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MaaS meets blockchain

an exploratory study on the promises of blockchain technologies for enabling a MaaS platform

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An exploratory study on the promises of Blockchain Technologies for enabling a MaaS platform

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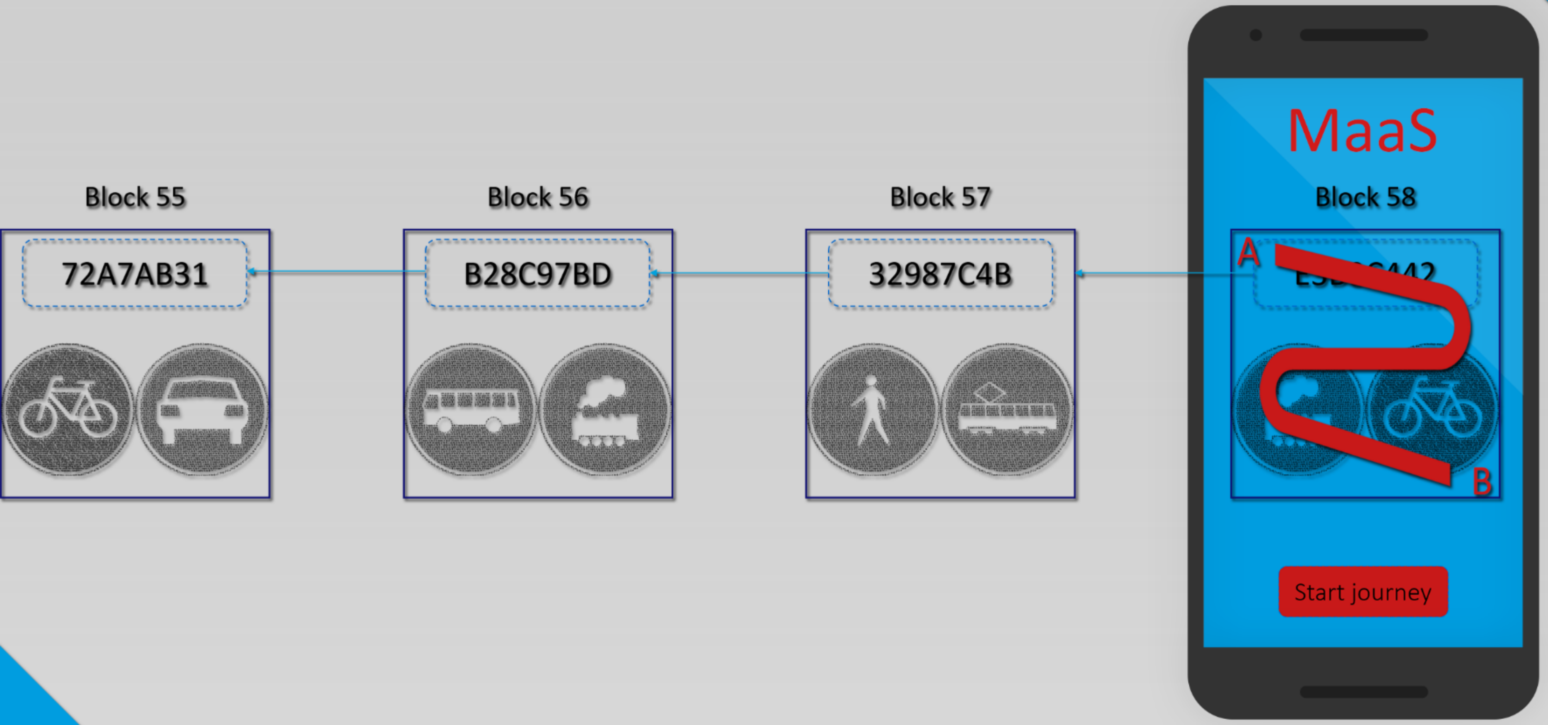

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Management Summary

Many people travel every day for various purposes. It is expected that the amount of travel will increase in the coming years. As a result, congestion will also increase. This is a result of major landscape trends, such as hyper urbanization, climate change, and demographic & socio-economic changes. Therefore, a change in mobility is required in order to achieve sustainable mobility for future generations.

A combination of new emerging technologies, such as automated vehicles, peer-to-peer sharing applications and the Internet of Things (IoT), have the potential to revolutionize individual and collective mobility. This is currently named the smart mobility transition. The aim of this transition is to reduce congestion and the other negative externalities of transportation, such as air pollution.

Businesses and governments are both experimenting with new initiatives that contribute to the smart mobility transition. The initiatives can be classified into four domains: vehicle technology, intelligent transport systems, data, and new mobility services. This research focuses mainly on new mobility services.

New mobility services challenges the current transportation ecosystem by providing alternative ways of transportation. Often, new mobility services are presented as digital platforms that match supply and demand by using new emerging technologies.

With the introduction of new mobility services, a different problem emerged. Namely, the services behave as competitors to each other and to conventional public transport. However, in order to fully utilize the new mobility services and fulfill the aim of the smart mobility transition, all of these options should be included a common platform, a Mobility as a Service (MaaS) platform. MaaS is introduced in 2014, to provide an user-centred approach for all mobility needs. However, MaaS is not yet widely adopted by travelers and transport providers. The underlying cause is that there are many mismatches of expectations and stakeholder perspectives of MaaS between commercial actors, governmental parties and users. The main problem that is addressed in this thesis is the integration and utilization of information that is required to enable a MaaS platform.

New technologies might provide new solutions for the realization of MaaS. The proposed technologies are: 5G networks, autonomous vehicle technology and Blockchain technology. 5G networks can be classified as the means to enable MaaS, not the solution. Autonomous vehicle technology might solve supply side challenges, not the issue that is addressed by this thesis. Practitioners identified Blockchain as most promising technology for the integration and utilization of information.

This thesis aims to research how Blockchain technology can enable the realization of MaaS. The main research question is: How may Blockchain technology enable the realization of a MaaS platform? The main research question is divided in three parts. In the first part, literature on the core business of MaaS, public value in smart mobility, and ecosystem theories are reviewed in order to create an assessment tool for the realization of a MaaS platform. The main MaaS actors that are identified in MaaS literature are: the MaaS operators, data providers, transport providers, end users, and regulators & policy makers.

The literature review of public value in smart mobility initiatives provides the main challenges for a balanced value proposition of a MaaS platform. A balanced value proposition is required, because both public and private actors are included in the platform. The main identified challenges are: the short versus the long game, costs of the transition, information asymmetries, and equity and inclusion. Blockchain technology might help enable a balanced value proposition, because it cuts out the middle man.

By conducting a literature review on ecosystem theories, the most useful theories is selected. The innovation ecosystem theory of Adner is identified as most promising method to assess the realization of a MaaS platform, because it is a structured way to assess the value proposition, while considering both organizational and technological challenges. The value proposition of an ecosystem is used to identify the set of actors that need to interact in order for the proposition to come about and finding the associate ecosystem risks.

The results of the literature reviews are merged into a model to analyze literature related to MaaS pilots. The author proposes a generalized approach of the value blueprint of Adner. In the model of Adner, all actors must be identified. This will work perfectly for a specific cases. However, the aim of this research is to provide a holistic approach to assess articles of multiple MaaS pilots. Therefore, the actors are constrained to the main actors that are identified in the literature of the core business of MaaS. The identified steps to construct a generalized value blueprint are:

- **Step 1:** Identify the possible end users.
- **Step 2:** Identify the minimum characteristics to which the project in the ecosystem must comply.
- **Step 3:** Identify the main actors in the ecosystem and label this actor as supplier, intermediary, or complementor.
- **Step 4:** Identify the risks in the ecosystem and what underlying causes can be found for these risks.

This approach provides not the full picture for a case specific implementation of MaaS. However, it enables to identify the main ecosystem risks in the core business of a MaaS platform. The public value challenges are not directly included in the model. However, they should be considered in the third part of this thesis. Part two consists of the assessment of relevant MaaS literature, to find the ecosystem risks that obstruct the realization of a MaaS platform. Literature is relevant if the research object of the articles is a MaaS pilot. The steps of the generalized value blueprint are used for this assessment. The results of this step show that the most suitable end user group cannot yet be identified. Also, the impact of MaaS on travel behavior is not yet clear. Therefore, more research should be conducted on this topic.

In step 2, the value blueprint is constructed and visualized in Figure 1. The value blueprint provides the positions and links of the actors in the ecosystem.

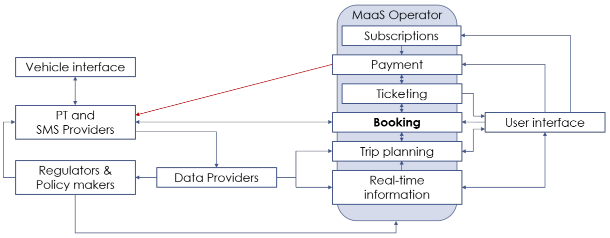

Figure 1: The MaaS Model. Source: own figure

Step 3 is to label the actors. The MaaS operator is the new entity in the ecosystem. The data operators and regulators & policy makers are complementors. Transport providers are suppliers.

Step 4 the ecosystem risks are identified. In total 15 ecosystem risk categories can be identified in literature, of which 7 are red risks. To limit the extent of the research, only the red (most critical) risks are considered in this research. The risks are: brand image (execution risk), operational costs (execution risk), inclusion of the needs of end users (execution risk), ride sharing and behavioral change (execution risk), integration of ticketing systems (co-innovation risk), open data (adoption risk), and data ownership (adoption risk). The risks should be addressed to enable the realization of a MaaS platform.

In part III, the promises of Blockchain technology are explored. Part II and Part III will be merged into a discussion to provide insights if and how Blockchain can address the red risks of MaaS and therefore enable the realization of a MaaS platform. Part III consists of two sections. First, the promises are explored through Blockchain literature. Secondly, a thematic analysis on several Blockchain and mobility projects is conducted.

The results of first section show that Blockchain technologies can be seen as part of the implementation layer of a software system. The purpose of Blockchain technology is to maintain trust in a decentralized network. This network is created around a Blockchain ledger. Only transactional data can be stored and shared in this ledger. Blockchain technologies provide the rules and standards that enable politically decentralized distributed ledgers. However in practice, it is difficult to create a fully politically decentralized software system. Therefore, several types of Blockchain networks exist, namely public, private and consortium.

Only the a public Blockchain network aims to be as politically decentralized as possible. For a MaaS platform, the highest level of political decentralization possible should be the goal to cope with the public value in smart mobility challenges.

In section two, a thematic analysis of mobility related Blockchain white papers is conducted. Four themes emerged from the documents, namely:

- Automation
- Store and map transactions

- Incentivize behavior
- Off-chain validation

The first three themes can be linked to the promises of Blockchain technologies. The last theme shows that there is always a connection with the real world, this is the boundary of the solutions that Blockchain technologies are able to provide. This statement also became evident in the literature review of the promises of Blockchain.

Part II and Part III are linked in a discussion. By using Blockchain technologies, new solutions can be proposed to reduce several of the identified red or most critical risks. The most promising result is that Blockchain Technology can be used to stimulate ride sharing and reduce data ownership risks. It can also be part of the solution for the risks of operational costs, needs of the end users, integration of ticketing systems, and open data.

The main research question can be answered as: Blockchain technologies partially influence the realization of a MaaS platform by providing unique solutions that are not possible without the use of Blockchain technology. However, Blockchain technologies are still in development and no main or best Blockchain technology can be identified, yet. Also, there are many different Blockchain variants available. Therefore, using Blockchain technologies will increase the technology architecture risk.

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Contents

List of Figures

List of Tables

1

Introduction

This chapter is used to introduce the research MaaS meets Blockchain. The background of the research is described in Section 1.1. This section is followed by the outline of the research in the form of a research framework in Section 1.2. From this framework, research questions can be derived. The research questions are described in Section 1.3. The relevance to the Innovation Sciences is described in Section 1.4. Last, the structure and outlay of this research is described in Section 1.5.

1.1 Background

Mobility as a Service (MaaS) emerged as a new sustainable transportation solution and is in initial stage of development (Goodall et al., 2017; Jittrapirom et al., 2017; Mulley, 2017). This section is divided in two subsections. First, the need for MaaS and the definition of MaaS is explored (1.1.1). Second, Blockchain technology is introduced and linked to MaaS research (1.1.2).

1.1.1 MaaS

A combination of new emerging technologies, such as automated vehicles, peer-to-peer sharing applications and the Internet of Things (IoT), have the potential to revolutionize individual and collective mobility (Docherty et al., 2017). This transition is currently named the smart mobility transition. The aim of a smarter mobility is to solve or reduce significant negative externalities that are contributed by transportation modes, resulting in more sustainable forms of transportation (Jeekel, 2017; Mulley, 2017).

The reason of the smart mobility transition can be found in some major landscape trends, namely: hyper urbanization, climate change, and demographic & societal changes (Kamargianni

& Matyas, 2017). Millions of people are expected to move to cities in the upcoming years, which results in an increase of congestion (Goodall et al., 2017). Besides, economic circumstances and norms and attitudes towards transport are changing (Smith et al., 2017). Also, local governments embrace the sustainable direction towards more livable cities. Therefore, many government officials believe that cities should be less vehicle-centred (Goodall et al., 2017). Two other business related trends are also pushing the smart mobility transition. Namely, the trends of digitization and servitization. These trends are opening new opportunities for new types of personal transport services (Smith et al., 2017).

In the Netherlands, these trends are also visible. Mobility in the Netherlands will grow with 1.2 percent each year (KIM, 2017). Already in 2022, congestion will increase by 28 percent (IenW, 2017). As a result, the NMCA forecasts that there will be multiple transportation bottlenecks in the Netherlands by 2040 (IenW, 2017). The major bottlenecks can be found in the five largest cities in the Netherlands, and in between those cities (Figure 1.1). The orange markings in Figure 1.1 are bottlenecks for both public transport and private transport. The yellow markings are bottlenecks for private transport only. Purple are bottlenecks for public transport.

Figure 1.1: Bottlenecks mobility in the Netherlands 2040. Source: NMCA report (2017)

Concluding, a change in mobility is required in order to achieve sustainable mobility for future generations. Therefore, many governments and business are currently experimenting with smart mobility initiatives (Mulley, 2017). No main or most successful trajectory can yet be identified within the smart mobility transition. However, Smart mobility initiatives could be categorized in one or multiple of the following domains: vehicle technology, intelligent transport systems, data, and new mobility services (Jeekel, 2017). Possibly, MaaS may fit in all domains. However, in this research the focus is around data and new mobility services.

New mobility services challenges the current transportation ecosystem and combines many new emerging technologies (Kamargianni & Matyas, 2017). The most known example of a new mobility service is the taxi-service Uber. Uber uses many new technologies such as Internet of Things (IoT), Artificial Intelligence (AI), and experimenting with automated vehicles in order to meet the needs of the customer (Lozinski, 2018). Presently, research on new mobility services is focused on sharing. Shared mobility services are part of the sharing economy theory, which aims for a sustainable society. A definition of the sharing economy is to take value of underutilized assets, such as vehicles, and making them accessible online to a community, leading to a reduced need for ownership (Richardson, 2015). Currently, many mobility start-ups and transport incumbents have great interest in shared services (Jittrapirom et al., 2017). A good example of a well functioning shared service is the car2go platform. In Amsterdam, car2go is renting electric vehicles at an hourly rate. The vehicle can be parked anywhere within a certain area, which is called free-floating (car2go Nederland, 2018). The aim of this initiative is to reduce the amount of unused parked cars in the centre of Amsterdam. Car-sharing is a solution for many transportation problems. However, it should be noted that a private owned vehicle uses the same amount of space on the road as a shared vehicle if there is no ride-sharing scheme available for the shared vehicle (Metz et al., 2016).

Thus, the shared services should include more than only sharing assets, ride sharing should be included as well. Fortunately, travelers have increasingly embraced new mobility options and apps over the last decade (Goodall et al., 2017). Next to car-sharing other types of shared services became popular. Examples are: bike-sharing service (e.g. OV-fiets), ride-sharing (e.g. blabla car), ride-hailing services (e.g. Lyft), and journey planning apps (e.g. Rome2Rio) (Goodall et al., 2017). A major problem of those new initiatives is that they behave as competitors to each other and to conventional public transport (Jittrapirom et al., 2018). However, in order fully utilize all new mobility services and fulfill the aim of the smart mobility transition, all of these options should be included on one common platform, a MaaS platform (Goodall et al., 2017). The aim is to create a data-driven and user-centric mobility ecosystem that challenges the the use of private vehicles (Goodall et al., 2017).

Thus, MaaS is the road towards a user-centred mobility paradigm, that may be as convenient as a private vehicle, while traveling is more sustainable, seamless, and reasonably priced (Goodall et al., 2017; MaaS-Alliance, 2018).

MaaS should change the way we travel. However since the introduction of the concept in 2014, MaaS is not a common idea in the transportation industry yet (Mulley, 2017). MaaS is a new mobility concept, and is in initial stage of development (Goodall et al., 2017; Jittrapirom et al., 2017; Mulley, 2017). According to MaaS-Alliance (2018), the definition of MaaS is: ”The integration of various forms of transport services into a single mobility service accessible on demand” (p. 01). MaaS may be a vision, because transportation should be so convenient that commuters can and will give up their private car (Goodall et al., 2017). Additionally from a policy perspective, maximizing social benefits is a major criteria for MaaS (Docherty et al., 2017). MaaS could also be seen as a phenomenon, because MaaS emerges due to changing behaviours and new technologies (Jittrapirom et al., 2017).

With all those different views of MaaS it is hard to co-innovate a MaaS platform that fulfills the requirements and goals of the many actors, creating sufficient value for users of the platform (Jittrapirom et al., 2017; Mulley, 2017). MaaS requires new forms of partnerships, in which private actors play a larger role in the creation of societal benefits (Smith et al., 2017). Currently, there are many mismatches of expectations and stakeholder perspectives of MaaS between commercial actors, governmental parties and users. One of the main problems of MaaS is the integration and utilization of information that is required to enable a MaaS platform (Jittrapirom et al., 2017). This is applicable on the supply-side, as well as the demand side. New technologies are currently explored to overcome the problems that form barriers to the realization of a MaaS platform. The three most promising technologies are described in the next section.

1.1.2 Blockchain

Several new emerging technologies might enable the realization of a MaaS platform. The rapid development of new technologies could change business models that are currently not viable. According to many practitioners, current emerging technologies that have the potential to enable Maas are: 5G networks, autonomous vehicle technology and Blockchain technology (MaaS-Alliance, 2018). These technologies might complement each other and can be used for different problems of MaaS. Not all technologies solve or reduce the problem that is addressed by this thesis. Namely, the integration and use of information.

The first technology, identified by MaaS-Alliance (2018), is a solution that solves technological infrastructure challenges. A 5G network enables more data-intensive solutions, such as more personalized and location-based services (Eckhardt et al., 2017). Therefore, 5G networks are recommended to create an technological infrastructure for a MaaS platform (Kamargianni & Matyas, 2017). Thus, it provides the means for the integration and utilization of information, not a solution.

Another technological opportunity is autonomous vehicle technology. Autonomous vehicles could solve many of the supply-side challenges (Goodall et al., 2017). However, there is still a big gap between the current situation and the desired situation of autonomous vehicles. Driverless technology is not yet ready for mass scale transport (McCluskey, 2016; Goodall et al., 2017). Therefore, more research should be conducted on how autonomous vehicles could solve supply-side challenges. Moreover, it is not a solution to the problem that is addressed by this thesis.

Another new technology that might enable the realization of a MaaS platform is Blockchain. Currently, there are several businesses investigating the use of Blockchain technology for MaaS, i.e. Toyota. Blockchain technology is one of the most interesting developments, according to many practitioners (MaaS-Alliance, 2018; McCluskey, 2016). Many new innovative platform providers use conventional brand recognition for building thrust (McCluskey, 2016). Blockchain technology is a trust protocol that ensures the integrity of the data exchanged among different users without going trough a trusted third party (Tapscott & Tapscott, 2016). The goal of using Blockchain technology is to put the power in the hands of the community and reward those who contribute equally for their efforts (McCluskey, 2016). This view is mostly used as the main benefit of Blockchain technology. However, it can also be seen as a new and highly effective model for organizing activity with less friction and more efficiency (Swan, 2015).

Sun et al. (2016) identified that there is a need to research the design and adoption of Blockchain-based sharing services for smart cities. Moreover, van Manen (2017) argues that

MaaS and the possibilities of Blockchain technology should be explored, because it might make a intermediate platform obsolete. Carter & Koh (2018) wrote a paper about Blockchain technology disruption in transport. The results of this paper shows that Blockchain has the potential to impact every area of the transport sector in the future (Carter & Koh, 2018). They also performed a survey about Blockchain technology in transport. The three statements that received most agreement are: Blockchain will make supply chains more transparent, Blockchain will be important in the future development of intelligent and connected vehicles, and Blockchain will enable MaaS (Carter & Koh, 2018). Thus, there is a strong interest in Blockchain technology and MaaS.

The benefits and use cases of Blockchain-based systems should be studied in a MaaS context (MaaS-Alliance, 2018). According to MaaS-Alliance (2018), Blockchain could solve issues of trust in payment and transaction procedures, the question of ”who owns the customer” and ”who should own the platform”. The ecosystem will not ultimately controlled by the goals of a profit seeking group, but by the users themselves (McCluskey, 2016). Some researchers argue that there should be a new (neutral) player, namely the MaaS operator, to realize MaaS (Smith et al., 2017). With Blockchain technology, the ’middleman’ may be expelled out of the value chain (Tapscott & Tapscott, 2016). Moreover, in a laboratory environment, Blockchain technology already shows some promising results for data security for MaaS (Bakker, 2018). The biggest challenge of MaaS and Blockchain technology is to find out how to monetize and market a platform without a middleman (McCluskey, 2016). If this platform is viable, it will also help to create a new form of sharing economy and MaaS into the bargain (McCluskey, 2016). Thus, the main problem relating to MaaS that may be addressed by using Blockchain technology is data management of the MaaS platform.

Concluding, several studies show that Blockchain might enable the integration and utilization of information for a MaaS platform. However, no one seems to answer to what extent Blockchain technology could provide a promising solution. Additionally, Blockchain technology might be useful for other challenges relating to the realization of a MaaS platform as well. Since MaaS is still mostly a theoretical concept, the realization of a MaaS platform with a successful business model is most interesting to research. Therefore, the research research objective can be described as follows: To provide insights on how Blockchain technology may enable the realization of a MaaS platform.

1.2 Research Framework

In this section, a research framework is designed in order to achieve the research objective. A schematic presentation of the research framework is visualized in figure 1.2. The research framework is formulated as follows: *(Part I)* a study of the theories of the core business of MaaS platforms, innovation ecosystems, and public value in smart mobility, results in a conceptual model (benchmark), *(Part II)* to be used to assess the current state of the realization of a MaaS platform, *(Part III)* to be used as model to assess if Blockchain technology might enable a MaaS platform. The results of this assessment will be used to provide first insights in how Blockchain technology may enable the realization of a MaaS platform.

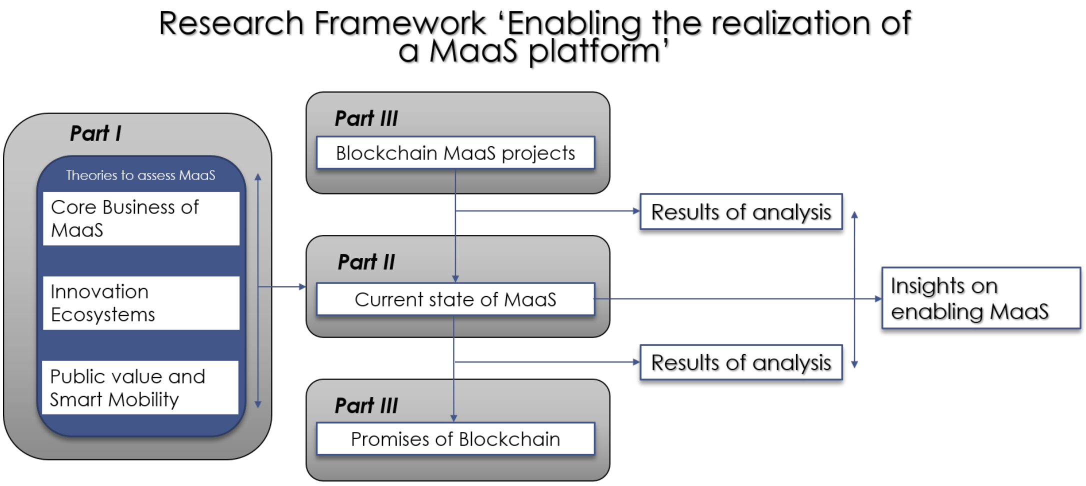

Figure 1.2: Research Framework. Source: own figure

This framework is used to formulate the research questions in the next section.

1.3 Research Questions

From the background and research framework a main research question can be formulated:

How may Blockchain technology enable the realization of a MaaS platform?

As mentioned in the research framework, the research can be divided in three parts. This is also applicable on the research question. For each part a sub-question is formulated. The first part relates to the realization of a MaaS platform. Currently, only MaaS pilots or platforms with very limited services exist. Therefore, a model should be created to assess the barriers that obstruct the realization of a MaaS platform. In other words, the current situation should be assessed. Therefore, the first research question is formulated as follows:

How may the realization of a MaaS platform be assessed?

In this part, the core business and ecosystem of a MaaS platform are defined. Next, ecosystem theories are assessed in order to find the right assessment tools. Moreover, MaaS requires new forms of partnerships, in which private actors play a larger role in the creation of public value (Smith et al., 2017). Therefore, theories that combine public value and smart mobility should be included as well. The next step is to assess the realization of MaaS. This question is formulated as follows:

What ecosystem risks that obstruct the realization of a MaaS platform can be identified in MaaS literature and what is the score of those risks?

Much research is conducted around MaaS pilots. The aim of this part is to use all insights of MaaS literature related to those pilots to identify and assess the ecosystem risks that obstruct the realization of a MaaS platform. In other words, the current state of MaaS is assessed. Now the realization of a MaaS platform is quantified. Therefore, the last part can be researched.

This part relates to Blockchain technology. As mentioned in the background part, Blockchain technology might be a solution to enable a MaaS platform. Therefore, the next research question is formulated as follows:

What are the promises of Blockchain technology and how may it enable a MaaS platform?

The term 'enable' used in this research can be described as addressing the ecosystem risks of the realization of a MaaS platform. In this part, the promises of Blockchain are explored. Moreover, actual Blockchain MaaS initiatives are analyzed. These promises will be linked to the risks of the realization of a MaaS platform and discussed if the risk might be reduced when Blockchain is introduced.

1.4 Innovation Science relevance

MaaS is a new disruptive form of mobility services, with great benefits from a user perspective and civil society (Goodall et al., 2017). The benefits for cities and individuals are compelling (Goodall et al., 2017). However, MaaS is still not widely accepted as a tool to enable more user-centered mobility. The challenges of MaaS could be divided in three categories: supply-side modeling, demand-side modeling, and governing & business models (Jittrapirom et al., 2017). From an Innovation Sciences perspective governing and business models are most interesting to research, since this is focused on creating knowledge of new technologies in relation with socio-economic aspects of innovation. MaaS could potentially transform the way human needs for mobility is provided. However, due to the complexity of the transition towards more sustainable transport, grounded arrangements of the mobility market, and the misalignment of goals, it is hard to enable the new disruptive innovation in a way that meets the requirements of all actors. Theories on public value and ecosystems, which were part of the innovation sciences curriculum, will be used as theoretical foundation of this research.

1.5 Thesis Structure

The three parts that are formulated in the research framework are also used throughout the research. The research methods are firstly described in the next Chapter (2). This Chapter is followed by the first part of this research.

The first part consists of four chapters. In the first Chapter, theories on the core business of MaaS are reviewed (3). The second Chapter focuses on public value in smart mobility initiatives (4). The third Chapter describes the ecosystem theories (5). The theories are merged together to formulate an benchmark model to assess the current state of the realization of a MaaS platform (6).

This benchmark is used for the assessment in part II of the research. The results are described in Chapter (7).

Part III consists of the promises of Blockchain technologies. The results are described in Chapter (8.

The insights of Blockchain technologies of Part III and the MaaS model will be discussed in Chapter (9). This thesis is finalized with a conclusion that answers the research questions (10).

2

Research Methods

2.1 Research strategy

The research strategy is a set of key decisions for conducting research (Verschuren & Doorewaard, 2010). The first decision is to do choose between a breadth or depth research. It is a choice between a broad overview of the phenomenon of the selected discipline, which gives more generalized results, or a thorough investigation of all the aspects of a phenomenon spread out over a span of time and space, which gives less generalized results (Verschuren & Doorewaard, 2010).

In this study, a broad overview suits better, because of the exploratory nature of the study and the limited amount of MaaS pilots.

The second question is to conduct a quantitative or qualitative and interpretive research (Verschuren & Doorewaard, 2010). Since MaaS and Blockchain technology are two new technological innovations, available literature and theories on these topics are limited. Qualitative research methods are recommended, because of the exploitative nature of the research.

The last key question is the decision to conduct an empirical study and/or desk research (Verschuren & Doorewaard, 2010). The aim at the start of the study was to conduct an empirical study on the risks of the MaaS pilots in the Netherlands. However, after a thorough consideration, desk research in combination with empirical research is better suited for this research in current space and time. Additionally, the researcher opted for a broad overview. Desk research enables the researcher to analyze a large amount of data sources in a short time (Verschuren & Doorewaard, 2010).

The main problem for an empirical study on MaaS in the Netherlands is that the proposed new MaaS pilots still have to be designed (Bakker, 2018). In the Netherlands, the aim is to start seven MaaS pilots in Q1 of 2019 (Bakker, 2018). The pilots are described in Appendix A.1. It is currently unfeasible to conduct a case study on the MaaS pilots in the Netherlands to find the underlying risks of MaaS. This view is validated by conducting exploitative interviews with several stakeholders of MaaS in the Netherlands. The interviewed stakeholders are: Ministry of Infrastructure and Water Management, municipality of Eindhoven, and province of Limburg. However, in present MaaS literature, several risks can already be identified.

For the Blockchain technology part, the researcher opts for a combination of desk research and empirical research. Blockchain technology is currently a big topic in academic literature (Gupta, 2018). Therefore, the promises of Blockchain can already be identified in Blockchain literature. Moreover, there are several white papers written about mobility related Blockchain solutions. Those white papers might be used as source to answer the last research question and limit the extent of the research.

Thus, a combination of desk research and empirical research is used for this research. With this information the strategy can be chosen. Five major strategies can be distinguished in literature (Verschuren & Doorewaard, 2010), namely:

- survey
- experiment
- case study
- grounded theory approach
- Desk research

In this research, desk research and case study approach are the most suitable due to the exploratory nature of the research.

By using case study approach, profound and full insights are gained on selective objects, referring to as cases (Verschuren & Doorewaard, 2010). The case study approach will only be used for part III of the research. The cases in this case study approach are mobility related Blockchain solutions. For most of the Blockchain projects, only white papers exist. A white paper is an official document that informs the reader about the new technology, methodology, product or service being launched. The main benefit of case study research is it offers the possibility to obtain a general picture of the research object (Verschuren & Doorewaard, 2010). However, the main limitation is the external validity of the research outcomes. Therefore, it is recommended to do follow well used procedures and techniques. The technique used in this research is a thematic analysis, described by Braun & Clarke (2006). The main benefit of a thematic analysis is that it is not designed for a specific research design. Therefore, it can be utilized for case study research (Vaismoradi et al., 2013).

It is a method for identifying, analyzing and reporting patterns (themes) within data (Braun & Clarke, 2006). A six step procedure, that is also included in the article of Braun & Clarke (2006), is used as guideline for a reliable and valid thematic analysis.

By conducting a desk research approach, material produced by others is used to answer the research questions (Verschuren & Doorewaard, 2010). The desk research approach is used for Part I, II and partially part III of the research. The main characteristic of desk research is that existing materials are used in combination with reflection, and the material is used from a different perspective than at the time of its production (Verschuren & Doorewaard, 2010).

There are two variants of desk research, namely: literature survey and secondary research (Verschuren & Doorewaard, 2010). The main difference is that the variants use different types of sources:

- Literature, that is used for a literature survey, can be defined as knowledge products of social scientists, such as articles and conference proceedings (Verschuren & Doorewaard, 2010).
- Secondary data, is used for secondary research, can be defined as empirical data that is compiled and used by other researchers (Verschuren & Doorewaard, 2010).

Due to the nature of the research, the use of literature is chosen for this research. This literature can be used in two ways. Literature can be used as a source of data, or as a source of knowledge (Verschuren & Doorewaard, 2010). When a source is analyzed to find the main concepts and theories, it can be seen as a source of knowledge. The method of assessing is called a literature review (Verschuren & Doorewaard, 2010). In the research, this method is used for Part I.

When a source is analyzed to generate data on a particular topic, literature can be used as source of data. This method of assessing is called qualitative content analysis (Verschuren & Doorewaard, 2010). This research method is used for Part II. A strictly qualitative content analysis concerns extracting information from a large quantity of sources that is relevant to answer the research question (Verschuren & Doorewaard, 2010). Some sort of category system is used to extract the information (Verschuren & Doorewaard, 2010). In part II of the research the category system is the model that is defined in part I.

Concluding, the research strategy is selected and the used sources and methods for the research are defined for the research. An overview of the type of sources and method for assessing is included in Table 2.1. The exact methodology is described in each research part.

Part	Research Question	Sources	Assessing
I	How may the realization of MaaS be assessed?	Literature as source of knowledge	Literature review
II	What risks that obstruct the realization of MaaS can be identified in MaaS literature and what is the score of those risks?	Literature as source of data	Content analysis
III	What are the promises of Blockchain technology and how may it enable MaaS?	Literature and media as source of knowledge Whitepapers	Literature Review Thematic Analysis

Table 2.1: Type of sources and methods for assessing used in the research.

2.2 Philosophical paradigm

The research is of a qualitative nature. Therefore, establishing a research paradigm is required for guidance through the research phases. A research paradigm embodies ideas about reality (ontology) and how knowledge can be gained (epistemology) (Maxwell, 2008). This study has an exploratory focus to analyze the phenomenon that consists of a MaaS platform and the relationship with Blockchain technology. The exploratory nature implies that knowledge of the phenomenon is limited. Therefore, critical realism is the paradigm that best fits this study.

Mostly, because this paradigm consists of two perspectives. The first perspective is ontological realism, that consists of the belief that there is a real world that exists independently of our perceptions and theories (Maxwell, 2008). This world will not accommodate to our beliefs. The second perspective is epistemological constructivism. Therefore, the understanding of this world is inevitably our construction, rather than a purely objective perception of reality, and no such construction can claim absolute truth (Maxwell, 2008). Both perspectives are important for this study, due to the newness of the MaaS concept. This study is constructed with ideas and research findings from other researchers and practitioners. Accordingly, this study is constructed on the believes of currently known about the reality, which could be different from the actual reality. Thus, each theory, model, or conclusion is necessarily a simplified and incomplete attempt to grasp something about a complex reality (Maxwell, 2008).

2.3 Part I - Theoretical Framework

In Part I, the theoretical framework will be conceptualized. A theoretical framework is constructed by the interpretation of the researcher. More specific, it incorporates borrowed findings from several sources in the form of modules that construct the theoretical framework (Maxwell, 2008). Therefore, a systematic tool is required in order to acquire and analyze the sources. First, one of the major sources of modules for the theoretical framework is prior theory and research (Maxwell, 2008). Several definitions of theory exist. However, in this research the definition of Maxwell (2008) is used. He defines theory as: ”a set of concepts and ideas and the proposed relationships among these, a structure that is intended to capture or model something about the world (p.48)”. The theory should be useful. A useful theory is defined as: a theory that tells an enlightening story about some phenomenon, and that gives you new insights and broadens your understanding of that phenomenon (Maxwell, 2008). In part I of the research, the phenomenon is the realization of a MaaS platform. While theory and research is a promising source, using existing literature also has some limitations. It should be noted that it can deform the way the study is framed and overlook important ways of conceptualizing the study (Maxwell, 2008). Besides, many researchers use existing literature too uncritically and exclusively. Therefore, the ideas and research findings should be critically assessed, in order to validate if it is a useful module for constructing a theory that could be used as basis for this study (Maxwell, 2008).

As mentioned earlier, a systematic approach is required to assess prior research. A literature review is conducted according to the steps identified by Rowley & Slack (2004). The steps are:

- evaluating information sources
- searching and locating information resources
- concept mapping to identify key concepts
- writing the literature review

The literature review in Part I consists of three modules, namely the context of a MaaS platform (2.3.1), public value theories (2.3.2), and ecosystem theories (2.3.3).

2.3.1 Context of a MaaS platform

In the first module, the context of the research is described. The core business and ecosystem of a MaaS platform must be defined by using literature related to MaaS platforms.

The first step is to evaluate information sources. Academic articles and proceedings should form the core of the literature review (Rowley & Slack, 2004). Additionally, several business and government articles might be included if highly relevant.

The next step is to search and locating information resources. The most comprehensive academic and business material related to MaaS can be found on the KOMPIS website. KOMPIS is a project, initiated by the Swedish government, to promote the emergence of combined mobility in Sweden (KOMPIS, 2018). In the online library of the project, many international MaaS studies are mentioned. The most relevant studies are used as input for the literature review[1]. The literature is relevant if there is some idea, theory, or concept is included, which could be used to define the core business and ecosystem of MaaS platform.

The third step is to use concept mapping to identify key concepts in the identified sources. A concept map is a visualization of the theories that are constructed around the phenomenon, and consists of the concepts and relationships among them (Maxwell, 2008). In the literature, the business architecture is part of the core business, with interactions between different actors, which is part of the ecosystem, which is part of the evolving market. These concepts are found in relevant literature and used to conduct the final step, writing the actual literature review on the context of a MaaS platform. The results of the literature review are described in Chapter 3.

2.3.2 Public value theories relating to Smart mobility

In the second module public value theories are described. Since this literature review is about theories, only academic research material should be used. For public value literature, articles on this topic are found through Scopus. The research query that is used is:

- TITLE-ABS-KEY (”Public value” AND ”Smart mobility”)

In total, 18 articles are found using this search query. The search results are sorted on the most cited articles. Three articles were most relevant for this research. The articles are: Docherty et al. (2017) Benevolo et al. (2016), and Castelnovo et al. (2016). The articles are most interesting because they are directly related to smart mobility and public value.

The key concepts that are found by creating a mind map are: smart mobility, quality of life, value creation, and public value. The results of the literature review are described in Chapter 4.

2.3.3 Ecosystem theories

The last module ecosystem theories are described. Since this literature review is about theories, only academic research material should be used.

For ecosystems theories, articles are found through the Web of Science database. The research query that is used is:

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[1] Url of KOMPIS literature `"https://kompis.me/bibliotek/forskning/"`, accessed 12 june 2018)

- TOPIC: (innovation) AND TOPIC: (ecosystem) AND TOPIC: (value) Refined by: WEB OF SCIENCE CATEGORIES: (MANAGEMENT OR BUSINESS) Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.

The categories management and business are used in order to limit the ecosystem literature for strategy purposes. Jittrapirom et al. (2017) argues that it is hard to create a business model brings value for private and public actors. Therefore, the most important theories from a business perspective and value creation within in the ecosystem should be studied.

In order to find the most relevant articles, usage count is used as sorting method. This sorting method is the count of the number of times the full text of a record has been accessed or a record has been saved in the last 180 days [2].

In total, using this search query 303 articles were found. The first articles on the list are used the most time in the last 180 days. The most relevant articles are used for this research.

Several ecosystem theories exist. Therefore, the mind map consisted on several theories and how they relate to each other. Thus, the first concept is ecosystems and this is subdivided in the most used theories, namely, business ecosystems, technology ecosystems, and innovation ecosystems. The results of the literature review are described in Chapter 5.

2.4 Part II - Conceptual Model

The literature that is used to find the risks in the MaaS platform is, again, extracted from the KOMPIS website. However, the literature is relevant if risks can be identified that relate to the core business of MaaS. Moreover, the research object of the article should be an actual MaaS pilot.

A directed content analysis is performed on the relevant KOMPIS articles. In Part I of the research, a model is created to assess the risks of MaaS. The four steps that are described in Appendix A.3 are used to formulate the model. In order to find the main risks for enabling a MaaS platform, the articles are read in a structured way:

- *Step 1:* The articles are read and statements of problems of the actors in the ecosystem are combined.
- *Step 2:* The statements of the problems are categorized in over-coupeling risks.
- *Step 3:* The articles are read again to find if all risks are identified and if the risks are correctly named.
- *Step 4:* Find solutions that are proposed in the literature.
- *Step 5:* Determine the colour of risks of a MaaS platform, based on the information extracted from the articles.

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[2] `https://images.webofknowledge.com/WOKRS517B2.3/help/CSCD/hp_usage_score.html`

2.5 Part III - Blockchain

This part consists of two modules, namely a literature review on the concepts of Blockchain technology (2.5.1) and a thematic analysis on several mobility related white papers (2.5.2).

2.5.1 Literature review Blockchain

The first part, a literature review is conducted to find explain the concepts of Blockchain technology. Several academic sources and books are used to formulate the bigger picture of Blockchain technology. Moreover, some non academic sources are included to gain more knowledge about certain topics. This part is validated by Meet-ups and conferences, where Blockchain technology and its promises are explained. The Meet-ups that were attended are summarized in Table 2.2.

Name of Meet-up	**Organizer**	**Location**	**Date**
RChain Amsterdam	Rchain Europe	Meet Berlage, Amsterdam	May 23, 2018
Blockchain Innovation Week	Blockchain Lab Den Haag	The Hague Tech, Den Haag	May, 24 & 25, 2018
Blockchain Innovation Conference	Vincent Everts	Rabobank, Utrecht	June 7, 2018
Blockchain; projectopzet en technische keuzes	InTraffic	InTraffic, Nieuwegein	June 13, 2018
Bridging Blockchain Eindhoven - 4th Edition (technical)	Crypto Knowledge Exchange Eindhoven	TU\e, Eindhoven	June 26, 2018
Blockchain Expo Europe 2018	Blockchain Expo	RAI, Amsterdam	June 27, 2018
Hyperledger Amsterdam Re-Boot with Brian Behlendorf!	Hyperledger Amsterdam	Circl, Amsterdam	June 28, 2018
Inaugural Cardano Meetup Rotterdam	Cardano Blockchain Netherlands	CIC, Rotterdam	July 18, 2018

Table 2.2: Attended Meetups

2.5.2 Thematic analysis

The last module is an thematic analysis. The empirical data used in this research are white papers that are written by organizations that propose a mobility related Blockchain solution. Blockchain technology white papers are used to outline the problems of a specific market and outlay the proposed solution in order to convince the public and investors. It should be noted that they are mostly commercial documents. However, they provide heaps of information about how the problems are solved. Therefore, it is an interesting source for a thematic analysis.

A limited amount of white papers are found due to the newness of the MaaS concept and Blockchain technology. Several search queries, relating to MaaS, are used to find them:

- (MaaS OR "Mobility as a Service") AND (blockchain OR block chain) AND (whitepaper OR White paper) — 7 hits
- ("shared mobility") AND (blockchain OR block chain) AND (whitepaper OR white paper) — 2 hits
- (mobility AND blockchain) AND (blockchain OR block chain) AND (whitepaper OR white paper)— 3 hits
- (TaaS OR "Transport as a Service") AND (blockchain OR block chain) AND (whitepaper OR White paper) 2 hits

In total 15 applicable white papers were found using Google.com. However, when reading through the white papers, not all were sufficient to use for a thematic analysis. The reason is that the information related to Blockchain is explained to a lesser extent or it is primarily focused on another industry. Therefore, not all white papers are analyzed. The white papers that are used are described in Table 2.3

Title whitepaper	**Organization**	**Date**	**Goal of platform**	**Used in Thematic analysis**
TSio Protocol: The Internet of Mobility	Travelspirit	01-12-17	MaaS	No, limited information
DOVU Whitepaper V2	DOVU	02-04-18	MaaS	Yes
The Planar Network Blockchain Transport	Blockchain transport	21-12-17	Tickets	Yes
Autonomous Smart Travel Ecosystem	Further	03-07-18	Travel	No, focused on other industry
A Practical Application of Blockchain for the Travel Industry	Winding tree	29-01-17	Travel	No, focused on other industry
OMOS Concept paper	OMOS	06-09-17	Transport	No, limited information
Iomob	Iomob	11-08-18	MaaS	Yes
A new Blockchain Platform Designed for the Future of Human Mobility	VMC	10-07-18	MaaS	Yes
Arcade City: Blueprint for a New Economy	Arcade City	12-09-18	Ridehailing	No, limited information
Whitepaper Helbiz mobility system	Helbiz	02-02-18	Carsharing	Yes
A2B Taxitoken Whitepaper	A2B	12-03-18	Taxi services	Yes
Yantha White paper	Yantha	20-02-18	Carpooling	Yes
Mass Vehicle Ledger MVL	MVL	01-04-18	Transport	Yes

Table 2.3: Mobility platform white papers.

The research question is answered by using a thematic analysis. An thematic analysis is a method to identify, analyze and report themes within the empirical data (Braun & Clarke, 2006). This method is used to explorer the meaning of Blockchain for a MaaS platform. The program that is used to conduct the analysis is NVivo. NVivo allows grouping and linking of concepts by building on features such as coding, creation of themes and diagrams (Sinkovics et al., 2008).

A number of decisions are involved before and throughout the thematic analysis. The first decision is to answer the question: What counts as a theme? (Braun & Clarke, 2006). According to Braun & Clarke (2006), a theme should capture something important about the data in relation to the research question, and it should resemble a pattern throughout the data.

Braun & Clarke (2006), identified six steps to conduct a thematic analysis. The steps are required to cope with validity and reliability issues.

- The first step is to familiarize with the data, in particular the depth and breadth of the content. This step involves repeated reading in an active way to find meaning and patterns.
- The second step is to generate initial codes. The main aim is to organize the data in meaningful groups.
- The third step is to search for potential themes.
- The fourth step is to review the themes, that they work in relation to the coded extracts
- The fifth step is to refine the specifics of each theme and overall story
- The last step is to produce the report, use compelling extracts that relate to the themes.

Part I

Part I - Theoretical Framework Realization of MaaS

3

Literature review MaaS ecosystem

An extended literature review is conducted to analyze how the MaaS ecosystem is constructed in MaaS literature. This information is required in order to create a model to analyze the main risks of MaaS. In first section of this chapter, the evolving market is described. Several authors have different opinions on this topic (3.1). Many stakeholders can be identified within the evolving market. They interact with each other through an ecosystem (3.2). This ecosystem is evolved around the core business of MaaS. The role of the actors are described in the third part (3.3). The core business can be delivered in various ways. This Business Architecture (BA) is described in the fourth section (3.4).

3.1 The evolving market

MaaS is not yet available on a large scale. Some interviewees even challenge the statement that there is a need for MaaS at all (Smith et al., 2018b). Therefore, there is a high uncertainly on the development of the market. Currently, the most important governing question relating to the evolving of market is: ”Who should develop MaaS?” (Smith et al., 2018a; Mulley, 2017; Kamargianni & Matyas, 2017; Hoadley, 2017). The MaaS initiatives could be categorized in three ways in which the market may evolve: Winner takes all, public transport takes all, or an ecosystem with open innovation and multiple initiatives is created (Figure 3.1) (Juffermans, 2018). The winner takes all is a market-driven approach, public transport takes all is a public-controlled approach through contracts, and the roaming ecosystem is a public-private approach (Smith et al., 2018a).

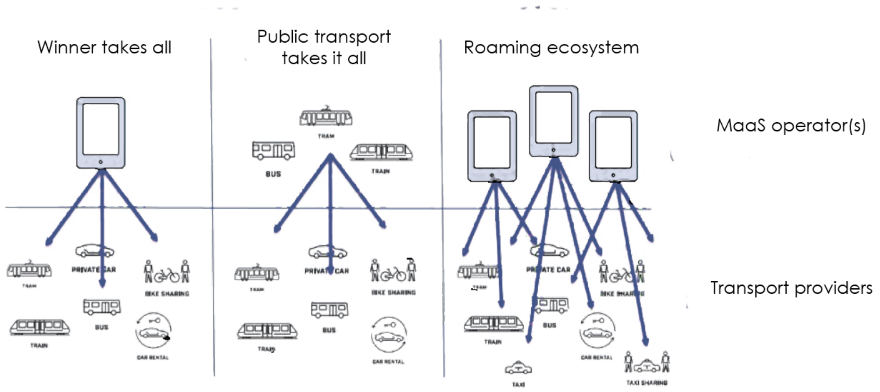


Figure 3.1: Three ways how the MaaS market may evolve. Source: MaaS Global

The definition of MaaS includes that a MaaS platform should create value through societal impact and reduce the negative externalities of transport Smith et al. (2018a). In other words, the aim of MaaS is to be the best value proposition for its users, that is more sustainable, cheaper and as convenient as a private vehicle (MaaS-Alliance, 2018).

Based on these goals, a fully commercial approach is not desirable (Hoadley, 2017). The risks of a fully commercial approach are: that it disincentives sustainable trips, it results in higher cost for user and unequal services, weakens connection between transport provider and user (Hoadley, 2017). Besides, it is unrealistic to think that one MaaS application, which explorers new mobility services, could solve all mobility-related problems affecting a given region (Derboni et al., 2018). Moreover, transport providers may become too dependent on the platform, which causes less bargaining power and high commissions.

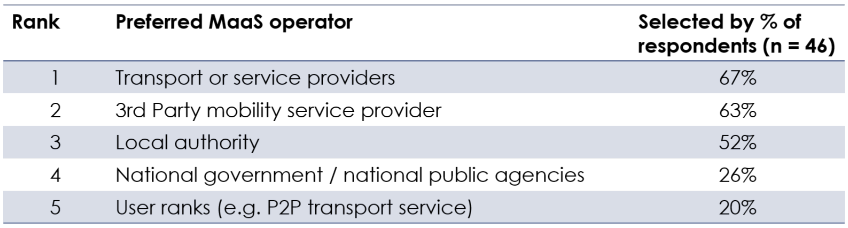
However, Smith et al. (2017) argues that the invisible hand of the market will secure social benefits and that the private sector is more capable to develop services that meet the needs of the traveler. This might be true. However, the supply side consists of both public and private transport providers with various incentives and conflicting goals. For example, Kamargianni & Matyas (2017), found that private transport operators prefer a fully commercial approach, because they believe that their services are more promoted.

For MaaS, the aim is to steer the development towards societal good, and not towards the needs of the private transport providers (Smith et al., 2018a). However, for the definition of MaaS it is important that both private and public transport providers have equal chances within the MaaS market, while the needs of the end-user and sustainability are met. This statement is also applicable on a public-controlled approach. Private transport providers experience that they have less chances in MaaS in a public-controlled approach (Smith et al., 2018a).

Therefore, a roaming ecosystem with multiple MaaS platforms is desired, within a public-private approach. Interestingly, Kamargianni & Matyas (2017) claims that the public-private partnership only emerges once the MaaS market is enabled. However, Smith et al. (2018a) argues that the public authorities should be actively involved with the development of MaaS and have a active role in providing standards for data sharing and integration, so that there are lower initial investment costs for creating a MaaS platform that fit the needs of the actors in MaaS. These platforms differentiate from each other by having different business models, targeting different types of customers.

For example, a MaaS platform that is created for school transport. This platform may be subsidized by regions or local governments. Or a MaaS platform is created solely for commuting purposes of employees, where the company could have some hard requirements, for example zero-emission transport only. The costs could directly be deducted from the company account instead of the employee account. Thus, there are enough different ways to differentiate from other platforms, as long if there is a roaming ecosystem available with open standards for sharing data.

Both public and private actors might be the MaaS operator. This statement is also supported by the results of delphi study of Jittrapirom et al. (2018). In Figure 3.2, the results of the delphi study are summarized. According to the experts, there is no clear winner that should be the MaaS operator.



Rank	Preferred MaaS operator	Selected by % of respondents (n = 46)
1	Transport or service providers	67%
2	3rd Party mobility service provider	63%
3	Local authority	52%
4	National government / national public agencies	26%
5	User ranks (e.g. P2P transport service)	20%

Figure 3.2: Most preferred MaaS operator. Source: Jittrapirom et al. (2018)

The transport provider, service provider or a third party are most preferred by the experts. These operators can be seen as private actors (Kamargianni & Matyas, 2017). Additionally, local and national authorities are also selected by many experts as MaaS provider. These actors can be identified as non-commercial, or public, actors (Kamargianni & Matyas, 2017). Concluding, both public and private actors may be the MaaS operator. Therefore, the ideal MaaS operator cannot yet be determined. Thus, the answer the question, 'who should develop MaaS?'. MaaS should not be developed by a public or private approach. MaaS should be developed in a public-private approach, because this approach best fits the needs of MaaS and balances the goals of public and private stakeholders. The MaaS operator may be a public or private actor.

3.2 Ecosystem of MaaS

The evolving market is described in previous the previous section. The public-private approach is most desirable. Many public and private stakeholders are required in order to enable a public-private approach of MaaS. Based on personal interviews and focus groups with involved actors, Kamargianni & Matyas (2017) designed a MaaS ecosystem including all involved public and private stakeholders. This is one of the most elaborated business ecosystem of MaaS. The ecosystem, with all stakeholders involved, is visualized in Figure 3.3.

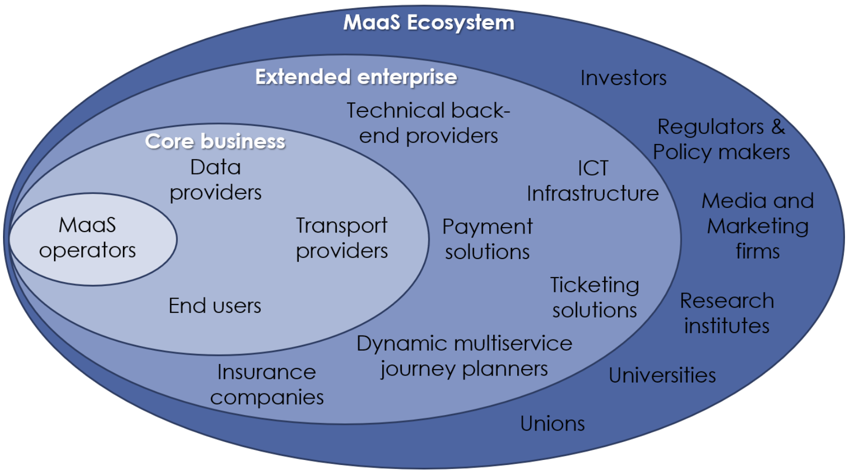


Figure 3.3: The MaaS business ecosystem. Figure based on Kamargianni & Matyas (2017)

Kamargianni & Matyas (2017) divided the ecosystem in several layers. The core business includes the partners which form the heart of MaaS. Next, the extended enterprise layer forms the complementors and suppliers of technology. The last layer consists of stakeholders that are not directly involved in the ecosystem, but have an impact on the development of MaaS.

Thus, the ecosystem consists of all stakeholders that are in some way involved in enabling MaaS. However, this research is focused on the core business of MaaS. In other words, the research is more focused on the actors that have an active role in the development of MaaS. The actors that are identified in the core business are: MaaS operator, data providers, transport providers, and end users. However, one important actor that is not in the core business layer are regulators & policy makers. Kamargianni & Matyas (2017) argues that the regulators & policy makers are also key actors. Jittrapirom et al. (2018) found that both local and national governments are important actors. Regulators & policy makers are part of local and national governments. Moreover, in the studies of Smith et al. (2018a); Li & Voege (2017), regulators & policy makers are mentioned as key actors with an important role as well. Therefore, regulators & policy makers should be included in the core business.

Concluding, the actors of the core business of MaaS are: MaaS operators, data providers, transport providers, end users, and regulators & policy makers. The all have an important role in the core business of MaaS.

3.3 The core business of MaaS

The ecosystem is converged towards the core business of MaaS in previous section. The actors that interact within the core business are also identified. Therefore, the roles of the actors in the core business should be further scrutinized.

Some authors researched the needs of the end user. These needs are used as basis for the core business model. Ebrahimi et al. (2018) focused on the requirements of the app. In other words, what should be included as additional services or added value. In this study, focus groups were studied in order to find the needs of commuters in Finland. Three needs were identified in the research. The first one is to have a mobile application where all modes of transport are integrated. Real-time information of the vehicles, such as location, and buying tickets for the whole trip is required for the entire trip (Ebrahimi et al., 2018; Derboni et al., 2018). Also, Derboni et al. (2018) found in their study about a Swiss MaaS pilot that communication channels are a requirement to talk directly to drivers of services, to have a more streamlined service. The next identified need in the study of Ebrahimi et al. (2018), is that there should be a dynamic travel itinerary optimizer that suggests alternative itineraries in case of delays. The last identified need is a service to show alternative itineraries between the origin and destination based on the needs of the traveler Derboni et al. (2018).

These requirement can also be found in the characteristics Jittrapirom et al. (2017) found trough a literature review. They derived nine characteristics of the core business of MaaS:

1. Integration of transport modes, bringing together seamless multi-modal transport.
2. Multiple tariff options. There are two types of tariffs that can be included in MaaS initiatives: a total mobility package and pay-as-you-go. Also the traveler acquires different km/minutes/points with the tariff options. MaaS development should endeavor ticket-less travel, by using a smart card or smart phone.
3. A digital platform to access all necessary services for trips. Key services are: trip planning, booking, ticketing, payment, and real-time information. Other services can be included as well.
4. Multiple actors. MaaS should be an interaction between multiple players within an ecosystem.
5. Different Internet of Things (IoT) technologies are required to enable MaaS.
6. A user-centered design and demand orientated perspective, through multi-modal trip planning and demand-responsive services such as Taxis.
7. Registration requirement for users to join the platform in order to enable service personalization.
8. Personalization in order to ensure that end users requirements and expectations are met more effectively and efficiently by considering the uniqueness of each traveler.
9. Customization in order to ensure end users can modify the offered services that best fits the travelers needs.

Based on these characteristics, the core business can be further explained in relation with the actors. In this part the actors are explained in the following order: MaaS operators, data providers, transport providers, regulators & policy makers, and end users. This section is concluded with a visualization of the core business of MaaS.

3.3.1 MaaS Operators

The role of MaaS operators is to provide a user-centered digital platform, that includes as least the following key services: trip planning, booking, ticketing, payment, and real-time information

(Jittrapirom et al., 2017). Additionally, subscriptions with with multiple tariff options should be included as well. The key services might be outsourced to complementors (Kamargianni & Matyas, 2017). However, this is not required for the functioning of the MaaS platform, which is operated by the MaaS operator.

This definition of the core business in line with the research of (Kamargianni & Matyas, 2017), who argues that the entire ecosystem is focused around the MaaS operator and that the major part of data processing and analysis is conducted by data providers. On the other hand, Smith et al. (2018a) argues that the MaaS operator delivers MaaS to travelers by providing a tailored travel itinerary and the payment of the plan, and through a single interface. According to the MaaS characteristics of (Jittrapirom et al., 2017), this is only a part of the core business of MaaS. However, Smith et al. (2018a) argues that there is a separate additional group of actors between the MaaS operators and the transport providers, the MaaS integrator group. A MaaS integrator assembles the offerings of the transport providers to MaaS operators (Smith et al., 2018a). More closely, the integrator is responsible for the data integration of the transport providers towards the MaaS operators. Furthermore, according to Smith et al. (2018a), contract management and financial clearing are also tasks of the MaaS integrators. However, with this definition, the added value of a MaaS operator is only limited to trip planning. Therefore, the MaaS integrator should only be responsible for the integration of data from the transport providers. With this definition, it can be included in the data providers group.

3.3.2 Data providers

The data providers are key suppliers for MaaS (Kamargianni & Matyas, 2017). MaaS requires many different types of data. Data from transport providers is required. The MaaS integrator should acquire and store transport provider data. This data includes at least: fixed routes, flexible routes, real-time vehicle data, and contract data (Kamargianni & Matyas, 2017). Other data providers might be included, such as: traffic data and weather data providers. Additionally, data of bookings, tickets, payments on the MaaS Platform may be outsourced to data providers. But for the ease of understanding of this research, these services will be included in the tasks of the MaaS provider.

3.3.3 Transport providers

The transport providers are the main suppliers to the MaaS operators (Kamargianni & Matyas, 2017). Transport providers can be divided in two groups. The first group is conventional mass transit bus and train providers that are running on concession agreements issued by authorities and subsidized (Hensher, 2017). New innovations, such as on-demand bus services, may fall in this category as well if they also run under government contracts. Therefore, this group can be defined as Public Transport (PT) providers. The second group is the Shared Mobility Services (SMS) providers. Examples of SMS are taxi, car-sharing, ride-sharing, bike-sharing, and car-rental. The SMS provides might be private firms, user initiatives, or local governments.

3.3.4 Regulators & Policy makers

According to Jittrapirom et al. (2017), MaaS requires a complete restructuring of the supply-chain of transport providers. The regulators & policy makers should make sure that this transition will diffused in a public-private approach. As mentioned in Section 3.1, regulators and policy makers have an active role in providing standards for data sharing and integration. Moreover, regulators & policy makers should induce public values into the core business. But most importantly, monitor if the needs of the end user are adequately met. Policy interventions might be required in order to solve inequitable market solutions.

3.3.5 End users

MaaS is developed around a user centered design. Thus, the MaaS provider should have one target customer group or different target groups (Mulley, 2017). Based on the business model, which is targeted towards consumers or business or both, the end users are individuals travelers or business travelers or both. The role of the end users is to adopt MaaS. This is easy to suggest, but much more difficult to make happen.

3.3.6 Core Business

Based on the description of the actors and the key services of a MaaS platform, the core business is visualized. The MaaS platform should be provided by the MaaS operator and includes six key services. The core business is visualized in Figure 3.4.

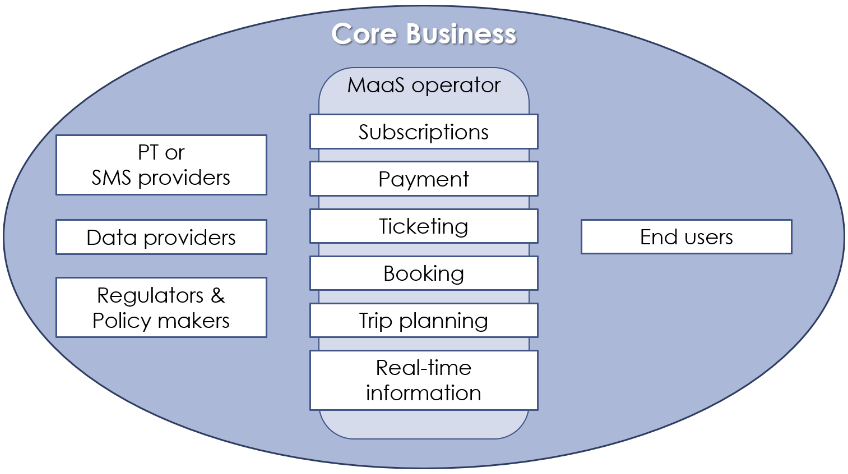


Figure 3.4: The core business of MaaS. Source: own figure

3.4 Business Architecture of a MaaS platform

Summarizing the previous part, the core business of MaaS is centered around an user-centered digital platform, operated by the MaaS operator. The main purpose of the platform is to provide integrated mobility to end users, rather than individual services. This platform can take various forms and can be delivered in several ways (Ebrahimi et al., 2018). The underlining blueprint or structure of the interactions should be studied and is labeled Business Architecture (BA).

Literature of MaaS shows that there are several BAs possible for MaaS. The most beneficial BA for MaaS is a Multi-Sided Platform (MSP) (Jittrapirom et al., 2017). A MSP facilitates interactions between travellers and all suppliers of transport services in a smart way (Ballon, 2009). The study of Ebrahimi et al. (2018) showed that a Multi-side platform is more customer-oriented and provide more varieties for travelers, because the threshold to become a supplier is relatively low. This platform should be stimulated to become a roaming ecosystem in order to create direct and indirect network effects (Jittrapirom et al., 2017). For example, increasing the number of car shares results in a more attractive platform for other users (direct network effect). If more transport providers join the platform, the utility of travellers will increase due to variation of offerings (indirect network effect). However, finding the right balance is hard to achieve due to the chicken and egg problem. This is the challenge of getting both sides on the platform (Jittrapirom et al., 2017).

No pure MaaS MSPs can be identified yet (Ebrahimi et al., 2018). The most known MaaS platforms, such as the Whimapp, are a hybrid between a Multi-Sided Platform (MSP) model and Intermediary Platform (INTP) model. An INTP is a platform, where a MaaS operator acts as a intermediary, that take over services from transport providers, integrates the services and sell it as one itinerary to end-users (Ebrahimi et al., 2018). The most important difference in relation with MSP is that distribution and marketing channels are conducted by the intermediary. Thus, the operators have no control over these channels. In the Netherlands, the INTP model is also referred as the Bol.com-model (MUConsult, 2018). Bol.com sells products, taken from different suppliers, under the Bol.com brand. The products are bought by the platform at an attractive purchase price and are sold to the end-users directly[1].

A MSP is a platform that enables the direct interaction between the end-users and the operators through the standards of the platform (Ebrahimi et al., 2018). The transport providers are still responsible for the pricing and communication of services on the platform. This model is also referred as the eBay-model (MUConsult, 2018). A small side note: nowadays, Bol.com uses this model as well. Thus, Bol.com is also a hybrid that includes INTP and MSP. With the eBay model, suppliers choose to sell their products through the eBay platform directly to the customer. The suppliers have to pay a commission fee for each product sold. The supplier can state the price, but the payment is going trough the platform. For example, Bol.com pays the supplier each month for all products sold (minus the commission fee)[2].

The main benefits of MSP for transport providers are that they may gain access to many potential users that use the platform daily for a small commission fee and the platform can be used alongside the other distribution channels (Ebrahimi et al., 2018). The main benefit for end-users is that they can reduce search time and reduce individual transactions (Ebrahimi et al., 2018). For the MaaS operator, a MSP reduces risks of ownership. For example, no services have to be purchased in advance and refunds for delays is managed by the transport providers.

In Figure 3.5, the BAs of INTP (a) and MSP (b) are visualized. Because MaaS is not fully embraced yet, limited research is conducted on which BA fit best the needs of the actors in MaaS. However, it is mostly reported that both BAs may be successful. For example, the rapport of

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[1] https://www.bol.com/nl/m/verkopenviabol/leveranciers/

[2] https://www.bol.com/nl/m/voorwaarden/overeenkomst-verkoper-zakelijk/index.html#bijlage-artikel-14

MUConsult (2018) claims that both BA models have the potential to become successful, because it depends on the complexity of the transport networks. For a more complex transportation network the INTP is more desirable, due to the less flexible transportation infrastructure, such as train, tram, and bus (MUConsult, 2018). The MSP is more desirable for less complex infrastructure, because it is more flexible (MUConsult, 2018). Thus, it is a logical step for current MaaS providers to work with a hybrid model. However, benefits are greater from a user perspective and from a suppliers perspective when using an MSP platform. MSP platforms are the most successful (international) digital platforms in other industries. Examples are: AirBnB, Alibaba.com, Booking.com, Facebook.com, and Uber.

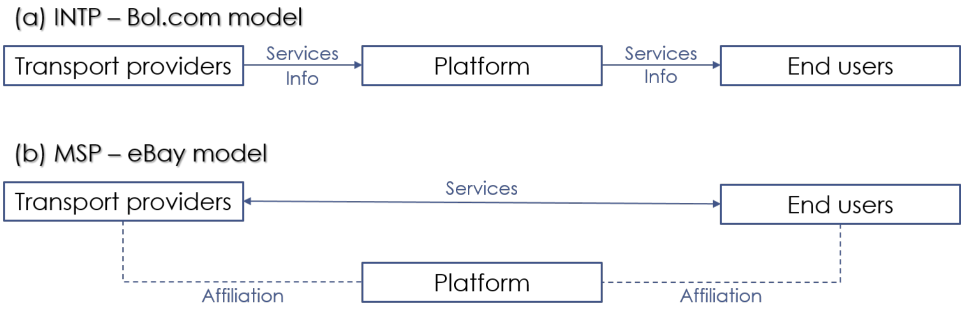

Figure 3.5: BA for MaaS. Source: Smith et al. (2018a)

3.5 Conclusion

A literature review is conducted in this section. First, the evolving market is described. The most preferred MaaS operator cannot be determined. Second, the future ecosystem is described and the main actors are identified. These actors are MaaS operators, data providers, transport providers, end users, and regulators & policy makers. Third, the core business is described with the most important elements of a MaaS platform. Last, the type of platform is identified in MaaS literature. The results of this section will be used to create a base model for MaaS. Thus, it will be the foundation of the model. Ecosystem theories and public value theories will form the underlying theories to analyze the risks of realizing a MaaS platform.

4

Literature review public value in smart mobility initiatives

MaaS can be categorized as new digital platform to enable the sharing economy. Many digital platforms start with the aim to empower people and crating a more digital open world (Mazzucato, 2018). However, this view is not the full picture, since most platforms are profit seeking businesses that extract value from both the supplier and demand side in order to maximize shareholder profits. Thus, for businesses the sharing economy is more about allowing market exchange to reach into peoples lives that were previously not reachable (Mazzucato, 2018). Therefore, public value should be considered for the realization of MaaS to balance the value between all actors in the ecosystem. The biggest challengers are defined in this chapter.

MaaS finds its roots in the smart city transition. A smart city can best be described as a vision to improved urban area (Benevolo et al., 2016). The main goals of smart city initiatives are reducing the sustainable development, improve economic growth, and better quality of life for citizens (Castelnovo et al., 2016; Benevolo et al., 2016). Smart mobility is one of the smart city initiative categories (Benevolo et al., 2016). The smart mobility goals are more directed towards mobility, but the goals can directly be linked to the overall goals of smart city initiatives. For example, the smart mobility goals of reducing environmental impact of transport and the increase safety belong the quality of life goal of smart city initiatives. The smart mobility goal to keep people moving belongs both quality of life and economic growth.

According to many researchers, quality of life for citizens is the most important objective of smart cities (Castelnovo et al., 2016). Quality of life represents public value (Castelnovo et al., 2016). Therefore, public value should be considered for MaaS. A public valuebased approach to smart city assessment allows us to address the multifaceted, interrelated, and dynamic structure of smart city governance.

Value is created as result of a complicated set of economic transactions and institutional arrangements between the actors within an ecosystem (Autio & Thomas, 2014). Many actors have different perspectives of value. From a private actor perspective, shareholder value is most important (Meynhardt et al., 2014). However, due to the goals of smart city initiatives value creation is becoming more complex. According to Meynhardt et al. (2014), the only way to foster trust and legitimacy in a modern democratic society is to constantly engage in dialogue with societal actors and groups. This statement introduces a perspective that is borrowed from the public sector, namely public value. Public value focuses not only on the creation of economic value and delivery of services, but also impacts on wider society (Castelnovo et al., 2016). In short, public value is about a change in peoples perception of living in a society, not just about money (Meynhardt et al., 2014). The complexity of value creation implies that a sustainable transition to MaaS must overcome further challenges to change and maximize public value (Jittrapirom et al., 2017).

According to Castelnovo et al. (2016), current benchmark frameworks of smart city initiatives mainly focus the impact of new ICT technologies on the performance of urban systems and how ICT platforms are governed. However, regulators & policy makers should take the dark side of ICT in consideration (Castelnovo et al., 2016). Examples of the dark side of ICT are: the digital risks, divides, and vulnerabilities. This is a result of centralized command and control of new ICT platforms (e.g. as in UBER or Lyft). Centralized command and control determines the distribution of value in many smart mobility initiatives (Pazaitis et al., 2017). Moreover, hidden costs, and long-term effects should be considered as well Castelnovo et al. (2016); Docherty et al. (2017).

(Docherty et al., 2017) identifies four challenges that affect public value of smart mobility initiatives:

- **The short versus the long game:** This challenge might result in market failure. For example, creating technological lock-in by driving fast toward a planned future and with limited actors in the MaaS ecosystem.

- **Costs of the transition:** For example, MaaS initiatives that are financed and controlled by investors will continue the trend to increased income inequality and lack of sustainability.

- **Information asymmetries:** This challenge might result in data harbouring of mulitnationals, lack of governments understanding MaaS, and less power for the government to manage the transport system.

- **Equity and inclusion:** MaaS could potentially solve equality and inclusion gaps. However, transport providers might only serve areas or end users that maximize their profits.

Concluding, this chapter is not about all (public) value theories. The aim for this chapter is to outline several value challenges that relate to creating and extracting digital value of a platform. All actors should be aware that value is a complex process and actors in the ecosystem do not act solely on altruism. The four public value challenges should be considered for a balanced value proposition of a MaaS platform and thus enable the realization of MaaS.

Blockchain technology might help enable a balanced value proposition, because it cuts out the middle man.

5

Literature review ecosystem theories

Ecosystem theories emerged due to the increasing interest and concern with interdependence across organizations and activities (Adner, 2017). In MaaS literature, most of the disciplines are merged together in an ecosystem approach (Goodall et al., 2017; Jittrapirom et al., 2017; Mulley, 2017), which is based on innovation theories and management theories. According to many researchers, MaaS is highly complex due to the variety of stakeholders (Goodall et al., 2017). Therefore, MaaS should be co-innovated with many stakeholders. By using ecosystem approach, the interactions between the stakeholders are described. However, various theories and tools for analyzing ecosystems exist. This also the major limitation of ecosystems literature, there is no clear construct for ecosystem theories (Thomas & Autio, 2012; Oh et al., 2016).

In order to analyze the different ecosystems a single definition should be used. The definition for an ecosystem that is used in this research is: *"A network of interconnected organizations, organized around a focal firm or a platform and incorporating both production and use side participants"* (Autio & Thomas, 2014).

The main difference with conventional networks in innovation management journals is that use side participants are included into the analysis (Autio & Thomas, 2014; Adner, 2017). Several variants of ecosystems can be identified in highly cited management literature (Thomas & Autio, 2012). The different ecosystem variants differentiate in rationale for ecosystem creation, delivery, and capture of value. According to Thomas & Autio (2012), the variants are: business, technology, and innovation ecosystems:

- **Business ecosystem:** The key source of value is efficiency and flexibility. This value is co-created through scale and scope economies. In literature the network is analyzed through a firm level perspective, and more recently from a platform level perspective.

- **Technology ecosystem:** The key source of value is innovation and positive externalities.

However, the analysis is conducted on platform level perspective.

- **Innovation ecosystem:** The key source of value is innovation and positive externalities as well. Moreover, a firm level perspective is used as level of analysis.

In figure 5.1, the variants of ecosystem literature are visualized. Moreover, the most cited references are included in the figure.

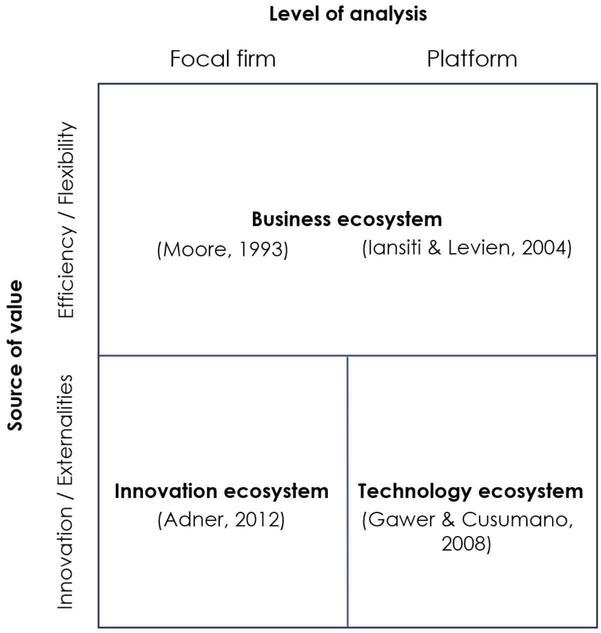

Figure 5.1: Variants of ecosystem literature. Source: Thomas & Autio (2012)

In this section, the main insights on the three types of ecosystems and their relations is described in the following order: business ecosystems (5.1), technology ecosystems (5.2), and innovation ecosystems (5.3). This literature review is conducted to provide a broad picture of ecosystem theories. The most applicable theory for MaaS is selected to assess the MaaS ecosytem.

5.1 Business Ecosystems

Moore (1993) introduced ecosystem thinking. A firm should create cooperative networks to foster innovation (Moore, 1993). Therefore, a firm cannot be seen as a member of a single industry, but it is part of a business ecosystem (Moore, 1993). According to Moore (1993), several ecosystems with competing services might survive in large industries.

Moore (1993) claims that the business ecosystem develops in four stages in time. The four stages are: Birth, expansion, leadership, and self-renewal.

- **Birth:** Entrepreneurs focus on defining what customers want and create a value proposition around this need. Cooperation with other businesses is essential in order to improve the value proposition.

- **Expansion:** The innovation should be expanded to new territories. Battles with other ecosystems may occur.

- **Leadership:** When the business ecosystems have strong enough growth and profitability, the elements of value within an ecosystem can now be seen as target for complementors. Current platform leaders may overdependent on suppliers with high scope and scale. These suppliers form new dominant hubs. Suppliers of parts of the business ecosystem create a bargaining power over the initial leaders, due to scale and scope. New leaders around hubs in the ecosystem emerge, possibly new ecosystems might emerge as well.

- **Self-renewal:** Rising new ecosystems and innovations results in the treat of obsolescence of the incumbent ecosystem. The leaders should innovate in the ecosystem in order to continue the fulfillment of the wants of the customer. Otherwise it will become obsolete.

Thus, Moore (1993) focuses on the stages of business ecosystems and what risks the ecosystem leader may experience through the stages of business ecosystems. Iansiti & Levien (2004) complements the stages of business ecosystem theory, by focusing on the health of the business ecosystem. Three types of indicators are important to assess the health of ecosystems:

- **Productivity:** The ability of the network, within the business ecosystem, to constantly transform technology and other forms of innovation into lower costs and new products.

- **Robustness:** The capability of the business ecosystem to survive disruptions, such as radical innovations and technological change.

- **Niche creation:** The capacity of the ecosystem to create meaningful new businesses and products with new emerging technologies.

The indicators of health can be used to assess current business ecosystems. Actors can actively improve the health of the business ecosystem. However, this depends on the role of the actor in the ecosystem. As mentioned by Moore (1993), important hubs are created within a business ecosystem. Actors in the ecosystem may occupy this hub. An actor can use this position to act as a indispensable keystone in the business ecosystem (Iansiti & Levien, 2004). Multiple keystone actors may exist in the business ecosystem. The actor can use this position to improve the health of the business ecosystem by providing a stable and predictable set of common assets (Iansiti & Levien, 2004). This can also be referred as a platform that offers solutions to others in the ecosystem (Iansiti & Levien, 2004).

The keystone actors can increase the productivity of the ecosystem by simplifying the complex task of connecting all actors in the network and facilitate the creation of new products by third parties (Iansiti & Levien, 2004). Robustness can be improved by incorporating new emerging technologies in the business ecosystem and making guidelines for actors in the network how they can cope with new and uncertain conditions (Iansiti & Levien, 2004). Lastly, the keystone actors can encourage niche creation by sharing their innovating technologies to selected third parties (Iansiti & Levien, 2004).

Concluding, the main goal of the keystone actors, that are situated at important network nodes in the business ecosystem, is to improve and maintain the health of the business ecosystem. The main incentive for keystone actors, to be actively involved in the business ecosystem, is their own survival and prosperity (Iansiti & Levien, 2004). However, when keystone actor is leaving the network the entire ecosystem collapses.

5.2 Technology Ecosystems

Business ecosystem theories focus on the flexibility and efficiency that maintain the survival of the business ecosystem. However, in most business ecosystem literature, the emergence of platforms is neglected (Gawer & Cusumano, 2014). Authors of business ecosystem literature assume that platforms are already formed. This is also the main critique on business ecosystems, because platforms are the hubs of ecosystems (Thomas & Autio, 2012).

However, platforms are increasingly studied by scholars (Gawer & Cusumano, 2014). Two types of platforms can be identified: internal or company-specific platforms, and external or industry-wide platforms (Gawer & Cusumano, 2014). An internal platform is a common structure, within a firm, that is used to develop different variations of products in a common way (Gawer & Cusumano, 2014). The main goal is to increase efficiency. For example, different types of cars, that are build by a single car manufacturer, share many components with each other.

An external platform are products, services, or technologies that provide the underlying structure where outside firms can develop their complementary products, technologies, or services upon (Gawer & Cusumano, 2014). Thus, the biggest difference between internal and external platforms is that external platform might create network effects (Gawer & Cusumano, 2014). The external platforms can be seen as the main hubs in a business ecosystem.

Gawer & Cusumano (2014) focuses on the creation of these external platforms by providing best practices for platform leaders. Platform leaders are the future keystone actors in the business ecosystem. The best practices consist of four steps.

The first step, identified by Gawer & Cusumano (2014), is to develop a vision of how a product, technology, or service could become a central hub in a larger business ecosystem. This is consistent with the theory of Thomas & Autio (2012). Thus, an element with platform potential should be identified or designed. Moreover, in this step, complementors should be identified that might enable the platform.

The second step consists of building the right technical architecture around the platform (Gawer & Cusumano, 2014). Other companies must connect easily with the platform, through simple interfaces. This can be achieved by adopting a modular technical architecture and intellectual property should be shared.

The third step consists of building a coalition around the platform. The right complementors should be attracted. Moreover, business models should be created that share risks and value with all stakeholders in the network (Gawer & Cusumano, 2014).

The last step consists of maintaining a central position in the ecosystem that is evolved around the platform and enhance the vibrancy of the ecosystem (Gawer & Cusumano, 2014).

Concluding, Gawer & Cusumano (2014) introduced steps to develop a platform. This is different from the business ecosystem platform by focusing on the development rather than the health of the platform.

5.3 Innovation Ecosystems

The main critique on platform or technology ecosystem theories is that a platform holds a hub position in a network of interactions. However, in some cases it is hard to reach agreement on who is the central hub in the network (Adner, 2017). Innovation ecosystem theories are focused on the focal value proposition within the business ecosystem (Autio & Thomas, 2014).

More specifically, Adner (2017) argues that business ecosystem of Moore (1993); Iansiti & Levien (2004); Gawer & Cusumano (2014) have a ecosystem-as-affiliation view. This means that these authors view ecosystems as communities of associated actors, defined by their network and platform affiliations (Adner, 2017). Innovation ecosystem theories can be viewed as ecosystem-as-structure. Thus, innovation ecosystem literature is focused on the value proposition as configurations of activities within the ecosystem and how to materialize this value proposition (Adner, 2017).

The value proposition of an ecosystem is used to identify the set of actors that need to interact in order for the proposition to come about (Adner, 2017). In other management and strategy literature, such as business model innovation and value chains, the level of analysis is firm strategy rather than the value proposition. Therefore, innovation ecosystems might be a more applicable to assess the introduction of a MaaS platform, because it not only focuses on the business model of the platform but it also considers the business model of the other actors. Therefore, an innovation ecosystem approach can be thought of increasingly critical (Adner, 2017).

The value proposition of a new innovation should be assessed for the three ecosystem risks of innovation (Figure 5.2) (Autio & Thomas, 2014):

- **Execution risk:** The challenges of bringing the innovation to the market with the required specifications and within the required time.
- **Co-innovation risk:** The extent to which the successful commercialization of the innovation depends on the successful commercialization of other innovations.
- **Adoption chain risk:** The extend to which the innovation must be adopted by actors in the ecosystem, in order achieve the full value proposition towards the end users.

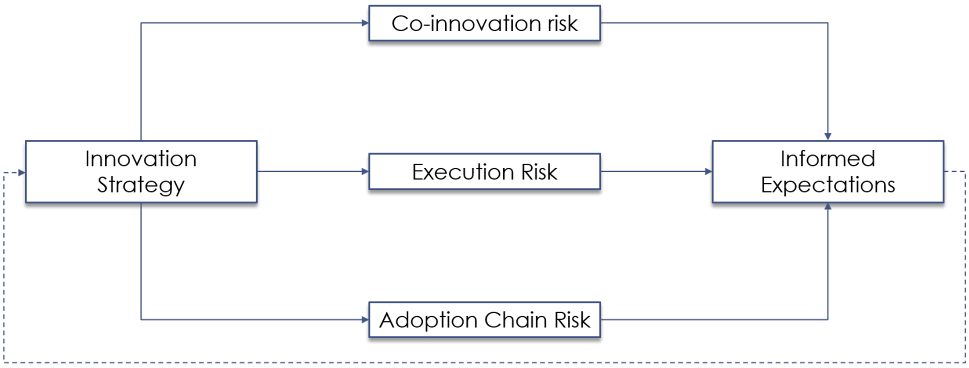

Figure 5.2: Three ecosystem risks of Innovation. Source: Adner (2012)

The execution risk is the ability of the organization to innovate. Therefore, this risk is minimally related to other actors in the ecosystem network. On the other side, co-innovation and co-adoption risks are often neglected when introducing new innovations (Adner, 2012). With the ecosystem-as-structure approach, the latter two risks might be revealed.

Adner (2017) argues that four elements underlie a ecosystem-as-structure approach:

- **Activities:** The actions that are required in order to materialize the value proposition.
- **Actors:** The entities that undertake the activities.
- **Positions:** The location of the actors in the flow of activities.
- **Links:** The transfers across actors.

These four elements are used to create the underlying value blueprint of an ecosystem. The main purpose of the blueprint is to find out how the value is expected to be created in the interdependent collaboration of the ecosystem (Adner, 2017). The value blueprint makes ecosystem and the dependencies explicit (Adner, 2012). It shows how the activities are positioned, how they are linked, and which actor is responsible for what (Adner, 2012). For each element two questions should be asked. The first question is: *What is the level of co-innovation risk this element presents?*. The second question is: *What is the level of adoption risk this element presents?*. Adner (2012) uses a green-yellow-red traffic light continuum in order to give the status of the risks in the value blueprint.

The colours of the traffic light have different meanings for the three innovation risks. For execution and co-innovation risks the colours mean (Adner, 2012):

- **Green:** The elements are ready and in place.
- **Yellow:** The elements are not yet in place, but there is a plan.
- **Red:** The elements are not in place and there is no clear plan.

For adoption risks the colours mean (Adner, 2012):

- **Green:** The partners are eager to participate and see clear surplus from their involvement.
- **Yellow:** The partners are neutral but open to inducement.
- **Red:** The partners prefer not to participate in the proposition.

If all traffic lights are green, the innovation will most certainly be successful. However, when there are yellow or red lights in the value blueprint, the cause of these problems must be understood and a viable solution should be identified (Adner, 2012). Thus, the value blueprint is an iterative process of finding the optimal solutions for a successful value proposition of an innovation. The main advantage is that different business models might be successful as long as the value proposition is benefitial for all actors in the ecosystem (Adner, 2017).

5.4 Conclusion

Several ecosystem theories exist. The goal of this section was to compare the most used ecosystem theories and tools. Moore (1993) identified that there are clear stages in a business ecosystem. Iansiti & Levien (2004) supplement this ecosystem thinking by introducing benchmarks to assess the health of ecosystems. (Gawer & Cusumano, 2014) provides best practices for creating platforms in an ecosystem as a platform leader. These practices can be used for the creation of a platform. However, it is hard to quantify these steps into a benchmark. Therefore, Adners wide lens perspective might be the best ecosystem theory and tool for analyzing MaaS for a number of reasons. First, the value blueprint provides a clear view of all interactions in an ecosystem. Second, MaaS has more organizational challenges rather than technical challenges. Therefore, the three ecosystem risks of innovation is an structured tool to find and solve those challenges. Third, (Adner, 2012) focuses more on new innovations and creating an ecosystem around it. Since MaaS is only in pilot phase, no ecosystem can yet be identified. The ecosystem approach also has some limitations. These limitations will be described in the next parts.

6

Framework to assess the realization of MaaS

In this Chapter, the MaaS ecosystem concepts, ecosystem theories, and public value theories are merged together in a base model for the benchmark to assess the impact of Blockchain for MaaS. As mentioned in chapter 5, the tools that Adner introduced with his innovation ecosystem theories might be most suitable for the benchmark. The value blueprint can function as underlying model for the benchmark. The identified core business, actors and BA are used as basis for the value blueprint. Although the innovation ecosystems theories of Adner (2012) are used for new innovations, it is more focused on creating a specific value proposition. In other words, the identification of actors in the ecosystem depends on specific cases. This concern is also expressed in the research of Almeida et al. (2015). They found that the identification of actors is rather subjective.

The purpose of this research is to have a more holistic approach, because MaaS is still in early development. Also, a base model must be applicable on multiple cases. Therefore, the value blueprint must be more generalized to assess the core business of MaaS. A way of achieving this generalization is to constrain the elements of the ecosystem for research purposes. The results of the literature review on the structure of MaaS might be merged into the value blueprint theory. The advantage of this generalization is that the most important risks for a MaaS platform can be identified in literature. However, this is not the full picture when creating a specific MaaS platform. For this research the author argues that this limitation is acceptable, because of the exploratory nature of the research.

As mentioned Chapter 5, the elements of the value blueprint consists of activities, actors, positions, and links. To reduce subjectivity of identifying actors, the actors that are identified in the literature of MaaS (3.3) are used as fixed entities and boundaries in the model. Also, the position and links are partly defined due to the business architecture.

With these assumptions and the holistic approach, some of the steps to construct a value blueprint should be adjusted. The steps, identified by Adner (2012), are described in Appendix A.2. The first step is to identify the end customer. This step will be similar to the step of (Adner, 2012). Thus, the step should be modified to: Identify the possible end users.

The second step of Adner (2012) is to identify your own project. For a more holistic approach, this step should be modified towards a more generalized question. The characteristics that every MaaS project should have, identified by Jittrapirom et al. (2017) and described in Chapter 3.3 might be a good alternative. Thus, the second step should be rewritten to: Identify the minimum characteristics to which the project in the ecosystem must comply. This step now corresponds with the first step of technology ecosystems, identified by Gawer & Cusumano (2014) , that is described is Chapter 5.2.

In the next three steps the suppliers, intermediaries, and complementors should be identified. This is also rather specific towards a case. As mentioned earlier, only the actors identified in MaaS literature are included to achieve a more generalized result. However, for the next steps it is important to know if the actor is a supplier, intermediary, or complementor. Therefore, step three to five will be reduced to one step. This step should be rewritten as: Identify the main actors in the ecosystem and label this actor as supplier, intermediary, or complementor.

The last step that is applicable on a generalized ecosystem approach is to find the co-innovation risks and the adoption risk for each actor. Also, possible causes should be analyzed in this step. The step should be modified to: Identify the risks in the ecosystem and what underlying causes can be found for these risks.

The final two steps of Adner (2012) consist of the iteration of the steps. This iteration is conducted in part III of the research by introducing Blockchain technology as solution and discuss if those risks are reduced.

Therefore, these two steps will not be included in the base model.

Concluding, the value blueprint of Adner will be used as base model. The elements of the value blueprint are limited to the core business which is identified in MaaS literature. For this reason the steps are modified for a more generalized approach. The steps for a generalized value blueprint are described in Appendix A.3. This is not the full picture for a specific implementation of MaaS. However, it enables us to identify the main risks in the core business of MaaS initiatives.

Part II

Part II - Conceptual Model

7

Assessment of the realization of a MaaS platform

The four steps to create a generalized value blueprint (Appendix A.3) are used to formulate the base model. The steps are used to analyze MaaS literature. The first step, identified in previous Chapter, is focused on the end users. In MaaS literature, researchers have different opinions on the target group for MaaS (7.1). The next step is to identify the minimum characteristics to which the project in the ecosystem must comply. Together with the third step, the generalized value blueprint can be described (7.2). The fourth and final step is to identify for each actor in the ecosystem the risks of innovation and underlying causes (7.3).

7.1 Step 1: Target group

Many different views on the target group can be identified in MaaS literature. Hinkeldein et al. (2015) argues that market segmentation is crucial for the development of integrated services. According to Hinkeldein et al. (2015), attitude-based mobility typologies are most suitable to distinguish target groups. This study was conducted in Germany. Six mobility typologies were identified in the study and have different attitudes towards MaaS (Hinkeldein et al., 2015):

- 15% of the population are traditional car lovers and score low on the openness to MaaS.
- 21% of the population are flexible car lovers and are rather neutral on the openness to MaaS.
- 8% of the population are urban-oriented public transport lovers. They are also, surprisingly neutral towards MaaS.

- 19% are identified as conventional bicycle lovers. They are only using bikes and are therefore not open towards MaaS. ”Why need more than your bike?”.
- 17 % of the population are ecological public transport and bicycle lovers. Their attitude towards MaaS is open. Therefore, this is an interesting target group.
- 20 % of the population, are identified as innovative technology loving multi-optionals. Since they are open to all forms of transportation, this is the biggest attitude based group.

Thus, an attitude based group perspective is an interesting way of identifying a target group. However, more resent research is focused mainly on age related segmentation as target groups. Current MaaS projects are mainly aimed towards young customers who wish to adopt a sustainable lifestyle. Mulley (2017) argues that millennial generation tends to have a different cultural view of personal ownership. Besides, over 90 percent of the younger generation has a smart phone (Mulley, 2017). On the other spectrum of age, Li & Voege (2017) believes that MaaS would have greater benefits for elderly travelers. Their argument is that, of the current elderly generation, 60 percent have experience with smart phones. Therefore, a MaaS platform and interface on a phone would be interesting option. Besides, elderly people conduct longer trips than younger ones (Li & Voege, 2017).

Other research is focused on specific, even smaller, age related target groups. Haahtela & Viitamo (2017) found that some age groups are unable to drive a car, for example children. MaaS could be a big opportunity for mobility, because parents do not have to bring them to the desired destination. This is also the case for elderly persons who are unable to drive. Although these target groups are more likely to adopt the services of a MaaS platform, these target groups are small in comparison with other groups.

Also, MaaS could benefit persons who have never owned a car. Fixed costs and depreciation of the car are mostly neglected when traveling by car (Mulley, 2017). Therefore, travelers who never owned a car are less likely to be discouraged by the relatively high marginal cost offered by a MaaS platform (Mulley, 2017). However, the reasons why they do not own a car should br further investigated. For example, it is possible that they rarely travel.

Concluding, the most suitable target group for MaaS cannot yet be identified. The reason is that it is still unknown to what extent different target groups are willing to give up their cars and current travel behaviour, if there is a proper MaaS platform available (Hensher, 2017). This impact of MaaS on travel behaviour are not yet defined (Jittrapirom et al., 2017). User perspectives are not yet studied on a large scale (Li & Voege, 2017). More research should definitely be conducted on this topic.

7.2 Step 2 and 3: Minimum characteristics and interactions

By using the ecosystem and characteristics of MaaS identified in Chapter 3, the value blueprint can be designed and described in the first part of this section (7.2.1). Actors in the ecosystem must perceive added value before they want to participate in the ecosystem. The benefits of participating are described in the second part of this section (7.2.2):

7.2.1 Value blueprint of a MaaS platform

The Value blueprint is visualized in figure 7.1. The main characteristics are already identified in Chapter 3

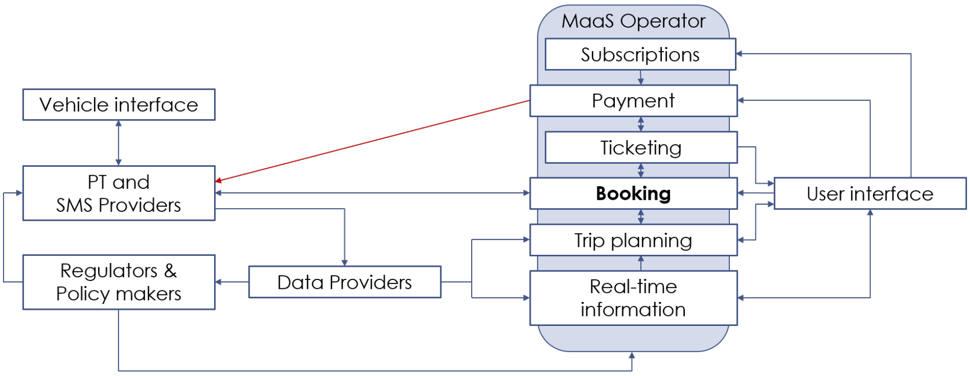

Figure 7.1: The MaaS Model. Source: own figure

The model can be analyzed from left to right and from an end user perspective. The end users have a interface which functions as single point of contact to the MaaS platform. Within this interface, the end user can plan a trip to a specific location, by using the trip planning tool. This tool requires data of fixed and flexible routes available, real time data of the vehicle and routes, and characteristics of the vehicle. This data is requested by data providers. These providers are complementors of the MaaS operator, because it is a service for an optimal platform. The data that is necessary must be provided by the PT and SMS providers. This data is partly gathered trough the vehicle interface. For example, location data from each vehicle is shared through the vehicle interface. The other part of the data is static. For example, the number of seats or sustainability factor.

The trip planning tool will provide several travel itineraries towards the end user. These itineraries might consist of several modes of transport and different providers. The end user can choose the itinerary that best fits their needs. This itinerary can be booked through the user interface. With one conformation of the end user, multiple trips are booked. The application sends the request directly towards the PT and SMS providers that are included in the itinerary reserves a seat on the vehicles of the PT and SMS providers. When the request is accepted by the booking agency of the PT and SMS providers, the user interface will issue a single ticket that can be used for the entire trip. Thus, the PT and SMS providers are suppliers of seats to the platform. The platform provides seats on all required modes of transport, on behalf of the transport providers, to the end user as single ticket. This ticket might be a qr code.

When the end user is going to travel, the ticket should be scanned at the beginning and end of the trip or using more advanced sensing methods might be used. For example, using the GPS data of the vehicle and end user to check if the end user did actually performed the trip as drafted in the personal travel itinerary. This is necessary to proof that the trip took place according the specifications of the ticket.

When it is proven that the trip took place,a payment should be made to the transport provider. The money required will be transferred to the transport provider from the balance that is managed in the user interface or through a subscription service. Other payment forms might be applicable, but that is outside the scope of this research.

Another requirement of the platform is to provide dynamic trip planning if there is a travel disruption. The real time data that is requested by the data provider and used to come up with alternatives. When the end user selects an alternative travel itinerary, bookings of the previous itinerary should be cancelled or modified. A new ticket will be generated.

The Regulators & Policy makers are intermediaries who create law and regulations that ensure the public interest and public urban space. The challenges that are identified in Chapter 4 should be addressed and monitored. The Regulators & Policy makers can use the data of the data provider to monitor the performance of the MaaS platform and transport operators.

Concluding, several activities are identified in the Model. The actors have different visions about the integration and hurdles can be identified in this model.

7.2.2 Identified benefits of the actors within the MaaS ecosystem

In conventional innovation literature, the only arbiter of value are the end users (Adner, 2012). However, in an ecosystem, all actors in the ecosystem should be satisfied. Thus, the notion of value should be explored for all actors in the ecosystem. The notion of value is the balance between costs and benefits (Adner, 2012). Cambridge-English-Dictionary (2018) defines ’value’ as ”how good or useful something is in relation to its price”. Thus, when a new platform is induced the benefits should outweigh the price of participating in an ecosystem. Therefore, the benefits for the actors, that are identified in MaaS literature, are described in this part.

MaaS operator

The MaaS operator will be a new payer between the end users and the transport providers. The MaaS operator creates value trough their unique business model. Business models consist of three elements, namely: how an organization creates, delivers and captures value (Eckhardt et al., 2017). If the business model is successful, a value surplus is created that can be seen as main benefit for the MaaS operator (Goodall et al., 2017). This surplus might be created by providing a competitive advantage over other MaaS operators. The MaaS platform should meet the needs of the end users and it should be hard to replicate (Eckhardt et al., 2017). Since no main or most preferred MaaS operator can be identified in MaaS literature, the notion of value surplus can be anything. For example, for a profit seeking MaaS operator, the value surplus might be profits. For a public MaaS operator, the notion of value might be social inclusion of vulnerable groups. All interviewees of the research of Smith et al. (2018b) agreed that new MaaS business models should be developed that fit all involved actors. However, there are many actors with various roles in the MaaS ecosystem with multiple expectations that must be satisfied (Smith et al., 2018b).

Data provider

The collection, storage, and processing is the value added of the data providers (Mulley, 2017). The amount of data that is required for a functional MaaS must be collected, stored, and processed almost instantly for each query. Therefore, the technology architecture of MaaS requires high levels of scale, speed and data variability (Kamargianni & Matyas, 2017). Big data and cloud computing should be fully exploited in order to provide the technological foundation for large scale data collection, storage and analysis. The main benefit for data providers is an excess of value that is gained by exporting the new technologies.

Transport providers

Several benefits can be identified for transport providers. MaaS can offer new sales channels where demand is more easily directed towards supply (Mulley, 2017; Jittrapirom et al., 2017). The main benefit is that there is the opportunity to access a wider market and gain more market share (Kamargianni & Matyas, 2017). For example, new mobility services may feed travelers from destinations, not served by a transport provider, towards their vehicles. MaaS could also simplify user accounts and payment management, because the platform requires standards in order to function (Mulley, 2017). MaaS might provide richer data on travel demand patterns and dynamics (Mulley, 2017). Moreover, MaaS might optimize demand and supply in rush hours, which results in less overfull vehicles and improved customers satisfaction (Kamargianni & Matyas, 2017).

Regulators & Policy makers

Hoadley (2017) found that, for local governments, the key factor for sustainable urban mobility is effective integration of planning and services. However, MaaS can only achieve its goals if integrated with other policy related measures such as low emission zones, pedestrianized areas, on-street parking policies, personal/work place mobility management (Hoadley, 2017). Therefore, MaaS should not be seen as separate transport solution, it should be seen as part of the larger smart mobility goals and solutions. The smart mobility goals for policy makers is to: reduce the environmental impact of transport, increase safety, while keeping people moving and supporting economic growth (Hoadley, 2017). MaaS might fulfill users needs and environmental aspect while addressing the challenge of urban mobility, which fits directly in the smart mobility aim (Jittrapirom et al., 2017).

Moreover, following the report of TSC (2018), one of the benefits of MaaS is that transport authorities could optimize how they manage transport systems and networks. Moreover, regulators & policy makers might use MaaS to monitor the new transportation initiatives fit in the smart mobility goals. This is a result of the rich data that is required for a functional MaaS platform and ecosystem. Data that might be of interest for policy makers of MaaS are: routes, passenger counts, distance traveled schedules, real-time information, and fare data (Hoadley, 2017). For example, policies may be created to manage urban public space. A possible policy intervention is to have a minimum amount of utilization of a shared car that is parked in urban public space.

End users

The main benefit for end users is that the services of transport, route planning, booking, ticketing, and payments are integrated in one system including real-time dynamic route planning Jittrapirom et al. (2017). Therefore, a fully functional MaaS is hassle-free, flexible, personalized, and on-demand (Kamargianni & Matyas, 2017). MaaS might fulfill the full range of mobility needs (Smith et al., 2018a). Moreover, MaaS could also be seen as travel companion, which provides additional perceived independence, safety, and security (Li & Voege, 2017). This can be seen as a benefit for vulnerable people.

Conclusion

Several benefits are identified in MaaS literature. There is sufficient evidence that each actor in the MaaS ecosystem benefits of MaaS. However, due the the newness of MaaS, the benefits are not yet validated. Moreover, the benefits must outweigh the amount the actor needs to invest to participate in the MaaS ecosystem.

7.3 Step 4: Identified risks of MaaS

The foremost challenge in the core business of MaaS is that multiple actors are involved in increased inter-organizational collaborations and responsibilities (Smith et al., 2018b; Jittrapirom et al., 2018). Thus, MaaS requires many stakeholders to work together in order to get the full potential of MaaS (Mulley, 2017; Kamargianni & Matyas, 2017; Jittrapirom et al., 2017). This is also the most important vulnerability. According to the study of Jittrapirom et al. (2018), multi-stakeholder cooperation is essential for a successful MaaS platform, but hard to achieve. For example, public transport providers are key actors and backbone for new MaaS platforms, because optimized fixed-route transit is the most efficient means of moving people along dense urban corridors (Smith et al., 2018a). When public transport providers do not want to participate, MaaS will not be successful. Moreover, according to Smith et al. (2018b), one of the major challenges for the development of MaaS are sharing of responsibilities and roles of MaaS. There is also a lack of inter-organizational trust and understanding by the actors of MaaS (Smith et al., 2018b).

In this Section, an in-depth content analysis is conducted to find the underlying risks and causes for in order to formulate a base model to assess Blockchain technology. There is a lot written about risks of MaaS.

According to Adner (2012), three risks of innovation exist. Execution, co-innovation, and adoption risk. Execution risk is mainly focused on the project itself. Since this research is focused around a core business of a MaaS platform, this is also where the execution risks can be found. These risks are described in Subsection 7.3.1. The risks of the data providers is described in Subsection 7.3.2. Only co-innovation risks are identified for data providers, since they are also new ecosystem entrants and complementors to the MaaS providers. Thirdly, the risks of transport operators are identified in Subsection 7.3.3. Both co-innovation and adaption risks for transport operators can be identified in MaaS literature, since the already operate in the transportation ecosystem. Lastly, the co-innovation risk of regulators & policy makers is described in section 7.3.4.

7.3.1 Identified Execution risks of creating a platform

According to Jittrapirom et al. (2017), MaaS requires a complete restructuring of the supply-chain of mobility service providers. The biggest challenge is that private actors have to play a larger role in the creation of public value (Smith et al., 2018b). For example, public value could be improved through less congestion and re-configuring of urban public space. However, MaaS will only be successful when value is created for all parties. According to the study of Jittrapirom et al. (2018), the lack of appropriate and attractive business models is a major vulnerability of MaaS pilots. The biggest issue is the protectiveness of current public transport business models (Jittrapirom et al., 2018). The execution risks are described in this section.

Technology Architecture

The first risk is technology architecture. Technology required for enabling a MaaS platform is only a green risk (Kamargianni & Matyas, 2017). According to Goodall et al. (2017), several researchers agree that the technology that makes MaaS work is already there, and that it is now time to make use of this technology.

Back end Architecture

The second execution risk is related to the back end architecture of a MaaS platform. The distribution channels should be harmonized (Smith et al., 2018b). This means that travel itineraries should created, booked, ticketed, and paid in one platform. The most ideal solution to this execution risk is a single identity for the end user. MaaS requires a single identity for a traveler to be used for all modes of transport (Li & Voege, 2017). Li & Voege (2017) argue that smart phones are peoples' new IDs, the new public transportation cards. For example, QR codes can be used as ticket. The biggest risk is that a single identity requires personal information of end users. For example, location data is required in order to confirm that the end user is at a specific location or the expiry date of a drivers licence. This data is highly sensitive. Thus, the challenge is to acquire the required information without compromising privacy and security (Li & Voege, 2017; Jittrapirom et al., 2017). Concluding, identity must be considered in the design of a platform. One identity should be the aim, but not at the expense of privacy and security (Li & Voege, 2017; Jittrapirom et al., 2017). This trade off is an orange risk for MaaS, because too little privacy and security will compromise trust of the platform, too much results in a dis-functional platform.

Brand image

The next risk, that can be identified in MaaS literature, is brand image. A MaaS platform is a new link between the transport providers and end users (Kamargianni & Matyas, 2017). Customers should be attracted when introducing a MaaS platform. According to the results of Smith et al. (2018b) and Jittrapirom et al. (2018), creating public awareness of MaaS and convincing potential customers to use it will be a long and challenging process. Excellent marketing and customer support are required for the realization of a successful MaaS platform (Jittrapirom et al., 2018). When the end users are attracted to use the MaaS platform, the perceived value of the end users should be in line with their expectations (Sochor et al., 2015). It will be a long and challenging process. Pilots might help to achieve additional awareness for MaaS and let end users experience and embrace the services of MaaS platforms. Due to the uncertainties, this is can be seen as a red risk.

Operational costs

A major requirement for MaaS is that customers must perceive added value through the MaaS platform. It should meet the service standards and needs of the user. However, this added value should be more than the increase in price due to the introduced platform that is fitted between supply and demand (Jittrapirom et al., 2018). Hensher (2017) argues that the biggest price related question is: 'How much are travelers willing to pay to improve journey experience?' This question is not answered in MaaS literature. However to stimulate the development of MaaS, the costs of using the platform should be as low as possible. Hensher (2017) also argues that fares for MaaS would be higher than those offered by conventional transportation services. This is a result of the resources that are required for MaaS, such as data analysis and dynamic routing (Kamargianni & Matyas, 2017). Due to the newness of MaaS and the capabilities required for a functional platform, this is a red risk.

Roles when system fails

Who should refund the end-users when there are delays or the system falters (Smith et al., 2018b). Within the MSP, the transport providers should be the ones that refund the end users (Jittrapirom et al., 2017). Concluding, good arrangements and contracts should be made with relevant actors (Kamargianni & Matyas, 2017). When good arrangements are formulated and contracts are made, the risk is reduced. Therefore, this risk can be identified as yellow risk.

Inclusion of the needs of end users

The results of a survey in the research of Haahtela & Viitamo (2017), conducted in several European countries, show that car user prefer flexibility, speed, reliability, privacy and the opportunity of transport goods. On the other hand, travelers of other modes, such as public transport and cycling, have similar requirements, but they relate their travel choice more on environmental concerns, price, flexibility, health and speed. However, the most important requirement that became evident in the research is that most commuters choose their mode of transport based on the time difference between using a private car and other modes of transport (Haahtela & Viitamo, 2017). These requirements are service characteristics should be used for the planning tool in MaaS. Moreover, the entire transportation network should be optimized towards those needs (Haahtela & Viitamo, 2017). Due to the high uncertainties of MaaS and the development, this can be seen as a red risk.

Ride sharing and behavioural change

Another risk is related to induce end users to use other forms of transport. It should be noted that a private owned vehicle uses the same amount of space on the road as a shared vehicle if there is no ride-sharing scheme available for the shared vehicle (Metz et al., 2016). Besides, tailored solutions of MaaS may lead to more vehicles on the road without a improved sharing motivated culture (Mulley, 2017; Smith et al., 2018a). Behaviour of end users should be changed towards using shared services. Otherwise, the added value of the platform will negligible in relation to public transport. Similarly, when behaviour is changed, MaaS will stimulate the development of shared services, because a need for shared services is created.

The requirement to change behaviour and habits became evident in the study of Haahtela & Viitamo (2017). They found that commuters are not eager about ride sharing. They feel uncomfortable with sharing a car with a stranger. Travelers will only use shared services if the price and service level are right for their needs (Haahtela & Viitamo, 2017). Moreover, Derboni et al. (2018) researched the same topic and found that the main issue of shared services is to change behaviour of travelers as well. Interestingly and contrasting to Haahtela & Viitamo (2017), Derboni et al. (2018) found that users are willing to use ride sharing, but were unable to find matches for their rides in the particular pilot. A possible solution, which is proposed by Derboni et al. (2018), is implementing incentive based strategies. This could work for both supply and demand side. The next generation of incentive based strategies is gamification (Hamari et al., 2014). Gamification is defined as using video game elements in non-gaming systems to improve user experience, enhancing positive patterns in service use, by changing behaviour of users (Hamari et al., 2014). The literature review of Hamari et al. (2014) shows that gamification may work for steering behaviour. An example of gamification is a rating system for drivers and passengers. Derboni et al. (2018) found that this will increase trust between parties, which result in a higher perceived level of service.

Matyas & Kamargianni (2018) found another way to diffuse other modes of transport. They found in their study that through subscription bundles, MaaS may introduce and promote shared modes of transport to travelers. The study shows that many travelers would try new transportation modes, such as shared services, if the modes are included in the subscription bundle (Matyas & Kamargianni, 2018). However, travelers prefer public transportation options in their plans, because of their habitual behavior. Therefore, to enable a sustainable MaaS platform, public transport is a requirement from the traveler perspective (Jittrapirom et al., 2017). When the new mobility services are more known to travelers the perspective may change. The study also showed that travelers perceived the additional modes of transport in a subscription as added value for transportation (Matyas & Kamargianni, 2018).

Concluding, gamification and subscriptions might enable the diffusion of MaaS and reduce the risks of an unattractive MaaS platform for both supply and demand. However, it is uncertain if MaaS can enable behaviour change. Therefore, this risk can be categorized as red risk.

7.3.2 Data providers

Since MaaS is relatively new, the business model of data providers cannot yet be determined. The main task for data providers is to make sure that the required information, that is requested by the MaaS platform, in order to give a unique travel itinerary, is delivered instantly and in an optimized way. For example, an end user requests a travel itinerary from a particular location to the nearby train station. This request is sent to the MaaS platform. The MaaS platform only requires information of vehicles that are nearby the end user. This request is sent to a data provider, which retrieves this information from their data warehouse. The MaaS platform will use this information to provide different travel itineraries for the end user. It might be a foundation or a profit seeking company. In MaaS literature, only co-innovation risks can be identified.

Technology architecture

Kamargianni & Matyas (2017) argues that technology architecture, required for data providers, is not yet ready for large adoption of MaaS services. The main problem is that traditional technology architecture will not be able to accommodate such unprecedented levels of scale, speed and data variability (Kamargianni & Matyas, 2017). MaaS requires excessive amounts of data. For example, the promise of real-time data flow and traffic forecasting is an issue (Jittrapirom et al., 2018). When a train is delayed or a bus that will be stuck in traffic, alternative options should be opted. This dynamic form of planning may significantly increase the perceived added value of MaaS, but also requires huge processor capacities (Kamargianni & Matyas, 2017). Without these capacities, the MaaS platform will be slow or not working at all.

Concluding, the co-innovation risk is that the technology architecture required for MaaS is not yet sufficient for a large scale MaaS adoption. Advances in big data need to be exploited in order to enable MaaS. The probability of success is yellow, mainly due to the advances in cloud computing. Thus, although it is a major risk, it is feasible to think that the demand of MaaS will grow steadily. Therefore, the data providers may gradually improve the technological architecture in order to meet the needs of MaaS platforms.

Data integration API

Moreover, data integration requires that different types and sources of data are merged, and is a major challenge for the implementation of MaaS (Jittrapirom et al., 2017). The whole supply network is based on this data. An open interface will facilitate data integration that is required for a functional platform. In order to achieve interoperability of data, also standards and protocols need to be proposed and, most importantly, adopted by the transport operators to share data required (Kamargianni & Matyas, 2017).

These standards and protocols are required to diffuse an unified Application Programming Interfaces (APIs). For example, there are already APIs for journey planning and, in rare cases, public transport fares (Hoadley, 2017). Li & Voege (2017) argue that lessons should be learned from Google Transit. They created simple and user friendly APIs, General Transit Feed Specification (GTFS) and GTFS Real Time. Therefore, the functions of Google Transit are growing fast. These lessons may be applied to MaaS as well. Thus, MaaS requires simple user-friendly APIs that allows individual operators to join MaaS simply and easily (Li & Voege, 2017). An example for data that should be shared is, real time data on bicycle sharing, e.g. location of bicycle stations, availability of parking slot, and bicycles at each station should be opened.

Concluding, the co-innovation risk that is applicable of data integration of all suppliers is the creation of simple user-friendly APIs. However, as demonstrated by Google, the probability of success is high. Thus, this is a green risk.

7.3.3 Transport providers

For transport providers, both co-innovation and co-adoption risks can be identified.

Co-innovation - data acquisition

The first co-innovation risk that can be identified in MaaS literature is that all vehicles of transport providers should have sensors installed in order to acquire the amount of data needed for MaaS (Kamargianni & Matyas, 2017). Most vehicles already have sensors installed and for other vehicles, for cars without sensors a smart phone might be sufficient (Lozinski, 2018). Thus, this risk is relative low, and categorized as a green risk.

Co-innovation - Integration of ticketing systems

MaaS requires that new types of tickets should be developed by the transport providers that at least have reasonable margins and with lower minimum fares (Smith et al., 2018b). The current ticketing range of transportation providers is too inflexible to create multi-modal transport. For example, the OV-bike can only be rented for a minimum of 24 hours or high minimum fares that limits the flexibility of mode switching. Moreover, monthly packages and special tickets should be created as well (Smith et al., 2018b). Additionally, tickets must be cancelled or modified when there is a disruption and the travel itinerary must be changed (Smith et al., 2018b). Payments should only occur after the trip is conducted. Also, ticketing systems should be installed in all vehicles that can work with these conditions (Kamargianni & Matyas, 2017). A solution that can be identified in literature is that the price should be based on the distance instead of zones that is now used most of the time (Haahtela & Viitamo, 2017).

Without proper incentives transport providers will not change tickets. Therefore, this risk is relatively high and the color of this risk is red.

Adaption - Availability of open data

In order to enable MaaS, transport providers should open data in a standardized format (Jittrapirom et al., 2017; van Manen, 2017). In other words, an unified public transportation data format is needed, which is not only focused on PT but also SMS providers (Li & Voege, 2017). Moreover, service agreements should be created for the division of service among the different the public and private transport providers. An example of open data can be found in the Netherlands. The platform BISON is responsible for public transport standards. The platform BISON (Beheer Informatie Standaarden OV Nederland) has the function of drafting, managing, harmonizing, and monitoring all standards that facilitate the exchange of information within public transport [1].

While many public transport operators have made their real time data available, operators of other transport services rarely open their data to third party developers and platforms Li & Voege (2017). Also, booking and ticketing is not opened up to third party providers. The main issue is that transportation providers are not willing to work with competitors, and to abandon their own data format (Li & Voege, 2017). Crucial actors may be unwilling to provide their

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[1] `http://bison.connekt.nl/over-bison/`

data and fulfill the data sharing requirements of MaaS (Jittrapirom et al., 2018). Especially pricing of the trip might be sensitive (Hoadley, 2017). According to Hoadley (2017), policy intervention is required for unified open data sharing standards. However, standards within the platform and data security protocols might reduce this risk as well (Kamargianni & Matyas, 2017).

Concluding, many transport providers are highly reluctant to open up their data. Therefore, this is a red risk.

Adoption - Data ownership

Additionally, shared data may be used for supply-demand optimization, to better understand travel demand patterns (Jittrapirom et al., 2017; Mulley, 2017). The big question is: who is allowed to use the data? For example, if the data is shared to a data provider, other transport providers might use the data in order to optimize their own transportation services and compete with the transport provider who shared the data. Standards and protocols should be developed for data ownership and sharing of data (Kamargianni & Matyas, 2017). These standards and protocols are not yet developed, that includes pricing. Therefore, this can also be categorized as red risk.

Adoption - Changing business models

There is a lack of trust between private and public actors. Private service operators prefer a privately owned MaaS platform, because they believe that the private platform has more incentives to promote their services (Kamargianni & Matyas, 2017). A disadvantage of a private platform is that it takes a long time to include public transport providers (Kamargianni & Matyas, 2017). This is a result of a lack of trust. Many transport providers are concerned that data providers and operator acquire dominant positions, which could lead in less independent public transport operators and suffocation of their business models (Smith et al., 2018b). This fear of losing control should be managed. The cause for this fear is that there is still a lot unclear about the roles of PT providers and SMS providers in the broader MaaS ecosystem. Smith et al. (2018a) is claiming that SMS providers can only complement public transport and can only be used for for the last few kilometers. Similarly, Hensher (2017) argues that most MaaS literature is focused on a changing role for the car. However, it is very unlikely that bus routes will change completely. Smith et al. (2018a) argues that MaaS will most likely shift away from public transport. Therefore, public transport should anticipate early on MaaS impacts and changing their business models. Innovations in public transport are required in order to compete with SMS providers. According to Haahtela & Viitamo (2017), continuous shuttle buses to several destinations in the city and outskirts might be a solution. However, (Hensher, 2017) argues that within the regulated market, the biggest improvement is to create smart bus operations. Examples are, bus-on-demand and a smart point-to-point service models. The major benefit of smart bus operations is that it may reduce the funds provided by governments for public transportation, while adjusting the routes and demand of end users (Hensher, 2017). Another advantage of smart bus operations is that some commuters prefer the bus since it avoids the imposed intimacy of a fully occupied car with strangers(Hensher, 2017). Therefore, it can be more competitive with SMS providers.

Thus, adoption risk is based on the fear of loosing control. It is likely that PT providers have to change their business models, while SMS providers gain many benefits from MaaS. Also, the pricing models prevent the integration between subsidized PT and profit seeking SMS (Jittrapirom et al., 2018). Contracts and arrangements about the roles the ecosystem and working areas should be negotiated in order to achieve value creation for all actors.

These contracts and arrangements can be included in packages. This solution identified by Mulley et al. (2018). They investigated the offering of mobility services packages by small community transport operators. The different packages are targeted to current users and potential new users. The results showed that there is strong enthusiasm for offering packages from an operator side. The major reason for this optimism is the opportunity of lock-in for customers Mulley et al. (2018). This lock-in cannot be seen as a benefit for travelers, since it limits their flexibility. A trade-off should be found between the flexibility of users and lock-in.

Since, there are already some solutions identified in literature, the fear of loosing control is a yellow risk.

7.3.4 Regulators & Policy makers

Currently, most transport providers are working on highly regulated provisions and temporary monopolies. Policy interventions are required in order to enable MaaS (TSC, 2018; Hoadley, 2017; Li & Voege, 2017). Regulators & Policy makers need to be involved in the development of policy for MaaS (Hoadley, 2017). There is always a trade-off between regulation and innovation. Too much regulation results in an unattractive MaaS, because the private sector is impeded to participate. While too little regulation might forsake the public interest. Finding the right amount of regulation is a key action in order to facilitate the development of a MaaS platform which includes both public transport and shared mobility services (Smith et al., 2018a). The interventions of regulators & policy makers should aim to solve the public value challenges identified in Section 4.

Concluding, the co-innovation risk that is applicable of regulators & Policy makers is to create a regulatory framework that enables the diffusion of MaaS and stimulate transport providers participate in MaaS platforms. There is a high interest of governments. However, creating frameworks is a slow process. Therefore, the probability of success in the short term is acceptable and the risk is yellow.

7.4 Conclusion

In this part, the four steps of the generalized value blueprint are conducted. The results show that there is no agreement of the best target groups for a Maas platform. The minimum MaaS model and interactions are identified in the next part in order to formulate the value blueprint. This is used to identify the risks in the next part of the research. The risks are described in the last part of this paragraph and are summarized in Table 7.1. Also in MaaS literature, some solutions are already provided. The risks and proposed solutions will be used to find linkages between Blockchain technology and MaaS.

Risk	**Type of risk**	**Related actors**	**Risk category**	**Proposed Solution**
Technology Architecture	Execution	MaaS operators	Green	Use current technologies
Back end Architecture	Execution	MaaS operators	Yellow	Single identity
Brand image	Execution	MaaS operators	Red	-
Operational costs	Execution	MaaS operators	Red	-
Roles when system fails	Execution	MaaS operators	Yellow	Arranements and contracts
Inclusion of the needs of end users	Execution	MaaS operators	Red	System optimized for travelers' needs
Ride sharing and behavioural change	Execution	MaaS operators	Red	Gamification and Subscriptions
Technology architecture	Co-innovation	Data providers	Yellow	Advances in big data and cloud computing
Data integration API	Co-innovation	Data providers	Green	Create simple user friendly APIs
Sensors in vehicles	Co-innovation	Transport providers	Green	Cheap sensors or smartphones
Integration of ticketing systems	Co-innovation	Transport providers	Red	-
Open data	Adoption	Transport providers	Red	policy intervention or data security protocols
Data ownership	Adoption	Transport providers	Red	Standards and protocols
Changing business models	Adoption	Transport providers	Yellow	Contracts and arrangements
Policy for MaaS	Co-innovation	Regulators & Policy makers	Yellow	-

Table 7.1: Risks Identified in MaaS literature

Part III

Part III - Blockchain

8

Blockchain to enable the realization of a MaaS platform

This chapter is focused on Blockchain technology. According to many MaaS practitioners, BT might be a solution to enable a MaaS platform. Therefore, the next research question that will be answered in this part of the research is: *What are the promises of Blockchain technology and how may it enable MaaS?* The term 'enable' used in this research can be described as reducing the risks of the realization of a MaaS platform identified in previous part. This chapter is divided in several sections. The first section related to the bigger picture of BT. In particular where it can be placed in software systems (8.1). BT have a certain purpose in software systems (8.2). With this purpose in mind, a definition will be formulated to understand the differences between conventional software systems and Blockchain software systems (8.3). Next, BT can be used to create several types of Blockchain networks, which have different properties (8.4). In the next section, the technical concepts of a Blockchain are briefly described (8.5). Several promises are explained in previous sections. With the basic understanding of BT, the next section is more focused on the link with mobility initiatives. A thematic analysis is performed to find how Blockchain is used in several mobility concepts (8.6). This chapter is finalized with a conclusion (8.7)

8.1 Blockchain technologies as part of a software system

Traditionally Information Technology (IT) has been viewed as a supporting tool for organizations. Presently, IT is viewed as a disruptor that leads to new unique business models and replace the traditional ones (Scott et al., 2017). Therefore, organizations are becoming more virtual-oriented. It means that many products and services are gaining digital presence (Tapscott & Tapscott, 2016). This digital disruption is spreading across many industries. The new IT enabled business model opportunities result in a change in the way organizations think about digital technologies. The opportunities of the new business models have to be explored, otherwise the next consumerdriven disruption start-up will conquer the market (Scott et al., 2017).

Blockchain technology is an IT, which is an element of a software system (Swan, 2015). Therefore, a software system should be further explored in order to find the main purpose of BT. A software system can be divided in two layers, the application vs the implementation layer. The application layer of a software system is concerned with the user needs (Drescher, 2017). The implementation layer is the means to create the application layer. The elements of the implementation layer are always technical by nature (Drescher, 2017).

These layers can be distinguished in two requirements, namely functional and non functional. Functional requirements determine the features of the layer, while nonfunctional requirements provide the guides and constrains of the layer (Peters & Panayi, 2016).

A schematic overview and definition of the layers and requirements are visualized in Figure 8.1. Additionally, examples of the requirements of a MaaS platform are also included in this Figure.

	Functional requirements	Nonfunctional requirements
Application layer	**Features that meet the user needs** Dynamic route planning	**Guides and constrains in order to meet the user needs** Easy to use
Implementation layer	**The (technical) elements to provide the features in the application layer** Saving transportation data	**Guides and constraints of the elements of the implementation layer** Maintaining integrity

Figure 8.1: Design of a software system. Source: own figure

The implementation layer is less visible to users. However, for software engineers this is the most important layer.

8.2 The purpose of Blockchain technologies

Blockchain technology might be included as an element within the implementation layer to comply to the nonfunctional requirements of a software system (Drescher, 2017). It is a novel way to manage data in software systems (Peck, 2017).

Within a software system, data is transmitted by copying it from one place to another (Mattila, 2016). The key challenge of the transmission of the data is integrity of the information that is transmitted (Drescher, 2017). In other words, the information received from one particular location should be verified if it is authentic and up-to-date (Mattila, 2016). This challenge is greater when the data source is an untrusted participant. The current way, without BT, to solve this problem is to place trust in an intermediary that focus on maintaining integrity of the information that is transmitted (Tapscott & Tapscott, 2016). Intermediaries can be seen as separate companies or organizations that have the verification of information as core business. Examples are Banks or the Chamber of Commence.

At banks, the transmission of data occurs in the form of transactions. Each transaction is validated with prior state of the database with all transactions and personal information of the person that initiated the transaction. The person should trust the bank that the information in the database is honest and that their personal information is safely stored.

Moreover, other companies require the transmission of data to enable their core business. Therefore, the verification of information can also be seen as a part of the core business. An example is Uber. The core business of Uber is to match supply and demand in the taxi industry. In this case, the transmission of data is the request of a trip from a traveler. The information of this request is validated by Uber using personal information of the traveler, such as Credit card information and location. A driver will be matched to this request, this is another transfer of information. Uber also uses personal information of the driver to make sure that the driver is legitimate. Both the driver and traveler trust Uber with their data in order to have a safe ride.

In these examples, the intermediaries are creating trust by using their brand recognition to solve the integrity problem (McCluskey, 2016). These intermediaries also maintain transaction records and perform the business logic and transaction logic that empowers commerce in the digital world (Tapscott & Tapscott, 2016). The intermediaries act as central authorities to maintain trust. The most considerable drawbacks of this solution is that those central intermediaries are harbouring data of individuals that have to use those software systems, and the invasion of privacy for commercial gains (Tapscott & Tapscott, 2016).

Until recently, central authorities where the only solution for creating trust and a decentralized network that providers the same amount of trust in a peer-to-peer network was not available. Presently, BT provide a new and alternative solution for creating trust in a software system without the need for central authorities. Thus, the purpose of BT is to provide tools for a decentralized trust network (Swan, 2015). According to Tapscott & Tapscott (2016), trust refers to: *Buying and selling goods and services, and the integrity and protection of information (p.11).* This definition is important, because it shows the boundaries of the solutions that BT might provide and can be used as input for the definition of Blockchain that is described in the next Section.

8.3 Definition of Blockchain and why is it different?

BT enable new forms of decentralized software systems, where components can find agreements on their shared states for decentralized and transactional data sharing across a large network of untrusted participants, without relying on a central intermediary that should be trusted by every participant in the network (Xu et al., 2016). In order to fully understand this definition, software decentralization should be further explored (8.3.1). Furthermore, decentralized and transactional data sharing should be explored as well (2.2)

8.3.1 Software (de)centralization

Software systems can be plotted on a 3-dimensional decentralization graph. According to Buterin (2018), there are three axes of decentralization of a software system, namely:

- *Political (de)centralization:* the amount of individuals or organizations that have ultimately control of the system.
- *Architectural (de)centralization:* The amount of computers/servers of which a system is composed of and the amount of computers that might break down before the system fails.
- *Logical (de)centralization:* the interface and data structures that the system present behave as one monolithic object or as amorphous swarm.

Both centralized software systems and decentralized Blockchain technology software system are logically centralized. In other words, they cannot function in the same way, when the system is split in half (Buterin, 2018).

However, conventional software systems are mostly products of a single intermediary. Therefore, it is politically centralized, because there is one CEO and a small set of investors. Moreover, it is mostly architecturally centralized, because there is one head office where the servers are installed (Buterin, 2018).

Blockchain software systems, in the purest form, are politically decentralized, because no one controls them. Moreover, they are architecturally decentralized, because there is no central point of failure. Additionally, there is a commonly agreed state and the system acts as a single computer (Buterin, 2018).

There are several reason why a political (8.3.1) and architectural (8.3.1) decentralized systems are gained additional interest by practitioners and scholars and are described in the next sections.

Why political decentralization matters

No single persons controls a purely politically decentralized software system (Tapscott & Tapscott, 2016). Decisions are made on the voting basis of all actors in the network. Moreover, all actors in the network can interact directly with other participants in the network, without the approval of the owner in the network. On the other side of the axis there is a fully politically centralized software system. Decisions are made by the owner in the network. All interactions must be approved by the central authority.

There are several reasons why a decentralized political approach is more desirable for creating a platform from a public value perspective. The four challenges that affect public value of smart mobility initiatives, which are described in Chapter 4, can be used to answer the question why a decentralized approach is more desirable.

The first challenge identified by Docherty et al. (2017) is the short versus the long game. This challenge can be explained by using the adoption S-curve of centralized software systems (Figure 8.2). When the digital innovators create a software system in the form of a platform, both users and third party complementors should attracted to the platform. Users will be attracted by using various marketing strategies and third parties will be attracted by open cooperating schemes (Dixon, 2018).

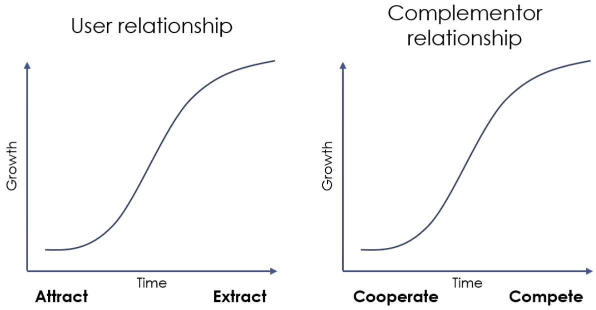

Figure 8.2: Adoption S-curves for central software systems. Source: Dixon (2018)

When the platform moves up the adaption S-curve, the power over user grows, due to the network effects (Jittrapirom et al., 2017). When the platform moves towards the end of the s-curve, the relationship with users and complementors changes from positive-sum to zero-sum (Dixon, 2018). This results in a challenge for digital innovators to maintain their profits. The innovators are solving the challenge by extracting data from users and compete with complementors over profits and audiences (Dixon, 2018). This change results in a barrier for innovations proposed by third parties, and privacy and security issues for users (Dixon, 2018).

With a political decentralized software system no large digital innovator is in control, it is controlled by the community to which anyone can join (Cohen & Chuen, 2018). Also, the aim of a decentralized platform is not to make profits. The surplus of value will flow towards the ones who contribute the most (McCluskey, 2016; Cohen & Chuen, 2018). This is also addresses the second challenge of identified by Docherty et al. (2017), namely the cost of the transition. The transition is not dependent on top-down solutions by profit seeking monopolies, but from bottom up co-creation solutions initiated by users and third parties that address a problem from a societal perspective (Cohen & Chuen, 2018).

The third challenge identified by Docherty et al. (2017) is information asymmetries. Centralized platform are characterized by strong information asymmetries between the operator and the users. This is a result of the political centralization in the form of autocratic control over the extracted data of users (Primavera, 2016). An open and decentralized platform has a more democratic control of data. There is an equal level of transparency across all the participants in the network (Primavera, 2016).

The last challenge identified by Docherty et al. (2017) is equity and inclusion. Politically decentralized software systems fosters innovation as it lowers the cost of participating in the software platform and the foundations of the platform can be used as foundation of new innovations (Cohen & Chuen, 2018). Everyone can participate in a politically decentralized software system. Therefore, the value created is shared among the participants (Tapscott & Tapscott, 2016) and local economic opportunities arise (Cohen & Chuen, 2018).

Thus, it can be concluded that a political decentralized system might overcome the public value challenge identified by Docherty et al. (2017).

Why Architectural decentralization Matters

Two types of software architecture can be distinguished in literature, namely: centralized and distributed (Drescher, 2017). Both can be seen as anti-poles of each other. Within those anti-poles several different combinations are possible. The software architecture is required to lay out the rules of how the nodes in the network are organized and interact with each other (Drescher, 2017). Both architectures are visualized in Figure 8.3. In a centralized architecture all notes within a network only interact with one central node. In a distributed network, all nodes are connected without having a central node. This connection might also be an indirect link, which is visible in Figure 8.3. Thus, there is no central element of control in this network. Therefore, it can be seen as partly decentralized network. However, a distributed architecture is only fully decentralized if the software system is also politically decentralized (Kozlovski, 2018).

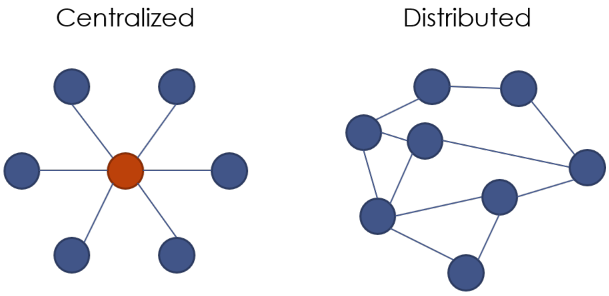

Figure 8.3: Centralized and distributed system architecture. Source: own figure

Drescher (2017) identified four advantages of distributed architecture over centralized architecture from an information technology perspective. The advantages are:

- *Higher computing power:* Distributed architecture have more connected computers with cumulative computing power
- *Cost reduction:* Each computer in a distributed system requires less capabilities, because they are part of the greater network. Therefore, creating, maintaining, and operating a distributed system is cheaper than a central system.
- *Higher reliability:* There is no single point of failure in a distributed network, the remaining notes can take over when part of the system fails.
- *Ability to scale naturally:* The required computing power can incrementally increased by adding more computers to the network.

Thus, distributed networks enable large software systems that are not possible with a centralized architecture. Therefore, a decentralized architecture is becoming more popular for creating global software systems. This in also applicable for software systems with a politically centralized command due to scale and price of the network (Kozlovski, 2018). However, it is a highly complex solution and not possible for small scale projects (Kozlovski, 2018).

8.3.2 Decentralized and transactional data sharing

BT enable decentralized and transactional data sharing across a large network of untrusted participants (Xu et al., 2016). Transactional data can be defined as a digital record of a transaction of a good or service, which includes all reference data of the particular transaction (Techopedia, 2018). Reference data that is always included in transactional data is the timestamp of the transaction and the transfer of ownership of the product or service. However, any information can be included as reference data in the record of a transaction.

Transactional data is stored in a database that is updated instantly when new transactions are conducted. For financial transactions this database is mostly called a ledger, for products and services this is mostly called a register (Drescher, 2017). The first application for BT was for financial transactions. Therefore, most practitioners only use the term ledger, instead of ledger and register. In this research the term ledger is used for ledger and register.

Ledgers serve for two purposes (Drescher, 2017):

- Means of proving ownership
- Document transfer of ownership

The proof of ownership requires *reading* of preserved state of the ledger. On the other hand, transfer of ownership requires *writing* of new transactional data to the ledger (Drescher, 2017). Proof of ownership requires transparency, because if anyone can see the current state of the ledger, the validation of proof of ownership is trivial. Transfer of ownership requires privacy, because writing new records to the ledger must be exclusively restricted to actors that are trusted by the entire network. In a central software system, those actors are the intermediaries described in SubSection 8.3.1.

The price of centralized software systems is trust, because the users need to trust the operators of reading, writing, and maintaining the ledger without being transparent about the records in the ledger (Primavera, 2016). The ledgers are not fully publicly available, because the records contain sensitive data of users and the intermediary itself.

However, when the central authority is removed, the price of fully decentralized software systems is transparency, all interactions are disclosed to all network's nodes (Primavera, 2016). This is an important trade-off for BT.

Ledgers have been used for commerce since ancient times (Walport, 2016). However, until 2008, the only notable innovation for ledgers was the transfer from a paper ledger to a centralized digital ledger (Walport, 2016). This is also one of the underlying cause why intermediaries were still necessary for transactional data sharing and integrated in almost all software systems (Tapscott & Tapscott, 2016). However, with the emergence of BT, new combinations of algorithms enabled the collaborative creation of digital distributed ledgers with additional properties and greater capabilities in comparison with central ledgers (Walport, 2016).

BT belong to Distributed Ledger Technologies (DLT) (Lewis, 2018). Distributed refers to the architecture of the ledger. Thus, the ledger is stored on multiple computers in a network, which communicates with the network to ensure the it is the most recent and accurate version (Beedham, 2018). However, in most DLT, the implementer has control of the structure, purpose, and functioning of the ledger. Therefore, it can be seen as a politically centralized system (Beedham, 2018).

As mentioned earlier, BT are different because they provide the rules and standards that enable politically decentralized distributed ledgers. This decentralization is achieved by using a immutable ledger that is maintained by a decentralized network where writing of new transactional data to the ledger is approved by a consensus mechanism (Beedham, 2018). It should be noted that BT can also be used for less politically decentralized solutions. This further explained in the next section.

Concluding, ledgers are used as databases for transactional data sharing in a network. Until 2008, this was not possible to do this fully decentralized. However, new DLT have enabled the creation of distributed ledgers. Blockchain technologies complements DLT by providing rules and standards for a distributed ledger, so that all components in the network can can find agreements on their shared state for decentralized and transactional data sharing across a large network of untrusted participants. A ledger that uses Blockchain technologies is called a Blockchain ledger.

8.4 Types of Blockchain networks

As mentioned in previous part, BT provide the tools for fully decentralized distributed ledgers. However, in practice it is hard to achieve and maintain a fully decentralized system. Therefore, current Blockchain networks can be categorized in three different variants, namely public, private, and consortium (Zheng et al., 2017; Peters & Panayi, 2016).

Zheng et al. (2017) identified six properties that distinguish the Blockchain variants:

- *Consensus determination*: In a public Blockchain any node can participate in the consensus process. In a consortium, only selected nodes are responsible for consensus determination. In a private Blockchain the consensus method is determined by one organization.
- *Read permission*: In a public Blockchain, anyone can read all transactions. In a consortium or private Blockchain, the owners might restrict access.
- *Immutability*: A public Blockchain is almost impossible to tamper. Transactions in a consortium or private Blockchain might be tampered, due to the limited amount of notes that are included in the consensus process
- *Efficiency*: Due to the consensus mechanism, public Blockchains are often slow and not capable for large amounts of transactions. Efficiency for consortium or private Blockchains are much higher, because of the limited amount of nodes.
- *Centralization*: Due to the open nature of a public Blockchain, it can be seen as fully decentralized system. Consortium Blockchains are only partly politically decentralized, because of the limited amount of notes in the network. Private Blockchains are fully centralized by one organization.
- *Consensus process*: In a public Blockchain any node can participate in the consensus process, thus it is permissionless. In a consortium or private Blockchain, verification

nodes are pre-selected by the central organization or consortium.

The variants are summarized in Table 8.1.

Property	**Public blockchain**	**Consortium blockchain**	**Private blockchain**
Centralized	No	Partly	Yes
Consensus determination	All miners	Selected set of nodes	One organization
Read permission	Public	Public or restricted	Public or restricted
Immutability	Nearly impossible to tamper	Could be tampered	Could be tampered
Efficiency	Low	High	High
Consensus process	Permissionless	Permissioned	Permissioned

Table 8.1: Variants of Blockchains. Source: Zheng et al. (2017)

Choosing the type of Blockchain depends on the goal of the project. For a fully decentralized software system project, a public Blockchain is most usable. However, there are still questions about the level of political centralization of public blockchains. Roubini (2018) argues that the major problem for public Blockchains is the centralization of mining power. Mining pools result in centralized consensus. Moreover, there are centralized exchanges that are vulnerable for hacks. Thus, the central intermediary, is replaced by many smaller intermediaries (Roubini, 2018).

Concluding, different variants of Blockchain networks emerged since the introduction of the Bitcoin Blockchain. They are mainly architecturally decentralized. However, the main differences is the level of political decentralization. That varies between the different variants. Even the most politically decentralized system is not fully decentralized. For a MaaS platform, the highest possible political decentralization should be the goal as explained in Section 8.3.1. Therefore, a public Blockchain network should be the premise for creating a MaaS Blockchain platform. If that is not reacheble, a consortium blockchain should be selected.

8.5 Technical concepts of a Blockchain network

As mentioned in previous part, BT provide unique rules and standards for a distributed ledger. The main characteristic of BT is that multiple transactional data records are grouped and linked to the previous group to form a chain (Beedham, 2018). This is also the main difference between conventional distributed ledgers.

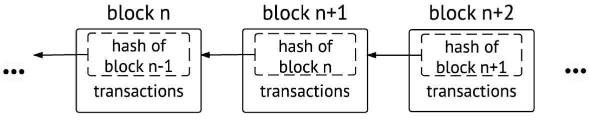

Figure 8.4: Basic Blockchain. Source: Christidis & Devetsikiotis (2016)

In Figure 8.4, a basic Blockchain architecture is visualized. Transactions that are included are the transactional data records. These transactions are batched in timestamped blocks (Christidis & Devetsikiotis, 2016). The average time to create a new block and the maximum amount of transactions included in a block depends on the selected Blockchain network.

One of the main characteristics of Blockchain ledgers is that the data is immutable (Zheng et al., 2017). This is achieved by creating a one-way cryptographic hash function of a Block. All data in a block, including the transactions, is hashed into one hash that represents the entire block, the Block header hash (Zheng et al., 2017).

Cryptographic hashing is mathematical function that transforms any digital input into a compressed string of alphanumeric characters (Drescher, 2017; Swan, 2015). This string is always a fixed length for any input. The output of the mathematical function is deterministic, which means that identical input will always result in identical output. Moreover, the function creates a pseudorandom result. This means that a minimal change in the input data results in a unpredictably different output. Also, it is a one-way function, because it is impossible to recover the original input data based on the hash value. The final characteristic of cryptographic hashing is that the chance to find identical output with different input is negligible. Therefore, it is collision resistant.

To go back to Figure 8.4, each block references to the previous block by including the Block header hash of the previous block (Christidis & Devetsikiotis, 2016). This can be seen as the a chronological link, or chain, between the blocks, the Blockchain. The only exception is the first block that is created, the genesis block. The genesis block contains the rules that the blocks have to follow and has no parent block (Swan, 2015).

Nodes that have access to the Blockchain networkcan examine the world state of the entire Blockchain ledger, which consist of all blocks in the chain. The link between each block and the cryptographic hash result in an immutable ledger. This means that even a small change in previous transactions will result in a completely different hash value. Therefore, the state of the Blockchain ledger can effortlessly be verified by comparing the hashes of the Block.

8.5.1 Transactions

The users of the Blockchain network interacts with the Blockchain ledger by creating a transaction. However, anyone can write the ledger. The right to transfer ownership to another account must only be restricted to the owner of the account who hands off ownership (Drescher, 2017). Only valid transactions should be approved (Gupta, 2017). To validate transactions that will be included in the Blocks, asymmetric cryptography is used to provide a digital signature that belongs the owner of the account (Drescher, 2017). More specifically, public-private-key cryptography is used for verifying transactions.

For each user in the Blockchain network, a pair of complementary keys are created by using cryptographic software (Drescher, 2017). One key can be shared with all users in the network. Therefore, this key is called a public key. The public key is similar to an email address. Anyone who knows the email address can sent emails to the public address. However, in Blockchain the public key can be seen as an wallet or account where all transactions of that user are stored. The other key is the private key. This key can be seen as a password to open the mailbox. This key should not be shared with anyone and should be stored in a safe way. In the Blockchain this private key is the digital signature to proof the account (public key) belongs to the particular user. With this proof, transactions can be signed to proof that the transaction executed by the right full owner of the wallet.

A valid transaction on the Blockchain requires several inputs. In figure 8.5, a basic transaction on the Blockchain is visualized.

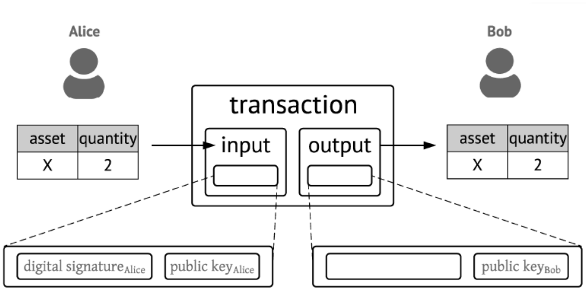

Figure 8.5: Basic transaction on the Blockchain. Source: Christidis & Devetsikiotis (2016)

In this example, Alice wants to sent two units of asset X to Bob. All transactions of all participants in the network are stored on the Blockchain ledger and can be seen by all nodes in the network. Therefore, if someone has the public key (wallet number) of Alice, one can verify that Alice has a sufficient quantity of asset X. The public key of Alice contains all transactions that Alice has sent and received on the Blockchain network. The total amount of unit X that is owned by Alice can be verified. For example, Alice has 10 units of asset X.

When Alice wants to sent the two units of X to Bob, Alice needs to know the wallet address (public key) of Bob. Alice creates and signs a transaction that modifies the ownership of two units of X, from her wallet address (public key) to the wallet address of Bob. The transaction is only placed in a Block when the digital signature of Alice is included in the transactional data. In both wallet addresses a new row is created. In the wallet of Alice, two units of X are reduced from her account, the wallet now contains eight units of X. The new row of Bob contains of the two units of X and the previous balance of his wallet.

Thus, only new rows are included in the wallets, in order to control concurrency, and because the Blockchain is immutable (Christidis & Devetsikiotis, 2016). The transaction should be verified if the digital signature belongs to the public key and if the amount sent does not exceed the balance on the wallet. Therefore, a consensus mechanism is required the verify the state of the Blockchain ledger that is shared across the notes of the network (Christidis & Devetsikiotis, 2016).

8.5.2 Consensus mechanisms

Consensus means that all independent nodes in the network reach agreement on a particular state of the ledger (Drescher, 2017). All transactions are included in Blocks. However, what counts as a valid transaction? The genesis block of a Blockchain ledger includes the rules that each transaction in the Blockchain network should conform to (Christidis & Devetsikiotis, 2016).

A consensus mechanism should validate these rules for each transaction in the Blockchain network. Thus, the transaction only becomes valid once it is included in a block and published in the Blockchain network (Peters & Panayi, 2016).

In a centralized system, reaching consensus is trivial. However, reaching consensus in a decentralized network with untrustworthy nodes is difficult (Zheng et al., 2017). This can be described as the Byzantine generals problem (Drescher, 2017; Zheng et al., 2017). The question that belongs to this problem is: "How do you make sure that multiple entities, which are separated by distance, are in absolute full agreement before an action is taken?"

All nodes in the Blockchain network need to agree on the transactions and the order that are included in a new block. If several notes have a different order of the transactions in a new Block, the block hash of those nodes will be unequal in comparison with the other nodes in the network. This is described as a fork, the chain is split in two world states and will no longer have a unique chronological state. (Christidis & Devetsikiotis, 2016). A distributed consensus mechanism can solve this problem.

Multiple distributed consensus mechanisms are developed to enable Blockchains. It depends on the variant of Blockchain network which consensus mechanism is most relevant (Zheng et al., 2017). It mainly depends of the consensus process in permissioned or permissionless as described in section 8.4.

For a permissionless Blockchain, all nodes should be able to vote on the order and content of the newly created Block. However, this is vulnerable for a Sybil attack (Christidis & Devetsikiotis, 2016). This means that a single entity can join the network with multiple nodes and have a big influence in the determination of the state of the new Block to favour the interests of this entity.

To reduce the change for a Sybil attack, the most developed Blockchain networks use Proof of Work (PoW) as consensus strategy (Zheng et al., 2017). With PoW, each note in the network can assemble a new Block. However, in order to let the network know that this is the only valid block, the node has to solve a cryptographic hash puzzle that requires expensive processing power to find the required block header hash (Zheng et al., 2017). This will discourage malicious nodes to create false blocks.

An minimum expected format of the Block header hash is included in the rules of the network (Christidis & Devetsikiotis, 2016). For the Bitcoin Blockchain, this expected format consists of a large amount of leading zeros in the Block header hash (Christidis & Devetsikiotis, 2016). For example, the last verified Block has the following Block header hash: 0000000000000000001a75a93cbc1d9df1f82d7aa10157d2e60ccc5f2529cd36[1]. In order to find the hash that meets the expected format, a random number is added in the Block (nonce).

This random number must be guessed by nodes that are participating in solving the cryptographic hash puzzle. The nodes that are trying to find the nonce that leads to the expected format of the Block header hash are called miners, the procedure to find the nonce in PoW is called mining (Zheng et al., 2017). This way of finding the right hash works, because the output of the hash function creates a pseudorandom result, as mentioned in Section 8.5. Therefore, miners have to conduct many computer calculations to guess the nonce that result in a hash that meets the minimum expected format.

When a miner reaches the format, the Block will broadcast to the entire network. The other nodes in the network should confirm the correctness of the Block header hash. This conformation is trivial, because of the deterministic nature of the hash function. When correct, the new Block will be permanently included in the Blockchain (Zheng et al., 2017). The miner

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[1] https://www.blockchain.com/btc/block/0000000000000000001a75a93cbc1d9df1f82d7aa10157d2e60ccc5f2529cd36

that finds the block header has will be compensated for its 'work' with a predefined amount of crypto tokens (Christidis & Devetsikiotis, 2016). The main drawbacks of Pow is that it requires much computing power and electricity (Zheng et al., 2017). Therefore, it is an expensive solution.

Currently some permissionless Blockchains are experimenting with an alternative consensus mechanism, namely Proof of Stake (PoS). In this consensus strategy the nodes in the network that want to create a new Block have to prove that they have a minimum amount of crypto tokens in possession (Gupta, 2018). Nodes with more crypto tokens are less likely to attack the system (Zheng et al., 2017). An alghoritm is used to assign the node that can create the next Block. Only nodes that have the minimum amount of crypto tokens, defined in the rules of the network. will be included. When this node includes falsified transactions, it will loose its stake (Christidis & Devetsikiotis, 2016).

However, the actual implementation is complex and several challenges still need to be solved (Christidis & Devetsikiotis, 2016). The biggest drawback is that the mining costs are nearly zero, attacks are not fully excluded (Zheng et al., 2017). Therefore, it is not yet used by the most common permissionless Blockchain networks, such as Ethereum (Zheng et al., 2017). However, when the most hurdles are solved these Blockchain networks will most likely transform to PoS (Christidis & Devetsikiotis, 2016).

For permissioned Blockchain networks, the costly PoW mechanism is not required, because there is no risk for a Sybil attack (Christidis & Devetsikiotis, 2016). For example, the consensus strategy used in well known permissioned Blockchain networks are, among other things, multi-signature and Practical Byzantine Fault Tolerance (PBFT) (Gupta, 2018). With multi-signature, a majority of nodes vote if the transactions are valid and the order of the transactions inside a Block (Gupta, 2018). With PBFT, which is an algorithm that is designed to settle disputes when Blocks in the network have an unequal hash (Gupta, 2018).

The main advantage of permissioned Blockchains is that the consensus strategies do not require many computer calculations and electricity (Gupta, 2018). Therefore, conducting transactions is less expensive, because there are no miners that should be compensated for their work.

Concluding, several consensus mechanisms exist. It depends on the type of Blockchain network which consensus mechanism is required. Permissionless Blockchain networks can only use PoW and in the future PoS to reduce the change of a Sybil attack. The biggest drawback of PoW is that it is a expensive mechanism. In permissioned Blockchain any consensus mechanism can be chosen, because the possibility of a Sybil attack is negligible.

8.5.3 What can be stored on the Blockchain Ledger?

As derived from the definition of Blockchain, transactional data is stored on the Blockchain. This transactional data can represent a token or a smart contract.

Tokenized assets

Tokens have emerged as the artifact of choice to represent something digitally on the Blockchain (Oliveira et al., 2018). Thus, a digital representation of an asset is stored on a Blockchain

(Christidis & Devetsikiotis, 2016).

According to a literature review of Oliveira et al. (2018), three classes of tokens exist. The classes are: Coin/Cryptocurrency, utility token, and tokenized security:

- *Coin/Cryptocurrency:* This class represents digital assets, such as money. The function of a coin/cryptocurency token is to uniquely represent an asset, thus it can be seen as an asset-backed token. The role of the token is to provide a right to a certain asset or as a unit of value exchange.
- *Utility token:* This class represents claims on services provided by the issuer of the token. The function of a utility token is to provide an access permission for a certain service, thus it can be seen as an usage token. The role of an utility token is to pay a fee for pay-per-use or access purposes to a platform and as a tool to enrich user experience and reward user behaviour on a platform.
- *Tokenized security:* This class represents digital shares with entitlement to profit-sharing or dividends. It is used as value storage to reward consensus on the platform, thus it is a work token. The role of the security token is to act as reward to shareholders in the Blockchain ecosystem.

Smart contracts

According to Drescher (2017); Gupta (2017); Tapscott & Tapscott (2016), running smart contracts is the most promising development of BT. Smart contracts are computer programs stored in the Blockchain ledger, representing agreements between parties in the form of business logic that is automatically executable and enforceable. This definition can be divided in three parts:

- *Computer programs stored on the Blockchain:* The main purpose of placing the smart contracts on the Blockchain is that the contract is decentralized (Swan, 2015). Therefore, the contract cannot be changed or altered once it is placed on the Blockchain and it can be inspected by every network participant. Similar to transactions that are stored on the Blockchain, smart contracts have a unique address (Christidis & Devetsikiotis, 2016). A smart contract is triggered by addressing a transaction to the smart contract (Christidis & Devetsikiotis, 2016). When the smart contract is triggered, the computer program will be activated. The creator of the contract must include all public key addresses of the nodes that are allowed to trigger the contract (Bashir, 2017). If other nodes send transactions to the contract, the code will not be activated.
- *Agreements between parties in the form of business logic:* A smart contract takes custody over digital assets until the contract is triggered. When the contract is triggered, the computer code that is included in the contract will run. The computer code contains business logic (Bashir, 2017). For example, if the vehicle is on time A at point B, then token 1 will be transferred to person A. If the car is not on time at point B, then token 1 will be transferred to person B. This example shows that a smart contract is deterministic (Christidis & Devetsikiotis, 2016). Therefore, the contract should describe all possible outcomes. Otherwise, the digital assets will be stuck in the smart contract forever (Bashir, 2017).

- *Automatically executable and enforceable:* When the smart contract is triggered, it will run its code automatically. Smart contracts do not rely on the traditional methods of law. They work on the principle of code is law (Bashir, 2017). It means that smart contracts are self-enforcing rather than legally enforceable (Bashir, 2017). There is no need for human judgment to enforce the contract, which allows complete automation (Swan, 2015).

It should be noted that smart contracts mostly require centralized input to interact with the real world. In the previous example, the smart contract need to verify if the vehicle is on time A at point B. The smart contract requires time information and GPS coordinates of the vehicle. This information should be sent to the smart contract. These inputs should be automated in order to achieve trust (Bashir, 2017). Thus, a smart contract requires external data to control the execution of business logic (Bashir, 2017). Oracles are used to feed the smart contract with the required input, without the robust security guarantees that Blockchain technology provides (Adler et al., 2018). An oracle is a trusted entity that sent data to a smart contract in a secure way (Bashir, 2017). The most important characteristic is that oracles are capable to digitally sign the transactions, to prove that the data is authentic. Different types of data can be transmitted by oracles. For example, data from Internet of Things (IoT) devices and data from transport providers, such as availability of vehicles.

Oracles must be trusted. However, it may still be possible that the data is incorrect due to manipulation (Bashir, 2017). For example, a transport provider may alter the GPS data to claim that the vehicle was at point B, while it never reached this point. When the data is sent to the smart contract, it is considered as the truth. This can result in serious trust issues for Blockchains. A solution is to use multiple oracles that provide the same input from different sources to the smart contract (Adler et al., 2018). The main question that still needs to be answered in order to have a fully decentralized Blockchain platform is how to trust the quality and authenticity of the data a third party provides (Bashir, 2017; Adler et al., 2018). Three types of oracles are currently experimented with, namely standard oracles, decentralized oracles, and hardware oracles (Bashir, 2017).

- *Standard oracles:* In some cases it is acceptable to accept data from a trusted third party, such as a large transport provider, because they loose their brand image when they cheat. However, the issue of centralization still exist.

- *Decentralized oracles:* These oracles are based on a distributed mechanism. For example, the transport providers runs a private Blockchain network with distributed consensus, where they store the required GPS data. This data is sent trough the oracle to use it as input for smart contracts on another Blockchain. This is substantially safer than a standard oracle, but manipulation is still possible.

- *Hardware oracles:* Real world data is gathered from IoT devices and sensors. Thus an oracle is included in the device or sensor. However, the device should then be tamper-proof in order to achieve a trusted decentralized source of input for a smart contract.

Concluding, smart contracts automate business logic on a Blockchain. However, they still require input from the real world. In order to have a fully decentralized Blockchain platform, it needs an infrastructure that can run, execute, and verify the smart contracts without a central authority that issues the data. This is a problem that still needs to be solved.

8.5.4 What are the current challenges for the implementation of Blockchain technologies?

Blockchain is a nascent technology. Many different types of Blockchain networks are under development. These types mostly have different technological characteristics, such as different consensus mechanisms. Therefore, it is hard to explain all challenges for the implementation of BT at this stage.

However, BT can be described as the technology of trade offs on several levels. Zheng et al. (2017) identified the levels of scalability, trust, privacy as most often described in Blockchain literature. A recent Master thesis of van den Pasch (2018) shows two additional issues, namely the levels of interoperatebility and governance of the Blockchain.

Level of Scalability

According to (Zheng et al., 2017; van den Pasch, 2018), scalablity is one of the most debated challenges. Immutability results that the Blockchain ledger that is stored at the nodes will always increase in size. Moreover, the transaction throughput of current public Blockchain networks is rather slow and the costs of the transactions is high (van den Pasch, 2018). Scalablity is a trade-off for decentralization. Decentralization requires an complex consensus algorithm. Private or consortium Blockchain networks, might increase the level of scalability (Gupta, 2017). However, these types are more centralized. Solutions that are currently explored are Storage optimization of Blockchain, redesigning blockchain networks to enable sharding (Zheng et al., 2017).

Level of Trust

The level of trust can be divided in three sub characteristics, namely security, finality, and liveness (van den Pasch, 2018). The first characteristic is security. For public Blockchain networks this is high, because the core technology is almost impossible to hack (Zheng et al., 2017). However, in a private Blockchain network it might be less secure due to the smaller amount of nodes and different consensus mechanisms. Moreover, the applications that build on top of the Blockchain networks are vulnerable for hacks when they are not coded correctly (Zheng et al., 2017). Next, the finality of a transaction takes some time, due to the consensus mechanism. Therefore, absolute finality cannot be guaranteed. However, several solutions are currently investigated to solve this issue. The sub-characteristic of liveness is related to public Blockchain networks. The more nodes it includes, the harder it is to stop the creation of new blocks (van den Pasch, 2018). In a permissioned Blockchain network, less nodes are included which might has an effect on the liveness of the network .

Level of Privacy

Maintaining privacy on a Blockchain is currently a difficult challenge (Christidis & Devetsikiotis, 2016). Less privacy is a trade-off for trust. Transactions on the Blockchain are not anonymous, they are pseudonymous. All transactions, including public keys, are disclosed to all network's nodes (Primavera, 2016). This data can be analyzed and the might lead to the identification of an identity that belongs to the public key (Christidis & Devetsikiotis, 2016). Also, the origin of the transaction can be identified (Zheng et al., 2017).

Multiple solutions are currently proposed to improve anonymity of Blockchain networks while maintaining its trust (Zheng et al., 2017). The first solution is mixing of addresses. Transactions from multiple input addresses are collected to one address and from there it will be sent to multiple output addresses (Zheng et al., 2017). The disadvantage of mixing is that there is a central node that should be trusted.

Also, a new public key can be made for each transaction (Christidis & Devetsikiotis, 2016). However, this new address has to be communicated to the counterparty for every transaction.

Moreover, the contents of the transactions are visible in order to validate it. Therefore there is no confidentially of the agreements that are placed on the Blockchain (Christidis & Devetsikiotis, 2016). Several solutions have been proposed to solve this issue (Zheng et al., 2017). For example with homomorphic encryption and zero-knowledge proofs (Christidis & Devetsikiotis, 2016). However, these proposed solutions are resource intensive, which limits the scalability of Blockchains (Christidis & Devetsikiotis, 2016).

In private and consortium Blockchains, privacy can be better guaranteed due to the simplified consensus mechanism and the ability to restrict reading permissions (Zheng et al., 2017).

Level of Interoperability

Different Blockchain networks cannot communicate with each other. Therefore, interoperatebility is impossible without a complementary off-chain solution (van den Pasch, 2018). This might effect the level of trust in the network.

Level of Governance

The governance of Blockchain networks can be split in on-chain and off-chain governance. For public Blockchain networks, the governance occurs mostly off-chain by a selected group of nodes (van den Pasch, 2018). This currently limits full decentralization. For private and consortium Blockchain networks this is also applicable, some party is responsible when the system fails. More research should be conducted to enable fully decentralized governance of Blockchain networks (van den Pasch, 2018).

8.6 Thematic analysis of mobility related Blockchain white papers

The promises of BT are described in previous Sections. In this section, empirical data is used to explore the link with BT and mobility. A thematic analysis is performed on mobility related white papers. These white papers are analyzed according to the steps of Braun & Clarke (2006). The white papers are described in Table 2.3. Out of those white papers four themes relating BT can be extracted. The themes and relevant coding are visualized in Figure 8.6. The identified themes are: automation (8.6.1), store and map transactions (8.6.2), incentivize behavior (8.6.3), and off-chain validation (8.6.4).

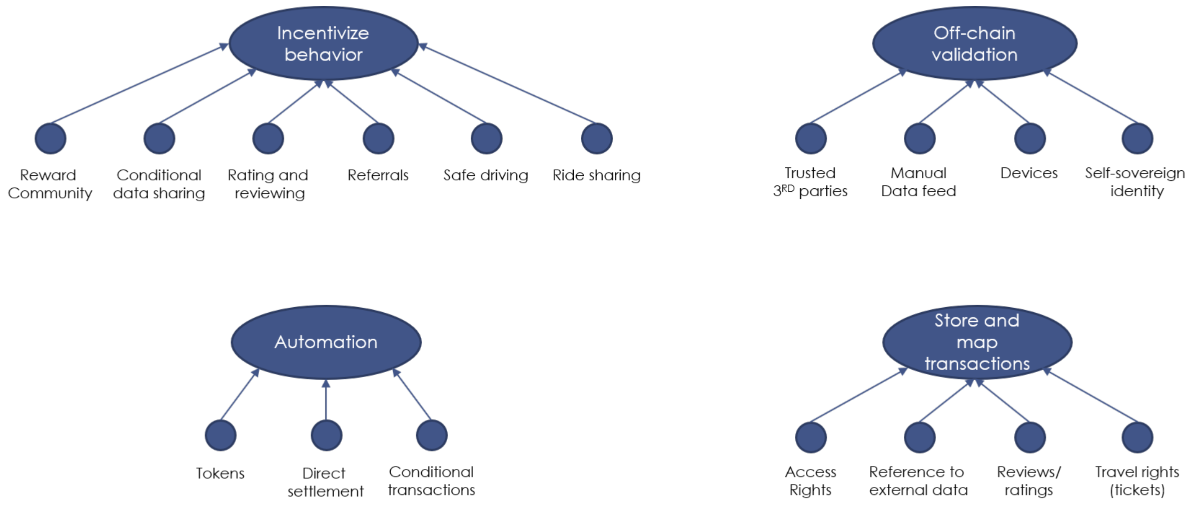

Figure 8.6: Themes identified in white papers. Source: own figure

8.6.1 Automation

BT are used to automate business logic. This is a requirement to substitute the intermediary.

The way this is achieved is by transferring digital tokens that can be tracked on a Blockchain ledger. In the white papers tokens can be divided in two groups:

- The first one is a digital representation of a fiat currency. Thus, tokens can have a value, that is similar to money. In the A2B white paper this is described as *”unified payment method for a trip in any of 46 cities”* and in the MVL white paper it is described as *”MVL Coin can be used to trade goods and services in the MVL Ecosystem”*. The main benefit of using tokens instead of fiat currency is that transaction fees are reduced. This is best described in the Helbiz white paper with the following statement: *that will allow participants to avoid financial transaction fees coming from the use of money in a traditional ecosystem”*. However, volatility is mentioned as major issue for a token that represents currency. A stable token can be used solve this issue. The white paper of Iomob describes this as: *”To avoid exchange rate risk payments are converted to stablecoins (e.g., [Dai]; stablecoins are cryptocurrencies that are pegged to stable assets such as fiat currencies or gold)”*.
- The second one is a token as unique identifier of data. This means that tokens can represent pieces of data that are shared in the network. For example, in the planar network all tickets have a unique identifier as described in the following statement: *”All tickets have a unique identifier that can be reported back to the network upon use”*. Moreover, in the white paper of DOVU, recorded data and personal information are tokenized. This

became evident in the following statement: *"Smart contracts add an additional layer of privacy by tokenizing recorded data and personal information"*.

Tokens are the means to conduct transactions in a world without an intermediary. Transactions in a Blockchain network occur in real-time. In other words, the Blockchain network acts as direct settlement service. For example, a piece of data is immediately exchanged for tokens. This results in additional security which increases trust. This became most evident in the following statement of the VAI white paper: *"By combining a token transfer with, for example, a data request from another car, value can be transferred between entities, while ensuring the value is only transferred when the data request is honored"*. Direct settlement including tokens result in additional flexibility. Due to less transaction fees and a safe transfer, micro payments are possible. The statement that best fit this claim is the following statement of Helbiz : *"The transparency of realized value combined with micro-payments opens opportunities for granular value-based pricing of data"*. Thus, Blockchain technology enables micro payments in return for small amounts of data which were otherwise not profitable.

Also, BT enables conditional transactions. The following statement of the DOVU paper describes the most: *"Smart Contracts to set conditions of use and the level of reward they are willing to offer to data owners, whilst data owners forever retain control to cancel the contracts, change and revoke permissions"*. Additionally, transactions can be placed on hold until verified. This is achieved by escrow smart contracts that hold the tokens until a validation transaction has been occurred. The best explaining statement for this claim is the following of the planar white paper: *"Some tickets allow the Passenger a choice of multiple operators. In this situation the money from the ticket sale could be put in escrow until the Passenger travels and their actual choice of Operator is recorded"*. It also can be used as bond as explained in the iomob white paper; *"All players ignore a stakeholder that attempts to participate in the network without maintaining a sufficient balance in the smart contract; iomob smart contracts hold these funds in escrow"*.

Concluding, automation is achieved by tokenizing both currency and digital assets. This has several advantages, such as less transaction fees. Furthermore, by using tokens, transactions are conducted with direct security which provides additional trust. Moreover, micro payments are enabled by using BT. Lastly, conditional transactions are enabled.

8.6.2 Store and map transactions

As mentioned in the literature review, BT is used as a new way to store and map transactions in order to achieve transparency. Therefore, digital assets are tokenized. When they are tokenized, additional information can be included as transactional data. Not all information should be stored on the Blockchain ledger. This became evident in the white papers. In most concepts that are described in the white papers, access rights to external sources are tokenized and stored on the Blockchain. In the A2B white paper the following statement is most applicable to this claim: *"All the access rights to the data will be managed on a public blockchain"*. Two type sources can be identified in the white papers, namely decentralized storage and vehicles:

- Decentralized storage is a big topic in the white papers. By providing access rights to decentralized storage, the Blockchain will be more efficient and the immutability will be maintained. This became most evident in the following statement of the VAI white paper: *"(...) we make blockchains more efcient by moving many processes off-chain, while still retaining a blockchains characteristic trustworthiness"*. Data that is stored on decentralized storage can be anything. In the DOVU whitepaper, vehicle information is stored: *"The blockchain can store data about the vehicles usage"*. In the VAI white paper, trip information is stored: *"We store data from every trip in a public database"*.

  There is also a possibility to encrypt the data and have selective access rights. This can also be seen as a conditional transaction that substantiated in the automation theme. This following statement of the MVL white paper explains this as: *"In this core layer, the data will be encrypted and will be accessible only if the person who contributed that piece of data gives permission to do so"*.

  This can be used to protect personal information as described in the DOVU white paper: *"This personal information could be encrypted and viewable only by parties that have either the legal right to do so or are being participants of the transactions"*.

  Since, all transactions of tokenized data are stored in the Blockchain ledger. The rightfull owner can see who uses their shared data. The following statement of the A2B white paper describes this as: *"In the near-future Blockchain gives near-real-time insight into where and how data is being used"*.

- Access rights can also be used to connect with a vehicle. This became most evident in the following statement in the DOVU whitepaper: *"The system may also provide connectivity to vehicle functions for remote locking/unlocking doors and engine startup/shut off"*.

External data will have the same immutability characteristics when the content is hashed and this hash is included in transactions in the Blockchain ledger. The claim is best substantiated by the following statement in the MVL white paper: *"Private data will be encrypted on the external distributed storage, with hash references of such private data stored on the blockchain"*.

Also, in many white papers, reviews and ratings will be tokenized and stored in a Blockchain ledger. This results in additional security for travelers. This is best described in the Yantha white paper: *"(...) we will build our review system over smart contracts where all the reviews are stored on public blockchain. Hence the reviews are not controlled by any centralized entity and will never be altered or deleted"*.

Moreover, traffic violations of transport providers can automatically be stored on the Blockchain as mentioned in the following statement of the A2B white paper: *"Violations of road rules will be automatically taken from the respective institutions and placed online"*.

Last and maybe the most important data that can be stored in a Blockchain ledger are travel rights. In order to travel, tokens can be changed for the right to travel certain trips with multiple modes of transport. The following statement of the Planar white paper summarizes this claim as: *"The transaction generates a Ticket which represents the passengers right to travel on the Operator's services"* and *"This Ticket is not a physical coupon but a digital asset that gives them the right to travel on one or more transport providers services"*. The multiple transport providers are only payed when the traveler uses their services, this provides additional flexibility for travelers. Again, this can be seen as a conditional transaction including an escrow contract that is described in the automation theme. The main benefit of this system is that the full pricing and history can be mapped, which increases trust as described in the A2B white paper: *"pricing and trip payment history into the distributed ledger, therefore the driver will not be able to cheat on the client with the price"*. Additionally, users have a immutable travel expense report that they can share when needed. In the VAI white paper, this is described as: *"By saving a history of transactions in the users wallet, a veried record is created"*.

Concluding, only transactions can be stored in the Blockchain ledger. Therefore, digital assets have to be tokanzied. Transactional data of the transactions on the Blockchain can include access rights to decentralized storage, such as vehicle and trip information. Also, conditional sharing of personal information can be managed when it is tokenized. Hash references of external data can be stored in the transactional data, so that the external data has similar immutability characteristics as data stored in the Blockchain ledger. Reviews and ratings is an example of an application that can be tokenized and fully stored in a Blockchain ledger. Additionally, BT enables the creation of conditional ticket rights which is great benefit for users of a Blockchain MaaS initiative.

8.6.3 Incentivize Behavior

There is no central authority that enables the correct functioning of a decentralized function. Therefore, actors should be incentivized to behave accordingly on the platform. This became most evident in the white paper of VAI with the following statement: *"Cryptonomics in this way can be seen as reverse game theory because we start with the desired outcome and work backwards to a design that provides actors with the right incentives to act in line with the interests of the network"*.

This is enabled by using micro transactions, which are explained in the automation theme. The white paper of DOVU describes this as: *"The transparency of realized value combined with micro-payments opens opportunities for granular value-based pricing of reward activities"*. This system of micro transactions also enable other forms of rewards, such as sharing data and change peoples behaviour. This can be derived from the following statement of the DOVU whitepaper: *Changing transport behaviour is one area that works really well through nudge economics, simple changes to habits, a change of route or transport mode, in return for tokens can have huge cumulative benefit"*.

In the white papers, several forms of incentivizing behavior are described, namely: rewarding trustless community, rewarding rating and reviewing, rewarding referrals, reward safe driving, reward data sharing and rewarding ride sharing:

- Rewards are necessary for a trustless community. When there is no central authority, the platform is entirely governed by its users. Therefore, users should maintain the platform and also get rewarded for their services. This is best described in the white paper of DOVU with the following statement: *"Fund encourages community participation and further opportunity to enhance the ecosystem by conducting value-adding activities, such as code audits, building community awareness, helping improve documentation, testing SDK function or answering community questions and being rewarded with tokens"*.

  Also, the nodes in the network that validate transactions and keep a record of the

Blockchain should be compensated in order to attract more nodes. This is best explained by the following statement of the VAI white paper: *"To incentive people and organizations to run nodes, a tiny transaction fee in VAI will be charged. The transaction fee is based on the size of a transaction. The goal of this transaction fee is to compensate for the energy used by the processors to validate transactions". In this statement, the rewards are payed by using small transaction fees. This is also the main view in the white papers".*

- As mentioned earlier, ratings and reviews on the Blockchain are used for additional security. Each review and rating can be rewarded with tokens as explained in the MVL white paper: *"If reviews are given by customers, who will be rewarded for doing so, drivers will get an incentive which will boost the service quality"*. On the other hand, travelers can also be encouraged to rate and review by giving back a small portion of the ticket price as mentioned in the statement of Yantha: *"A small portion of ride charge will be reserved as cash back for carpool host and guest rider"*.
- Similar, actors can be attracted to the platform by using a reward bonus. This is best described in the Yantha white paper: *"Here, at Yantha, we firmly believe that the reward for work well done is the opportunity to do more, and hence we have devised a system which will not only provide the referrer with immediate benefits, but will act as an egg in the beer for him throughout the entire year.*
- Drivers can also be encouraged to drive safe. This claim can be substantiated from the following statement in the MVL white paper: *"The vehicles data will be properly managed as accurate and consistent data regarding incidents such as an accident will be recorded. The ecosystem will reward those who drive safely"*.
- In centralized platforms, data is used to optimize the services of the platform. Data will be collected of each input of the user or device. However, in a decentralized platform, no data is stored on central servers and owners of the data are in full control of the data they accumulate and share. Therefore, an incentive mechanism should be created to share data to third parties in order to optimize the services provided through the platform. Almost all white papers claim that the owner of the data is in full control of their data and the sharing of this data should be rewarded accordingly. The statements that validates this claim is from the Helbiz white paper: *" (...) enables a new kind of mobility data marketplace where Helbiz aims to provide users with seamless options through the application to share their data with 3rd parties in exchange for tokens"*.

  However, some of the accumulated data is highly sensitive, such as personal information. Therefore, the sensitive information should be excluded from sharing. Therefore, a protocol should be made with conditions for sharing data. This is best described in the Iomob white paper: *"the protocol will set rules on what information can or must be released, under what conditions, and the associated exchanges of value"*.
- Lastly, ride sharing can be incentivized by using tokens. This can be a reward for offering a ride. This claim is best described by the following statement of the Yantha white paper: *"As a result, many carpooling apps spend a lot of time in acquiring new customers who*

> *will be host drivers, while we believe retaining them is what will truly solve the problem. We solve this problem by Proof of travel, ie. even if a host driver is not able to find a guest rider, he is still rewarded in the form of ridecoins hence motivating him to share ride details resulting in more active rides on the platform".* Or rewarded to use a shared service, as described in the statement of Iomob: *"End-users will receive cryptoincentives in the form of IOM tokens. These tokens will only be redeemable to obtain discounts on payments to service providers that operate on the iomob network".*

Concluding, there are endless possibilities to incentivize behavior in a Blockchain network. This is mostly referred as cryptonomics or tokenomics. In the white papers, several options to incentivize behavior can be found. Some are mandatory in order to enable a decentralized platform, such as rewarding trustless community. Others can be used to change behavior of travelers, such as rewarding ride sharing. However, the tokens that are used to reward behavior must be payed for, for example with transaction fees.

8.6.4 Off-chain validation

The last theme that can be found in the white papers is off-chain validation. This is a requirement to automate transactions. The main problem of Blockchain is that data that is once stored on the Blockchain is immutable. Therefore, trusted entities, mostly referred as oracles, are required to bring and validate external data onto the Blockchain. For example, smart contracts are only triggered by transactions with the required information. This claim can best be derived from the following statement from the DOVU white paper: *"(...) connect to the DOVU blockchain platform using Oracles, unlocking benefits such as smart contracts, secure/trusted transactions, conditional reward systems, micropayments, and novel alternatives to standard authorization in all kinds of mobility services".*

Oracles can be seen as data feeds to enable transactions on the Blockchain. This implies that transport providers have to open up data related to the trips they offer. This can be derived from the following statement: *"Other types of actors such as taxi companies, public transportation companies can also join and offer their services".* A more direct statement can be found in the white paper of A2B: *"Drivers will have to open their data to be able to use A2B Taxi platform benefits".* However, this data can also be conditionally shared, as described in the store and map transactions theme. An example of data that must be shared can be found in the following statement of Iomob: *"verifying whether a particular taxi can perform service a specific day of the week or other arbitrary regulations on the industry".*

By using this method, the transport providers act as trusted 3rd party that can validate transactions by providing the required data as input. The authenticity of the data should be trusted. Several other trusted 3rd parties are required to enable the solutions in the white papers. For example, each offered service should comply with the regulations of a certain authority. In this case, authorities should validate that the offered service is indeed complying with the regulations. They should provide proof of compliance. In the Iomob white paper, this is described as: *"The organization running a hub establishes relationships of trust with compliance validators that are in charge of actually verifying mobility providers, and a hub only trusts mobility providers that have been vetted by validators it trusts".* Another trusted third party that can be found in the white papers is a cryptocurrency exchange. Tokens have to be bought and sold to fiat currency by users of the platform. The following statement of Iomob best affirms this claim: *" (...) payments by end users are made using fiat currencies"*.

There are also manual data feeds required for some of the solutions that are proposed in the white papers. For example, rating and reviewing drivers. This is substantiated from the following statement of Yantha: *"motivating both to review each other, by sharing their ride experience and increasing authenticity for the community"*. However, this is prone to errors and false inputs. Therefore, some sort of proof of a valid review should be included.

Instead of using a trusted third party or manual input, devices can validate transactions. Devices can provide the data that is required to enable automatic transactions. This is best described by the following statement of Helbiz: *"The Helbiz Module can store vehicle usage data and information about vehicle owners, drivers and passengers. This profile information can help validate a smart contract between two parties and manage the payment of services between them without the need for a financial intermediary, thus saving transaction fees"*. This is a solution to reduce false data in the Blockchain ledger. However, the devices should be secured in order to make sure that the data cannot be altered. For example, in the Yantha white paper, GPS is encrypted: *"GPS parameters are always kept encrypted and data is transferred over secured protocol https, making platform more secure and hacker-proof"*.

Moreover, a concept that is mentioned in almost all white papers is proof of identity. Identity is used to digitally sign transactions. Identity is also required to validate users. This can be derived from the statement of the Iomob white paper: *"Conversely, a validator may also verify the identity of a user and that, for example, they are in possession of a valid drivers license and of legal age in connection with a car rental, or an active cell phone number"*. However, this results in privacy issues. A self-sovereign identity is the solution to privacy issues. With a self-sovereign identity, users have complete control over their personal data, as described in the following statement of Iomob: *"To manage identities within the network, we aim to use Hyperledger Indy [5]. Indy is a project that provides a distributed-ledger-based foundation for self-sovereign identity and will be used to give users complete control over their personal data"*. It can also solve the issue of a public key that can be linked to a person. This is described in the following statement of the Planar white paper: *"The Passenger does not have to be aware that they have a digital wallet on the Blockchain network and as there is no practical upper limit to the number of wallets available, a new wallet can be created for one-off transactions"*. Also, a self-sovereign identity can be used to proof that a user has a valid document without revealing the document, this is mostly referred as zero-knowledge protocol. This statement is substantiated from the following statement of the VAI white paper: *"veried proof they have a drivers licence, without actually handing over the drivers licence to a third party"*.

Concluding, in order to have automated conditional transactions, data feeds are required to interact with the real world. Sources of data might be trusted third parties, users, or devices. This brings several challenges on the table. The data source and the data itself should be validated in order to maintain trust on the platform. Identity should also be validated. However, this is privacy sensitive. A solution is a self-sovereign identity.

8.7 Conclusion

In this chapter, the promises of Blockchain technologies are explored. It started with a Section about software systems. Blockchain technologies can be seen as part of the implementation layer of a software system. The purpose of Blockchain technology is to maintain trust in a decentralized network. This network is created around a Blockchain ledger. Only transactional data can be stored and shared in this ledger. Blockchain technologies provide the rules and standards that enable politically decentralized distributed ledgers. It is different, because Blockchain technologies provide the tools for a political and architectural decentralized system. However, this is not always fully implemented in Blockchain networks. Therefore, several types of Blockchain networks exist, namely public, private and consortium. Only the public Blockchain network aims to be as politically decentralized as possible. Transactions are included in Blocks, these blocks are linked to the previous block by cryptographic hashing. The content of the block is validated by all nodes in the network through a consensus mechanism. Public Blockchain networks require more difficult consensus mechanism than the other types. An asset is tokenized in order to be included in the ledger. This means that a token represents an asset, and the transactional data of this asset is stored and shared on the ledger. Also smart contracts can be stored as transaction in the ledger. This is basically a contract that takes temporary control over a token and sent it to another node in the Blockchain network, when the conditions of the contract are met. The main problem of smart contracts is that smart contracts rely on centralized input to interact with the real world. The biggest challenges for implementing Blockchain technology in the real world are scalability and privacy.

Thus, the promises of Blockchain technologies can be summarized as follows: they to provide the tools for a fully decentralized ledger where a digital representation of an asset can be shared with untrusted participants within the network, and this transaction can be conditioned with business logic that is included in a smart contract. Once the data is included in the Blockchain ledger, it can be seen as the truth. However, Blockchain requires input of real world data, which lacks the security characteristics of sharing data in Blockchain networks.

The last part of this chapter consisted of a thematic analysis of mobility related Blockchain white papers. Four themes are identified, namely: automation, store and map transactions, incentivize behavior, and off-chain validation. The first three themes can be linked to the promises of Blockchain technologies. The last theme shows that there is always a connection with the real world, this is the boundary of the solutions that Blockchain technologies are able to provide. In the next chapter, the promises of Blockchain technologies and the link with the identified risks of MaaS are discussed.

9

Discussion MaaS and Blockchain technology

In this Chapter, Part II and III of the research are discussed in order to provide insights on Blockchain and MaaS. By using the results of Chapter 8, a discussion can be started on how BT might enable the realization of a MaaS platform. The risks of a MaaS platform are summarized in Table 7.1. The red risks in this table are the most substantial risks. In this chapter a discussion is started on how those risks might be reduced by using BT. The red risks are: brand image (9.1), operational cost (9.2), inclusion of the needs of end users (9.3), ride sharing and behaviour change (9.4), integration of ticketing systems (9.5), open data (9.6), data ownership (9.7). This chapter is finalized with a conclusion and a new table that also includes the BT solution (9.8).

9.1 Brand image

The fist red risk is the execution risk of brand image. Based on the results of the thematic analysis, there is no evidence that BT might reduce this risk. Although, a Blockchain based referral system might attract users and create awareness of the platform. However, referral systems can also be created without the use of BT.

9.2 Operational cost

The second execution risk is operational cost of the platform. This risk might be reduced by using BT. Automation, a theme that is substantiated in the thematic analysis, might result in lower operational cost. By using tokens and smart contracts, many business logic can be automated. Moreover, micro-transactions are possible whereby expensive bank fees are substituted. Thus, there is evidence that BT results in less operational cost.

However, limited information is available how much it would cost to run the nodes and the Blockchain network. It depends on which Blockchain network type is used for the platform. With a fully decentralized public Blockchain network, the nodes in the network have to achieve consensus which requires much computing power and energy. Therefore, transaction fees might be unnecessary high. The main reason for this complex consensus mechanism is that anyone can be a node. Additionally, a public Blockchain network is not yet capable of handling large amounts of transactions. This can also limit the throughput of transactions. The main benefit of a public Blockchain network is that it will not be controlled by the goals of a central profit-orientated group. Therefore, no commissions that most platforms use to compensate the shareholders are required.

With consortium or private Blockchain networks, the owners of the network might choose a less complex consensus mechanism. Thus, requiring less computing power and energy. The main reason is that the nodes are selected or voted for by the users or owner of the platform. Therefore, transaction fees might be lower than a public Blockchain network and the transaction throughput is higher that a public Blockchain. However, this leads to a more centralized system, that is less immutable.

Additionally, the amount of nodes might have an effect on the transaction fees. Each added node in the Blockchain network stores and broadcasts the entire Blockchain ledger. Moreover, the community has to maintain the platform and they will be rewarded for their services. This might increase the transaction fees as well.

Concluding, BT reduces operational costs by automating transactions. However, it is still unknown how much the fees will be reduced. It depends on the design of the platform and the type of Blockchain network used. Therefore, the color of the risk will be reduced to yellow by using BT.

9.3 Inclusion of the needs of end users

More research should be conducted on the needs of the users, as became evident in MaaS literature. As mentioned in the thematic analysis, BT can be used to create a marketplace for travel data or to make the data publicly available or for a small fee to compensate the users that provide their data. The platform substitutes the intermediary. Therefore, the data can be used by any actor in the network in order to optimize the services on the platform and create more services that meet the needs of end users.

Additionally, the barriers for entry on the platform are lower. Without an intermediary, the only actors in the network that can refuse a new player to participate in the network are regulators and policy makers. Therefore, even small transport providers that fill a particular niche can provide their services to the platform. Moreover, lower barriers to entry result in increased competition. This will stimulate innovations and services that better fit the needs of the users.

Concluding, the needs of the users are not yet clearly defined. However, BT eliminates data harbouring. The data can be used by all actors in the network to improve the services to fit the needs of the users. Moreover, low barriers to entry result in perfect competition. Therefore, the needs of the user must be the goal of the platform instead of the goals of a central profit-orientated group. Thus, by using BT the risk of the inclusion of the needs of end users will be reduced to a yellow risk.

9.4 Ride sharing and behavioural change

BT provides the technological architecture required to enable ride sharing and behavior change. One of the key themes that emerged in the white papers is to incetivize behaviour. There are endless possibilities to incentivize behavior on the platform. Evidence can be found in the white papers that ride sharing can be incentivized using BT, by stimulating both drivers and travelers. Also behavior of drivers can be incentivized as well, to indirectly stimulate ride sharing, such as: reward safe driving, ratings, and reviews. Which provides additional trust for travelers.

The only limitation is that a reward mechanism should be balanced to maximize behaviour change, while minimizing the transaction fees to pay for the behavior change. For example, less sustainable options may be taxed to pay for the reward system. However, if these rides are becoming too expensive, it might has an effect the attractiveness of the platform. An optimal balance should be found.

Since incentivizing ride sharing is specifically mentioned in many white papers, and incentivizing behavior is one of the key themes in BT, it can be argued that the color of the risk will be changed to green by using BT.

9.5 Integration of ticketing systems

The risk of integrating ticket systems is also influenced by using BT. The most interesting application is that travel rights can be created stored on a Blockchain ledger. These travel rights can be transformed to a QR-code which can be read by ticketing systems. Also, interoperability with current ticketing systems can be achieved by showing the travel right to the transport provider who can create a valid ticket based on this travel right.

BT partly solves the problem of the inflexible fares. As mentioned in the white papers, several mode options can be included in a travel right. For example, a train and bus ride can be included in the same ticket. Also, a bond is required in order to travel, which reduces the risk of invalid tickets. However, transport providers still have to create flexible fares that enable mode switching without high minimum fares. Therefore, the co-innovation risk still remains. However, BT provides the tools to manage the integration of ticketing systems. Therefore, it can be argues that this risk will be reduced to a yellow by using BT.

9.6 Open data

The risk of closed data is still valid when using BT. A functional Blockchain network requires large amounts of data to verify transactions and smart contracts. Oracles are used to share the data to smart contracts. Transport providers still have to open up data related to the trips they offer. In MaaS literature opening pricing data of the trip is identified as major issue.

By using BT, (pricing) data can also be conditionally shared only to the traveler, who requires the data. For example, a fare is only shared with the traveler that asks for it. However, this is only possible when the transport operator can be seen as a trusted third party. When private vehicle owners or not trusted third parties are included, the fares should be more transparent. Ideally, this is stored on a public Blockchain.

Increasing privacy on a Blockchain is currently a major topic for research. An example of a solution that is currently studied is a zero-knowledge protocol. Oracles can provide only yes or no statements to validate a transaction instead of providing the full location. For example, a smart contract needs to verify if a vehicle is at a certain location. The oracle that provides the GPS location can sent a yes or no answer to the smart contract.

Moreover, conditional data rights can be used provide access to route information of vehicles that are nearby the traveler. This data can be used for dynamic route planing of the user.

Conditional data rights for transport providers are also better protected in a consortium Blockchain rather than a public Blockchain. However, this results in a more politically centralized system. A balance between privacy and decentralization should be found

As can be derived from this part, BT can be used for conditional data sharing. This might facilitate transport providers with the tools to open up their data in a secured way. However, conditions for data sharing and standards are still required. Therefore, the risk is reduced to a yellow risk.

9.7 Data ownership

BT substitutes the intermediary for a MaaS platform. As mentioned in Chapter 8, central intermediaries are harbouring data of individuals that have to use those software systems, and invade user privacy for commercial gains. BT facilitates transactions without the use of intermediaries. Therefore, the data required for a functional platform is not stored, maintained and shared at a central authority. Storing, maintaining, and sharing of data is now the responsibility of the data providers, such as third parties, users, or IoT devices.

BT provides the tools for conditional sharing of data. For example, access rights for decentralized data can be managed on the Blockchain. For travelers, this means that they can control what personal data they want to share with who. For example in several white papers, a digital marketplace is created to incentivize sharing travel data with transport providers in return for rewards. The travelers can choose to share this data, it is not mandatory.

However, a major issue for BT is the validation of data that is not stored on the Blockchain. The quality and authenticity of data that users provide must be validated. A validator is required to validate data that is not stored on the Blockchain. For example, proof of identity is required for some of the projects in the white papers. The validator must be a government that can guarantee that the driver has a valid drivers license. The validations can be stored at a decentralized database. These validations can be hashed and this hash can be stored on a public Blockchain. Thus, when the validation file is changed, the hash of the file and the hash reference will be inconsistent. This will provide similar immutability characteristics as data stored on a Blockchain ledger.

Moreover, storing only the hash values of the files makes it possible to use zero-knowledge protocols, that minimize the information shared and add additional privacy for users. This is also applicable for oracles that share data with smart contracts. This data needs to be validated as well, because once it is included in the Blockchain, it cannot be altered.

Validation and privacy issues are currently researched by organizations and scholars.

Thus, the question of who owns the data in a Blockchain enabled platform can be answered with the provider of the data. This is a result of disintermediation, conditional data sharing capabilities, and decentralized storage of data. Therefore, the data ownership risk is reduced to a green risk.

9.8 Conclusion

In this Chapter, the red risks and how BT might reduce these risks is discussed. The writer argues that brand image is the only risk that remains red. Furthermore, BT might be an interesting solution to stimulate ride sharing and for data ownership. Therefore, those previously red risks now turn green. The other risks turn yellow, because BT may be part of the solution, but it cannot solve all problems of that risk.

Most risks are reduced by using BT. However, it is important to note that Blockchain is still a nascent technology. Therefore, the full implementation of BT in a MaaS platform should be further studied. Several design choices have to be made before a Blockchain MaaS platform will be successful. Also, there are still some limitations, such as privacy and scalability that need to be solved. Thus, including BT results also in a higher risk for technology architecture of the MaaS platform, which turns from green to yellow.

The results of the discussion are summarized in Table 9.1

Risk	**Type of risk**	**Related actors**	**Risk category**	**Risk category Blockchain**	**Identified Solution**
Technology Architecture	Execution	MaaS operator	Green	Yellow	More research to reduce the limitations of Blockchain technology
Brand image	Execution	MaaS operators	Red	Red	-
Operational costs	Execution	MaaS operators	Red	Yellow	Automation
Inclusion of the needs of end users	Execution	MaaS operators	Red	Yellow	Barriers to entry
Ride sharing and behaviour change	Execution	MaaS operators	Red	Green	Incentivize behavior
Ticketing systems	Co-innovation	Transport providers	Red	Yellow	Travel rights
Open data	Adoption	Transport providers	Red	Yellow	Conditional data sharing
Data ownership	Adoption	Transport providers	Red	Green	Disintermediation, conditional data sharing capabilities, and decentralized storage of data

Table 9.1: Impact Blockchain technology on identified risks of a MaaS platform.

10

Conclusion

In the first section the research questions are answered (10.1). With this information, the main research question can be answered (10.2). Due to the exploratory nature of this research, several directions for further research can be identified (10.3).

10.1 Sub questions

The first research question is *How may the realization of a MaaS platform be assessed?*

The actors in the core business have different expectations of the goals of a MaaS platform. In a viable value proposistion all actors should at least benefit from the new innovation. Therefore, an ecosystem approach is most interested to assess the realization of a MaaS platform. Adner (2012) proposed an innovation ecosystem theory that is focused on a value blueprint. The value blueprint is an iterative process of finding the optimal solutions for a successful value proposition of an innovation. It is a structured way to assess the ecosystem around an innovation.

Since public actors are included in the core business, not only economic value should be included in the value proposition. Value that is relevant for public actors is named public value. Public value focuses not only on the creation of economic value and delivery of services, but also the impacts on wider society.

The main critique on the value blueprint of Adner (2012) is that the identification of actors in the ecosystem depends on specific cases, and therefore the selection of actors is subjective (Almeida et al., 2015).

Therefore, a generalized value blueprint is proposed by the author of this research. The steps of this value blueprint are described in Appendix A.3. The main difference between the value blueprint of Adner (2012) is that the actors in the ecosystem are limited to the actors identified in the core business of MaaS. Also, the last steps consist of the iteration of the steps. This iteration is conducted in part III of the research by introducing Blockchain technology.

This assessment worked well for the assessment of literature that is based on different MaaS pilots. It provides first insights of the main ecosystem risks of the innovation in a structured way. However, it should be noted that it is unusable for practitioners if they want to use this for their own MaaS project, because case specific risks are neglected by the model. For specific cases, the value blueprint of Adner (2012) should be used.

The second question is: *What ecosystem risks that obstruct the realization of a MaaS platform can be identified in MaaS literature and what is the score of those risks?*

Several ecosystem risks can be found in MaaS literature of several MaaS pilots. Firstly, it should be noted that the pilots have no specified target group. It means that the pilots are mostly focused on creating a working digital platform, rather than a user-centric approach.

The ecosystem risks can be divided in execution risk, co-innovation risk, and adoption risk. What stands out is that the technological architecture execution risk is green. Which means that the elements are already in place. This implies that the realization of MaaS is particularly an organizational challenge rather than a digital challenge.

This is emphasized with the identified red risks. The red execution risks are brand image, operational costs, inclusion of the needs of end users, ride sharing and behaviour change. The red co-innovation risk is integration of ticketing systems. The red adoption risks are open data and data ownership. Integration of ticketing systems is the only red risk with a technical nature. The red risks should be reduced first, before analyzing the yellow and green risks. The green and yellow risks, identified in MaaS literature, are summarized in Table 7.1. Due to the scope and time, this research is focused on reducing the red risks. A green risk is not implying that a MaaS platform will be successful, it means that the ecosystem risks are controllable.

What are the promises of Blockchain technology and how may it enable a MaaS platform?

Blockchain technology is a rather complex technology that aims to solve organizational problems in a network of untrusted participants. Blockchain technologies can be included as a part of the implementation layer of a software system. Therefore, it might contribute to a solution, but it will not provide the full solution.

The promises of Blockchain technologies are to provide the tools for a fully decentralized ledger where a digital representation of an asset can be shared with untrusted participants within the network, and this transaction can be conditioned with business logic that is included in a smart contract. Decentralization is required in order to meet the needs of all actors in the ecosystem.

The results of the analysis on mobility related Blockchain white papers show that Blockchain is used to incentivize behavior, for automation purposes, and to store and map transactions. Moreover, also a theme emerged, that shows the boundaries of the solutions that Blockchain technologies are capable to provide. This theme shows that off-chain validation required for data that is shared on the Blockchain. The main problem is that the data source and the data itself, that is extracted from the real world, should be validated in order to maintain trust in the Blockchain network.

10.2 Main research question

The main research question is: *How may Blockchain technology enable the realization of a MaaS platform?*

The realization of a MaaS platform is difficult to achieve. Mainly, due to organizational risks that obstruct a viable value proposition. The main problem that defined in the introduction is the integration and utilization of data that is required for the realization of the MaaS platoform. Blockchain technology directly affects the integration and utilization of information.

By using Blockchain technologies, new solutions can be proposed that affect the identified red or most critical ecosystem risks. These solutions cannot be created without the use of Blockchain technologies. Therefore, it can be argued that Blockchain technologies partially influence the realization of a MaaS platform. Several statements can be formulated out of the results of this research:

The results of this research show strong evidence that Blockchain technology can be used to stimulate ride sharing by incentivizing behaviour. Tokens can be used to reward both the traveler and the driver for providing and using these services.

Moreover, strong evidence is found that Blockchain technologies can be used to reduce the the data ownership risk of the platform. The solution that Blockchain technologies provides is the combination of disintermediation, conditional data sharing capabilities, and decentralized storage of data.

Furthermore, the results show contrasting evidence that operational costs are reduced when Blockchain is used. The solution is that several transactions can be automated. However, the running cost of a Blockchain network are still unknown and depends of the type.

Moreover, evidence can be found that the needs of end users are taken into account when using Blockchain technologies, because it eliminates data harbouring. Therefore, the barriers of entry are lower for transport providers to participate in the network. The data can be used by all actors in the network to improve the services to fit the needs of the users.

Next, the results of this study show that integrating ticket systems is also influenced by using Blockchain technology. The solutions proposed is that travel rights can be created stored on a Blockchain, and this can be used as proof of ticket. However, one of the main problems of integrating tickets, namely inflexible fares, cannot be solved by using Blockchain technologies.

Blockchain technology can be used for conditional data sharing. This might facilitate transport providers with the tools to open up their data in a secured way. However, conditions for data sharing and standards are still required. Therefore, Blockchain technologies only provides a part of the solution required to enable open data.

However, Blockchain technologies are still in development and no main or best Blockchain technology can be identified, yet. Thus, using Blockchain technologies will increase the technology architecture risk.

10.3 Suggestions for future research

Several suggestions for future research can be derived from this thesis:

- It is still unknown to what extent different target groups are willing to give up their cars and current travel behaviour, if there is a proper MaaS platform available. Therefore, this should be researched in order to find the most relevant target groups for MaaS.
- The definition of MaaS and the views of the different actors should be further explored, in order to identify the best candidate for the MaaS operator and the goals of the platform.
- Current research is mainly focused on the realization of MaaS and integration of transport modes. However, the needs of the end users should be further explored. A bottom-up approach for MaaS might be an interesting topic to research. Also, minimum required reward to steer behaviour should be researched.
- A more in depth case study on the risks of one or multiple of the MaaS pilots in the Netherlands is interesting to research. Those risk might also be reduced by using Blockchain technologies.
- Brand image is the only risk that remains red when Blockchain is introduced. A research to explore solutions to solve this risk is necessary.
- 5G networks and autonomous vehicles are also identified as promising solutions for MaaS, the impact of these technologies should be further researched. Perhaps a combination of those technologies, including Blockchain, may reduce many risks of enabling a MaaS platform.
- Conducting a research to diminish the limitations and the hurdles of implementing Blockchain technologies in a MaaS platform is interesting.
- Compatibility with other technologies should also be further explored, such as cloud computing.
- Solutions for the identified yellow risks should be explored in future research in order to reduce the risk to a green risk.
- Facilitating open data is still a major issue. This is not only applicable for MaaS, but for all data driven smart city initiatives.
- A minimum viable product (MVP) can be researched to assess if all solutions proposed in this thesis are feasible in the real world.
- More research should be conducted to enable fully decentralized governance of Blockchain networks. Additionally, research should be conducted on maintaining privacy on the Blockchain and how to scale the transactions on the Blockchain. Moreover, the validation issues and the interaction with the real world should be further investigated in future research.

- More research must be conducted on a fully decentralized ecosystem around the Blockchain network, such as decentralized storage.

A

Appendixes

A.1 MaaS pilots in the Netherlands

The pioneers of actual MaaS pilots are Sweden and Finland. Both countries have a different approach to MaaS. Finland is focused on enabling a new transport paradigm, while Sweden is more focused on reducing the negative externalities of the current transportation system and achieving societal goals (Smith et al., 2017). Therefore, the developments of MaaS in Finland have more market-driven characteristics in relation with the developments in Sweden (Smith et al., 2017). The most known and first real MaaS pilot was the UbiGo project in Gothenburg, Sweden. This initiative is part of the Go:smart project, a collaborative project with participants from academia, business and society and for the majority funded by the Swedish government (lindholmen, 2018). The aim was to develop and test an innovative travel broker service that facilitate and reward sustainable travelling in urban areas (lindholmen, 2018). Because of the setup of the project, a large amount of documents and scientific papers is available about the project. . In Finland a start-up, named MaaS Global, created the first commercial MaaS platform (Smith et al., 2017). This start-up commercialized in 2016 by introducing the Whimapp in the Helsinki region (Global", 2018). This start-up is still in pilot phase. In the Whimapp travelers can buy a subscription that delivers all their transportation needs. The company is owned by several large shareholders, including Transdev, which is a large public transportation provider and a Turkish vehicle manufacturer (Global", 2018). MaaS Global wants to expand to other cities in Europe, including Amsterdam. However, no start date for the pilot is announced yet (Global", 2018).

In the Netherlands, there are some small scale MaaS start-ups. Mainly focused on Business-to-Business (B2B) services, an example is Beamrz. This start-up is struggling around their business model, especially the business-to-consumer (B2C) market. For example, the Beamrz platform only includes ride sharing at the moment Beamrz (2018). Therefore, more pilots and research is needed to introduce MaaS in the Netherlands. Currently in the Netherlands, several MaaS pilots are initiated by local governments and the Ministry of Infrastructure and Water Management (IenW), in order to conduct more research on the feasibility of MaaS (Bakker, 2018). Similar to the Ubigo project, the pilots will be extensively researched, monitored and evaluated. The overarching aim of the projects is to enable and upscale the pilots to a national level (Bakker, 2018). However, the pilots have all different characteristics and various goals. The first pilot is located in the south of the province of Limburg. The aim of this initiative is to have border-less, flexible, and sustainable mobility. The second pilot is located in the city of Utrecht. This pilot aims to reduce car use and expand other modes of transport. The third pilot is located in the city of Amsterdam. The goal is to retain accessibility of the Amsterdam Zuid-as without relying only on cars, due to many planned road constructions around this area. The fourth project is located in the province of South-Holland, in the area of Rotterdam-The Hague airport. The aim of this pilot is to ensure the connectivity of the region in a sustainable, inclusive, and multi-modal way. This pilot differs from other pilots, because the additional goal is to up-scale the pilot to other airports. The fifth pilot is located in the city of Eindhoven. The aim of the pilot is to become carbon-neutral as a city, by introducing an emission free MaaS platform for employees of the municipality. The sixth pilot is located in the provinces of Groningen and Drenthe. The aim of this project is to provide an open MaaS platform for urban depopulated areas, that result in a better and cheaper transportation alternatives. The last pilot is located in the Twente region in the east of the Netherlands. The goal of this project is to keep the region accessible, while keeping the costs at a civil acceptable maximum. The seven pilots would be great research for MaaS and Blockchain technology. However, during the start of this research, the projects are in the early stage of development and no concencus is achieved yet on the design of the pilots Bakker (2018).

A.2 Steps to construct a value blueprint.

1	Identify your end customer.	Who is the final target of the value proposition?
2	Identify your own project.	What is it that we need to deliver?
3	Identify your your suppliers.	What inputs will we need to deliver?
4	Identify your intermediaries.	Who stands between us and the end customer?
5	Identify your complementors.	For each intermediary, does anything else need to happen before this intermediary can adopt the offer and move it forward to the end customer
6	Identify the risks in the ecosystem.	What are the co-innovation risks and adaption risks for this element?
7	For every partner that is not green.	Work to understand the cause of the problem and identify a viable solution.
8	update the blueprint regulairy	It is a live document.

Source: (Adner, 2012)

A.3 Steps to construct a generalized value blueprint

- **Step 1:** Identify the possible end users.
- **Step 2:** Identify the minimum characteristics to which the project in the ecosystem must comply.
- **Step 3:** Identify the main actors in the ecosystem and label this actor as supplier, intermediary, or complementor.
- **Step 4:** Identify the risks in the ecosystem and what underlying causes can be found for these risks.

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