of the Sharing Economy Industry – Insights from the German Carsharing Industry* by Taneli Vaskelainen focusses on the development of the car sharing industry in Germany [128]. As car sharing providers will play a significant role within MaaS, Vaskelainen considers a future key player within a MaaS system in Germany. The following thesis will examine MaaS from a multidisciplinary point of view, by developing a cross-sectoral catalogue of requirements, while most of the existing publications focus on specific sectors or deal with MaaS on a general level. The given approach is similar to the one in [2]. Here a catalogue of requirements is used, to examine the feasibility of MaaS in specific cities, inter alia, in Munich. Nevertheless this examination is based on only eight criteria and focusses on the level of local authorities. Technical aspects or national regulations are not subject to this publication. Overall, multimodal mobility in general and the concept of MaaS in particular become more and more relevant, also from a scientific point of view. However, the interdisciplinary approach in the following study combined with the focus on the feasibility of MaaS in Germany is new.

The thesis will be structured as follows: in the first step there will be a short description of the current German mobility system and its major problems. In the second step, the concept of MaaS with its core characteristics is described. This concept builds on our current mobility system and is characterized by a high degree of multimodality and mobility services. After the introduction of MaaS, there will be a short evaluation in how far MaaS can meet the identified challenges and to seize the current chances in the mobility sector. Chapter 3 describes which requirements are needed to implement MaaS in a specific region, and in how far Germany complies with these conditions. For this purpose, a general catalogue of requirements for MaaS is developed and used to examine the conditions for MaaS in Germany. This examination will be done for a specific region in Germany. The results will be used to identify actions to implement MaaS in Germany. Chapter 4 deals with the question, if far MaaS provides suitable conditions to implement electric mobility in Germany or not. An examination of technical and non-technical aspects will lead to an assessment, if the MaaS concept is able to support the integration of electric vehicles in Germany. The last chapter

gives a conclusive evaluation, if MaaS is feasible in Germany and if MaaS can strengthen the development of e-mobility in Germany. Furthermore, an outlook for future research, by identifying open questions, is given. Figure 4.1.1 summarizes the described structure.

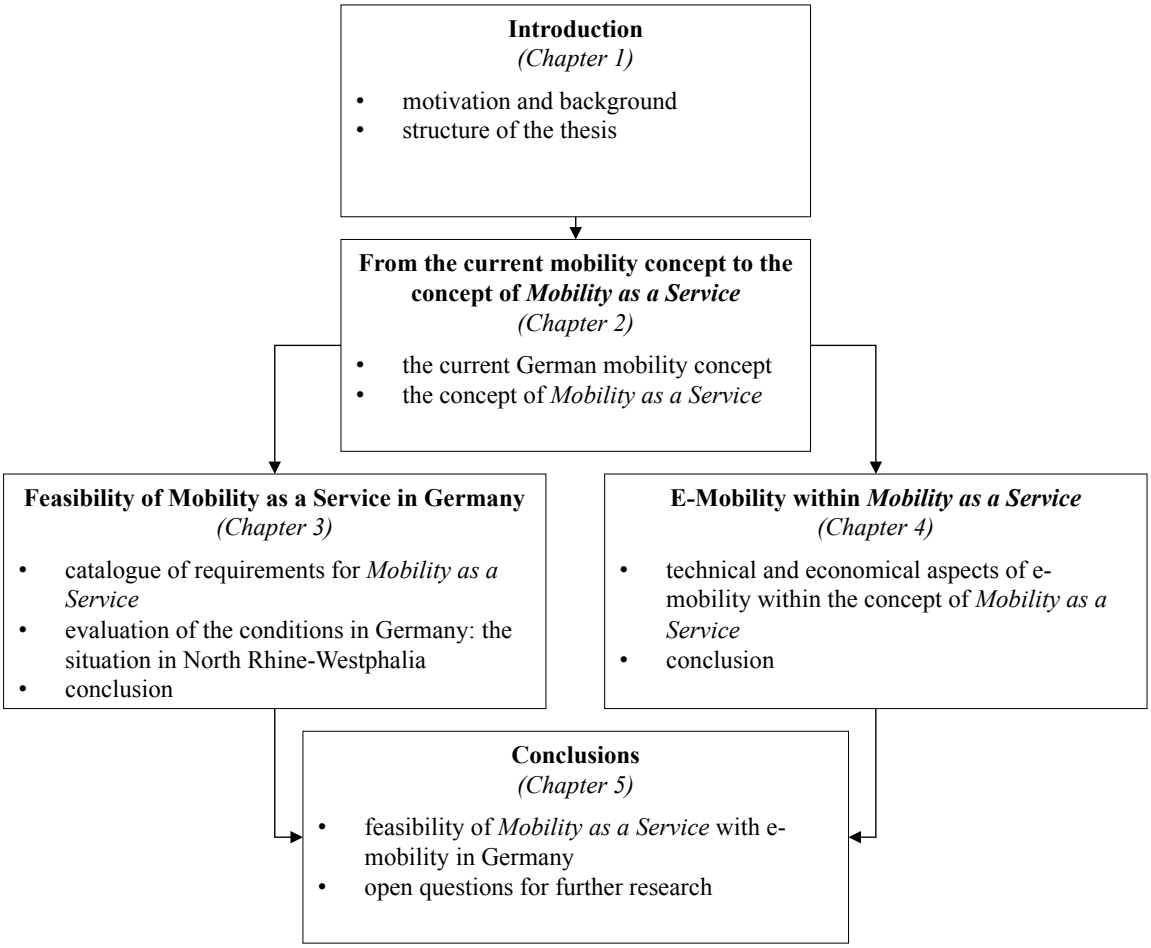


Figure 1.0.3: Structure of the thesis

2 From the current mobility concept to Mobility as a Service

The following chapter deals with our current mobility system and the mobility system of MaaS. Describing the current mobility system is not only important to identify potential for improvement, but also because our current mobility system is the starting point for MaaS: implementing the concept of MaaS does not imply to reconstitute a new mobility system. It is about developing the current mobility system and using existing mobility services and infrastructures. After the current mobility system is described, there will be an introduction of MaaS, by defining MaaS and explaining its core elements and characteristics.

2.1 The current mobility system

Our current mobility system consists of different mobility services which exist next to each other. The customer has the option to choose between different mobility providers like the *Deutsche Bahn* as a public transport provider, *sixt* as a car rental or – of course – their own private car. To use different mobility solutions for one trip, the customer has to use a variety of applications. This situation is depicted in Figure 2.1.2: A huge amount of providers, apps and services exist next to each other in an isolated way. There is a high inflexibility between different providers and it is the most comfortable way to use one specific mobility solution for each and every purpose instead of using a variety of solutions and therefore, the best for specific conditions [73, p. 8]. In Germany the predominant solution is the private car.

The provisional report *Mobilität in Deutschland*, published in June 2018, examines the structure of the mobility system in Germany in 2017 [23]. It analyses the "modal split" of mobility behavior in Germany. The modal split is the percentage share of different means of trans-

port. Figure 2.1.1 shows the percentage share of passenger kilometers of individual and public transport modes.

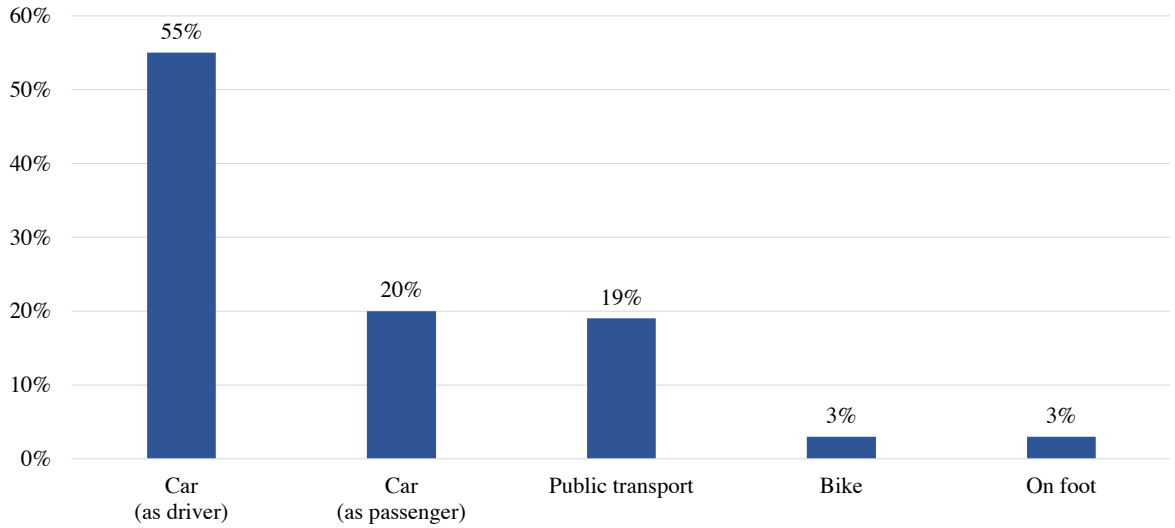


Figure 2.1.1: Modal split in Germany in 2017 (modified from [23, p. 13])

The bar chart shows that 75 percent of the passenger kilometer were covered by car as driver or passenger. 19 percent of the passenger kilometers were traveled by public transportation services and six percent were travelled by bike or on foot. These results demonstrate that the use of a car is the core transport mode in Germany. Therefore it is not surprising that 78 percent of the German households own at least one car [23, p. 11]. Overall, German private households own more than 43 million cars [23, p. 10]. As already mentioned, the current mobility behavior leads to tremendous challenges like climate change and congestions. At the same time, the use of a private car is highly inefficient: the "on the way time" per day is only 79 minutes [69, p. 28]. This number shows that if the car is used for every single ride of a day, the degree of utilization is approximately five percent per day: private cars are parked in 95 percent of the time. Furthermore a private car in Germany is in average used by approximately only 1.5 passengers on average while public transport services like busses and trains are commonly used by more passengers [23, p. 7]. Figure 2.1.2 summarizes the main characteristics of our current mobility system.

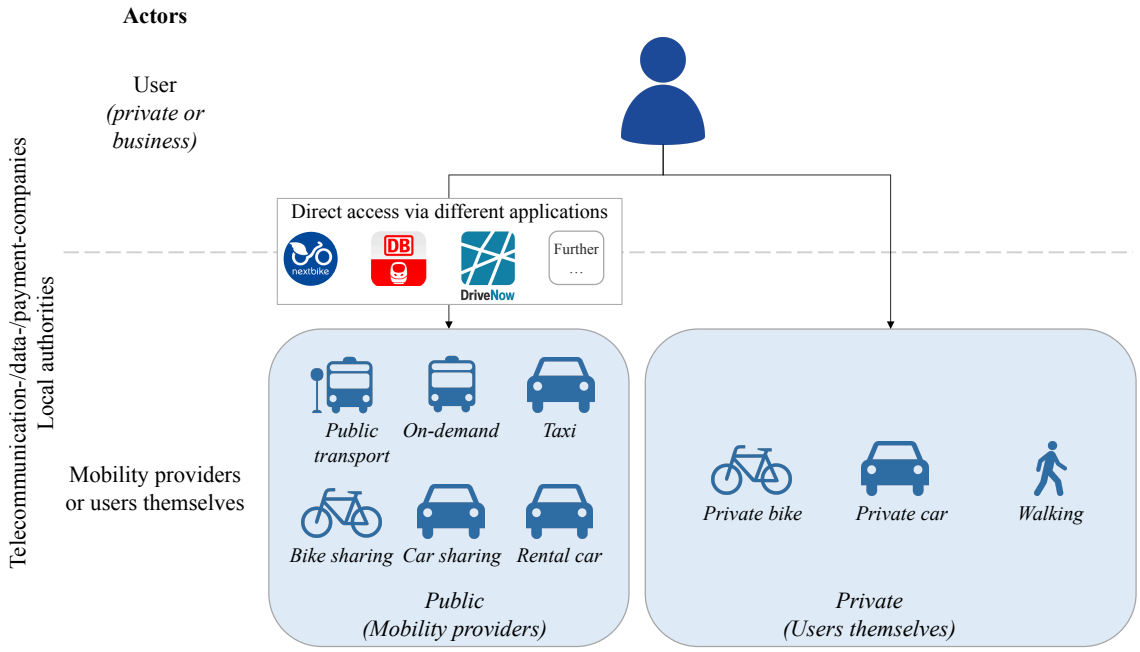


Figure 2.1.2: The current mobility concept (modified from [74, p. 5])

The illustration above shows the main actors in our current mobility system: users and mobility providers. A high percentage of rides are made by private means of transport like cars or bicycles. The public transportation services are less important compared with private means of transport. Access to services predominantly takes place due to specific applications which represent the interface between user and mobility provider. A description of the mobility providers who are part of the current mobility system can be found on page 10.

2.2 The concept of Mobility as a Service

The concept of MaaS has its roots in Helsinki, Finland. Here the company *MaaS Global* operates the first MaaS-application called *Whim*. MaaS is even part of the long-term transport policy of the Finnish government, which is proof of its rising importance [91]. *MaaS Global* is currently expanding to other countries such as the United Kingdom (West Midlands), Belgium (Antwerp) and the Netherlands (Amsterdam) and has more than 40,000 registered users by its own account [87].

The concept of MaaS represents a tremendous disruption in the mobility sector. The *Mobility as a Service for Linking Europe*-project (MAASiFiE) defines MaaS as “multimodal and

sustainable mobility services addressing customers' transport needs by integrating planning and payment on a one-shop principle" [3, p. 9]. According to this definition, MaaS integrates all processes concerning combined mobility. The target of MaaS is to provide one comprehensive and user-oriented service as an alternative to owning private car. In [72, p. 16] Peraphan Jittrapirom et al. describe the principle of MaaS by means of the following core characteristics.

The first characteristic of MaaS is the **integration of different transport modes**: MaaS includes different kinds of mobility services like car and bike sharing, public transport, rental cars, taxis and further mobility services (see also Table 2.2.1). Due to this integration, it is possible to book a trip as a combination of different mobility services ("multimodal trip") and thus "to encourage the use of public transport services" [72, p. 16]. The following Table 2.2.1 gives an overview of selected types of services which can be included into MaaS. The table describes the services shortly and shows examples of operators who provide the services.

Transport mode	**Description**	**Example/ Application**
Long distance public transport	Nationwide public transport (predominantly by train) between cities	*Deutsche Bahn* [43]
Local public transport	Public transport within a city (by bus, subway, tram or train)	*DSW21* Dortmund [49]
Taxi	Individual transportation for a single person or a little group in a car	taxi centrals, *myTaxi* [96]
Car rental	Individual transportation with a leased car	*Hertz* [67]
Station-based car sharing	Individual transportation with a leased car (often spontaneous and for a shorter time than car rental); the cars are located at fixed stations in the urban area	*Cambio Car-Sharing* [31]
Free-floating car sharing	Individual transportation with a leased car (often spontaneous and for a shorter time than car rental); the cars are spread in the urban area	*Car2Go* [36]
Bike sharing	Station-based (sometimes free-floating) bike rental; bikes can be booked and paid via an application	*Nextbike* [101]
Ride sharing	The user hires a driver (private or commercial) via an online application to either "share the ride" with others (carpooling) or to ride on their own	*uber* [124], *BlaBlaCar* [13]
On-demand services	Demand-oriented public transport services with flexible, intelligent route-planning	*door2door* [46], *ioki* [132]

Table 2.2.1: Possible transport modes within the MaaS-concept

The table shows traditional mobility services like taxis, public transport services or car rentals. In addition to these services, there are some new transport modes which have become popular in recent years and which already exist in our current mobility system. The idea of free-floating or station-based car sharing services is comparable to the idea of car rentals. The difference compared with traditional rental car services is, that innovative concepts are more flexible and are based on a shorter term rental. The service of bike sharing is similar to the car sharing concept, except that bicycles instead of cars are shared. Ride sharing is based on online platforms where private or commercial drivers can be hired, booked and paid. Users can travel on their own, together with other passengers or together with the driver who has the same destination. On-demand services are comparable with public trans-

port services without a defined route or time schedule. The routes of the transport vehicles are planned according to current demands. Therefore an intelligent software calculates the best possible route along passengers who request the service.

The second characteristic is the chance to choose between **different tariff options**. Figure 2.2.1 shows three options that are currently provided by *Whim* in Helsinki [88]. The first option is to use a "pay-as-you-go" tariff in which the customer pays only the services they have actually used, for example based on kilometers that were covered by different transport modes. The second option is to provide a limited "mobility package". The customer pays a monthly fee and has limited access to different mobility services without paying for every single use. The third option is an unlimited "mobility packages" where the user can use every mode of mobility as often and as long as they want to.

	Whim To Go	Whim Urban	Whim Unlimited
Monthly payment	Free	49€	499€
Local public transport	Pay per ride	Unlimited Single Tickets	Unlimited Single Tickets
Taxi (5km radius)	Pay per ride	10€ per ride	Unlimited
Car	Pay per ride	49€ per day	Unlimited
City Bike	Not included	Unlimited (30min)	Unlimited
Cancel anytime	✓	✓	✓
Add-ons incl regional HSL >			
	Read more	Read more	Read more

Figure 2.2.1: Provided plans by Whim in Helsinki [88]

The third characteristic of MaaS is a **digital platform as "face" to the end-user**. This platform can be a mobile app or website which allows to plan, book and pay a trip. The user can request real-time information about travel times, prices or extended information like weather forecast or their own travel history. The owner of this platform can either be a third party or one of the mobility providers, as described on page 54 in chapter 3.2.3.

MaaS consists of **multiple actors** who create an ecosystem. One of the actors is the (private or business) user who demands mobility services. A second actor is the mobility provider such as public transport providers or taxi/car-sharing companies. As already mentioned,

the platform owner could be a third role in the MaaS ecosystem (if no one of the transport providers owns the platform). Jittrapirom et al. describe some supporting roles like telecommunication/data companies, local authorities and payment companies in addition to the "main actors".

The organization and the efficient management of the MaaS-concept requires the **use of different technologies**. The user needs a mobile device (e.g. a smartphone) and an internet connection like $WiFi$, $3G$, or LTE to get mobile access to the platform. GPS, electronic ticketing, electronic payment and a database management system are necessary to offer user-centric and efficient service which includes all processes that are connected to mobility services.

The target of MaaS is to support the use of public transport services and to represent an efficient mobility system. Therefore within MaaS **demand orientation** and demand oriented services are particularly important. These kinds of services can fill gaps between non-demand oriented services. To fill these gaps, MaaS needs to be as reliable as possible to offer an alternative to a privately owned car.

To ensure a personalized mobility service for each user, a **registration** is indispensable. The registration requirement makes it possible to provide end-users a personalized mobility offer including a simple payment and booking process.

Personalization is the eighth characteristic of MaaS. Based on the travel history an individual mobility service can be provided and address their specific needs. The user is able to individualize their mobility offer and to create their own mobility package. An individualized offer of mobility services can make MaaS an attractive solution for end-users.

Figure 2.2.2 summarizes the described core characteristics of MaaS.

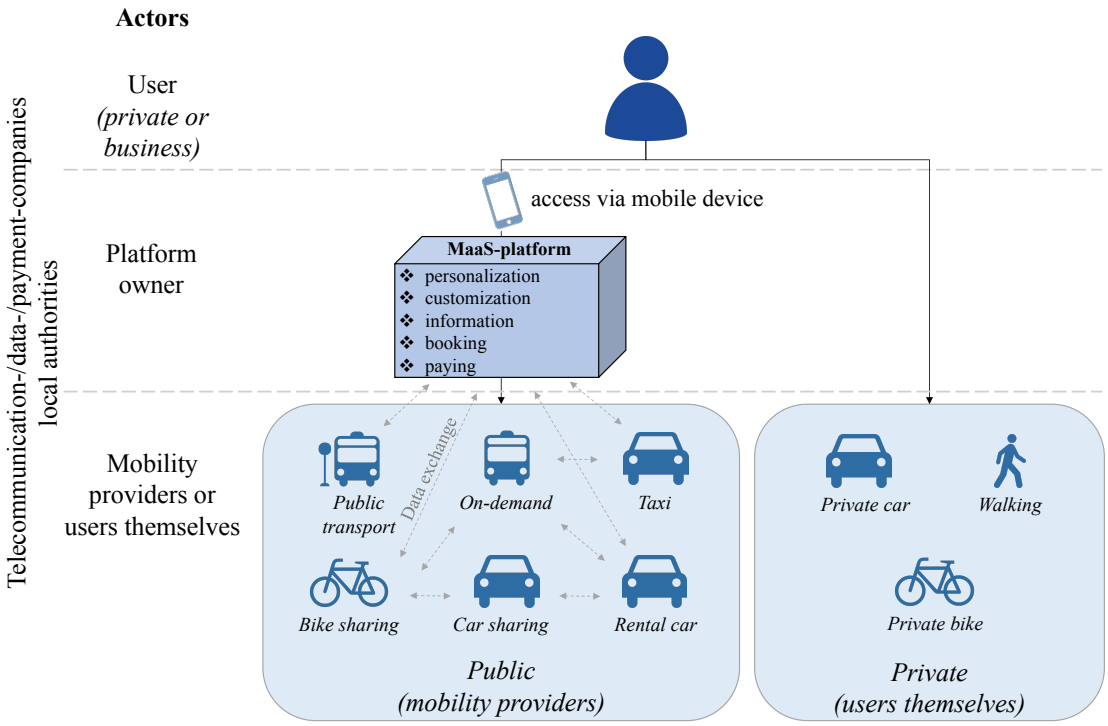


Figure 2.2.2: The concept of Mobility as a Service (modified from [74, p. 5])

The customer who has access to the MaaS-platform via a mobile device is the key player of the MaaS-system. The MaaS-platform is operated by the platform owner. Via the MaaS-platform, the customer can book mobility services of all mobility providers that are part of the MaaS-system. Due to a high degree of data exchange between different mobility providers as well as the mobility providers and the platform, it is possible to provide an efficient mobility system and to ensure a correct settlement of the services. The cross-sectional areas are taken by telecommunication- data- and payment-companies that ensure a working technical framework of the system. Local authorities and and higher regulatory instances are responsible for developing the regulatory framework of the MaaS-system.

The description of the core characteristics of MaaS shows the concept's high potential to improve the current mobility system and to make it more efficient. Figure 1.0.2 on page 3 has already shown the main challenges which affect the current mobility sector and the chances available to improve the current mobility system. The core elements of MaaS, take up these chances. The digital MaaS-platform which includes all necessary processes in conjunction with mobility services, benefits from the opportunities due to the trend of digitalization: the wide distribution of smartphones allows unlimited access to the platform at any time and at any place. Digital paying and booking processes allow an easy use of all mobility services

and a high degree of data exchange lead to an efficient use of the mobility services which are part of the MaaS-concept. Many of these services like car and bike sharing are based on the concept of sharing, which means that MaaS profits from a rising sharing economy. MaaS is therefore using the potential of improvement in our current mobility system which can help by facing current challenges like climate change, urbanization and air pollution. Possibly MaaS provides good conditions to integrate electric vehicles into the mobility system as well (see chapter 4). Due to this capability of MaaS, it is useful to examine the feasibility of MaaS in Germany. Examining the conditions for a successful implementation of MaaS in Germany is the target of the following chapter.

3 Feasibility of Mobility as a Service in Germany: Example of North Rhine-Westphalia

The following chapter analyzes the feasibility of MaaS in Germany. First a catalogue of requirements for MaaS is developed. Second, in chapter 3.2, this catalogue is used to analyze the feasibility of MaaS in North Rhine-Westphalia (NRW). Hereby it is analyzed, how well NRW is prepared for MaaS and which steps are necessary to implement and operate MaaS. The approach within this part of the thesis is comparable to [2] where requirements were developed to evaluate the "MaaS Readiness Level Indicators" [2, p. 1] for different areas.

3.1 Catalogue of requirements for Mobility as a Service

The developed catalogue of requirements is divided into the following four categories:

1. Technology
2. Regulation and Politics
3. Economy
4. Infrastructure

Each requirement consists of five stages. Stage one represents the worst performance, which means that the specific region is not ready for MaaS. Stage five represents the best case and therefore good conditions for the MaaS implementation.

3.1.1 Technical requirements

Implementing the concept of MaaS requires the fulfillment of technical requirements. These requirements include already developed comprehensive solutions like applications or pilot projects combined with suitable paying models in the mobility sector. The distribution of smartphones and the availability of a reliable internet connection to get access to the MaaS-platform are key technical requirements for MaaS.

Availability of comprehensive smartphone applications and pilot projects in the mobility sector

One of the core characteristics of MaaS is the integration of multiple mobility providers to one mobility service. The combination of different services on one platform is essential to create a reliable and fail-safe system as an alternative solution to the privately owned car. The "final architecture" of an information system is important to provide a user-friendly benefit and to use synergies between different transport services [11, p. 2]. The construction of such an information system can only work if "mobility providers [...] pay attention to this topic and cooperate to satisfy the need of an heterogeneous mobility behavior free from barriers on different levels" [12, p. 369]. The availability of applications or projects across different systems is therefore an indicator of the readiness level of MaaS. The application represents the MaaS-platform which is the "face to the user". Anais Luisa Habermann et al. examine necessary functions of mobile applications for public transportation from the perspective of the user [61, p. 5]. Here a "high usability" is mentioned as the most significant factor for the acceptance of a smartphone application which provides mobility services. Usability of a mobility application means the opportunity to book "mixed-mode journeys" via one application instead of using "numerous websites" to book single services [61, p. 2]. The importance of applications and smartphones can also be shown by the example of the success of car sharing in recent years: in [53, p. 8] Matthias Finger et al. identify applications and smartphones as the "main success factor for the strong increase of car sharing".

It can be presumed that a high degree of cooperation and connections between different kinds of mobility services, is a better starting point for MaaS than a mobility system with completely isolated mobility services. For this reason the availability of comprehensive smartphone applications and pilot projects which allow the booking of multimodal journeys, are an indicator of the readiness level for MaaS: if solutions already exist which allow the booking of multimodal services with standardized interfaces for new providers – maybe even on a nationwide level – the conditions for MaaS are satisfying. If these solutions are not available or if the functionality and coverage of these solutions are on a low level, the conditions for MaaS are not promising. Table 3.1.1 shows five stages of the availability of comprehensive smartphone applications and pilot projects in the mobility sector for a region.

Stage	Characteristic
1	There are no pilot projects or smartphone applications which support the usage of single or combined mobility services.
2	There are some applications and pilot projects, which support single or combined mobility services. The functions are limited to information and applications do not allow booking or paying.
3	Many applications are available to support the mobility service-usage. Applications give real-time information and they allow users to undertake booking and payment transactions. At the moment there is no application or pilot project that combines these functions for different services.
4	Some applications which provide the opportunity to book and pay for different services are available. These applications often provide just two or three services and it is difficult to predict if it is feasible to add more services into the existing applications and if it also works for a higher amount of users.
5	There is at least one nationwide platform which exceeds the status of a pilot project. A consistent interface allows it to integrate more and more mobility services.

Table 3.1.1: Stages of the availability of comprehensive smartphone applications and pilot projects in the mobility sector

Tariff systems, revenue sharing- and paying-models

The collaboration between different mobility providers and the concept of booking and paying via one platform for every service raises the question in how far different tariff systems, in particular the public transport system, can be integrated into MaaS [53, p. 6]. A heterogeneous public transport system requires a high degree of coordination in order to allow booking and paying via one platform. This high degree of coordination is also necessary, if

further mobility services like car sharing providers will be integrated into MaaS. Here it is necessary to achieve a uniform way of paying and ticketing with standardized interfaces to enable the integration of additional mobility providers [50, p. 42]. Therefore systems are needed which ensure an appropriate billing service between the different mobility providers and the platform operator.

In order to examine the conditions for MaaS, it is useful to evaluate the heterogeneity of the mobility landscape in the specific region. Furthermore it is important to evaluate whether there are solutions which enable a standardized payment and settlement process for different mobility providers. Table 3.1.2 shows five stages of the suitability of current tariff systems and opportunities of revenue sharing.

Stage	Characteristic
1	There is heterogeneous tariff-landscape in the mobility sector, especially in the sector of local public transportation. There are no efforts of standardization of the tariff system and currently there are no solutions providing a uniform payment and billing system. Therefore current solutions do not allow the collaboration between different mobility providers.
2	Even if there are efforts of a harmonization of the tariff system, there is still a very heterogeneous tariff landscape. There are no solutions available which have the target of a standardized payment or billing system and allow the collaboration between different mobility providers.
3	In recent years there have been strong efforts to harmonize the tariff system in the mobility sector. There are also first solutions which provide a standardized payment and billing system for different providers.
4	In recent years there have been strong efforts to harmonize the tariff system in the mobility sector. There are also solutions which provide standardized interfaces and billing, which makes it possible to offer different mobility services via one booking system. These solutions are already used at least by local public service providers.
5	There is a very homogenous tariff landscape in the mobility sector. A standardized payment and billing system is used by different kinds of mobility operators like local public transport, car sharing or rental car providers.

Table 3.1.2: Stages of the suitability of the current tariff systems and opportunities of revenue sharing

Distribution of smartphones

The preceding chapters already pointed out the great relevance of digitalization and applications when implementing MaaS. The use of these applications and the access to the MaaS-platform requires usage of smartphones. Otherwise it would be impossible to take part in the MaaS-ecosystem and to make use of it. Therefore it is useful to examine the distribution level of smartphones within the specific area.

In order to analyze the distribution of smartphones, it is useful to examine the percentage share of smartphones (less than 50 percent on the first stage and more than 90 percent on the fifth stage). Accordingly the stages in Table 3.2.4 can be identified.

Stage	Characteristic
1	Overall less than 50 percent use smartphones.
2	Overall usage of smartphones is over 60 percent.
3	Overall usage of smartphones is over 70 percent.
4	Overall usage of smartphones is over 80 percent.
5	Overall usage of smartphones is over 90 percent.

Table 3.1.3: Stages of the distribution of mobile devices

Availability of internet connections

The availability of an extensive availability and capacity of internet connections is essential to use the MaaS-platform. The connection has to be guaranteed in rural areas, in densely areas and next to gatherings like main stations or in trains. Without internet connection it is not possible to plan and book a trip or the next step of a trip on the ride. Absence of internet connection could exclude customers from the usage of MaaS. Therefore it is essential that the telecommunication infrastructure ensures availability and capacity of internet connections [53, p. 8].

The lowest stage of fulfillment is a poor internet connection even in densely populated cities. The highest stage represents the best conditions for MaaS: the availability of internet connections is ensured even in rural areas, in trains, buses and other gatherings with many users in one place.

Stage	Characteristic
1	The internet connection is very poor. Also in areas with a high density of population, there is no reliable $3G$- or LTE-internet connection.
2	Central areas have a basic internet connection, at least with $3G$-standard. LTE-standard or a reliable internet connection in rural areas is not available.
3	In central areas there is a reliable $3G$- or LTE-internet connection. In rural areas or at the railroad network, the connection is largely poor.
4	In most of the areas, there is a reliable $3G$- or LTE-internet connection. Also rural areas or on the railroad network there is at least a $3G$-connection.
5	The internet connection is very good. Even in rural areas there is LTE-availability of almost 100 percent. On the railroad network there is good working $WiFi$-connection for everyone or the mobile internet works reliable.

Table 3.1.4: Stages of the availability of internet connections

3.1.2 Regulatory and political requirements

The implementation of MaaS requires a political and regulatory environment which supports its realization. As well as political support for this realization, the political pro-activity of regulations in the field of transport and mobility has to be considered. These regulations include passenger transportation and data rights.

Political support and pressure

The quality and design of mobility and infrastructure highly depends on political regulations and political financial support. In [103, p. 274] Lasse Nykänenen et al. identify policy as one of the most significant driver for MaaS. They describe political regulation as a “backbone for the business model development” [103, p. 274] of MaaS. Therefore it is useful to examine the pressure on politics to act as this driver and to support MaaS. Pressure caused by national or international climate targets or by regulations concerning air pollution in cities could lead politics to induce the change in the mobility sector and to be the required “backbone” for MaaS. Also additional regional-specific elements like congestions, air pollution or the lack of space in cities can cause high political pressure to support MaaS or similar mobility systems.

Best case scenario for MaaS is high political pressure to change the mobility system. In this case, a high degree of political support for MaaS can be expected. In the worst case scenario there is no political pressure, which leads to a lack of political support for MaaS.

Stage	Characteristic
1	Politically there is no pressure to change the current mobility system. There are no effective subsidies that support mobility initiatives like MaaS or similar projects.
2	There is some national political pressure to develop the current mobility system. The pressure focusses on general climate targets, but there are no time-sensitive drivers that lead to a specific political support for MaaS or alternative new mobility concepts.
3	There is a high pressure in politics because of ambitious national and international climate targets. Nevertheless the support and the pressure is more relevant to the long term and politics currently focusses on singular measures, e.g. supporting e-mobility by subsidies.
4	Besides national and international climate targets there are other region-specific drivers that lead to increasing political pressure. Nevertheless there is no comprehensive concept which supports sustainable and extensive changes.
5	National and international climate targets and further region-specific drivers have led to comprehensive political measures in recent years to support concepts like MaaS.

Table 3.1.5: Stages of the political support and pressure for MaaS

Pro-activity of regulation

Beside regulation itself also its degree of pro-activity is relevant to the implementation of MaaS. In [53, p. 10] Matthias Finger from the *Florence School of Regulation* points out that it should be avoided to pursue a reactive regulation. It is rather important to anticipate increasing conflicts and developments and to "develop a forward looking vision" [53, p. 10]. This "forward looking vision" and the resulting policy makes it possible for all actors of MaaS to prepare for regulations and to adapt their business model within MaaS according to these regulations. An early, pro-active regulation will also minimize the risk for actors of MaaS to violate regulations that were made in consequence of new developments in the mobility sector. Lasse Nykänen et al. come to the conclusion that regulations "enable and push development forward by blurring existing silos between MaaS stakeholder and transport models" [103, p. 274]. Politics can therefore only act as driver for MaaS if it prepares the ground for its development by supporting the merge of currently separated kinds of mobility.

For the implementation of MaaS the best condition is explicit regulations – also for new and innovative mobility services – before the implementation of MaaS becomes fulfilled. The worst condition is, not to consider developments in the current law. Table 3.2.8 shows the five stages of the pro-activity of regulation.

Stage	Characteristic
1	Even for existing mobility solutions there is no legal certainty that allows operators of such services to fulfill legal requirements.
2	After the development of new mobility solutions politics deal with regulations for these solutions. These regulations can prevent the new solutions to become successful.
3	Even if regulations are made after the development of new mobility solutions, these regulations support new mobility business models to become successful.
4	Legislation observes new developments very carefully. That makes it possible for legal requirements for every new solution to be worked out very fast.
5	There are already lots of regulations that deal with the topic of MaaS or with comparable projects, even if these projects are not yet well developed. Therefore legislation is very well prepared for MaaS and comparable projects.

Table 3.1.6: Stages of the pro-activity of regulation

Data providing regulations

Due to a high degree of collaboration between different actors, a working MaaS system requires data exchange. Hence, a corresponding regulation has to allow the exchange of user and traffic data and to use these data to provide MaaS. However, not only the regulation itself determines the use of data, but also its degree of standardization [103, p. 275]. There has to be one comprehensive and standardized regulation to have a reliable legal basis for MaaS. This data regulation needs to be consistently for the whole operating area of MaaS and it needs to be in line with international regulations like European right. The international standardization is particularly important, if MaaS should be implemented in a union of different states [53, p. 3]. The design of these regulations is very complex as they have to regulate "if and for which cases companies should be legally required to provide certain data" [53, p. 9]. In [53, p. 9] Matthias Finger also mentions the risk that powerful companies like *Google* could get the control over a huge amount of data. For this reason, the data providing regulations for MaaS is a balancing act between strictness and the availability of data to provide MaaS: according to Markus C. Beutel et al. it is necessary to make a "trade-off between the convenience of getting information, booking and billing via one platform and privacy,

by giving away their personal data to several providers of mobility services at once" [12, p. 369]. On the one hand the high number of actors and different mobility providers within MaaS require a high degree of standardization. On the other hand this standardization could hamper innovations in the mobility sector [53, p. 10]. For the above mentioned reasons, the topic of data providing regulations requires special attention and its structure has to be defined in close cooperation with all actors.

On the highest stage these balancing act has already succeeded, so that there is an international regulation system which allows to store, transport and process data for MaaS. The lowest stage describes either no regulation or very strict regulation which makes it impossible to implement the MaaS system in line with this regulation.

Stage	Characteristic
1	There is either no regulation or the existing regulation is very strict which makes it impossible to implement the MaaS system in line with this regulation.
2	There are data regulations but they are not standardized. They differ from region to region so that it is hard for companies to prepare for the different regulations and to comply with them.
3	There are standardized regulations concerning the handling of data. These regulations are strict and might have a negative impact on innovative and new business models.
4	There are standardized regulations. These regulations are passive and react to current developments instead of creating guidelines in a pro-active way.
5	The current regulations are tailored to store, transport and process data in the mobility sector and to use them for MaaS.

Table 3.1.7: Stages of the data providing regulations

Passenger transportation regulations

Depending on the region, different kinds of national mobility and passenger regulations need to be respected by MaaS operators. The reorganization of the mobility concept could necessitate adjustments of passenger regulations. The connection of all transport modes implies that passenger rights need to be adapted to these new circumstances. The adaptation becomes more important if the integration of all transport "modes is deepening" [53, pp. 6-7]. Therefore it is important to figure out on the one hand a level that does not hamper the de-

velopment of new mobility services. On the other hand the quality of the mobility services needs to be ensured.

The best conditions for MaaS are given, if the adaptation of passenger rights is already fulfilled so that they are no obstacle for MaaS anymore. The worst condition is if the passenger rights are very strict rights which exclude certain mobility services.

Stage	Characteristic
1	The passenger transportation right is very strict and depends on the mode of transportation. Mobility offers like ride sharing in connection with MaaS cannot be reconciled with the current passenger transportation right.
2	There have been little adjustments to passenger rights in the last few years. The adjustments have been very minimal so that there are still obstacles for mobility providers within MaaS.
3	There are still many open questions concerning the legality of some mobility offerings within MaaS because there is no explicit regulation in the passenger transportation right.
4	Even if the adjustments in the passenger transportation rights have been significant, the MaaS concept has to be adapted and some services are still not reconcilable with the current right.
5	MaaS is a significant part of the individual's transportation rights. In recent years it was adjusted and it is no obstacle for mobility providers and the development of MaaS.

Table 3.1.8: Stages of the passenger transportation rights

3.1.3 Economic requirements

The following section deals with economic requirements for MaaS. Conditions like the availability of a critical mass for MaaS, the profitability of mobility services and the role of the car industry are analyzed.

Critical mass and demand for Mobility as a Service

A sufficient demand is necessary to develop a profitable business model. Therefore a high demand for MaaS is relevant to motivate different actors like the platform provider or mobility service providers to invest in this concept. A high degree of customer acceptance of new

mobility services, in particular of sharing models, is important because they are key elements of MaaS. In [95], Corinna Mulley comes to the conclusion that the success of MaaS depends on the "cultural shift away from personal car ownership and reliance, towards the multiple, often shared and public MaaS offerings" [95, p. 249]. The willingness of potential MaaS-users to replace the own car and to shift to a multimodal mobility behavior creates a higher demand for MaaS and makes it more attractive for mobility providers. Matthias Finger remarks: "the money that is not spent on cars becomes available for other mobility services" [53, p. 6]. Hence, the viability of "new mobility services" depends on the willingness of people to spend their money on new services instead of spending it for their own car. In addition an adequate demand for shared services and MaaS supports the network effect: the more people take part in the MaaS system (instead of using their own car), the more efficient and reliable it can work: more users lead to a wider selection of different mobility services and make it profitable to build up a dense network of different services. This is also why Finger remarks in [53, p. 5] that the opportunities for new mobility services emerge from a wider range of customers. As a consequence, the density of population in the considered area is an additional factor: the higher the density of population, the easier it is to build up a network and the greater the pool of potential users for MaaS is.

For the reasons outlined above, a high density of population, a high acceptance of sharing models and a decreasing importance of cars as a status symbol are necessary requirements for MaaS. The following five stages of readiness concerning the critical mass and demand for MaaS are derived from the above mentioned criteria.

Stage	Characteristic
1	Due to the low acceptance of sharing models, the high relevance of cars as status symbols and a low density of population, there is no real demand for MaaS.
2	In general there seems to be a change in the acceptance of sharing models. But due to the high relevance of cars as status symbols, the sharing economy in the mobility sector is still not developed. The demand for a concept like MaaS is very low – also because of a moderate density of population.
3	Surveys show that more and more people are using public transport services instead of their own car – an evidence for a decreasing relevance of the car as status symbol. A relatively high density of population supports the development of car sharing services.
4	Some projects and a higher willingness, than in the last years, to use a shared instead of an own vehicle, shows that there is more and more demand for MaaS. Even if there is a high density of population it is necessary to see if the projects which try to build up a working sharing-network can be expanded.
5	Lots of projects, also with a higher amount of participants, show that it is possible to build up larger sharing networks. Concepts like bike and car sharing are an established part for the mobility systems and there is a huge demand of these systems.

Table 3.1.9: Stages of the critical mass and demand for MaaS

Profitability of new mobility business models and the role of the platform operator

The implementation of MaaS requires the development of new business models: apart from the MaaS-platform operator there need to be additional mobility services which complement current services. Furthermore, current services need to be expanded to build up a working mobility infrastructure without private cars. According to Finger, the global trend of not buying a car – mainly in cities – requires the development of new mobility solutions which consider these new passenger needs for alternative mobility services [53, p. 6]. Therefore the mobility sector should be an attractive market sector for start-ups and established companies that have innovative power and the resources for investment-activities in the field of mobility. As main driver for this attractiveness Finger identifies the commercial viability of such models [53, p. 6]. For this reason, new companies and service providers have to be able to compete with already established mobility providers and to build up a profitable business.

It is also necessary to examine the environment in which new players in the mobility sectors act: are there any entry barriers that hamper the success of new transport models?

For MaaS, a mobility landscape with a positive development of profitably operated new mobility services is conducive. Furthermore, the development of new business models by already established mobility companies, like car companies, is helpful: these companies often have the resources, core competences and the financial power to build up professional new mobility services, even if they are profitable in a long term only. An unattractive landscape for investments and the development of new business models hinders the implementation of MaaS. On the contrary, a landscape which allows it to build up innovative mobility business models will support the implementation of MaaS. The following Table 3.2.12 gives an overview of stages of the profitability of new mobility business models in a region.

Stage	Characteristic
1	Mobility is not profitable and innovative business is limited to established public transport companies. Therefore no "new" companies or established companies with new business models are interested in investments in the mobility sector.
2	Making profit in the business sector is difficult. Most efforts to develop new business models or to provide comprehensive mobility services are made by established transport companies, but there is no competition with "new players".
3	More and more new players begin to provide mobility services which are based on a platform that combines different services. Also mobility providers like car sharing companies have been mostly successful in recent years. However, none provides a comprehensive service which is comparable to MaaS.
4	Currently there are many different kinds of models for a comprehensive mobility service and sharing services become more and more successful. Most of them are on a regional level, but there is also potential for a scalable platform. There is an increasing competition between established mobility companies and "new" providers of mobility services.
5	The high profitability in the mobility sector is the reason why there is a high degree of innovative power in the field of MaaS. In recent years more and more mobility providers have become successful and are available for the user via one comprehensive platform that operates in a profitable way.

Table 3.1.10: Stages of the profitability of new mobility business models

Role and support of the car industry

Traditionally the car industry is a key player in the mobility sector in many countries of the world [84, pp. 1-9]. Therefore it is impossible to restructure the mobility system of a region without the car industry. Also in the concept of MaaS, cars play an important role: car and ride sharing, taxi, on demand services and rental car companies operate with cars. The willingness and ability of the car industry to support a change in the mobility sector is therefore a significant part for the development of MaaS. In addition, the car industry often influences political decisions. For this case it is even more important that the car industry supports a change in the mobility sector. This support will be ensured, if the car industry realizes its chances which are caused by new mobility business models or higher profits by an increasing annual maintenance spent on shared vehicles. According to a *McKinsey* study from 2016 the vehicle unit sales will grow – even if shared mobility becomes more important – at a rate of approximately two percent [73, p. 4]. The automotive revenue pool will increase about 52 percent by 2030 compared with 2016. The share of revenues from new business models will be approximately 22 percent in 2030 (compared with 0.8 percent in 2016) [73, p. 6]. Figure 3.1.1 summarizes the development of the global automotive revenue pool from 2016 until 2030.

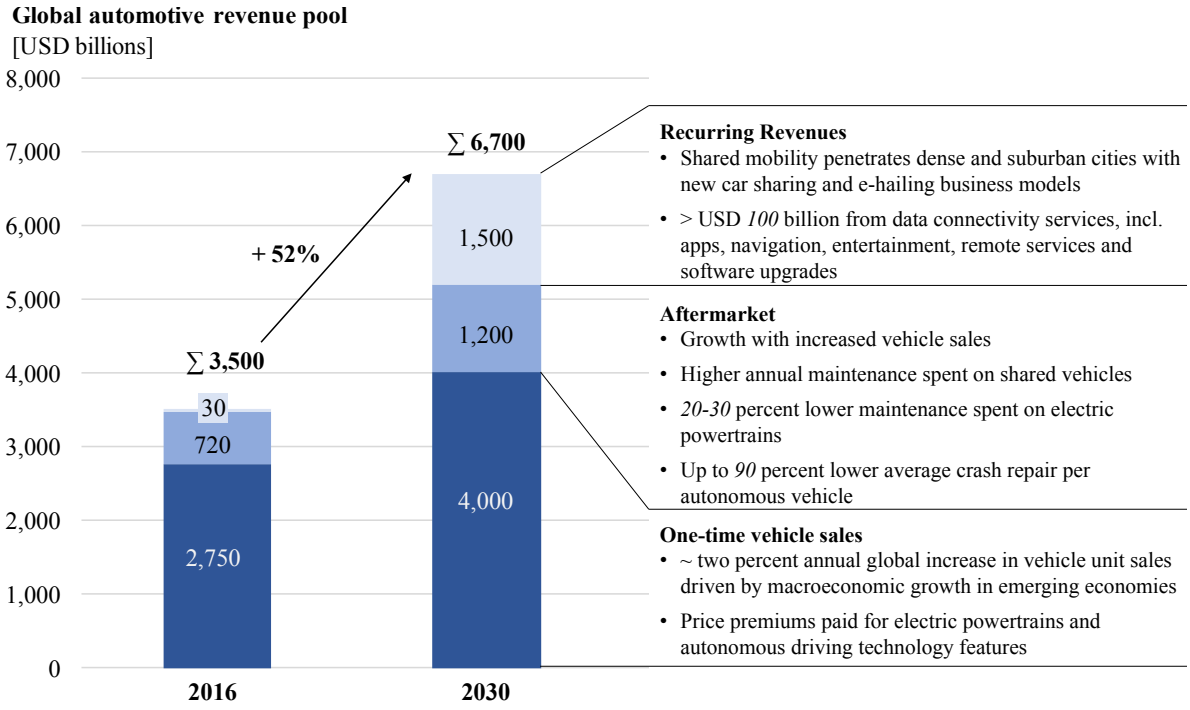


Figure 3.1.1: The global automotive revenue pool today and in 2030 (in USD billions, modified from [73, p. 6])

The question is, which role the car industry will overtake in the future mobility sector: on the one hand car companies could enter partnerships with mobility service providers like car sharing or rental car companies. On the other hand, car companies could act as mobility service providers themselves. They could develop their own business models by offering single services (for example car sharing services) or comprehensive services which include different kinds of mobility offers and the operation of the MaaS-platform.

The following Table 3.1.11 gives an overview of different roles of the car industry. On the first stage the car industry does not see any potential for its revenue pool, which would be the worst conditions for MaaS. On the fifth stage the car industry is already integrated into a comprehensive mobility system and cooperates with other mobility providers.

Stage	Characteristic
1	The car industry has not realized the development of "sharing" a car instead of "owning" a car and the increasing importance of mobility services. Therefore car companies do not invest in such services and do not support the development of MaaS.
2	The car industry realizes the trend of an increasing market for mobility services. Nevertheless they are not willing to invest in this market because they see those services as competition for their current core business of selling cars.
3	The car industry sees the potential of mobility services. By cooperating with mobility service providers like car sharing companies, the car industry tries to become part of the mobility service business. At the moment they do not provide own mobility services and hesitate to enable extensive investment activities in the mobility service sector.
4	The car industry starts to see the advantages of new mobility concepts. Car companies begin to build up their own mobility services (e.g. car sharing) to be part of this new concept and to generate additional profit.
5	Mobility services maintain as a core business of car companies. Nevertheless they maintain their partnerships and support with start-ups and other mobility service providers. The car industry has become an important part of the MaaS system.

Table 3.1.11: Stages of the support for MaaS by the car industry

3.1.4 Infrastructural requirements

Infrastructural requirements refer to the quality and diversity of the current mobility system. Not only the conditions of the services themselves are important for MaaS but also its degree of collaboration with each other.

Quality of the current mobility system

The concept of MaaS builds on the current mobility system. The quality of current mobility services is therefore an important factor to implement MaaS. The higher the quality of the current mobility services, the easier it is to merge existing services to one mobility service like MaaS: the implementation does not have to start with the development of mobility services themselves in the first step. This is the reason why in [53] it is recommended to "focus the application of MaaS on areas where good physical connections are already in place" [53, p. 8]. Therefore, it is useful to examine the quality of the mobility services which will be part of MaaS.

The valuation of the quality of the current mobility system has to be made for each mobility service which could be part of MaaS. Therefore there will be a separate consideration for five basic services: firstly public transport, secondly taxi, thirdly rental car, fourthly bike and car sharing and fifthly ride sharing and on-demand services. For each of these services there has to be an examination of the degree of distribution or development, the competitive situation and specific challenges. The stages in Table 3.2.19 are used to evaluate the conditions for each of the mentioned services.

Stage	Characteristic
1	Compared with other regions the distribution and availability of the service is very poor. Specific challenges hamper the development of the considered service.
2	The quality of the service is increasing but it is still below average compared with other regions because of specific challenges that hamper the development of the considered service.
3	Even if there are political efforts to support the service, there are still difficulties concerning this service.
4	The quality of the considered service can be evaluated positively. Nevertheless there is a higher potential for the service and it remains to be seen if this potential can be used in the next few years.
5	The availability and quality of the considered service is excellent. There are positive conditions for the service in the considered region.

Table 3.1.12: Stages of the quality of mobility services

3.2 Evaluation of the conditions for Mobility as a Service in North Rhine-Westphalia

The following chapter evaluates the conditions to implement MaaS in Germany. This evaluation is done with the help of the catalogue of criteria which was developed in the previous section 3.1. It can be presumed that there are major differences concerning the identified requirements in various regions of Germany. This is why the following examination will focus on a specific region of Germany: North Rhine-Westphalia (NRW). NRW, located in the west of Germany, is the most densely populated federal state and one of the largest metropolitan areas in Germany. Therefore an implementation of MaaS in this region is very promising. Nevertheless, for some criteria there will be a national discussion of the corresponding conditions of MaaS, because in some cases an isolated consideration for NRW is not useful.

3.2.1 Technical conditions

The following first part of the examination deals with the technical conditions to implement MaaS in NRW. This chapter considers the availability of comprehensive smartphone applications and pilot projects which are already implemented in NRW. Furthermore there is an

examination of the smartphone distribution and the availability of internet connections in NRW.

Availability of comprehensive smartphone applications and pilot projects in the mobility sector

Multimodality, the combination of different mobility services, is very unusual in everyday life in Germany. The cooperation between different mobility services is predominantly limited to public transport operators, such as local public transport operators and the *Deutsche Bahn*. These operators often share data and provide each other with booking- and paying options, but they usually do not integrate other modalities to their platforms [11, pp. 3-4].

However there are some projects in Germany which are based on the integration of several mobility services on one platform. Table 3.2.1 gives an overview of some of these projects.

Project (operator)	**Range of functions; integrated providers/services**	**Scope**
Moovel [40] *(Daimler)*	Searching, booking and paying; Car sharing *(Car2Go)*, taxi *(mytaxi), Deutsche Bahn*, local public transport for Stuttgart *(VVS)* and Hamburg *(HVV)*	Germany (in particular Stuttgart and Hamburg)
Qixxit [110] *(Deutsche Bahn)*	Booking of tickets for *Deutsche Bahn*. Searching and leading to the booking page of airlines (long distance bus companies planned)	Germany
Mobility-Broker [92] (Cooperation)[1]	Searching, booking, paying; car sharing *(cambio)*, bike sharing *(velocity Aachen)*, local public transport *(ASEAG)*	Aachen
Mutti [14] *(Bogestra)*	Searching, booking paying; local public transport *(Bogestra)*, bike sharing *(nextbike/metropolradruhr)*, taxi (only information, no booking/paying)	Bochum/ Gelsenkirchen
Mobility inside [93] *(INFRA Dialog)*[2] Not realized so far	Searching, booking paying; nationwide local public transport services (long-term: integration of third party mobility providers)	Germany

Table 3.2.1: Illustrative MaaS pilots (or similar projects) in Germany (modified from [58, p. 122])

The above projects have different ranges of functions, amounts of integrated services and acting-scopes. The application *Moovel*, operated by *Daimler* includes functions of booking and paying. The provided services are in-house offerings of *Daimler* such as car sharing, and taxi services. Moreover this application includes local and national public transport services like the *Deutsche Bahn* or *VVS* services. The offer of *Qixxit* by the *Deutsche Bahn* focusses on in-house offerings of the *Deutsche Bahn*. However the application also leads the user to other service-providers such as airlines or long-distance bus providers: booking is possible for *Deutsche Bahn* railway service only. The other mentioned projects in Table 3.2.1 work in a different way and allow an "undiscriminated provider access" [11, p. 2]. The project *Mobility-Broker* in Aachen is operated by a cooperation of different companies such as the *RWTH Aachen University*, the IT-company *regio iT* or the local public transport operator *ASEAG*. Therefore the *Mobility-Broker*-platform includes independent mobility companies, which gives the opportunity to add more and more companies to it. The user gets provided

[1] Cooperation of *RWTH Aachen*, *DLR*, *ASEAG*, *regio iT*, *IVU*, *Stadtwerke Osnabrück*

[2] *INFRA Dialog* is a co-operation of 20 different transport companies in Germany like *Verkehrsverbund Rhein Ruhr (VRR)*, *Bogestra* or *DSW21* [137], [93, p. 4]

with a reliable and close mobility service which consists of different providers. All integrated services can be booked and payed via the application as well. Also the application *Mutti* which is operated by a local public transport provider, offers different kinds of mobility services like the booking of bike sharing services or information about taxi services and the local public transport service. The project of *Mobility inside* is the attempt of more than 20 different mobility providers and transport companies from Germany to provide a nationwide and comprehensive mobility platform. In a long term also third party mobility providers such as car sharing companies are meant to be integrated into this platform. This project is also supported by the German government but is not yet implemented [21].

The analysis shows a number of pilot projects trying to build up a comprehensive mobility service in the region of NRW. The presented projects mainly focus on a limited region. The option to integrate additional services to existing platforms is currently not sufficiently realized and in general the following dependency is obvious: the higher the number of mobility service partners, the lower the platform-functionality. *Quixxit* or *Mutti* are examples showing this contrary relation between functionality and number of mobility providers. *Mobility inside* seems to be the only project which provides a nationwide mobility service with access for additional mobility providers with a high functionality. This project is not yet realized. Hence NRW can be classified as stage four as shown in Table 3.2.2.

Stage	Characteristic
4	Some applications which provide the opportunity to book and pay for different services are available. These applications often provide only two or three services and it is difficult to predict if it is feasible to add more services into the existing applications and if it also works for a higher amount of users.

Table 3.2.2: Availability of comprehensive smartphone applications and pilot projects in the mobility sector in NRW

Tariff systems, revenue sharing- and paying-models

At first glance there is a high heterogeneity in the tariff system of the local public transport system in Germany. In NRW there are approximately 130 different local public transport providers [29]. According to [114, p. 41] this heterogeneity is one of the most frequent reasons for passengers complaints in NRW. Due to that, there are strong efforts to harmonize different tariff systems in NRW [29]. The result of these efforts is shown in Figure 3.2.1.

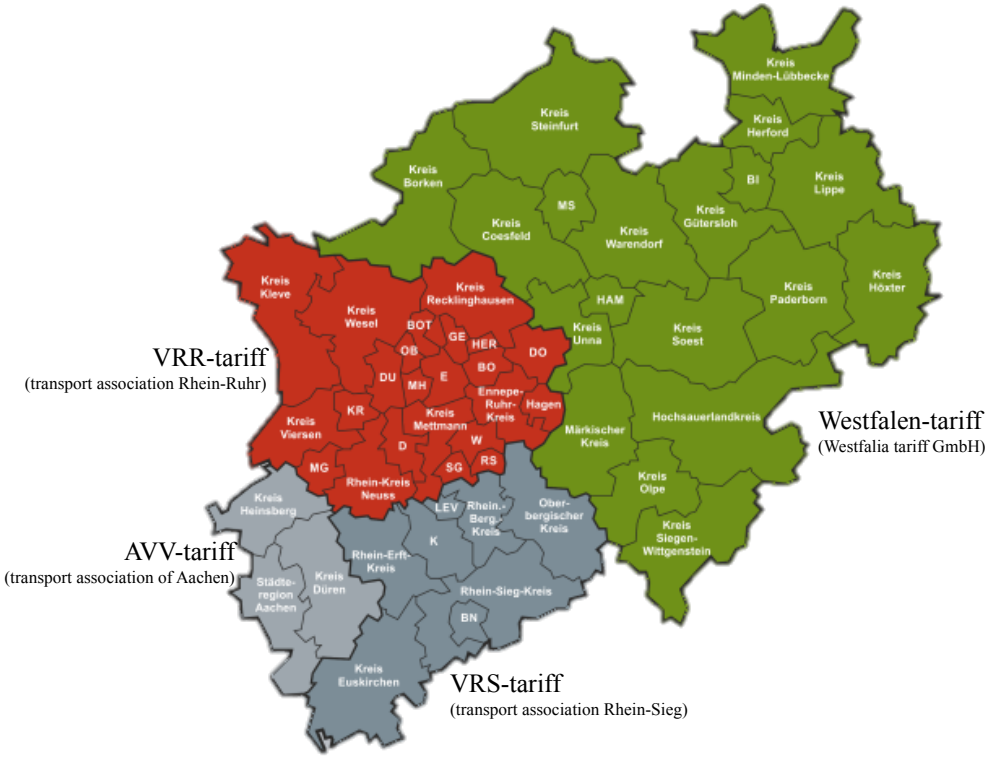


Figure 3.2.1: Local public transport tariff systems in NRW since 2017 (modified from [29])

Since 2017 there have been four different tariff systems in NRW: the *VRR-tariff*, the *AVV-tariff*, the *VRS-tariff* and the *Westfalen-tariff*. Each tariff system has its own price structure. Since 2002, the *Kompetenzcenter Marketing NRW (KCM)* provides a NRW-wide ticket which allows it to travel the entire NRW-region [121]. In connection with the ticket a clearing system has been developed which allows to share the revenues between different providers. According to the *KCM* this system has been modified severeal times since 2002 [121, p. 8]. Initially the structure of the system was highly complicated and it was based on bilateral agreements, but today there is a central clearing system. This system allows a transparent, comprehensible and fair distribution of the revenues [82, p. 8]. It is also used by the company of *VDV eTicket service*, which provides electronic tickets in different tariff zones in Germany. The principle of *central clearing* is depicted in Figure 3.2.2. [129]

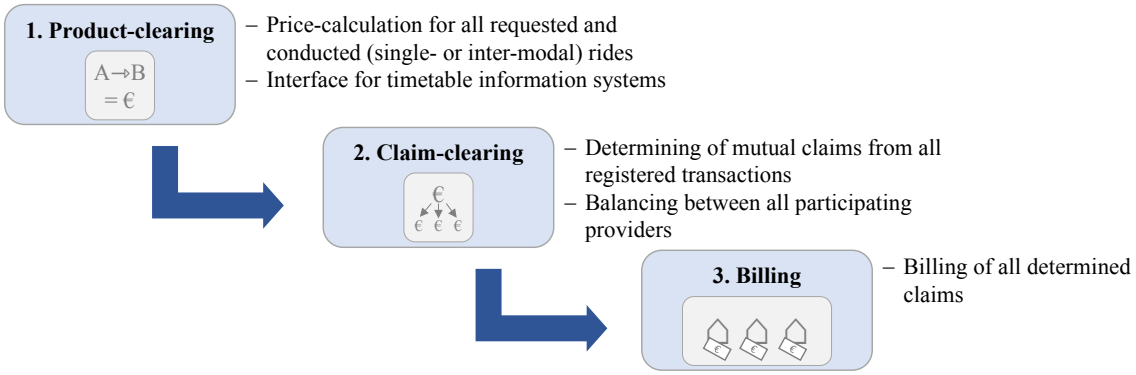


Figure 3.2.2: Principle of the *eTicket*-clearing (central clearing) (modified from [129])

The figure shows the three steps of the clearing system. Firstly there is the price calculation of requested or conducted rides. The system is able to consider different tariff zones and different modes of transportation: according to [130] it allows not only the integration of different local public transport companies but also the integration of other mobility services like car or bike sharing companies. By providing a corresponding interface, it is possible to display the calculated price to the end user immediately. Secondly, the system balances the mutual claims between all providers that take part. Thirdly, the determined balances are billed to the different providers. The described principle is ablte to calculate costs for multimodal trips and makes it possible to offset the payments to the providers which take part in the MaaS system: according to its spokesman, the *VDV eTicket Service GmbH* is convinced of the high *eTicket Service*-potential in connection to combined mobility services [131]. He assumes a completion of central background systems at the beginning of 2019, so that there is no organizational or technical restriction for linked mobility services. From his point of view, the *VDV eTicket Service* is prepared for multimodal mobility services [131]. Nevertheless he remarks that the responsibility for the specific implementation and usage of this system is located at the local mobility companies. The *VDV*-spokesman sees local differences in the bundling of services. Transport companies in regions like Schwäbisch-Hall (*KOLIBRICARD*) or in the area of the Bodensee (*Bodo-ecard*) use the *VDV eTicket Service* for innovative use cases, like pay-as-you-go tariffs [131]. Already 69 transport services in NRW are using the principle of *eTicket Service* but in contrast to the before mentioned regions the use in NRW is less innovative. The spokesman remarks that more and more local public transport providers are dealing with the topic of MaaS and that some of them are trying to offer a comprehensive mobility service at least in a local area [131]. In [11, p. 5] the *eTicket* is described as the de facto standard electronic ticket in Germany as well. It is supposed that this kind of electronic ticket is “suitable for most, if not all, mobility modes

[...]" [11, p. 5]. The German government supports the introduction of the *eTicket* and hereby tries to improve the attractiveness of alternative and combined transport services [16, p. 50].

The illustrated clearing system shows that it will be possible to combine various kinds of mobility with different tariff-systems in the short term. The statements of the *VDV eTicket Service* show that the organizational and technical requirements are already in place or will be fulfilled soon. Here it depends on mobility providers to use new ticketing-options. The efforts to harmonize the tariff-systems and the high degree of *eTicket Service* usage in NRW lead to the assumption that mobility providers in a next step use these opportunities to provide a comprehensive and combined mobility service in the form of MaaS as well. Nevertheless it is not sure if mobility providers will truly fulfill this step or not. Therefore the region of NRW can be classified as stage four concerning the suitability of the current tariff systems and revenue sharing.

Stage	Characteristic
4	In recent years there have been strong efforts to harmonize the tariff system in the mobility sector. There are also solutions which provide standardized interfaces and billing, which makes it possible to offer different mobility services via one booking system. These solutions are already used at least by local public service providers.

Table 3.2.3: Current tariff systems and revenue sharing in NRW

Distribution of smartphones

In August 2017, 81 percent of Germans over 14 years used a smartphone at least occasionally [60, p. 3]. In recent years the amount of smartphone users has raisen rapidly: in May 2014 the share of smartphone users was only 55 percent [60, p. 3]. Also in the group of people, of 65 years and older, the use of smartphones is increasing: since January 2016 it increased from 28 percent to 41 percent in 2017 [60, p. 3]. Because of the comparable age structure [119, pp. 13-14], it can be assumed that the distribution of smartphones in NRW is comparable with the distribution in entire Germany.

All in all there is a high and increasing usage of smartphones in NRW, which is positive for the implementation of MaaS. Due to that NRW reaches stage four in the distribution of smartphones.

Stage	Characteristic
4	Overall the usage of smartphones is over 80 percent.

Table 3.2.4: Distribution of smartphones in NRW

Availability and capacity of internet connections

In Germany the average internet download speed is $22.7 Mbps$ and the availability of LTE-internet is about 65.7 percent [102]. These data correspond to position 32 compared with other European countries. Germany has therefore one of the worst LTE-internet coverage in Europe [102]. According to the *Global Competitiveness Report*, Germany reaches only rank 42 of 134 in the field of internet bandwidth [115, p. 127].

Using the MaaS-platform requires not just a reliable overall mobile internet connection. Especially the internet connection during train rides has a significant importance. For this reason it is useful to analyze the internet connectivity in trains more detailed. The following Table 3.2.5 shows the network coverage of different mobile network operators within the rail network of the *Deutsche Bahn* in 2016.

Mobile Network Operator	LTE	3G/UMTS	LTE or 3G/UMTS
Telekom	52.4%	23.3%	64.45
Vodafone	43.7%	13.1%	51.1%
O_2	29.1%	10.9%	37.0%
Bundled	78.5%	38.2%	87.2%

Table 3.2.5: Percentage of network coverage on the *Deutsche Bahn* - rail network (modified from [42])

The table shows that the best internet provider has a network coverage ($3G$ or LTE) of around 64 percent. The worst network has a coverage of around 37 percent. The *Deutsche Bahn* plans to provide WiFi in its local transport trains in the future. This technology works with the help of mobile network operators as well. For this purpose, the different networks are bundled to provide a connectivity which is as good as possible. Even if this technology is reliable on the whole rail network, the maximum coverage is 87 percent. [42]

A closer look at the region of NRW does not lead to a better result compared with all of Germany. The figure shows the *Telekom* $3G$-connection quality in NRW.

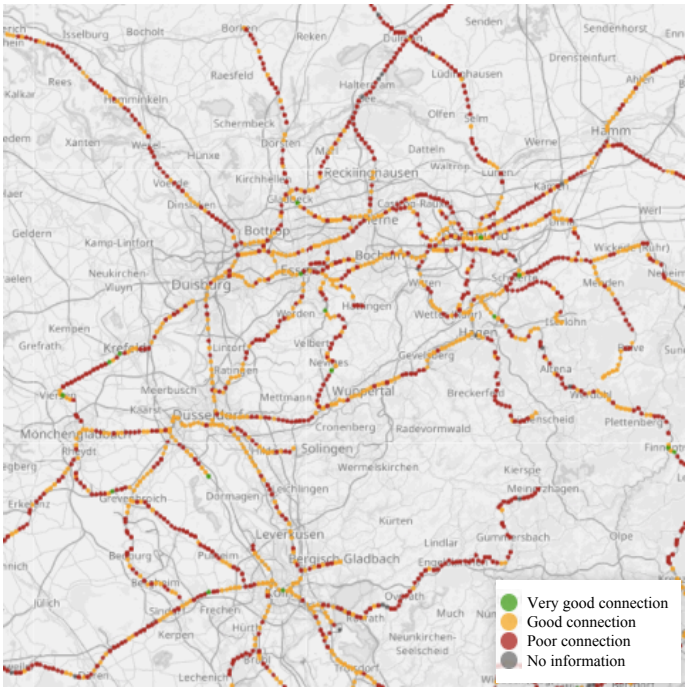


Figure 3.2.3: *Telekom* $3G$-connection quality on the *Deutsche Bahn* - rail network measured in 2016 (modified from [42])

There is predominantly a "poor" or "good" $3G$-connection quality on the railroad network of the *Deutsche Bahn*. Just in a very few sections the connection quality is "very good". Unfortunately the three different valuation results "very good", "good" and "poor" are not specified in more detail in [42].

As shown above, the availability and capacity of internet connections in Germany and NRW are partially insufficient. Especially a closer inspection of the rail network shows that the internet connection can become a real obstacle when implementing MaaS. Therefore NRW can be classified as stage three concerning the availability of internet connections (see also Table 3.2.6).

Stage	Characteristic
3	In central areas there is a reliable $3G$- or LTE-internet connection. In rural areas or at the railroad network, the connection is largely poor.

Table 3.2.6: Mobile internet connection quality in NRW

3.2.2 Regulatory and political conditions

The following section deals with regulatory and political conditions for MaaS in NRW. The discussion will focus on political support, the pro-activity of regulation, data providing regulations and passenger transportation regulations in Germany.

Political support and pressure

In Germany the pressure for change in the mobility sector is increasing. Air pollution in cities, more and more congestions and the challenge to meet national and international climate targets, are the main causes for increasing political pressure. This pressure is induced by domestic media, by decisions of the European Commission, by German courts or by non-governmental organizations.

According to a press release by the German representation of the European Commission on 15 January 2018, Germany and four other countries could be sued at the European Court of Justice because of violation of the EU-directive concerning air quality (directive $2008/50/EG$) [30]. To avoid the prosecution, the European Commission expects actions which ensure air pollution control. The directive $2008/50/EG$ determines inter alia limited levels for the concentration of the nitrogen oxide NO_2. Figure 3.2.4 shows the annual mean value of the NO_2-concentration in Germany.

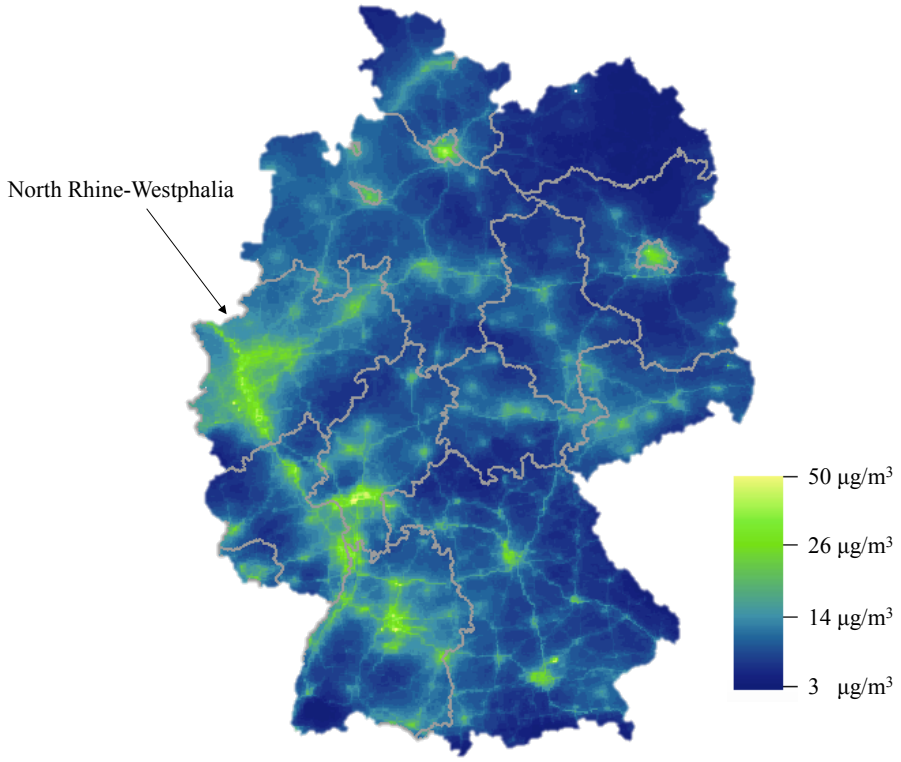


Figure 3.2.4: Annual mean value of the NO_2-concentration in Germany in 2016 (modified from [127])

The permitted maximum annual mean value of $40\mu g/m^3$, which is fixed in directive $2008/50/EG$ becomes violated in several densely populated areas in Germany. NRW is particularly affected by these violations: in 2016, the maximum value of $40\mu g/m^3$ was exceeded at 60 of 127 measuring points in NRW [83]. According to a federal state government report of NRW the main causes for the high NO_2-concentrations are high traffic loads and a huge amount of diesel vehicles [83, p. 5]. It is remarked that a reduction of the NO_2-emissions is not possible without reducing the emissions that are induced by motor vehicles [83, p. 5]. Concerning increasing air pollution, the *Federal Administrative Court* in Leipzig decided that municipalities have to ensure the compliance with the maximum value of NO_2-concentrations. Municipalities are therefore obliged to take corresponding actions which can even include driving bans for particularly pollutive vehicles such as diesel cars (*BVerwG, Leipzig, February 27, 2018, 7 C 26.16*) [27]. The courts decision in combination with the threat of a persecution by the European Commission lead to a high pressure on the municipal, federal and national level. One proposal of the national government to face this challenge was the implementation of a free local public transport service in five different model cities, also in NRW. Certainly this idea was severely criticized – also by municipalities: according to the CEO of the *German Association of Towns and Municipalities*, Gerd

Landsberg, this proposal is a visionary idea, which is too expensive at the moment and has at best a longterm-perspective [112].

The increasing amount of congestions has become a major problem in the last few years as well. According to the annual congestion report of the *German Automobile Club* (*ADAC*), NRW is by far the federal state with the largest congestions problems: in 2017 there were overall 450,000 kilometers of congestions in NRW [4]. In Bavaria, which is in second place, only 282,707 kilometers of congestions were measured at the same time. Overall, the congestion in Germany reached an all-time high in 2017: there was an increase of congestions of approximately four percent compared with 2016 [4]. In [120] the *ADAC* requests actions from the federal government of NRW to face this challenge. Besides higher investments into road infrastructure, the *ADAC* recommends investments into cycling path infrastructure [120, p. 3]. A further recommendation is the development of shared services (bike and car sharing) and corresponding app-solutions to support these services. The expansion of park and ride parking lots for a better connection between different modes of transport is an additional proposal of the *ADAC* to face the challenge of increasing traffic. [120, p. 7]

The given aspects in addition to the national and international climate targets, which were discussed in the first chapter, are an indicator for a high political pressure to induce changes in the mobility sector in the near future. As shown, this pressure is caused by different actors such as the European Union, non-governmental organizations or municipal associations. Municipalities are under particular pressure: on the one hand they are responsible to provide a sustainable, economic and ecological mobility system for their region. On the other hand municipalities are dependent on political (and financial) support from the federal and national governments. On the national level, the coalition agreement of the current state government in Germany includes corresponding targets in the sector of mobility: inter alia there should be a legal framework for new mobility services like ride pooling or a support for car sharing offers [24, p. 14].

Political conditions for an implementation of MaaS are promising: the threat of legal actions by the European Commission has led to time-sensitive pressure that forces politics to initiate specific actions within the mobility sector. The discussion about driving bans for some vehicles as “last chance” shows that there is a lack of sustainable actions and ideas to face the current challenges and the increasing pressure. Nevertheless it remains to be seen, if this pressure leads to essential political actions. Therefore NRW reaches stage four concerning political support and pressure for new mobility concepts, as shown in Table 3.2.7.

Stage	Characteristic
4	Besides national and international climate targets there are other region-specific drivers that lead to increasing political pressure. Nevertheless there is no comprehensive concept which supports sustainable and extensive changes.

Table 3.2.7: Political support and pressure concerning new mobility concepts

Pro-activity of regulation

The previous chapter has shown lots of challenges in the mobility sector in Germany and NRW. In addition to these challenges, there are additional obstacles due to some regulations which influence the development of the mobility sector. Examples of such regulations are the German transportation right (*PBefG*) or data providing regulations. While the impact of these regulations will be discussed in a later section, this section focusses on pro-active adjustments of regulations to support new mobility models such as MaaS. The following discussion does not just focus on the region of NRW because the regulation is predominantly made by the national government.

The director of the *Center of Automotive Management*, Stefan Bratzel takes the view that there is a low degree of regulation pro-activity. In his opinion there is merely a fight against symptoms, but no fight against the real causes of the current challenges. From his point of view this leads to the fact that courts need to do politics. An example is the case of the *BVerwG*-decision concerning driving bans for diesel vehicles (*BVerwG, Leipzig, February 27, 2018, 7 C 26.16*), which was discussed in the previous chapter. [76]

Another example of a missing pro-activity of regulation is the car sharing law (*CsgG*), which was passed in 2017. This law has the target to support the concept of car sharing in Germany. Key element is *§ 3* which allows priorities for car sharing vehicles (*§ 3 CsgG*): authorities are allowed to provide car sharing providers special permits with regard to separate parking lots for car sharing vehicles (*§ 3 II 1 CsgG*) and reduced parking costs (*§ 3 II 2 CsgG*). The law also regulates the use of public space as location for station-based car sharing providers (*§ 3 I CsgG*). When the car sharing law was passed there were already 1.7 millions registered car sharing users in Germany [10]. One of the first car sharing providers, *cambio CarSharing*, has already operated since 1990 [100]. Therefore it cannot be said that the *CsgG* was pro-actively implemented. The *CsgG* is rather a reaction to the increasing pressure and criticism

in recent years. The mobility researchers Weert Canzler and Andreas Knie are criticizing that the already changed social behavior concerning traffic has no chance of a breakthrough under the current regulatory conditions [34, p. 478]. Canzler and Knie request a consequent political program to force a change in the mobility sector [34, p. 478]. The *CsgG* is one example for the assumption that this consequence is currently missing. The actual implementation and responsibility to support car sharing companies become imposed to the local authorities: the *CsgG* creates just the conditions for this support but it represents no guarantee that mobility concepts like car sharing get political and regulatory support. The car sharing companies *cambio CarSaring* in Aachen and Cologne and *Stadtteilauto* in Münster confirm this impression: according to these providers the *CsgG* has no practical implications. It merely provides legal security for special permits for car sharing providers which already exist for up to ten years [32] [33] [116]. Concerning parking costs and fees none of the three providers confirmed an improvement as well [32] [33] [116].

The example of car sharing shows that there is no pro-active regulation in the mobility sector. Regulations which are made afterwards do not have significant impact on the conditions for new mobility services.

The lack of positive changes for car sharing providers after the enactment of the *CsgG* is an indicator for this assumption. As it will be shown in chapter *Passenger transportation regulations*, some existing regulations do indeed hamper the development of new mobility services. Therefore the region of NRW reaches the second stage in the degree of pro-activity of regulation in the mobility sector as shown Table 3.2.8.

Stage	Characteristic
2	After the development of new mobility solutions politics deal with regulations for these solutions. These regulations can prevent the new solutions to become successful.

Table 3.2.8: Pro-activeness of regulation in NRW

Data providing regulations

At least since the European Commission passed the General Data Protection Regulation (*Regulation (EU) 2016/679 (GDPR)*) in 2016 which has to be fulfilled since May 2018, data providing regulations can not be considered as a national issue. The GDPR standardizes the

data regulation within the European Union [105, p. 3]. Furthermore, it determines significantly higher penalty fees in case of violations [105, p. 3]. As it is shown below, the new regulation is seen as a huge challenge by German companies. Experts like the researcher Alfred Hermanni see a slow policy making by the European Union as one reason for a competitive disadvantage of European and German companies compared with non-European companies [66, p. 22]. Nevertheless the GDPR represents a profound change and European standardization of the previous data regulations for most companies in Germany [105, p. 3]. As a result of this profound change, the problem of standardization and European-wide regulation seems to be solved on the one hand. On the other hand a survey of the *Center of European economy research* shows, that the GDPR brings new challenges for German companies. Figure 3.2.5 shows the results of this survey.

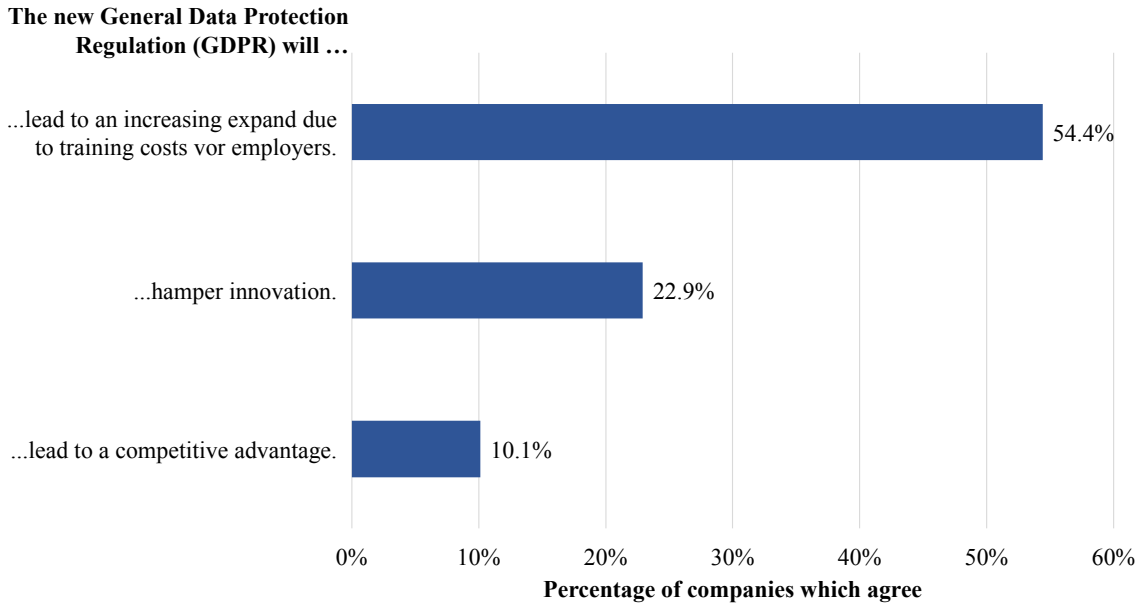


Figure 3.2.5: Results of a survey by the Center of European Economy Research concerning the GDPR that has been applicable since May 2018[3][104]

More than 54 percent of the companies in Germany that are acting in the information-economy expect an increasing expense due to the GDPR [104]. Around 23 percent of the interviewed companies are even expecting that the GDPR will hamper innovation [104]. In [64] Irene Bertscheck, the leader of the *Department of Digital Economy* at the center of European economy research, argues that the new GDPR can be a locational advantage for European companies as well. However, companies themselves do not expect this advantage: according to the survey only ten percent of the companies expect a competitive

[3]Basing on 682 interviewed information-economy companies in Germany

advantage over non-European companies. Tobias Kollmann, researcher for E-Business and Entrepreneurship at the *University of Duisburg-Essen*, concurs this assessment of disadvantages occurred by strict data providing regulations – in particular for German companies. In his opinion data providing regulations often become strictly interpreted in Germany [80, p. 163]. For the future he assumes that a strict data providing regulation in times of "Big Data" will not be a locational advantage. He advises that data providing regulations, even if they are important, should be downgraded to a level of necessary constraint [80, p. 163].

All in all the data providing regulations in Germany are very strict, not only because of the GDPR. Many companies see this development as a hamper for innovation. However innovations and a healthy amount of data providing regulations is one of the main requirements for MaaS. Data are the base to provide the user a comprehensive and individual offer of information about all mobility services and to design the MaaS-system as efficient and user friendly as possible. The assessments of German companies and researches show that it is questionable if the new GDPR in connection with the strict interpretation of data providing regulations in Germany will create positive conditions for the implementation of MaaS. Nevertheless it is positive that there is an international standardized regulation. This makes it at least possible for companies to adapt to this regulation.

These results lead to a classification of the conditions concerning data providing regulations in NRW on stage three (see also Table 3.2.9).

Stage	Characteristic
3	There are standardized regulations concerning the handling of data. These regulations are strict and might have a negative impact on innovative and new business models.

Table 3.2.9: Data providing regulations in NRW

Passenger transportation regulations

In Germany passenger transportation is regulated in the *Passenger Transportation Law* (*PBefG*). This act contains requirements and regulations of the commercial transport of passengers. According to this law, every transport of passengers needs to be approved in case payment for transportation is higher than operating costs (*§ 1 II 1 PBefG*). Depending on the mobility service which should be provided, there are different criteria that need to be

fulfilled, to get official approval for the operation of this service. These criteria, which can be the professional competence or the assurance of a high safety degree (*§ 13 I 1 - 4 PBefG*), should obviously ensure a high quality of the mobility services. Other criteria which have to be fulfilled, refer to the need of an additional mobility service in the affected region: according to *§ 13 II-V PBefG* applied services get no approval if existing services satisfy the demand. Therefore for example the density of taxis or the demand for transport orders has to be examined. The *PBefG* contains no specific information or criteria for "new" mobility services like car sharing, ride sharing or on-demand services. However, according to *§ 2 VII PBefG* it is allowed to test new mobility services for limited time of four years.

In [34, p. 478] Weert Canzler and Andreas Knie critizise that the development of new mobility patterns is not possible against the background of currently existing regulations [34, p. 478]. The transport researcher Günter Knieps from the *University of Freiburg* claims that the *PBefG* hampers new mobility services as well. He sees a law-protected monopoly for public transport services in the mobility sector [79, p. 3]. He remarks that this monopoly avoids the development of the high potential and technical progress that could be realized in a competitive environment. Knieps recommends a revision of the *PBefG* by allowing free competition on the mobility market and by abolishing the needs assessment in *§ 13 PBefG* [79, p. 1]. Also Canzler and Knie come to the conclusion that it would be helpful to allow fundamental changes in the mobility sector at least in a regionally limited area. They propose the option for municipalities to give special permits, financially supported by the federal government to make mobility services perceptible in everyday life [34, p. 480]. The *CsgG* allows such permits already for car sharing companies but as it was shown in the section *Pro-activity of regulation* this opportunity is currently not comprehensively used by municipalities. Also the permit to allow the test of new mobility services according to *§ 2 VII PBefG* is temporally limited and therefore does not represent a sufficient support of new mobility services. Canzler and Knie note that in recent years there have been no interest groups, which shows efforts to achieve a fundamental change in transport political issues [34, p. 478].

The idea of MaaS is the merger of different kinds of transport with the target to build up comprehensive service which avoids the necessity to own a car. Therefore it is useful and necessary to provide a wide range of mobility services which complement each other. In the previous paragraphs it was shown that public transport services and taxis enjoy special protection in Germany. Due to that, the mobility market is not competitively organized. According to the quoted researchers, this lack of competition avoids the development of alternative mobility services. In addition to that, the *PBefG* does not include regulation

concerning "new" mobility services which cannot be categorized as public transport, rental car or taxi services. Hence often courts have to decide about the admissibility of new business models as it will be shown in chapter 3.2.3. With regard to the implementation of MaaS in Germany the results show that the legal conditions are not conducive. Therefore Germany can be classified as stage one concerning the conditions for MaaS given by the *PBefG*, as shown in the following table 3.2.10.

Stage	Characteristic
1	The passenger transportation right is very strict and depends on the mode of transportation. Mobility offers like ride sharing in connection with MaaS cannot be reconciled with the current passenger transportation right.

Table 3.2.10: Passenger transportation right in Germany

3.2.3 Economic conditions

The following chapter reviews the economic conditions for MaaS in Germany and NRW. Firstly the demand for shared services will be discussed. Secondly the profitability of mobility business models will be assessed. Finally the role of the car industry concerning mobility services will be analyzed.

Critical mass and demand for Mobility as a Service

The availability of a critical mass for MaaS depends on the demand for shared and multimodal mobility. The availability of this critical mass makes it possible to build up a close, profitable and reliable mobility system which can avoid the use of private vehicles. Figure 3.2.6 shows the development of the amount of registered car sharing users since 2008 in Germany.

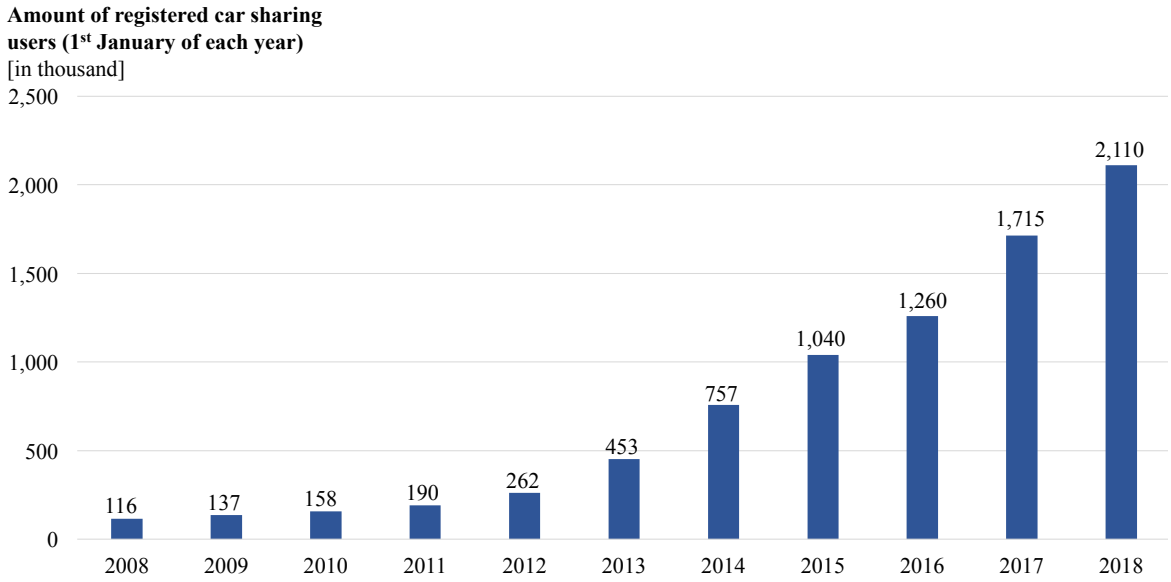


Figure 3.2.6: Amount of registered car sharing users since 2008 in Germany [71]

The amount of registered car sharing users has continuously increased: in 2018 there were more than two million registered users compared with 116,000 registered users in 2008 [71]. This high amount of registered car sharing users is an indicator for an increasing demand for shared mobility services in Germany.

In [122, p. 8] it is noted that flexibility and individuality in the mobility sector become more and more important. According to [122, p. 8] "individuality" does not mean ownership of private vehicles anymore. It is rather important to have an independent mobility management with the opportunity of flexible and seamless connections [122, p. 8]. This is why especially for young people the attractiveness and willingness to buy a car has become less important while they put emphasis on multimodal mobility [122, pp. 9-10]. Already in the past younger people used private cars less often than others [122, p. 9]. Therefore a higher connectivity between different mobility providers, a higher degree of automation in the mobility sector (e. g. mobility-platforms), an easy booking and paying process and more mobility with lower CO_2-emissions are mentioned as necessary conditions to support this development in the future [122, pp. 13-14]. In how far MaaS is able to provide a good environment for electric vehicles will be discussed in chapter 4. It is noted that people have to be convinced of new mobility concepts. Barriers are aspects like the risk of the absentee of a car sharing offer, the absentee of interfaces between different mobility modes and the fear of change [122, p. 14]. This fear can be caused by new accessing modes to the mobility services (like an application) and by the handling of different car models instead of one's own familiar car [122, p. 14].

As an additional, important factor when introducing new mobility services, a high visibility of these services and enough opportunities to test them is named [122, p. 15]. The success of already available car sharing providers shows, that this visibility is already reality in some areas: mainly car sharing providers that often act at interfaces between different services (e.g. at public transport stations), lead to a higher amount of users. These users help to reach new users and to build up a bigger network [122, pp. 14-15]. [122]

The *German Mobility Panel* examines mobility behavior in Germany [135]. The panel confirms the trend of a change in mobility behavior [135, p. 17]: particularly in the last ten years, there has been a movement away from motorized individual traffic to alternative mobility modes such as bikes and public transport services. This shift has been mainly induced by young people (18–35 years) and people in middle age (36–60 years). As reasons for this change, the mobility panel identifies the trend of urbanization and an increasing acceptance of public transport services and multimodal mobility. [135]

A further important aspect for a critical mass of MaaS is the density of population in the respective region. The following Figure 3.2.7 shows the density of population in Germany. According to this figure, NRW has many areas with a high density of population and is one of the largest agglomerations in Germany. Therefore NRW is the federal state with the fourth-highest density of population with 524 inhabitants per square kilometer on average. This is significantly higher than the average density in all of Germany (230 inhabitants per square kilometer). Only city-federal states like Berlin, Hamburg and Bremen have a higher density of population than NRW. [118]

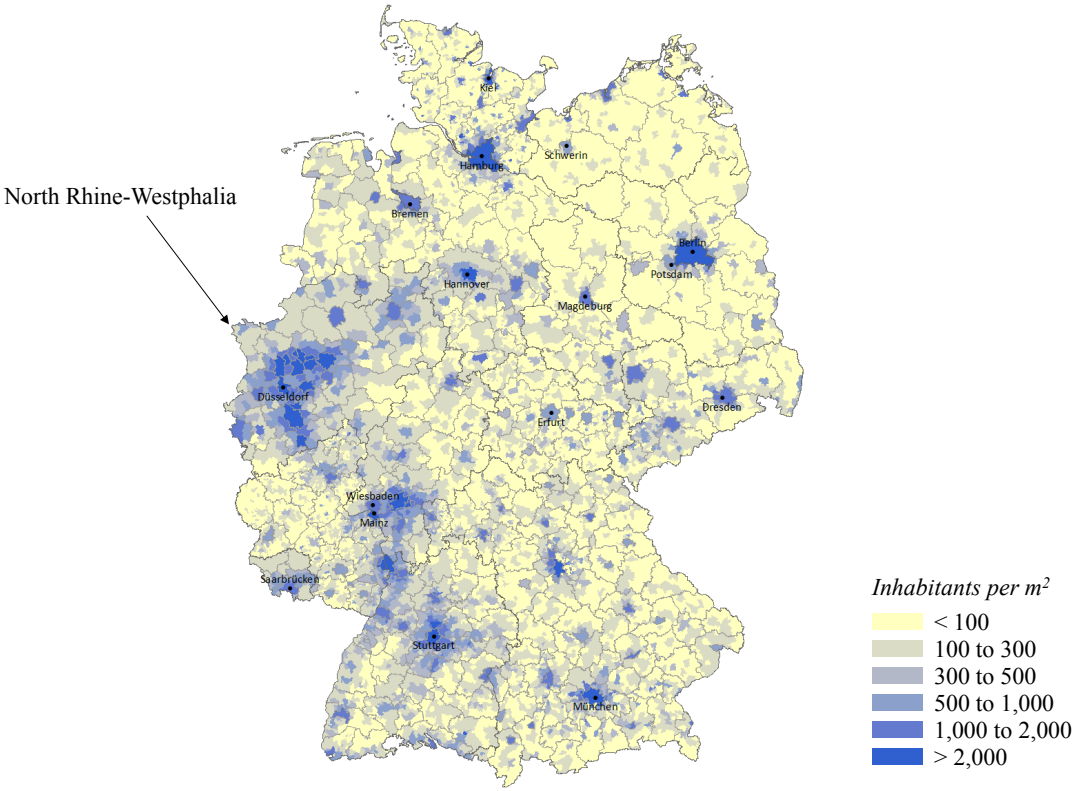


Figure 3.2.7: Density of population in Germany in 2015 (modified from [44])

On the one hand the increasing acceptance of a multimodal mobility behavior and shared services show that there is an increasing demand for MaaS. On the other hand the presented studies point out that this demand is merely a chance for new mobility concepts like MaaS: the mentioned barriers demonstrate that the concept of MaaS can only work if there is a reliable, smooth and individual mobility service at all times. Only if this is ensured for the entire system, it is possible to convince people to use mobility in a multimodal way and to reach a critical mass for MaaS. A further positive aspect for MaaS in NRW is the high density of population, which helps to build up a close mobility network between different cities.

All in all the demand for MaaS can be assessed positively: in Germany there is an increasing demand for shared services and a fundamental change in mobility behavior. The high density of population in NRW supports these positive conditions. As shown in Table 3.2.11 NRW can be classified as stage four concerning the demand for MaaS.

Stage	Characteristic
4	Some projects and a higher willingness, than in the last years, to use a shared instead of an own vehicle, shows that there is more and more demand for MaaS. Even if there is a high density of population it is necessary to see if the projects which try to build up a working sharing-network can be expanded.

Table 3.2.11: Critical mass and demand for MaaS in NRW

Profitability of new mobility business models and the role of the platform operator in Germany and NRW

The examination of the profitability of MaaS for different actors can be divided into two groups: the first group are the providers of the mobility services that can become part of the MaaS system. The second group are possible operators who could provide the MaaS-platform.

As they are generating profit with their service, most of the transport providers are subjected to the *PBefG* which has already been examined in chapter *Passenger transportation regulations*. The *PBefG* hampers the access of many mobility providers a priori and prevents equal competition in the mobility sector as already discussed. Therefore some mobility business models that are successful in other countries are not feasible in Germany. One of these business models is *uber*. With the help of a smartphone application, *uber* acts as a broker between passengers and private drivers who provide transportation services comparable to a taxi. *uber* receives a provision for brokering the transport service. According to a decision of the *Higher Regional Court* (OLG) in Frankfurt am Main, this service is not consistent with the *PBefG* (*OLG, Frankfurt am Main, June 9, 2016, 6 U 73/15*). For this reason *uber* had to change its business model and the *uber* drivers were only allowed to cover their operating costs, so that the service was not subject to the *PBefG* anymore [63, p. 158]. This business model made it impossible for *uber* to generate profit. Therefore the service was stopped in the meantime [63, p. 158]. The example of *uber* shows that there are significant legal entry barriers for ride sharing services in Germany.

The situation of on-demand services is comparable to the situation of ride sharing services. However, here it is currently not clear if on-demand services are compatible with the *PBefG*. One of the first providers for on-demand services is *VW* with *MOIA* in Hamburg [94]. Ac-

cording to the local government, this service will be initially allowed in a testing period, based on *§ 2 VII PBefG* [28, p. 2]. After this period, it is planned to allow this service as rental car service basing on *§ 49 IV PBefG* [28, p. 2]. It is questionable if this permission for on-demand services as rental car service will be accepted by courts. A report which was made on behalf of the parliamentary group *Bündnis 90/Die Grünen* describes the need to reform the *PBefG*. This report comes to the conclusion that a regulation which includes on-demand services as well is necessary [75, p. 51]. By including these services in the *PBefG* it will be feasible to regulate the operation of these services and to specify corresponding conditions for on-demand services.

Other mobility services are widespread and seem to be profitable business models in Germany. As it will be shown in the next chapter, the car sharing and bike sharing offer in most German regions and also in NRW is continuously increasing. Nevertheless the providers have to face challenges which result in insolvencies of some car sharing providers like *Spot-Car* or *CiteeCar* [100] in recent years. Other large car sharing providers like *DriveNow* (operated by *BMW*) and *Car2Go* (operated by *Daimler*) plan to merge in the near future [52]. In [100] Gunnar Nehrke, director of the *Bundesverband CarSharing* in Germany, analyzes the cause of problems of some car sharing providers, even if the demand for these services is increasing. He identifies two different ways of expansion for car sharing providers: the "demand-oriented model" and the "supply-oriented model". The supply-oriented model is characterized by a fast market launch with several hundreds of cars at once combined with an offensive marketing strategy. This strategy is useful for free-floating offers where it is important that there is a comprehensive availability of cars in the whole market region. The supply-oriented strategy leads to a high risk of losses or even insolvencies, if it is not possible to reach a high utilization of the cars. The demand-oriented model in contrast counts on a slow sustainable growth. Here, the car sharing providers start with a small market region and a low amount of cars. The providers expand their offer successively, depending on the demand. Nehrke analyzes that profitable and long-standing car sharing providers, like *cambio* or *stadtmobil* pursue the demand-oriented strategy. Car sharing companies which expand according to the supply-oriented model in contrast are dependent on solvent investors. The demand-oriented model often results in the already mentioned insolvencies (*Spotcar, CiteeCar*) or merges (*DriveNow* and *Car2Go*). Supply-oriented car sharing providers are often operated by car companies, which see these services as a strategic investment and as opportunity to face the challenge of an increasing sharing economy [100]. Nehrke sees more potential for the more sustainable demand-oriented models, with a lower growth, in the long term. Therefore he remarks that a higher growth of the car sharing market requires political,

financial and regulatory support, to accelerate the expansion of demand-oriented services with a lower risk for the operators [100]. The *CsgG*, which was already presented in chapter *Pro-activity of regulation*, can be seen as one approach to deliver this support for car sharing companies. As already remarked the effect of this approach is currently not very high. [100]

In addition to mobility service providers, MaaS also requires a platform provider. The examples of comprehensive mobility projects like *Moovel*, *Qixxit* or the *Mobility Broker* which were presented in the chapter *Availability of comprehensive smartphone applications and pilot projects in the mobility sector*, show that the idea of providing MaaS is obviously not unattractive in Germany and NRW. As it will be shown in the next chapter, car companies are more and more beginning to not just sell cars but also the service of mobility. Car companies provide different kinds of mobility offers like car sharing services, car rental services or a combination of different mobility services in cooperation with other mobility providers (see also page 56). The examination of existing mobility platforms on page 33 shows that there are different kinds of platform operators which provide combined services in Germany: sometimes the operators are local public transport companies (like in *Mobility Broker* in Aachen or *Mutti* in Bochum), sometimes the operators are car companies (like *Moovel*) and sometimes the operator is represented by a cooperation of many different mobility providers (like *Mobility Inside*). In NRW private providers for mobility platforms as well as public-owned providers can be found. According to the results of the examination by Kamargianni and Matyas, which were presented in the derivation of the catalogue of requirements, mainly the platform-owner model of the future project *Mobility Inside* is very promising: the cooperation of many different transport companies from entire Germany is a good condition for the scalability of the service [93, p. 2] [74, pp. 7-8]. It can be presumed that every participating company will provide the service to its customers. As soon as the project is realized, there is a high amount of potential users. *Mobility Inside* positions itself on a nationwide level and does not limit its area of operation on a special region [93, p. 5]. *Mobility Inside* mentions another advantage of their cooperation-model which is related to the examination of Kamargianni and Matyas as well: by cooperating, it is possible to face the challenge of an increasing competition, which is caused by foreign companies or companies from other sectors [93, pp. 2 and 6] [74, pp. 7-8]. Here *Mobility Inside* points out the high degree of trust people have in established local transport companies [93, p. 4].

All in all there are positive conditions for the profitability of mobility business models in Germany. The example of the increasing car and bike sharing market in Germany shows that the transport providers are able to generate profit with their business. However, the shared

mobility market is increasingly competitive and not every mobility provider can survive on the market, which was shown by the insolvencies of *SpotCar* and *CiteeCar*. The existing mobility platforms in NRW prove that such a mobility business model can be profitable in Germany. The heterogeneity of operating models for mobility platforms in NRW is very high: there are different options available and it can be presumed that the most profitable and best working model will survive. Nevertheless, some conditions like the *PBefG* hamper the development of new business models. Also the described project of *Mobility Inside* needs to prove if a cooperation of many different mobility companies can work. Overall NRW can be classified as stage four concerning the profitability of the mobility sector and the role of the platform operator.

Stage	Characteristic
4	Currently there are many different kinds of models for a comprehensive mobility service and sharing services become more and more successful. Most of them are on a regional level, but there is also potential for a scalable platform. There is an increasing competition between established mobility companies and "new" providers of mobility services.

Table 3.2.12: Profitability of new mobility business models

Role and support of the car industry

A common thesis-paper of the *Verband der Automobilindustrie (VDA)* and the *Bundesverband Deutsche Startups* shows that the car industry is already focussing on the new developments in the mobility sector, like sharing trends and the merge of private and public transport [85]. The car industry has realized that trends lead to the fact that "owning" has become less important in recent years [85, p. 5]. The thesis paper also draws attention to the aspect that many automobile manufactures already adapt to this development by expanding their service portfolio and by providing mobility services like car sharing or information systems [85, p. 5]. Furthermore car companies strive for cooperations with other mobility providers in form of start-ups or public transport services [85, p. 5 and 9]. This trend is proved by *Oliver Wyman* consulting company, which figures out that automobile manufactures present themselves as investors for start-ups within the mobility sector [136]. Table 3.2.13 gives an overview of mobility offers provided by car companies.

Car-company	Mobility offer	Description
BMW	*ReachNow*	Comprehensive mobility service, including car-renting and driving service [111] (merger with *Car2Go* is planned for 2018 [52])
	DriveNow	Car sharing offer (in cooperation with *Sixt*) with approximately 1,000,000 customers [48] (merger with *Car2Go* is planned for 2018 [52])
	ParkNow	Application as interface between customers and parking operators [51] [106] (merger with *Car2Go* is planned for 2018 [52])
Daimler	*Car2Go*	Car sharing offer with approximately 3,000,000 customers [39] [35] (merger with *DriveNow* is planned for 2018 [52])
	Moovel	Mobility service provider that allows to book and pay different mobility services from other providers, like *Deutsche Bahn*, local public transport (Stuttgart and Hamburg), *mytaxi* or *Car2Go* [40]
	mytaxi	Ordering, paying and rating of taxi services via application [41]
VW	*MOIA*	Mobility service provider with comprehensive mobility-services like on-demand services. They have the aim to "become one of the world´s largest mobility service providers" [133] [94]
Ford	*Ford car sharing*	Car sharing offer in cooperation with *Flinkster (Deutsche Bahn)* [54]

Table 3.2.13: Mobility offers provided by car companies

The table shows that there is an expansion of the service portfolios of car manufactures in the field of mobility services. The described services often do not just include one single service. Instead they offer a combination of different mobility services. Therefore car companies sometimes cooperate with providers from other business sectors like *BMW* and *Sixt* or *Daimler* and local public transport providers. In addition to that there are cooperations between car companies as well: *BMW* and *Daimler* are planning to merge their mobility service offers and try to "create the worldwide leading provider for mobility service offers" [52]. Also *VW* strives to become a leading provider of mobility services in the future by its offer *MOIA* [133].

Even if there is an increasing importance of mobility services, the *VDA* considers that cars will remain the "backbone of our mobility system" [85, p. 6]. This statement can also be confirmed by the expectation of an increasing revenue pool of the mobility sector in the

future which is already depicted in Figure 3.1.1. Figure 2.2.1 on page 10 lists transport modes within MaaS and shows that most of these transport modes are based on cars. This verifies the estimation of a great importance of cars in the future as well. The car industry in Germany seems to realize that there is a change in the mobility sector. It also realizes that, as a consequence, the mode of using a car will change from "owning" to "sharing". The presented thesis paper [85] shows that the car industry has identified that this change does not necessarily imply a reduction of the high importance of cars in the future. By adding mobility services to their service portfolios car manufactures already have shown that they have identified their profit potential. It can be expected that the car industry in Germany might support MaaS in case it is ensured that their profitability does not suffer. The presented examples show that more and more car companies in Germany are positioning themselves as all-round-providers for mobility services. Car companies build up own mobility offers that include direct cooperations with other providers (like in the example of *Moovel* and the cooperation with public transport companies) or they support mobility start-ups as described by *Oliver Wyman* consulting company. This development is on the one hand a promising chance for the MaaS-concept: car companies have huge financial resources and can therefore support innovative developments in the mobility sector. On the other hand it is unclear if the high degree of cooperations and partnerships will be maintained. Here it is possible that – once the mobility service business is built up – the car companies will not be willing to share this field with other providers. This development could hamper the further development of a MaaS-system.

Right now the car industry is one driver for the development of mobility services in Germany. Building up their own services, cooperating with other mobility companies and by supporting start-ups, car companies are an important factor for MaaS. The investments of car companies show that they have realized the increasing importance of mobility services. It has to be observed if car companies are willing to share this field with other providers in the future. This is the base to build up an open MaaS-system, which allows the integration of many different providers. The support of the car industry in Germany reaches stage four as shown in Table 3.2.14.

Stage	Characteristic
4	The car industry starts to see the advantages of new mobility concepts. Car companies begin to build up their own mobility services (e.g. car sharing) to be part of this new concept and to generate additional profit.

Table 3.2.14: Support for MaaS by the car industry in Germany

3.2.4 Infrastructural conditions

Germany is one of the most developed countries in the world. This high development is also evident from the *Global Competitiveness Index* from 2017–2018 [115], which ranked Germany on place fifth of 137. In the field of infrastructure Germany reached rank 10. These results show that the quality of the infrastructure is backward compared with other sectors in Germany. An "inadequate supply of infrastructure" [115, p. 126] is even named as one of the most controversial factors for developing business activities in Germany. Nevertheless the German infrastructure is, also according the *Global Competitiveness Index*, one of the best in the world, which is basically conducive for MaaS. The following chapter analyzes the infrastructural conditions in more detail. The examination will include public transport, taxi, rental car, bike sharing, car sharing, ride sharing and on-demand services in NRW and Germany. [115, pp. 126-127]

Public transport services in NRW

According to the *Global Competitiveness Index*, Germany reached rank nine of 137 [115, pp. 126-127] in the sector of railroad infrastructure. Countries like Switzerland (ranked first) [115, p. 279] or the Netherlands (ranked sixth) [115, p. 219] reached a better ranking than Germany which can be explained by the investments in the rail network: according to [6] Germany had an investment per capita in the railroad infrastructure of 64 Euros in 2016. Compared with Switzerland (378 Euros per capita), Sweden (170 Euros per capita) and the Netherlands (133 Euros per capita) the German investment in railroad infrastructure is on a low level. The *Bundesverkehrswegeplan* 2030 budgets 112.3 billion Euros for investments in railroad infrastructure [22, p. 14]. This is an increase of 55 percent compared with budget in the *Bundesverkehrswegeplan 2003*, which was only 72.3 billion Euros [18, p. 35]. Therefore it can be expected that the investment per capita for the railroad network in Germany will increase in the next few years.

The *Quality Report SPNV Nordrhein-Westfalen* 2016 provides detailed information about the quality of public transport services in NRW [114]. In general the railroad network in NRW consists of 3,767 railroad kilometers and 770 railroad stations [114, p. 8]. Since they are indicators for the quality of the railroad infrastructure in NRW the following three aspects will be analyzed: firstly the degree of punctuality of trains, secondly unexpected train failures

and thirdly expected train failures. At first there is the degree of punctuality of trains in the public transport service of NRW. Figure 3.2.8 shows the average unpunctuality-development of Regional Expresses (RE), Regional Trains (RB) and Suburban Trains (S-Bahn) in NRW from 2011 to 2016.

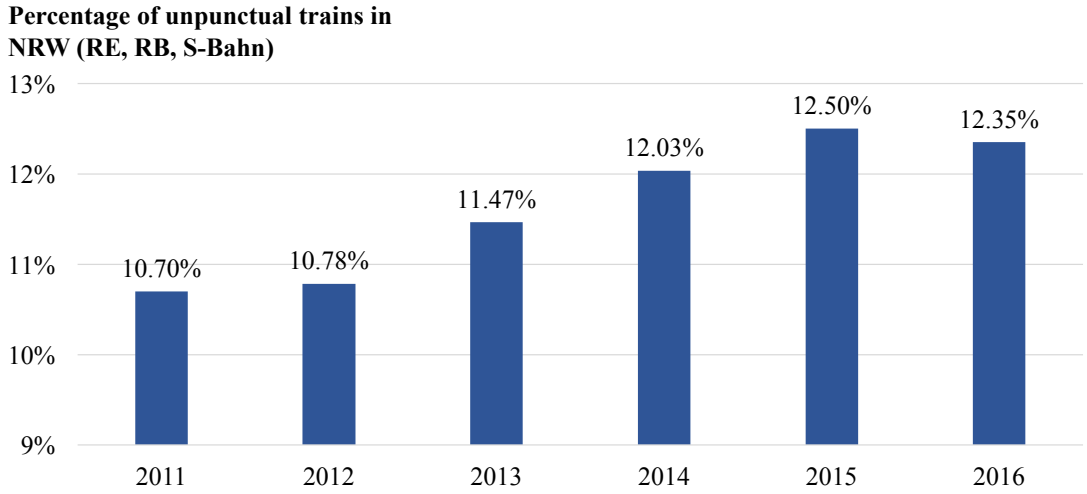


Figure 3.2.8: Average unpunctuality rate of RE, RB and S-Bahn trains in NRW between 2011 and 2016 (own presentation with data from [114, pp. 20, 26, 27])[4]

The figures show that there was a continuous increase of unpunctual trains in NRW between 2011 and 2015. In 2011 there was an unpunctuality rate of eleven percent while in 2015 the unpunctuality rate was 12.5 percent. In 2016 the share of unpunctual trains slightly decreased to 12.35 percent. High utilization and long distances are the main causes for delays.The railroad between Essen and Cologne, which is one of the main transport axes in NRW, is particularly affected [114, pp. 20, 26, 27]. Another aspect, which leads to delays, is the fact that RE´s often use the same tracks as long distance trains. Due to that the priority of long distance trains leads to delays in the local public transportation traffic [114, p. 20].

The next two indicators that can be used to evaluate the quality of the public transport service in NRW is the amount of unexpected and expected train failures. The share of unexpected train failures in NRW doubled from 2015 to 2016, which means that 2.4 percent of the trains failed. The main reason for these expected failures was construction work at the railway infrastructure. In the same time unexpected train failures decreased to one percent compared with 2015. The reason for this decrease is the fact that in 2016 there were no extensive

[4] According to this evaluation a train is “unpunctual” if it is 3:59 minutes late. Train failures are excluded and become separately examined.

incidents like heavy storms or strikes. The main challenge in 2016 was a shortage of train drivers. [114, pp. 28, 30]

The shown aspects concerning the public transport service in NRW point out lacks in the the railroad infrastructure. These lacks are caused by bottlenecks in the railroad system, by missing employees and the necessity of extensive construction works. The reason for the deficits is the low investment per capita compared with other countries in recent years. The new *Bundesverkehrswegeplan* 2030 proposes a significantly higher investment for the next few years. Due to an increase of passengers that will continue until 2030 it is questionable if the increase of investments compensates the higher passenger numbers and leads to a better quality of the railroad infrastructure [114, p. 14][17, p. 52]. Simultaneously the higher investments imply more constructions and thereby in the middle-term additional train failures and delays. These circumstances classify NRW as stage three concerning the quality of the public transport service (s. also Table 3.2.15).

Stage	Characteristic
3	Even if there are political efforts to support the service (public transport services), there are still difficulties concerning this service (public transport services).

Table 3.2.15: Degree of the quality of the public transport infrastructure in NRW

Taxis

As already described in the section *Passenger transportation regulations*, taxis have a special importance in Germany. According to § 13 *IV* 2 *PBefG*, circumstances like a high taxi density can cause the prohibition of further transport service in a specific area. It can be expected that a high density of taxis prevents the development of new mobility offers like ride sharing or agency services for individual transport like *uber*. On the other hand, taxis themselves are also part of the MaaS system. Hence it is worthwhile in a double sense to examine the density of taxis in NRW compared with other regions.

The last survey about the taxi density in Germany was implemented in 2012 by the federal ministry of transport. The results are depicted in Figure 3.2.9. The figure shows the amount of inhabitants per taxi in the federal states of Germany in 2012.

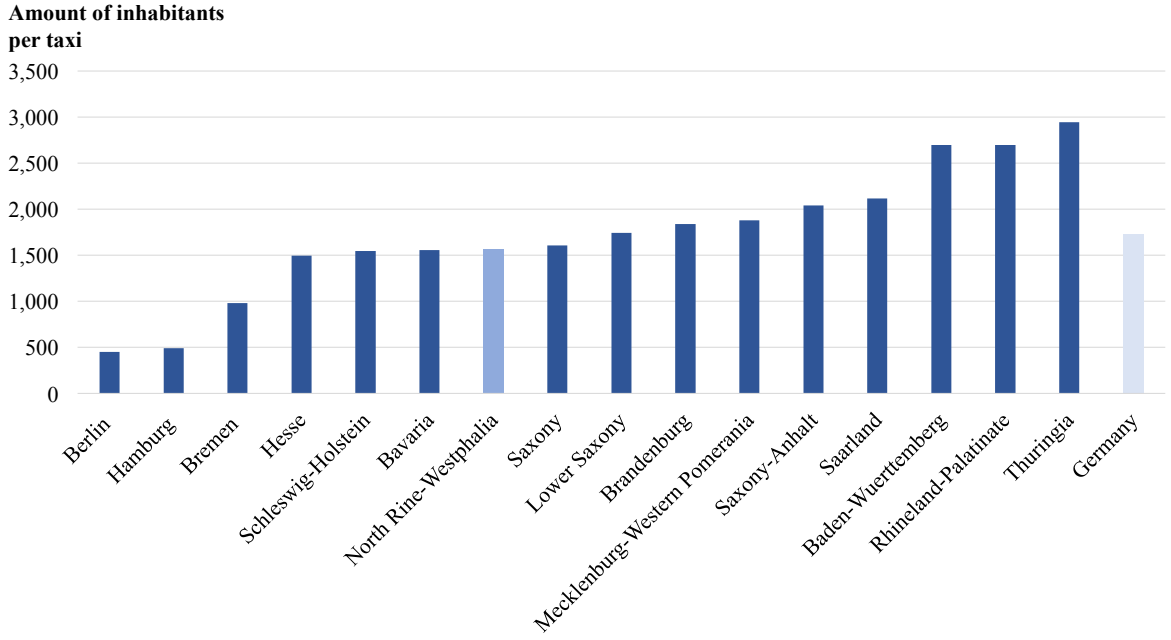


Figure 3.2.9: Amount of inhabitants per taxi and rental cars in the federal states of Germany (own presentation, based on data from [19, p. 8])

The graph shows that the density of taxis in NRW is slightly higher than the nationwide average of 1,728 inhabitants per taxi. Six federal states in Germany have a higher density of taxis (that means, a lower amount of inhabitants per taxi) and nine federal states have a lower density of taxis than NRW. Therefore on the one hand the taxi density in NRW seems to be high enough to represent a comprehensive mobility service. On the other hand the special protection of taxi services by the *PBefG* could hamper other mobility services which can be part of MaaS.

All in all taxi services in Germany and NRW have an ambivalent effect on MaaS: they are an important service to provide a reliable mobility system within MaaS. However, the *PBefG*-regulations concerning taxis can have negative effects on other mobility services. These results imply the classification of stage three.

Stage	Characteristic
3	Even if there are political efforts to support the service (taxi services), there are still difficulties concerning this service (taxi services).

Table 3.2.16: Quality of the quality of taxi services in NRW

Rental Cars

According to the consultancy *Nedrelid*, the German car rental market is the second largest in Europe after France [98, p. 7]. Due to the growth of car sharing companies and agencies for mobility services like *lyft* or *uber*, the consultancy sees some challenges in the market of rental cars. According to *Nedrelid* these service are comparable with car rentals for a "short time span" [98, p. 17]. Hence, these services act as competitors for the conventional car rental companies. Nevertheless *Nedrelid* assumes that the new mobility services mean no "existential threats to classical car rental operators" [98, p. 17]. Some operators conversely see the offer of car sharing services as an additional offer that can also be provided by car rental companies themselves. One example of such an operator is *sixt* which offers *DriveNow* together with *BMW* (see also Table 3.2.13).

For MaaS it is significant, in how far rental cars themselves can support the close network of mobility services by having a high distribution degree. Compared with car sharing offers, rental cars have the advantage of a higher availability because of the long term oriented business model: usually the reservation of a car is made in advance and the booking duration is based on days or weeks instead of minutes or hours as in the concept of car sharing. Figure 3.2.10 shows the amount of inhabitants per rental car in the federal states of Germany in 2012 (based on the same survey as Figure 3.2.9).

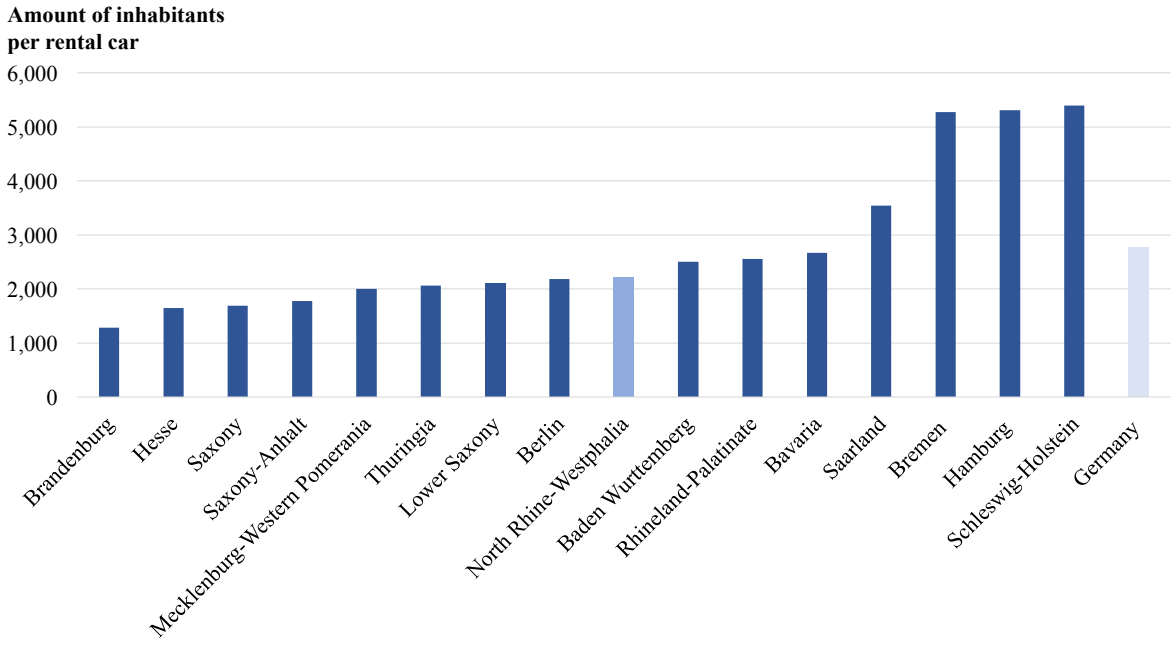


Figure 3.2.10: Amount of inhabitants per rental car in the federal states of Germany (own presentation, based on data from [19, p. 11])

The national average of inhabitants per rental car in Germany is 2,763. With 2,215, the amount of inhabitants per rental car in NRW is a little lower than the average. The density of rental cars in NRW is slightly higher than in entire Germany. Eight federal states have a higher density as NRW. However the degree of the density is very similar to each other in most of the federal states.

Overall the situation of the market of rental cars in Germany and NRW is good for MaaS: there is a distribution of car rentals in NRW over average and a high degree of competition with new mobility operators in general. This situation induces the expansion of the product range of classical car rental operators, who begin to offer car sharing services in addition to their original business. This situation is positive for the development of a MaaS system and can lead to a higher quality and a higher range of services in the mobility sector. All in all NRW can be classified as stage four concerning the quality of the rental car service because of the good availability of rental cars in combination with a higher competition (Table 3.2.17).

Stage	Characteristic
4	The quality of the considered service (rental car services) is good. Nevertheless there is a higher potential for the service (rental car services) and it remains to be seen if this potential can be used in the next few years.

Table 3.2.17: Quality of rental car services in NRW

Car and bike sharing

Germany is Europe's largest market for car sharing offers. While at the beginning of 2016 there where 1.2 million users of car sharing in Germany, the consulting company *Deloitte* expects more than three million for 2020. As reasons for the positive situation for car sharing, *Deloitte* mentions the high amount of densely populated, medium or big cities. Additionally, the strict regulations on the market are challenging for alternative providers like *uber*. Therefore it is useful to have a closer look at NRW concerning the car sharing market, in order to evaluate whether the car sharing conditions are as positive as they are in entire Germany. [113]

Figure 3.2.11 shows the amount of car sharing cars per million inhabitants in 2017 in the federal states of Germany and the change of this amount since 2015.

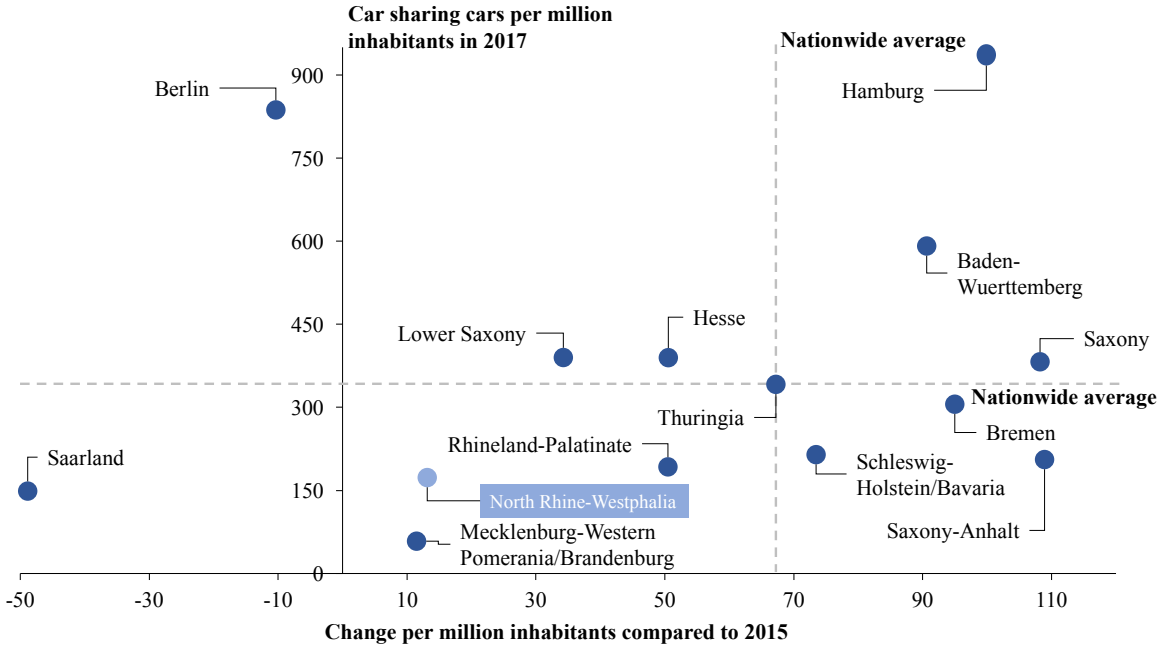


Figure 3.2.11: Amount of car sharing cars (station based and free float) in 2017 and absolute change compared with 2015 in the federal states of Germany (own presentation, based on data from [26] [25])[5]

The figures show that the national average of car sharing cars per million inhabitants in 2017 was 342. Since 2015 there was an increase of 53 cars per million of inhabitants in average which corresponds with an increase of 18 percent. In NRW the amount of car sharing cars is just 177 cars per million of inhabitants and the increase since 2015 is 13 cars per million of habitants. The data show that, even if there is a high density of population in NRW, the availability shared cars for the citizens compared with other regions in Germany is not good. Only three federal states, Saarland, Mecklenburg-Western Pomerania and Brandenburg have less car sharing cars per million of inhabitants than NRW.

The valuation of the bike sharing availability in Germany can be done by considering the amount of bike sharing stations per million of habitants in Germany. The amount of bike sharing stations per million of habitants and the absolute change since 2010 for the federal states in Germany is shown in Figure 3.2.12.

[5]The values are average values of cities with over 50.000 habitants

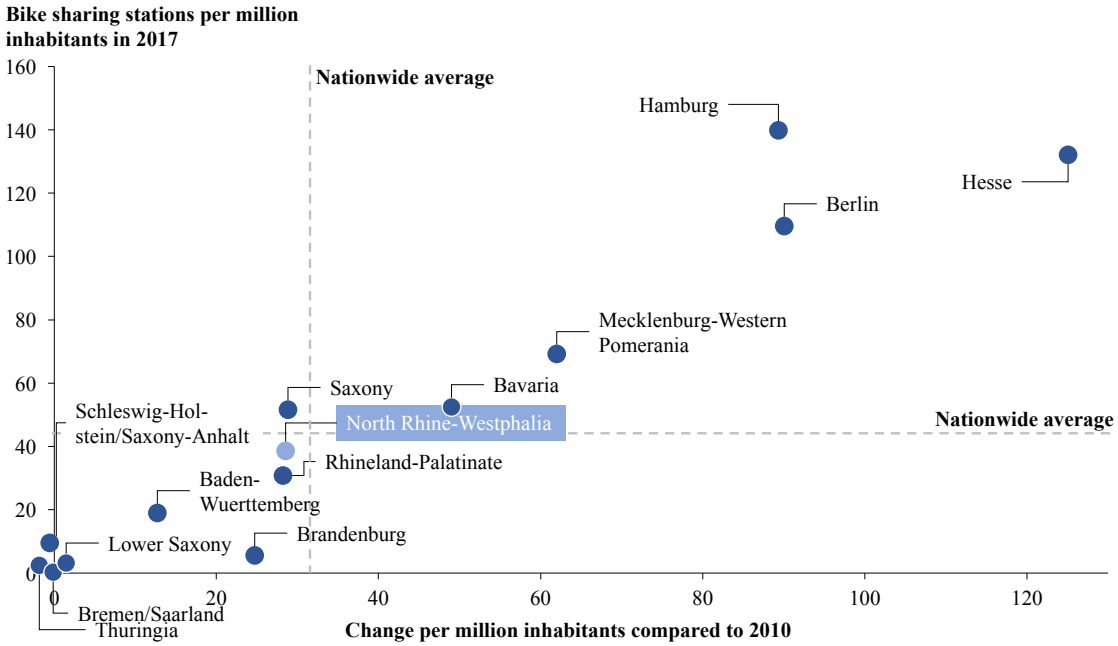


Figure 3.2.12: Amount of bike sharing stations (per million of inhabitants) in 2017 and absolute change compared with 2010 in the federal states of Germany (modified from [70])

The figures show that the national average of bike sharing stations per million of habitants is 44 stations. On average, the national absolute increase since 2010 was 32 bike sharing stations per million habitants. This development shows that most of the bike sharing stations in Germany have been built in the last seven years. The amount of bike sharing stations in 2017 in NRW per million inhabitants was 40, which is also slightly less than the German average. All in all, the development and offer of bike sharing stations in NRW approximately correspondents to the German average.

In conclusion the car and bike sharing infrastructure in Germany is on a high level compared with other countries. Therefore it can be expected that car and bike sharing offers would have a large proportion in a MaaS system in Germany – especially compared with ride sharing offers (see also chapter *Ride sharing*). Nevertheless, especially the quality of the car sharing infrastructure in NRW lags behind the average quality in Germany. Because of its high density of population and the positive forecast for the future, the quality of the car and bike sharing infrastructure in NRW can be classified as stage four (see also Table 3.2.18).

Stage	Characteristic
4	The quality of the considered service (car and bike sharing services) can be evaluated positively. Nevertheless there is a higher potential for the service (car and bike sharing services) and it remains to be seen if this potential can be used in the next few years.

Table 3.2.18: Quality of car and bike sharing in NRW

Ride sharing and on-demand services

The challenges in Germany concerning ride sharing services like *uber* that were mainly induced by the *PBefG* were already depicted in the previous chapters. Next to these services, there are also services which are not subject to the *PBefG*. These are services like *Blabla Car* where it is the core idea, that a private driver shares his ride and the costs for the ride with the user [13]. The payment for the transportation is therefore not higher than the operating costs and the *§ 1 II 1 PBefG* is not fulfilled. According to [117] ride sharing services which include online carpooling offers like *Blabla Car*, online booking services for commercial rides with private cars like *uber* or taxi services that can be booked and payed online like *mytaxi* do have a penetration rate of 7.2 percent in Germany (status in March 2018). That means that approximately 5.9 million people are registered customers of such services. Compared with other countries this is a low amount: in Finland there is a penetration rate of 13.8 percent and in the USA of even 17.8 percent. However it is expected that the amount of registered ride sharing customers in Germany will increase until 2022 up to twelve million customers [117]. Unfortunately there is no detailed statistic for the penetration rate of ride sharing services in NRW available. Nevertheless the comparison to other countries shows that ride sharing services in Germany are not less developed. The reason for the low penetration in Germany could be caused by the high regulation degree due to the *PBefG*.

The case of on-demand services was already discussed in chapter 3.2.3. The challenges of these services are comparable to the ones of ride sharing services. Here the *PBefG* is the main hurdle as well. Nevertheless on-demand services are even less developed than ride sharing services. The services of *MOIA* for example will be introduced in 2018 [94]. The on-demand service of *door2door* runs since September 2017 [47]. A third on-demand service which is operated by *ioki* runs since July 2018 [132]. The examples show that on-demand services in Germany and in NRW are at the beginning of its development. Due to that there

are currently no statistics available that show the quality or quantitative distribution of on-demand services. Nevertheless the obstacles for on-demand services seem to be similar to the hurdles of ride sharing services.

To put it all together, ride sharing and on-demand services in Germany are not well developed and are hindered by the *PBefG*. Nevertheless there are some cases which show that ride-sharing and on demand services in Germany are growing. Therefore NRW can be classified on stage two concerning the quality of ride sharing and on-demand services.

Stage	Characteristic
2	The quality of the service (ride sharing and on-demand services) is increasing but it is still below average compared with other regions because of specific challenges that hamper the development of the considered service (ride sharing and on-demand services).

Table 3.2.19: Degree of the quality of ride sharing and on-demand services in NRW

3.3 Results and need for action

The following chapter summarizes the evaluation of the conditions for MaaS in NRW, as described in the previous chapters. As a first step the readiness factor will be assessed in turn of quantity and quality with the help of the catalogue of requirements for MaaS. As a second step needs for action to support and realize the implementation of MaaS in NRW deriving from this assessment are presented.

Quantitative results

Figure 3.3.1 gives an overview of the quantitative valuation of the requirements for MaaS according to the developed catalogue of requirements and its application for NRW. Therefore it pictures the stages reached so far of NRW with regard to the requirements of the four subjects *Technic*, *Regulation & Politics*, *Economic* and *Infrastructure*. Furthermore, the figure shows the average stage for each of these subjects and the overall readiness factor for MaaS in NRW.

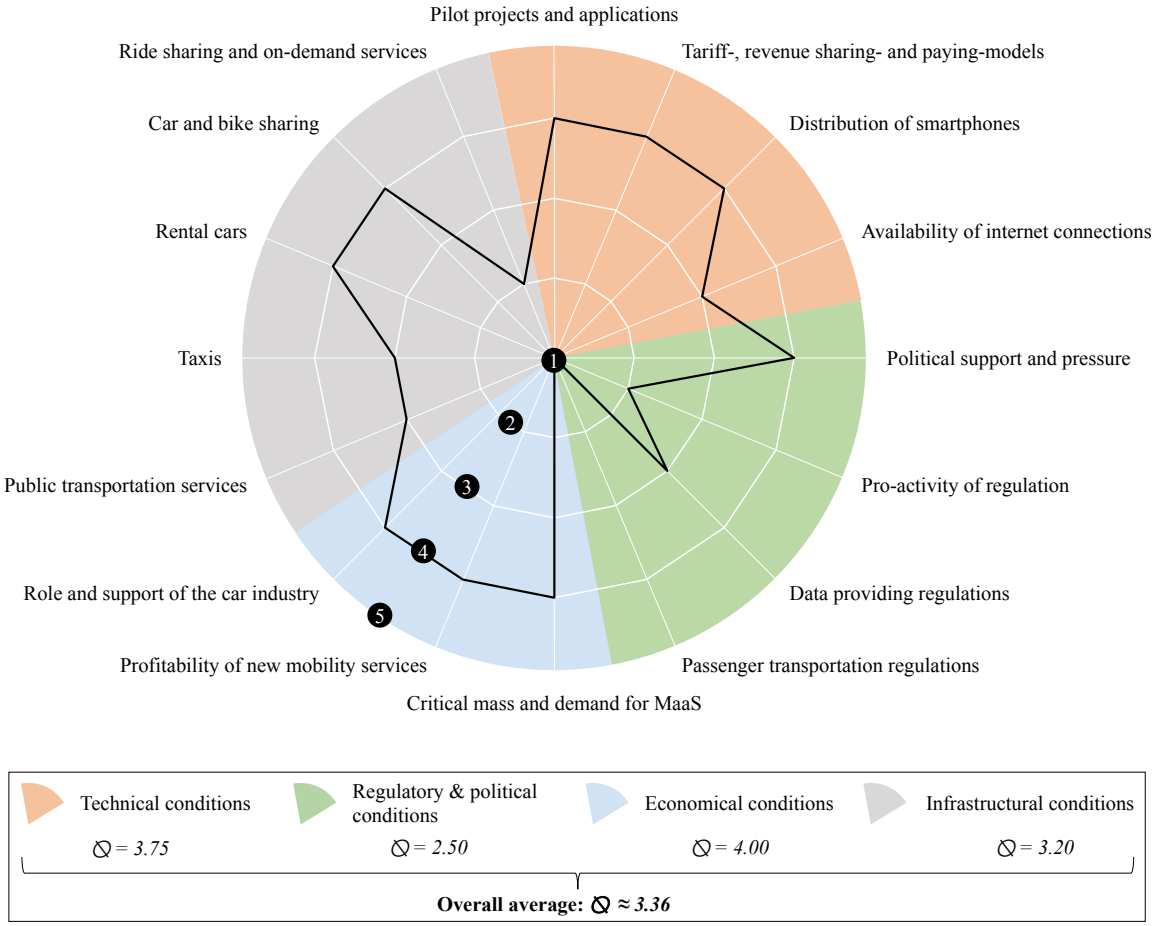


Figure 3.3.1: Quantitative results of the evaluation of the conditions for MaaS in NRW (presentation inspired by [2, p. 9])

The overall readiness factor for MaaS in NRW is 3.36. The sector of *Regulatory and Political conditions* got an average 2.50 points and therefore has a negative impact on the overall readiness factor. Regulatory and political conditions need to be improved. The *Infrastructural conditions* got 3.20 points on average. The *Technical conditions* were rated with an average of 3.75 points. The *Economic conditions* are rated with four points. The results show that the economic and technical conditions are well-positioned while there are some deficits in the regulatory and infrastructural conditions.

Qualitative results

Figure 3.3.2 gives an overview of the qualitative results of the evaluation. Therefore the main challenges and positive aspects for each evaluated category are summarized.

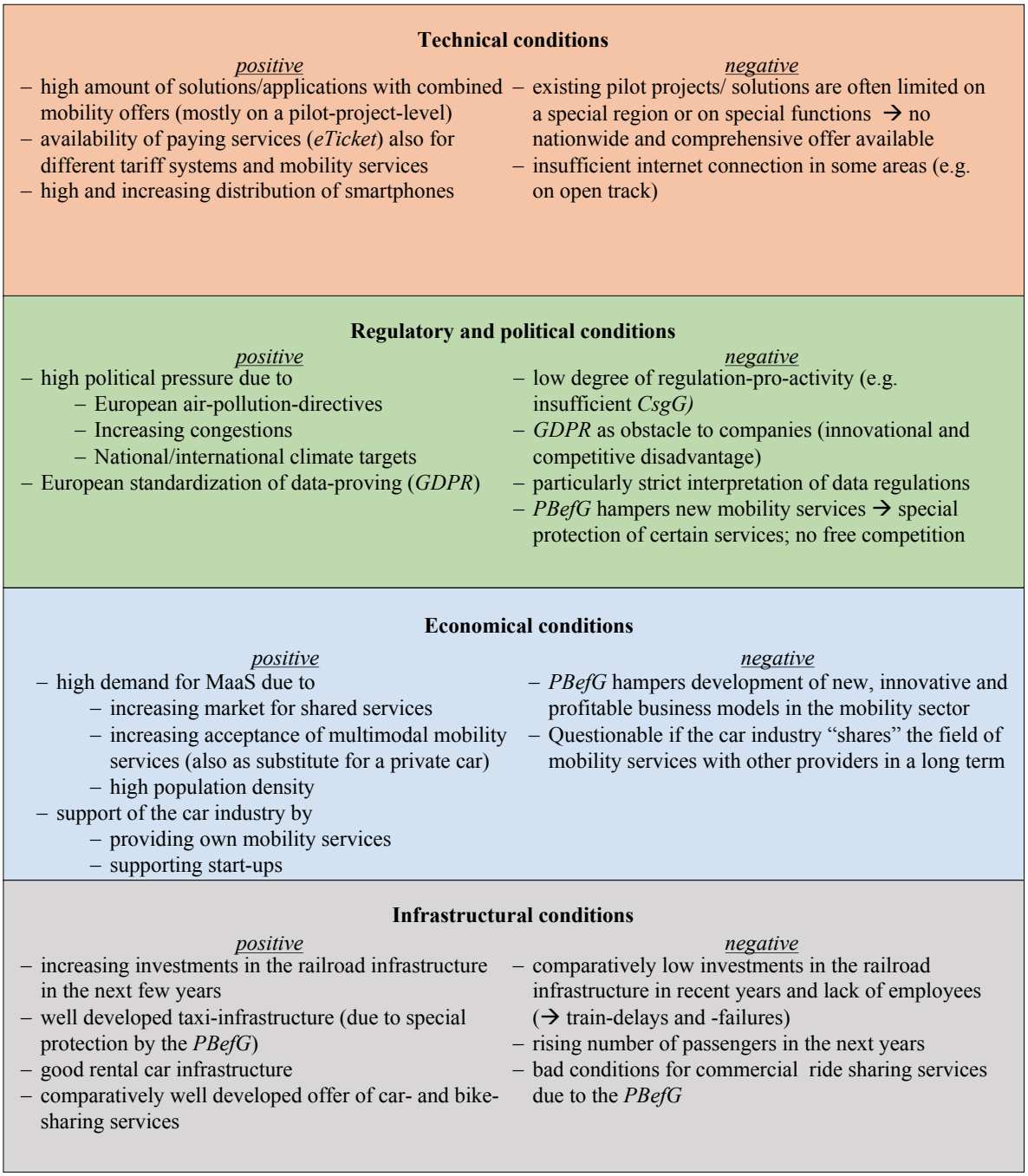


Figure 3.3.2: Qualitative results of the evaluation of the conditions for MaaS in NRW

One positive aspect in the sector of technical requirements is the availability of many solutions that provide different kinds of mobility services, also in a multimodal way. These solutions differ in the range of functions and are mostly only piloted. Therefore there is no solution with comprehensive functions that is nationwide available. Nevertheless with the *eTicket* there is already a solution available for an electric ticket system, which will also

have interfaces for different kinds of mobility services in a short time. The comparatively high and increasing distribution of smartphones in Germany is also a positive aspect for the development of MaaS in NRW. Nevertheless insufficient internet connection – especially on open tracks – is a challenge to the implementation of MaaS in NRW.

Concerning the regulatory and political conditions for MaaS in NRW, it is positive that there is increasing political pressure, to bring about changes in the mobility sector and to support measurements and projects which help to reduce individual traffic. This pressure is caused by European air-pollution-directives, an increasing amount of congestions and national and international climate targets. On the one hand the European *GDPR* is positive for MaaS because it means a standardization of data protection regulations. On the other hand the strict interpretation of data regulations in Germany can lead to innovation hurdles and higher costs for companies. The *PBefG* is also a challenge for the implementation of MaaS: it provides special protection for some mobility services (e.g. taxis) while others have no free access to the mobility market (e.g. commercial ride sharing services). In addition to that, new mobility services like ride sharing or on-demand services are not explicitly compatible with the *PBefG*. The *CsgG* is an example of the lack of pro-activity of regulation: the law was introduced when car sharing was already widespread. Furthermore, the *CsgG* means no active support for car sharing services. Instead, the responsibility to support car sharing providers is transferred to municipalities.

A positive aspect concerning the economic conditions for MaaS is the high demand due to an increasing market for shared services (like car sharing), an increasing demand for multimodal mobility and a high density of population with many cities located next to each other in NRW. Another positive aspect for new mobility business models is the huge amount of car companies which provide their own mobility services or which give financial support to start-ups in the mobility sector. However, it is questionable if the car industry in a long term will open its services for other providers. In this case it would be possible to develop a comprehensive mobility system which consists of many different providers. The *PBefG*, which was already mentioned as regulative challenge for MaaS, is also a challenge on the economic level: the *PBefG* hampers the development of innovative business models in the mobility sector. As a consequence, the infrastructure of ride sharing and on-demand services in NRW is not well developed. Car and bike sharing services are well developed in NRW as well as taxi and car rental services. The local public transport sector – especially the railroad infrastructure – faces challenges due to low investments in recent years and a tendency to more delays and train failures. It is not sure if the increasing investments in the next couple

of years are enough to compensate the low investments in recent years and at the same time to deal with an increasing amount of passengers. All in all, the main challenges for MaaS in NRW can be found in regulatory and political conditions, while the economic and technical conditions for MaaS in NRW are more positive.

Needs for action

On the technical level an expansion of the internet quality also in rural areas is necessary, to ensure access to the MaaS-platform at any time. Pilot projects which are already available provide a good base for one comprehensive mobility platform. It might help, if the operators of the pilot solutions join together and develop a standardized interface to integrate further mobility providers. The solution of *eTicket* which is already established, provides a technical solution for a universal ticket system – also for new mobility services. It is conceivable that municipalities take the initiative on the strategic level to develop comprehensive and multimodal mobility services in their cities by including the operators of the existing pilot projects [122, p. 16].

On the regulatory level, the *PBefG* has to be revised. According to [34] and [79] the focus of this revision should be on free competition between all mobility services without a special protection of taxi services or the exclusion of certain services like ride sharing or on-demand services. This revision does not mean a "deregulation" for new mobility services: if ride sharing and car sharing and on-demand services become integrated into the *PBefG*, it will be possible to regulate these services and to build up a balanced mobility system with different mobility services. Furthermore, there have to be pro-active acts which support services like ride sharing or on-demand services, in particular in the initial phase of its development. The *CsgG*, which was implemented to provide such a support, does not seem to be sufficient to bring advantages for these service in the practice. New, pro-active engagement could improve the economic conditions for these services and could support the visibility of new mobility services in everyday life, which would lead to a higher awareness level. Due to the fact that "on-demand-orientation" is one core element of MaaS (see also chapter 2.2), it would be necessary to include these services into the *PBefG* as well.

On the infrastructural level there is a considerable backlog in the sector of the railroad infrastructure. Here higher investments have to be made in the next few years to compensate for

the low investments in recent years and to eliminate bottlenecks on the main routes in NRW. On the other hand the investments need to rise to be prepared for the increasing amount of passengers in the coming years: one aim of MaaS is to reduce the motorized individual traffic which will unavoidably lead to more passengers for public transport services.

In order to implement suitable conditions for MaaS in NRW, the above described steps need to be realized. The main hurdle for the implementation of MaaS is currently not on a technical or infrastructural aspect, but it is on the regulatory level: There is a lack of political willingness to bring about real change in the mobility sector. Nevertheless an implementation without political support will be difficult: it is hard to imagine that existing pilot projects which provide multimodal mobility services can develop to a comprehensive MaaS-system, if there is no general and strategic support by politics and municipalities.

4 Feasibility of e-mobility within the concept of Mobility as a Service

In the previous chapter 3.2 the feasibility of MaaS in Germany was analyzed. The following chapter deals with the question if MaaS can help to promote e-mobility by supporting the implementation of electric vehicles in Germany. Due to a higher efficiency and the environmental friendly drive, electric vehicles have the potential to improve the current mobility system [5, p. 987] [90]. Thus it will be analyzed, in how far the idea of multimodality and "understanding mobility as a service" is advantageous to integrate electric cars in Germany. Within MaaS, cars are predominantly used for service offers like car sharing, taxi or rental cars. This indicates that it is useful to consider the integration of electric cars in fleets and service offers, which are imbedded in a multimodal and comprehensive mobility concept: what does this kind of use of electric cars mean for the implementation of e-mobility in Germany? In the following chapter this question is discussed from the technical and non-technical point of view by evaluating existing examinations and studies.

4.1 Technical view

The following section analyzes the technical conditions to integrate electric cars into the MaaS-concept. At first there is a closer look to the charging infrastructure which is necessary to integrate electric vehicles into MaaS. In a second step there will be an analysis in how far MaaS can support the research and technical development of electric vehicles. After that there will be a discussion about the meaning of ranges of electric cars within the concept of MaaS.

The development of a needs-oriented charging infrastructure is seen as a core success factor to develop e-mobility in Germany [7, p. 6]. According to [107, p. 47] and [77, pp. 14-15] the charging infrastructure for electric cars can be divided into private, semi-public and public charging stations. Table 4.1.1 gives an overview of typical usage, connection powers and investment costs for the three different types of charging stations.

Type of charging station	**Placement and typical usage**	**Typical connection power (approximately)**	**Investment costs (approximately)**
Private	– Placed on private ground (private access) – Long-term charging (e.g. in a garage with lower connection power) – No payment system necessary (private access)	*3.7 – 11 kW*	*200 – 1,250 Euros*
Semi-public	– Placed on private ground (can be accessible for everyone, e.g. parking lots of supermarkets or workplaces) – Power connection and necessity of payment systems depend on specific usage	Up to *22.2 kW*	*1,250 – 3,250 Euros*
Public	– Placed on public ground (free accessible) – Focus on short term charging (e.g. recharging on a longer trip) – High power connections and payment systems are useful	Up to *100 kW*	*50,000 Euros*

Table 4.1.1: Existing types of charging stations (based on [78], [107], [86, p. 3], [45])

Private charging stations are placed on private ground like a garage and are used to charge an electric car over night and for longer times. Therefore the power connections of these stations range between 3.7 and $11.0\ kW$ [78, p. 33]. Due to the private access, it is not necessary to integrate payment systems into the charging station [107, p. 47]. The investment costs of private charging stations are between 200 and $1{,}250$ Euros per station [45, p. 8]. Semi-public charging stations are located on private ground which is not necessarily accessible for everyone: these stations can be placed at parking lots of employers or supermarkets or in car parks [78, p. 3395] [86, p. 4]. The necessity of payment systems depends on the usage of the station: in the case of a supermarket parking lot, the charging process can be for free and can be seen as a kind of promotion. In other cases it can be necessary to install payment system at semi-public stations [78, p. 23]. Also the power connection of these

stations depends on the usage. In case of long-term parking like at the workplace, there is no need for a high power connection. In case of short-term parking like at a supermarket, power connections of up to 22.2 kW can be useful [78, p. 23]. The investment costs of semi-public charging station are between 1,250 and 3,250 Euros [45, p. 9]. Public charging stations are accessible for everyone. These stations are for users who do not have a private charging station or who need to recharge their car during a long-distance trip. Here a power connection of up to 100 kW is useful [78, p. 30]. The investment costs of public stations amount to approximately 50,000 Euros per station [86, p. 3]. Figure 4.1.1 shows the structure of the charging infrastructure in 2020 as planned according to the roadmap for the charging infrastructure of the *National platform for e-mobility* in Germany [97, p. 46].

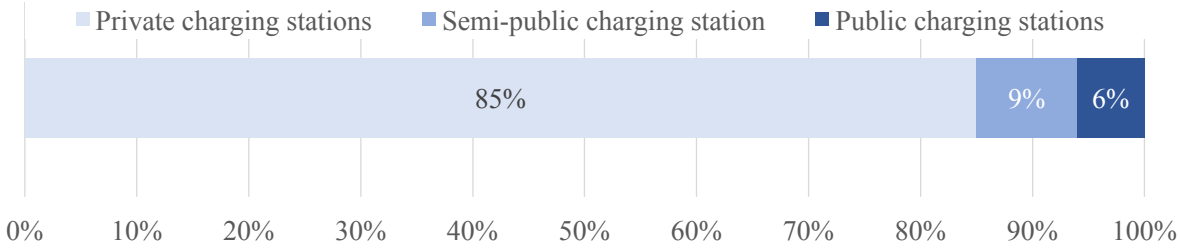


Figure 4.1.1: Planned structure of the charging infrastructure in 2020 in Germany according to the *National platform for e-mobility* [97, p. 46]

The figure shows a high percentage of private charging stations in 2020. Just 15 percent of the charging stations are assumed to be public or semi-public. In [107, p. 266] this assumption is confirmed: currently there seems to be no necessity to build up an expensive, comprehensive public charging infrastructure in Germany. Contrary to that, the charging infrastructure within MaaS is based on semi-public and public charging stations. According to [45, p. 9] station based car sharing fleets will be charged by semi-public charging stations. Due to the limited access to these charging stations it is not necessary to provide complex billing systems [45, p. 9]. In case of other mobility providers within MaaS, like free-floating car sharing providers, it will additionally be necessary to build up public charging stations because cars from these providers will mostly be parked in public areas [62, p. 2595]. MaaS combined with electric vehicles will therefore lead to new challenges in building up a comprehensive public and semi-public charging infrastructure. It will have to be figured out, in how far this high degree of public charging infrastructure with higher power connections can be integrated into the German power grid. Also the efficient distribution of the public charging infrastructure will have to be examined, to reach a high degree of utilization. The responsibility to build up the expensive public and semi-public charging infrastructure needs to be discussed in the future as well. Here it is conceivable that the car sharing providers

themselves provide their customers with a comprehensive charging infrastructure. Other parties have an interest to build up the charging infrastructure as well: for example supermarkets can use semi-public charging stations in their parking lots as marketing activities to acquire new customers [38, p. 68] [86, p.4]. Alternatively a third party or the public sector can build up a charging infrastructure in the future.

The potential of MaaS to support the development of an efficient charging infrastructure and the further development of electric vehicles is another aspect that has to be examined. According to the car sharing provider *car2go* by *Daimler*, car sharing operators can contribute to the development of a charging infrastructure for two reasons: firstly car sharing operators provide lots of "important information to cities about the flow of traffic within a city, the charging behavior of customers and thus the optimal positioning of charging stations" [37, p. 2]. Secondly, *car2go* sees an advantage in the parallel development of car sharing fleets and the corresponding public charging infrastructure: this parallel development "ensures a reasonable utilization of the charging network right from the beginning" [37, p. 2]. In [38, p. 9] Sabrina Cocca et al. mention the development of a sufficient demand for the developed offers (like the infrastructure) as a key challenge to establish electric vehicles. Besides the development of this sufficient demand, fleets of car sharing providers are a test field for new developed electric vehicles: *Car2go* points out the high potential of electric car sharing fleets, to "overcome typical teething troubles with the new technology" in "a high performance practical test" [37, p. 5]. Also other car companies use fleets to test new models or technologies under real conditions [134, p. 3].

Next to the development of a comprehensive public an semi-public infrastructure, there is the challenge of the limited range of electric vehicles. According to [37, p. 3] in 99 percent of the rides in urban areas, the range of electric cars is already sufficient. Nevertheless also against the background of a currently not well developed charging infrastructure the current ranges of electric vehicles are an obstacle for the expansion of e-mobility. Therefore in [107, p. 76] Peters et al. argue that it is not useful to replace conventionally driven cars by electric vehicles. It is rather necessary to integrate electric vehicles into fleets or multimodal mobility concepts. By providing this multimodal mobility concepts, MaaS is a suitable solution to implement electric vehicles with current ranges. MaaS provides a solution for every specific purpose instead of one solution for every trip [73, p. 8] so that it has less requirements on electric cars: if the range of the electric vehicle is not sufficient for a purpose, the user can use another mobility service. In addition to that, shared vehicles provide the possibility to switch the car during a long-distance ride.

As mentioned above, the integration of a comprehensive charging infrastructure into the power grid is challenging. However, electric vehicles, and electric vehicles which are operated in fleets in particular, can be used to supply the stability of the power grid [123, p. 459] [108, p. 12] [68, p. 1208]. This concept is called *Vehicle-to-Grid* (V2G). The idea of the V2G-concept is to connect electric cars with the power grid in a bidirectional way. Therefore electric cars can provide negative or positive power for regulation by being charged or discharged [123, p. 460]. Figure 4.1.2 shows the idea of the V2G-concept in connection with electric car fleets.

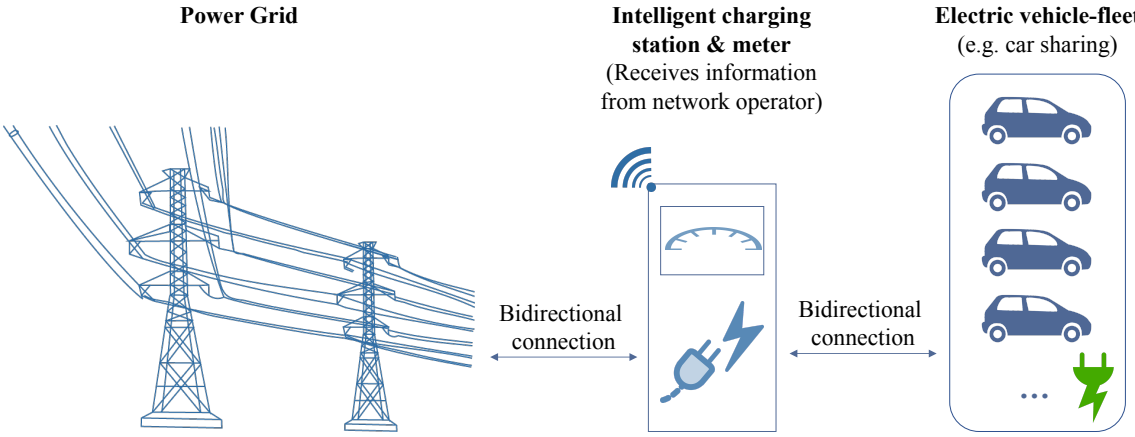


Figure 4.1.2: The V2G-concept with electric car fleets (modified from [123, p. 460])

In general the V2G-concept works with individual and privately owned electric vehicles. However, the use of V2G combined with fleets has several advantages. Firstly as typical of the energy market, the trading blocks for energy have to be at least one megawatt in Germany [1] [123, p. 459]. Therefore the V2G-concept with individual cars requires the pooling of many cars, which can then feed the power system with energy. Within fleets this pool is naturally given [123, p. 459]. Secondly this natural pool means that there is a smaller number of participants in the system: instead of lots of different private car owners with different types of cars and charging technologies, there is just one operator for all cars with a homogenous fleet and charging technology. It can be assumed that this makes the system by far less complex than the artificially created pool for the V2G-concept. Thirdly fleet operators have a high flexibility to control the charging processes of their cars because the operators often provide more cars than actually used [108, p. 12]. This control of the charging processes or utilization of cars makes it possible to block cars for the V2G-concept and therefore to generate additional profit by providing energy if it is particularly needed.

The technical conditions of MaaS to integrate electric vehicles can be summarized as follows:

1. The necessary charging infrastructure within MaaS is different from the currently planned infrastructure. Instead of a focus on a private charging infrastructure, there has to be a comprehensive public and semi-public infrastructure within MaaS.

2. Fleet-based mobility services within MaaS like car sharing offers provide a test field with a high utilization degree and lots of data availability. Fleets within the MaaS-concept provide good conditions for the V2G-concept, which can help to integrate charging stations into the power grid.

3. MaaS is a multimodal concept with different mobility services. Therefore there is a solution for every specific purpose and it is possible to integrate electric vehicles with lower ranges than conventional cars.

4.2 Non-technical view

The following section focusses on non-technical aspects concerning e-mobility and MaaS. The first step is a discussion about non-technical conditions to make electric cars accessible for the mass market. In a second step the identified conditions and requirements are matched with the core characteristics of MaaS to analyze in how far MaaS provides these conditions. The third part deals with main hurdles to provide a positive environment for electric cars within MaaS. This part focusses on the profitability of electric vehicles in fleets of mobility providers.

In [108, p. 6] Weert Canzler and Andreas Knie point out that e-mobility represents a new kind of mobility, which has to be embedded into a systematical approach. This approach means a high degree of scientific and economic collaboration to build up an intermodal mobility concept. Core characteristics of this concept are mobility services in the form of professionally operated fleets instead of privately owned electric cars [108, p. 12]. According to Canzler and Knie electric vehicles in professionally operated fleets have several advantages over privately owned electric vehicles: they point out that electric cars are still more expensive compared with conventional cars. Operating electric cars in a fleet makes it possible to organize their usage and to reach higher mileages compared with private cars. Canzler and Knie also remark that the operation of electric vehicles in fleets provides a higher flexibility of charging because the operators often provide more cars than actually used. The advantage

of this flexibility regarding the stability of the power grid with the help of the V2G-concept has already been discussed in chapter 4.1. Participating in this concept can be an additional source of revenue for the fleet operators [123, p. 465].

The study *Services for E-mobility* of the *Fraunhofer Institute* evaluates the ability of mobility services to support the expansion of e-mobility as well [38, p. 4]. Hereafter the main results of this study will be described. Afterwards there will be a review in how far the mentioned elements from the study comply with the MaaS concept.

According to the study it is necessary to supplement technological developments in e-mobility with service innovations to create a mass market and sustainable business models for e-mobility [38, p. 10]. To evaluate the current situation, the study's authors interviewed 27 experts from start ups, researching institutes, car companies, consulting companies and mobility providers [38, pp. 14-15]. For several reasons, the need and importance of services for e-mobility was assessed as "high" or "very high" by these experts [38, p. 17]. From the interview partners' point of view, mobility services can help to compensate disadvantages of electric cars like limited ranges, long charging times or high investment costs [38, p. 17]. The high investment costs are related to the cars themselves and to the corresponding charging infrastructure [38, p. 17]. According to the study, car sharing providers have the potential to make electric cars more visible and to provide an **easy access**. An easy access can be ensured if the processes for the application, registration, payment and charging are kept as simple as possible [38, p. 19]. Car sharing providers realized the high potential of mobility services to establish electric cars: according to Gisela Warmke, the director of the car sharing company *Cambio GmbH* services have a key position on the way to the end-user of electric cars [38, p. 18]. On order to realize the easy access to car sharing services, the study proposes the use of **smartphone applications** [38, p. 18]. A further issue mentioned by the interviewed experts was the aspect of **multimodality** for e-mobility, which allows to compensate the low ranges of electric vehicles as it was already discussed in chapter 4.1 [38, pp. 18, 25]. Multimodality will result in a high **collaboration** and **merging** of different mobility providers [38, p. 23]. The study recommends to develop **platform-models** with common standardizations to enable the interlock between different kinds of mobility [38, p. 39]. Platform-models could provide an "all-round carefree package" for the customers' mobility needs, which ensures the easy use of electric vehicles [38, p. 36]. In addition to that, services that support e-mobility have to be aligned with the users' needs. The study points out that these needs are on the one hand a **guaranteed mobility** at any time and on the other hand **customization** [38, pp. 32, 41]. The study proposes **different price** and service levels

which can be chosen by the user, depending on their willingness to pay and use mobility services [38, p. 36]. Table 4.2.1 summarizes the above mentioned conditions to support the integration of electric cars into the mobility system by the support of services. Additionally the table shows corresponding core characteristics of MaaS (which were presented in Table 2.2.1 on page 10).

Identified service-conditions to establish the use of electric cars	**Corresponding characteristics of MaaS**
– Easy access to the services (e.g. with the help of a smartphone application)	– Digital platform as "face to the end-user" and use of different technologies
– Multimodal mobility services (collaboration between different mobility providers)	– Integration of different transport modes
– A platform-model with common standardizations	– Digital platform as "face to the end-user" and use of different technologies
– Mobility guarantee for the end-user	– Demand orientation and integration of different transport modes
– Customization/individual price models	– Registration, personalization and three different tariff options

Table 4.2.1: Identified service requirements for the use of electric cars from [38] and corresponding characteristics of MaaS

The table shows that MaaS fulfills the requirements for services to support e-mobility which were identified in the examined study. An easy access to the different mobility services, including fleet services like car sharing, is ensured by the MaaS-platform which summarizes all mobility services. The combination of all services and the integration of different kinds of transport modes ensures a multimodal mobility concept. The condition of a platform model with common standardizations and the use of different technologies is realized by the MaaS platform. The demand-orientation and integration of different transport modes within MaaS leads to mobility guarantee for the end-user. The requirement of customization is realized within MaaS by registration and customized price and service models. In conclusion, the core characteristics of MaaS fulfill the service requirements to support e-mobility in Germany.

One key element of above mentioned services is the integration of electric vehicles in car sharing fleets. Therefore it has to be examined if the integration of electric cars into fleets is economically useful for fleet operators. At the moment the percentage of electric vehicles in car sharing fleets in Germany is 10.3 percent (plug-in-hybrids included), which is fifty times higher than the percentage of electric cars in general [99]. However the integration of electric cars into car sharing fleets comes along with some disadvantages. The study *Integration of electric vehicles in car sharing fleets* by Claus Doll, Martin Gutmann and Martin Wietschel examines the integrability of electric vehicles in car sharing fleets [45]. They identify challenges a car sharing provider has to deal with when integrating electric vehicles into a fleet. Major challenges are the limited range of electric vehicles and charging times. Charging times have to be planned and reduce the availability of electric vehicles in car sharing fleets [45, p. 9]. For these reasons the study of Doll, Gutmann and Wietschel predicted in 2011 already that the percentage of profitable integrable electric vehicles in car sharing fleets will be approximately 12.7 percent in 2015 (plug-in-hybrids excluded). This percentage is subject to the condition that the purchase of the car is subsidized by up to 5,000 Euros. In [134] Willi Loose from the *Bundesverband CarSharing* analyzes the current situation of electric vehicles in car sharing fleets in Germany. Loose defines three different groups of car sharing providers and identifies current challenges and chances. The first group are car sharing providers who operate fleets of 100 percent electric or hybrid cars. The second group are car sharing fleets that are operated by car companies and the third group are car sharing providers that are independent from car companies. Table 4.2.2 gives an overview of these groups.

Provider	**Amount of electric vehicles in the car sharing fleets[6]**	**Percentage of electric vehicles in the car sharing fleets[6]**
"New" car sharing providers with solely electric vehicles in their fleets	431	100.0%
Car sharing fleets of car companies	1,020	13.5%
Car sharing fleets that are independent from car companies	321	2.0%
Total	1,772	10.3%

Table 4.2.2: Electric vehicles in car sharing fleets of different providers in Germany in 2018 (modified from [134, p. 2])

The table shows that the percentage of integrated electric vehicles in the different groups differs significantly. These differences are caused by the various backgrounds of the groups: the "new" car sharing providers, who are exclusively operating electric vehicles were either developed as supported e-mobility projects or as part of energy communities in smaller cities, to use self-produced charging energy. The second group, car sharing fleets that are operated by car companies, has more than 13 percent of electric vehicles in its fleets. Here the fleets are used to promote and test electric vehicles. Car companies use their car sharing fleets as "driving showcases". However, a profitable operation is not possible. The third group, independent providers, have just a small amount of electric vehicles in their fleets. Here the providers often integrate electric vehicles in their fleets with the help of federal funding projects. The different groups show that it is currently not possible to integrate electric vehicles into car sharing fleets in a profitable way and without an external support by federal fundings or car companies. The largest number of integrated electric vehicles originate from car sharing fleets that are operated by car companies. Another survey with 18 different station-based car sharing providers confirms that an insufficient profitability is the main reason against the integration of more electric vehicles. [134]

The results of the examination of non-technical aspects concerning MaaS and e-mobility show that it is necessary to make electric vehicles more attractive for mobility providers. On the one hand it shows that mobility services like car sharing companies have a huge potential to support the development of e-mobility and to provide an easy access to electric vehicles for the users. On the other hand the high costs of electric vehicles combined with a lower utilization degree make the integration unattractive for mobility providers. Currently integrated electric vehicles can be found in car sharing fleets that are operated and financially supported by car companies or in federal or state projects. It is questionable if these federal state funded fleets can also be operated without financial support [134, p. 2]. However, in December 2017 the German government revised the funding guideline for e-mobility [20]. In [99] Gunnar Nehrke, the director of the *Bundesverband CarSharing*, criticizes this revision for three reasons: first he criticizes the financial amount of the funding. Only 40 percent (for smaller companies up to 60 percent) of the additional costs of an electric vehicle compared with conventional cars are eligible. From his point of view this kind of support does not consider the lower utilization rate of electric vehicles in the car sharing fleet. Second Nehrke criticizes the short term orientation of the funding: after its release in December 2017 the applications for funding had to be made until the end of January 2018 [109, p. 1] [99]. From Nehrke's point of view, this tight time schedule makes it hard for car sharing providers to find

[6] Plug-in hybrids included

suitable cooperation partners like municipalities and charging infrastructure operators that are necessary to implement electric car sharing. The third reason why Nehrke criticizes the funding guideline is the limited funding of the charging infrastructure: the funding guideline excludes financial support of the connection costs of a charging station [109, p. 4] [99]. As a result it can be noted that current funding projects by the government are assessed as insufficient by the car sharing companies. From their point of view the current funding guideline is not adequate to compensate the financial risk of car sharing providers integrating electric vehicles into their fleets.

All in all the examination of the non-technical aspects concerning e-mobility and MaaS can be summarized as follows:

1. MaaS provides all identified non-technical conditions that are necessary to support e-mobility in Germany and to make the use of electric vehicles more attractive for the users they. The users can get an easy access to electric cars by using the mobility services that are provided within MaaS.

2. Due to higher investment costs and a lower utilization compared with conventional cars, the integration of electric vehicles into fleets of mobility providers like car sharing is currently not profitable. The integrated electric vehicles are predominantly integrated in fleets that are operated by car companies who use fleets to promote their electric vehicles.

3. Apart from the profitability, mobility services and MaaS provide positive conditions for electric vehicles – and are even seen as “necessary” to promote e-mobility. Therefore it is worthwhile to expand the state fundings to integrate electric vehicles into fleets and to make this integration more attractive for operators.

4.3 Results

The examination of the conditions for e-mobility within the MaaS-system shows that are there positive and negative aspects on the technical and non-technical level. Table 4.3.1 summarizes challenges and chances of e-mobility and MaaS.

Challenges	Chances
Technical aspects	
– Necessity of a comprehensive **public/semi-public charging infrastructure**	– **Availability of data and information** to build up an efficient charging infrastructure
– Unclear situation who is **responsible to build up** the public/semi-public charging infrastructure	– Parallel development of the charging infrastructure and mobility services with electric vehicles ensure a **high utilization degree of the developed charging infrastructure**
	– Mobility service fleets are used as **test fields for new developed electric vehicles**
	– The **multimodality of MaaS** makes it possible to integrate electric vehicles with lower ranges (“there is a solution for every specific purpose”)
Non-technical aspects	
– Integration of electric vehicles in car sharing fleets is currently **not profitable**	– MaaS has the **potential to promote the use of electric cars**
– Integration of electric vehicles **depends on external financial support** (by state funding or car companies)	– Core characteristics of MaaS **provide positive conditions to establish e-mobility** in Germany

Table 4.3.1: Technical and non-technical challenges and chances of MaaS combined with e-mobility

In general MaaS provides a good environment to encourage the use of electric vehicles in Germany. It was shown that the implementation of electric vehicles needs to be embedded in a comprehensive change in the mobility sector instead of just “replacing” conventional vehicles by electric cars. Only if electric vehicles are implemented in a multimodal mobility system with easy access for the user, e-mobility can become successful in Germany. Here fleets are particularly suitable as they make electric vehicles available for a wider range of end-users who do not have to invest in their own electric car and the corresponding charging infrastructure. Embedding of the implementation of electric cars into a “new” mobility system allows the handling of their specific characteristics like a limited range, higher investment costs or the necessity of a charging infrastructure. Therefore concepts like MaaS do not just have the potential to support e-mobility. Mobility concepts like MaaS are rather necessary to implement electric vehicles in Germany. Many requirements that are necessary to integrate electric vehicles into our mobility system can be fulfilled by MaaS because of its multimodality and service-orientation. Therefore it is important to deal with the remaining

challenges of implementing electric vehicles into MaaS. Table 4.3.1 shows that there are two main challenges that have to be met. On the one hand there is the necessity to find a way to build up a semi-public and public charging infrastructure. Even though this is a huge challenge, MaaS has the potential to support the development of this infrastructure: it ensures a high utilization degree of the developed infrastructure and can provide valuable data to ensure its efficiency. On the other hand the profitability of electric vehicles in mobility service fleets has to be ensured by long-term oriented funding projects which face the needs of mobility providers. Due to the high potential of MaaS to boost the use of electric vehicles, these funding projects should not just focus on the support of mobility providers but also on the concept of MaaS in general: actions which support the implementation of MaaS indirectly support e-mobility as well. For this reason the needs for action to implement MaaS identified in chapter 3.3 also support the development of e-mobility.

5 Conclusions

The following chapters bring together the main results of this thesis. Furthermore they critically reflect these results to identify open questions which have to be examined in future research.

5.1 Feasibility of Mobility as a Service with e-mobility in Germany

The introduction of this thesis points out that the current mobility system is subject to tremendous challenges and chances. It is shown that the current mobility system is characterized by a high degree of private mobility, inefficiencies and separated mobility services. For this reason, this thesis discusses MaaS as an alternative mobility system. On the one hand the discussion focusses on the feasibility of MaaS in NRW, which is examined with the help of the catalogue of requirements. On the other hand the ability of MaaS to establish electric vehicles in NRW is analyzed. Figure 5.1.1 shows the main results of the examination, following Figure 1.0.2 in the introduction of this thesis.

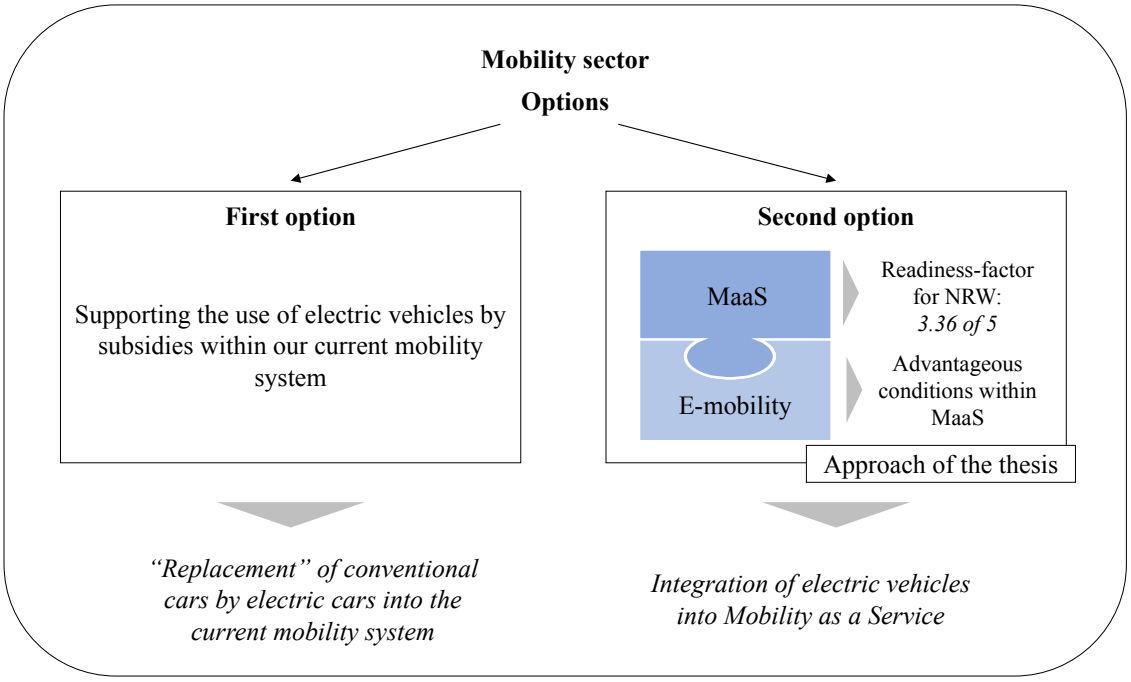


Figure 5.1.1: Core results of the thesis

In general it is shown that a realization of MaaS in NRW is possible. Considering all 16 requirements, which positively influence the implementation of MaaS, NRW is rated with readiness factor 3.36. Furthermore MaaS provides benefits for the integration of e-mobility. Nevertheless both the implementation of MaaS and the integration of e-mobility into MaaS require need for action. Here it has to be taken into account that actions which are undertaken to support MaaS, also support the implementation of e-mobility: being service-oriented and following a multimodal integration of different kinds of mobility, MaaS simplifies the use of electric vehicles for the user. It is shown that the core characteristics of MaaS coincide with the requirements which were identified to establish the use of electric vehicles. Furthermore MaaS provides conducive technical conditions regarding the V2G-concept and limited ranges of electric cars. Therefore it can be concluded that within the concept of MaaS, which represents the second option in Figure 5.1.1, it is possible to "integrate" electric cars. The first option conversely would rather "replace" conventional cars by electric cars in our current mobility system, without embedding this replacement into a comprehensive change in the mobility sector.

The identified core challenges of implementing MaaS are on the regulatory level. To implement MaaS, it is necessary to adjust the current passenger transportation law, the *PBefG*, in Germany. "New" mobility services like car sharing, ride sharing or on-demand services have

to be integrated into the *PBefG*. This will allow to regulate these services and to reach legal certainty for corresponding business models. The core idea of MaaS is, to provide a reliable mobility service as an alternative to the private, inefficient use of cars. Legal certainty for mobility services is therefore essential to reach a high diversity of mobility offers and to support the development of public mobility services. The focus should not be on competition with private cars. MaaS is rather a development of our current mobility system with a successive merging of private and public mobility. The improvement of the *PBefG* would also lead to a better quality of the new mobility services. As on-demand services are a core characteristic for MaaS the development of this service has to be supported in particular. In addition, there have to be increasing investments into the existing railroad infrastructure, in order to be able to face the challenge of the desired increasing amount of passengers for public transport services. On the technical level there has to be an improvement of the internet infrastructure and a standardization of interfaces for mobility providers who would like to join a mobility platform. As MaaS provides such a good environment for the integration of electric vehicles, all these measures indirectly support e-mobility as well. However, the integration of electric vehicles within MaaS has also to be supported directly by two main measures. Firstly it is necessary to focus on the development of a public and semi-public charging infrastructure. Current plans are focussing on private charging, which does not correspondent to the concept of MaaS. Secondly, the implementation of electric vehicles in fleets of mobility services within MaaS has to be supported. Current promotion programs are not sufficient to make electric vehicles economically attractive for fleet operators, because of high initial investment costs for the cars as well as the charging infrastructure and because of a lower degree of utilization. Only if the above mentioned measures are token, the advantages of e-mobility provided by MaaS can be used.

The thesis examines a high amount of different aspects concerning the implementation of e-mobility and MaaS in Germany. Nevertheless some questions and topics are not discussed in detail and will have to be examined in further studies. The following chapter gives an outlook on questions that should be evaluated in future research.

5.2 Future research

MaaS and e-mobility affect a wide range of different sectors. Therefore this thesis is an interdisciplinary examination of technical and non-technical aspects and questions. Future

research that will examine the implementation of MaaS in German will have to focus on different issues. Figure 5.2.1 gives an overview of aspects which were not discussed in a sufficient way within this thesis. The implementation of MaaS is a successive process and therefore also additional aspects of research can pop up successively. Thus, the depicted aspects are not finally defined and will have to be completed and adjusted step by step in future works.

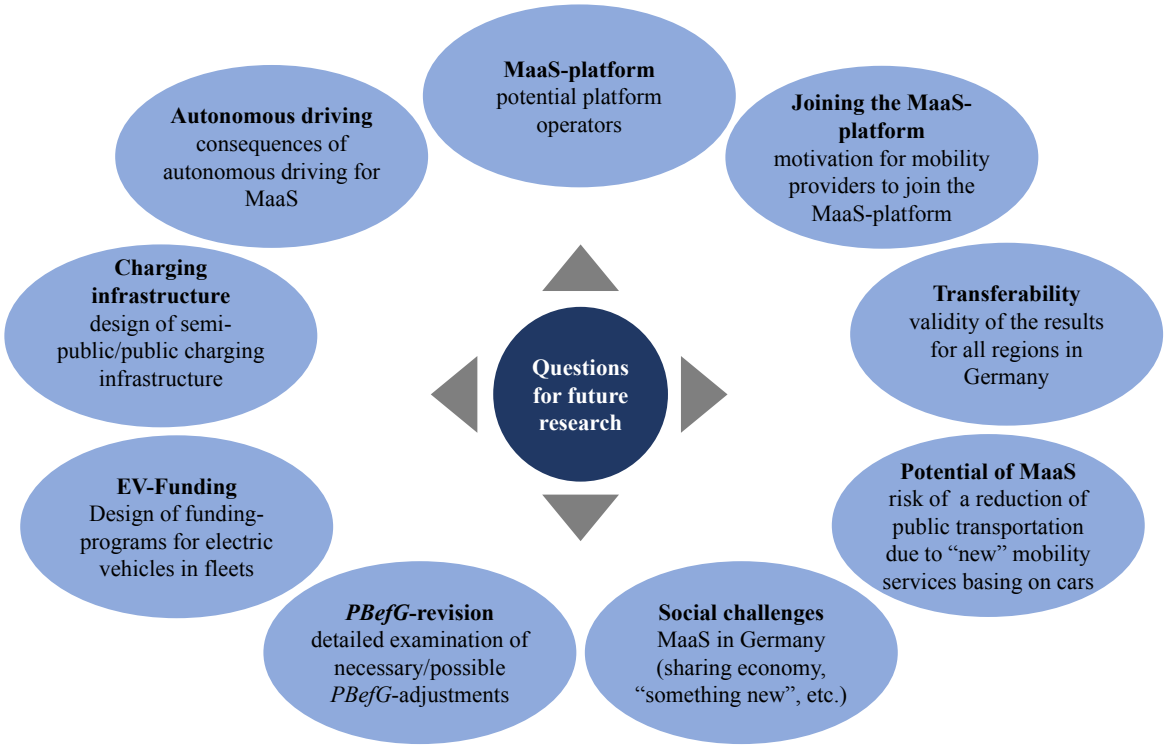


Figure 5.2.1: Future Research

In general this thesis proposes two main options for the role of platform operator. The role can be taken over either by the public or the private sector. Here it needs further examination to find out which of the models is the best to implement MaaS in Germany. This is related to the question, how mobility providers can be motivated to join a MaaS-platform. The thesis already presents some projects where different mobility services are integrated into one single platform. Therefore the experiences of these projects have to be considered, when examining the best "design" for MaaS in Germany. It should also be analyzed if the results of this thesis are valid for other regions in Germany. Some conditions, like the high density of population, are particularly good in NRW while other regions in Germany do not provide such conducive conditions for MaaS.

The thesis points out the general potential of MaaS to improve the current mobility system and how to be prepared for upcoming challenges. By providing new mobility services, like car sharing, there is the risk of increasing individual transport. This can occur, if people use individual transport services which are provided in the MaaS system instead of using public transportation: some people who use public transportation services today may use car-based services like car sharing or rental cars within MaaS. In future research, it has to be investigated, how this can be avoided and how primarily private car owners can be motivated to use MaaS. The examination of the general willingness for MaaS also has to be discussed in more detail in the future. As MaaS has a demand-oriented and personalized focus, there have to be comprehensive surveys that accompany the implementation process of MaaS and give detailed information about customer needs for MaaS. The MaaS concept also needs to be proved from a legal point of view. This thesis makes some proposals how to improve the *PBefG*. The detailed preparation of this improvement has to be done by a legal assessment. In this context it also has to be evaluated, if there are further legal obstacles to implement MaaS in Germany.

The design of sustainable funding programs to improve the profitability of electric vehicles in fleets will have to be analyzed in the future as well. Additionally the detailed design of a suitable charging infrastructure for e-mobility within MaaS has to be explored: How is it possible to integrate public and semi-public charging infrastructure into the current energy network? What does an optimal distribution of charging stations within MaaS look like? By highlighting the advantages of MaaS for e-mobility, the thesis motivates to deal with these questions in more detail in the future. It was already pointed out that the implementation of MaaS is a vivid process. Therefore it is continuously necessary to observe new technologies and their implications for MaaS. One of these technologies will be autonomous driving. This technology could have the potential for new business models and mobility services that can complement the MaaS-system. Here again it has to be figured out if there are any synergies between autonomous driving and MaaS, like in the case of e-mobility and MaaS. As MaaS is a comprehensive and vivid topic, its implementation has to be accompanied by interdisciplinary research.

The potential of MaaS combined with today's challenges in the mobility sector makes it worthwhile to pursue the implementation of MaaS. This thesis shows that there are manageable obstacles to implement MaaS in Germany. In the light of the chances that are related to MaaS, the efforts to overcome these obstacles will be rewarding.

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