Mobility-as-a-service – The expected effects on sustainability of transportation and system features

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Abstract

The European Green Deal that went into force in July 2021 has significantly changed the needs of transportation services. Due to this the Mobility-as-a-service (MaaS) concept and its effects on the sustainability of transportation services should be researched and examined to what extent the MaaS-concept will be able to contribute to reducing private vehicle kilometres and to increasing the share of sustainable transportation modes following the goals set by the Finnish government.

This thesis creates a literature review to study the MaaS-concept and the effects of MaaS-services on the sustainability of the transportation system, answering the research questions: Are MaaS-services capable to decrease the number of private vehicle kilometres, What are the central factors affecting the environmental sustainability of the MaaS-services, What are the most critical factors affecting the success of MaaS-services and What system features are supported to be implemented by the MaaS-research? The results of the literature review are used in creating a list of system features supported by the MaaS-research, fulfilling the first two steps of Design Science Research Methodology.

MaaS-concept is capable in reducing private vehicle kilometres but is limited to acting as a complementary transportation mode alongside private cars. This effect is affected by a number of contextual factors. Environmental sustainability of MaaS-service is affected by the cooperation between MaaS-stakeholders. The success of MaaS-services is affected by issues in achieving profitable business model, the users' lack of willingness to pay and the cooperation between the MaaS-stakeholders. The thesis includes a list of 51 system feature-requirements supported by MaaS-research. These results provide a base for MaaS-service development and highlight key factors to consider while creating new MaaS-services.

Keywords
mobility-as-a-service (MaaS), ride-hailing, sustainable transportation, private car, transportation, sustainability, literature review, narrative literature review, design science research, sustainable information systems, sustainable human-computer interaction, sustainable interaction design

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Foreword

I would like to thank Dorina Rajanen for all the enormous help with writing this thesis throughout the past year.

I would like to thank my family for supporting me through the university and metaphorically speaking, keeping my bicycle on the road even in the most terrible winter weather.

Most importantly, I want to thank Beatriz for having the patience to listen through all the nights of me complaining “não quero escrever meu livro”, while endlessly encouraging me and keeping me motivated throughout the long and demanding writing process.

Obrigado.

Joona Kallio

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Abbreviations

API – Application Programming Interface

DPM – Data Privacy and Management

DSR – Design Science Research

DSRM – Design Science Research Methodology

EC – European Commission

EU – European Union

GC – General Concept

GDPR – General Data Protection Regulation

HCI – Human-Computer Interaction

HSL – Helsinki Region Transport

IS – Information Systems

MaaS – Mobility as a Service

PBD – Payment and Bundle Design

PER – Personalization

RQ – Research Question

SF – Service and Functionality

SID – Sustainable Interaction Design

SSO – Single Sign On

URA – Usability, Reliability and Accessibility

Contents

1. Introduction

The European Green Deal was released to the public on 11th of December 2019 and was made into a regulation for the countries of the European Union (EU) called "Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law')". The regulation went into force on 29th of July 2021 and had all the 27 European Union Member States commit to turning European Union into climate neutral continent by the year 2050. (European Climate Law, 2021.) The regulation binds the European Union to target reducing domestic greenhouse gas emissions by at least 55 percent compared to the level of 1990 by the year 2030, and to reach the overall climate-neutrality goal by 2050, in the end making Europe a climate-neutral continent (European Climate Law, 2021). The associated document to the European Green Deal, "Sustainable and Smart Mobility Strategy – putting European transport on track for the future", outlined that the success of the European Green Deal depends on the ability of the European Union countries to make their transport system sustainable. The document sets the goal for the transport sector, that the transport sector's emissions should be reduced by 90 percent by 2050. The document lists the raising *demand for new innovative solutions for multimodal digital transportation solutions following the Mobility-as-a-service concept*, while also mentioning that cities have been witnessing a shift towards shared and collaborative mobility services, such as car-sharing and ride-hailing. (European Commission & Directorate-General for Mobility and Transport, 2020.) Related to these plans and regulations, the Finnish Ministry of Transport and Communications has outlined that in act to reduce the domestic greenhouse gas transport emissions to half by 2030, *the Finnish private vehicle kilometres should no longer increase compared to level of 2019 and that public transport, walking, cycling and other sustainable transportation methods should increase their share of travelled kilometres significantly* (Ministry of Transport and Communications, 2020).

This is a difficult to tackle problem as many stakeholders with conflicting views, expectations, and interests are involved and need to cooperate (for example, the public, the transport companies and authorities, the government). The recommendation for exploring digital-based transportation solutions to this problem makes it a suitable research problem in the field of Information Systems (IS). The research problem can be defined as "How to use digitalization and in particular mobility as a service to make the transportation more sustainable?" Furthermore, the demanded digital solutions, being aimed at improving societal goals related to sustainable transportation, can be designed and developed by employing design science research methodology (Hevner et al., 2004; Peffers et al., 2007) and contribute to the areas of sustainable IS (Melville, 2010) and sustainable human-computer interaction (HCI) (DiSalvo et al., 2010) through concepts such as "sustainability through design" (Mankoff et al., 2007), and "sustainable interaction design" (Goodman, 2009). In this thesis, the research problem is tackled by investigating how Mobility-as-a-service concept and related artifacts (systems and services) can fulfil the sustainable transportation objective set by the European Green Deal regulation.

Mobility-as-a-service (MaaS) concept has been acknowledged in Finland and was accommodated for in the Act of Transport Services in 2017 (Laki Liikenteen Palveluista, 2018). Some of the key objectives of the legislation were to create conditions for digitalization and new transportation business models, make market access easier and to promote the interoperability of the different transportation modes (Lajas & Macário, 2020). The legislation requires the transport service providers to provide third-parties with data about their routes and timetables through application programming interfaces (Mladenović & Haavisto, 2021), while giving new provisions for interoperability and ticket payment systems to enable single trip tickets for door-to-door travel chains (Lajas & Macário, 2020).

MaaS-concept was first presented in 2014 (Sakai, 2019) before the implementation of the European Green Deal in 2019. The European Green Deal has changed the needs for the transportation services since the additions made into the law for the MaaS-concept, bringing the sustainability at forefront in discussions of the future of the transportation. It has been said that the central promise of the MaaS-concept is to provide the users with individual freedom and instantaneous mobility. It has though been noted that this promise inherently works against the objectives of reducing congestion and traffic emissions. (Pangbourne et al., 2020.) Because of these reasons, in this thesis the Mobility-as-a-service will be investigated and researched as to what extent the MaaS-concept will work along or against the goals of European Green Deal and the current goals of the Finnish government in reducing greenhouse gas emissions by lowering the number of kilometres driven with private vehicles. This research will then be utilized in creating a list of system features, whose implementation in MaaS-services is supported by the research.

Big question for MaaS-services is where exactly MaaS-services will bring the best results in terms of cost savings and sustainability. In the case of the Finnish MaaS-initiatives, there is a large discrepancy between the opinions of the public sector actors. Some of the interviewed actors from the big cities found that there is no need for MaaS in the city centres, where public transportation and walking are already accessible solutions. Meanwhile the actors from smaller cities and municipalities argued that MaaS is better suited for larger cities with enough users and high variety for shared services and multimodal combinations of transportation-services. (Mladenović & Haavisto, 2021.) Furthermore, Finnish public sector actors do have contradictory views on will MaaS-services reduce or increase car use, and find that decrease of car use can depend heavily on the location, as people might not have other travel-option available (Mladenović & Haavisto, 2021). As there is uncertainty about the actual effects of the MaaS-services, this thesis concentrates on understanding the MaaS-concept and its possibilities for improving the sustainability of the MaaS-services.

Through the perspective of sustainable interaction design (SID) paradigm, sustainability should be the central focus of interaction design (Blevis, 2007). Through this view, designers are often seen as complicit for unsustainability of the current interactive products, with unsustainable user behaviour happening not due to having bad users, but due to bad design (DiSalvo et al., 2010). Through these views, it can be argued that the possible unsustainability of the MaaS-service should not be blamed on the behaviour of their users, instead opting to blame the design of the service. To advance the creation of sustainable MaaS-solutions, this thesis' research process and findings are framed under the Design Science Research Methodology (DSRM) (Peffers et al., 2007) in an effort to identify issues surrounding MaaS-services and define research-supported system design requirements for the created MaaS-solutions.

To understand the possible effects of MaaS-concept and enable the creation of sustainable MaaS-services, the research questions (RQs) for this thesis are as follows:

- RQ1: Are MaaS-services capable to decrease the number of private vehicle kilometres?
- RQ2: What are the central factors affecting the environmental sustainability of the MaaS-services?
- RQ3: What are the most critical factors affecting the success of MaaS-services?
- RQ4: What system features are supported to be implemented by the MaaS-research?

The questions are answered by a narrative literature review (Baumeister & Leary, 1997; Green et al., 2006). Research question 1 will provide answers for the clarification of the research problem around MaaS by identifying critical issues and benefits of MaaS. These answers provide knowledge to the first step in a design science research (DSR) process (see e.g., Peffers et al., 2007) by clarifying the dimension and importance of the research problem of MaaS design for sustainable transportation. Answers to RQs 2-4 will provide input to subsequent activities in a DSR process (steps 2 and 3 in the DSR process model by Peffers et al., 2007) based on the gained knowledge from the literature review by identifying factors contributing to successful MaaS designs and a list of desirable features for MaaS systems.

The thesis starts with presenting the background relevant for the research in chapter 2 and describing the used research methods in chapter 3, followed by the literature review to Mobility-as-a-service-concept in chapter 4. In chapter 5 the MaaS-system features supported by the literature review will be presented, with discussion and conclusions following in chapters 6 and 7, respectively.

2. Background

In this chapter the background for the MaaS-research will be set by discussing sustainable transportation, the Mobility-as-a-service-concept, sustainable HCI and the Design Science Research Methodology.

2.1 Sustainable transportation

As a reaction to the ongoing climate change, different countries and organizations have begun to create and implement different legislative efforts to tackle the challenges rising from the changes in the climate. The European Green Deal requires, that the European Union reduces 90 percent of greenhouse gases coming from their transport for the European Union to be able to become a climate-neutral economy by 2050. To achieve these goals, European Commission requires the European Union to make all their transportation modes more sustainable, make sustainable transportation alternatives widely available in multimodal transportation systems and enact incentives to drive the transition towards zero-emission mobility. (European Commission & Directorate-General for Mobility and Transport, 2020.)

The digitalization of the passenger transport has been expected to have great effects on the European transportation system, with it improving the efficiency and the sustainability of the transportation network. The improving sustainability is not though guaranteed, with a lot of the results being left for how the digitalization will be realized. In scenario analysis from 2015 to 2050, the demand for passenger transport in European Union has been expected to rise significantly even in the most environmentally responsible digitalization scenarios. The demand has been expected to rise by 33 percent of the responsible digitalization scenario to 72 percent of selfish digitalization scenario compared to the passenger transportation demands of 2015. In terms of final energy consumption these scenarios range from decreasing energy consumption to overall energy consumption staying the same despite the increase in demand for passenger transportation. (Noussan & Tagliapietra, 2020.)

The three technologies that can have significant part to play in digitalization of the passenger transportation are mobility-as-a-service, shared mobility and autonomous driving (Noussan & Tagliapietra, 2020). Shared mobility enables the users to get short-term access to different transportation modes on as-needed basis, through services such as car sharing, bike sharing or on-demand ride services (Shaheen et al., 2016). Autonomous driving enables the use of autonomous cars without requiring human input for their operation (Athanasopoulou et al., 2019), and opens up mobility possibilities for users who do not drive (Curtis et al., 2019). The role set out for MaaS and shared mobility is to reduce the modal share of private cars towards using public transportation or shared cars. The development of autonomous cars will have a role through their effects on flexibility and convenience of the private cars and these changes might determine an increase in the demand for private cars or might enable the development of car sharing services. In similar sense, the unsustainable development of MaaS and shared mobility could end up with increased demand for shared mobility services by the

users of other transportation modes, such as the public transportation. (Noussan & Tagliapietra, 2020.)

While all the three mentioned technologies do share aspects with each other, with for example shared mobility- and autonomous car sharing-services being possible to be shared through MaaS-applications, MaaS-concept presents possibilities for major changes for the future of public transportation. For example, the European Green Deal emphasizes that the automated and connected multimodal mobility will play an increased role in accelerating the shift towards sustainable and smart mobility. As a result of this The European Commission has stated that they would help in developing MaaS-solutions through their funding instruments. (European Commission & Secretariat-General, 2019.) Also in the European Green Deal the European Commission encouraged the airlines to start selling increasing number of multimodal tickets to enable the shift towards more sustainable transportation links (European Commission & Directorate-General for Mobility and Transport, 2020). The European Commission's interest in MaaS-solutions emphasizes the role of MaaS-concept in making large changes towards automated multimodal mobility. As the sustainability of digitalization of passenger transportation is notably dependent on the quality of the digitalization scenario, it becomes particularly important to understand how one is able to direct the digitalization towards the best possible end results. As a result of this, this thesis concentrates on MaaS and aims to clarify how different aspects of MaaS will need to be addressed in MaaS-service design to get the environmentally best results out from the MaaS-services.

2.2 Mobility as a service (MaaS)

Mobility-as-a-service or MaaS has often been defined as a concept aiming to combine different transportation modes to allow seamless trips through the use of the single interface (Utriainen & Pöllänen, 2018). The concept of MaaS was created in Finland and was first presented in June of 2014 (Sakai, 2019). MaaS-concept has been brought up to be important in improving the efficiency of urban transport network, while mitigating the potential risks of ride-hailing-services and self-driving vehicles (Ho et al., 2020). There has been set considerable expectations for the MaaS and its capabilities for reducing annual emissions of passenger and light duty vehicles. For example, if the MaaS-concept would scale up for the early-adopting niches of the UK population, MaaS-services have been expected to cut UK's annual emissions by 1.4 percent against the levels of 2015 (Wilson et al., 2019). Related to this, the most typical reasons driving the implementation of MaaS-services from public sector perspective are to reduce car dependency, to lower the use of private cars, to provide public accessibility (Jittrapirom et al., 2020), to increase the use of public transportation and to receive better quality demand data (Polydoropoulou, Pagoni, & Tsirimpa, 2020). The drivers for the private sector on other hand are to increase the market share, increase revenues, gain higher quality demand data, gain more visibility for the company and to create partnerships with larger transportation operators (Polydoropoulou, Pagoni, & Tsirimpa, 2020).

As a relatively young concept, MaaS does have interpretive flexibility in its definition. For instance, the expert interviews with the Finnish public sector showed that while the most common answer for defining MaaS was seeing MaaS as a single interface or comprehensive platform combining multimodal services into a single journey, the details in definitions of MaaS greatly varied between the interviewees. These variations included such things as all the applications that include mobility-services are MaaS-applications, all the services that can be bought alongside with the mobility-services are

MaaS-services and that all mobility implemented as service can be described as MaaS. (Mladenović & Haavisto, 2021.)

2.3 Sustainable IS and sustainable HCI

Sustainability is a multi-faceted concept, which includes many issues around energy use, device re-use, reduction of waste and enabling sharing of devices and energy resources. Information systems can be used support sustainable lifestyles on individual, group and societal levels. (Mankoff et al., 2007.) For example, information systems can be created to support sustainable lifestyles on societal level by supporting cultural change towards higher acceptance and usage of more sustainable transportation modes.

Research on sustainable HCI can be categorized in a few genres: persuasive technology, ambient awareness, sustainable interaction design, formative user studies and pervasive and participatory sensing (DiSalvo et al., 2010). While there are multiple orientations towards environment within the current HCI-research, which have different methodological choices and favoured outcomes, they often do share the same ideas: Humans cause and are harmed by pollution and resource depletion and that designers, businesspeople, engineers and scientists do have a responsibility to humans and the whole planet. (Goodman, 2009.) One of these main orientations is called Sustainable Interaction Design (SID). According to this approach, the sustainability can and should be the central focus of interaction design (Blevis, 2007). SID calls for changes in manufacturing, use and disposal practices, and highlights the role of designers to mitigate the material effects of intensive lifestyles towards less damaging future (Goodman, 2009). In this approach the designers are often seen as complicit in the lack of sustainability of the current interactive products, and unsustainable user behaviour happening due to bad design of the systems instead of blaming on bad users (DiSalvo et al., 2010). In pursuing sustainable future, the SID-projects often involve persuasive interventions to motivate behaviour changes in both the users and the designers (Goodman, 2009). However, more promising approaches are participatory design by involving users and stakeholders in the system design and the macro-perspective by bringing the infrastructure and politics to the forefront of the sustainable HCI research (Goodman, 2009).

Service suppliers and the consumers are often driven by their own self-interest, creating outcomes which are against the society's long-term interests. If the society and the existing regulations allow the externalization of costs of unsustainable actions, the companies which adopt ecologically sound practices may be in competitive disadvantage (Watson et al., 2010). To avoid such issues, the governments would need to create regulations to direct the competition between the suppliers and the consumer behaviour to meet the society's interests (Watson et al., 2010). While issues around the environment are a major source of political debate, the majority of research and design in sustainable HCI does not acknowledge or address this debate in their research (DiSalvo et al., 2010).

Sustainable HCI is highly relevant for MaaS-services. It is plausible that launch of a MaaS-services could incentivize the users to change from using public transportation-services for the MaaS-services and end up creating unsustainable travelling behaviours, while lowering the use of more sustainable transportation modes through for example heavy price competition. From the approach of SID, it is arguable that the effects of the MaaS-concept on the sustainability of the transportation services are not fault of the concept itself, instead putting the responsibility of the effects on the designers of the

MaaS-services themselves. From this viewpoint, it would be highly beneficial to understand the effects affecting the sustainability of the MaaS-services, so that the designers would be capable to design MaaS-services following the principles of sustainable HCI and avoid creating unsustainable future through negligence and ignorance towards MaaS-research. This requirement also extends to the political debate. To minimize the issues rising from the lack of interest in political debate, the MaaS-research should be investigated to find out the critical issues affecting the political support of MaaS-services, and how the policymakers' actions and attitude towards MaaS-concept may change the sustainability of the MaaS-services.

2.4 Design Science Research Methodology

Design Science Research Methodology (DSRM) is a methodology for conducting design science research in Information Systems field. The creation of DSRM was motivated by the previous lack of commonly accepted frameworks for design science research in IS. DSRM was created by researching earlier influential design research and by using the gained knowledge together with consensus-building approach in creating the methodology. (Peffers et al., 2007.)

DSRM consists of 6 activities, called "Problem identification and motivation", "Define the objectives for a solution", "Design and development", "Demonstration", "Evaluation and Communication" The first activity of the Design Science Research-method is called "Problem identification and motivation", requiring the research to define the specific research problem and justify the value of a solution. In this phase the research problem is defined and broken down to smaller issues, helping the researchers to understand the complexity of the research problem. Justifying the value of solution motivates the researcher and the readers of the research to pursue the solution and accept the research results, and to understand the reasoning behind the solution. (Peffers et al., 2007.)

The second activity is called "Define the objectives for a solution". This activity is often done by researchers by transforming the problem into system objectives or requirements, or by making these efforts implicit part of the programming, data collection or search for the problem. The detected problems do not necessarily translate to objectives for the solution due to the design process acting as one part of partial and incremental solution. (Peffers et al., 2007.) The third activity of DSRM is called "Design and development". In this activity, the done research is used in determining the artifact's desired functionality and architecture, followed by creating the actual artifact following the created design. (Peffers et al., 2007.)

The research done in this thesis follows the first two activities of the DSRM-process, and aims to creating a design to be used in developing a sustainable MaaS-services, while also partially following the third activity of DSRM-process by specifying the artifact's desired functionality based on the prior research. While the thesis does not strictly use the DSRM-process, the thesis can be argued to be relevant from the viewpoint of DSRM in creating a design fit for a MaaS information system.

3. Research Methods

This chapter discusses the research methods used in the research. The motivation for the research and the research questions will be specified in the section 3.1. The research process is specified and discussed in detail in the section 3.2.

3.1 Research planning

To answer the research questions, a literature review was carried out as a narrative literature review following the guidelines of Green et al. (2006). The answers to the RQs provided a narrative overview to Mobility-as-a-service concept and the factors that contribute to implementing successful MaaS services and systems that align with the goal of providing sustainable transportation.

The research is motivated by the implementation of the European Green Deal, which has changed the environmental context around the MaaS-services after their conceptualization in 2014. The European Green Deal and subsequent national plans have emphasized the need to reduce transport emissions and the use of private cars. The Finnish public sector actors have had contradicting opinions about the effects the MaaS-services could have on the use of private cars, and in which areas the MaaS-services could be operated in (Mladenović & Haavisto, 2021). Following this uncertainty, the aim of the research is to find out the capabilities of MaaS systems, and would they be able to meet the expectations set for them by the Finnish government and the European Union. The research questions and their motivations are as follows:

The Finnish Ministry of Transport and Communications stated that the Finnish private vehicle kilometres should no longer increase compared to the level of 2019 (Ministry of Transport and Communications, 2020). Meanwhile the European Union Commission's Sustainable and Smart Mobility Strategy outlines that seamless multimodality enabled by digital solutions, such as MaaS-concept, together with shift towards shared collaborative mobility services should enable a reduction of number of vehicles in daily traffic (European Commission & Directorate-General for Mobility and Transport, 2020). As stopping the increase of private vehicle kilometres is considered as one of the main goals in improving the efficiency of the transportation system, and with European Commission considering that MaaS-concept should contribute to reducing the number of vehicles in daily traffic, the capabilities of MaaS-services to reduce the use of private cars should be investigated. Because of this the following research question was made:

RQ1: Are MaaS-services capable to decrease the number of private vehicle kilometres and to lower private car ownership?

If the MaaS-services were to be used within the transportation sector, the development of the MaaS-services would highly benefit of knowing which factors are central in affecting how environmentally sustainable the created MaaS-service will be. From viewpoint of sustainable interaction design, the unsustainable behaviour of the users is caused by bad system design and not because of bad users (DiSalvo et al., 2010). Knowing the central factors affecting the environmental sustainability would enable the

MaaS-stakeholders to direct the MaaS-development towards environmental sustainability and avoid environmentally costly system design mistakes from occurring during system development. To find out these factors, the following question was formulated:

RQ2: What are the central factors affecting the environmental sustainability of the MaaS-services?

Regardless of how environmentally sustainable the MaaS-services could be, their effect on the transportation sector could be limited by different factors, preventing the launch of MaaS-services, or making the services unprofitable in long-term. Knowing these critical factors in advance would enable the people behind MaaS-services to prepare for these issues through planning, and hopefully enable the creation of mutually beneficial MaaS-services. As such, the following research question was created:

RQ3: What are the most critical factors affecting the success of MaaS-services?

For the environmental and financial success of the MaaS-service, the resulting MaaS-application requires a multitude of system features to attract the users into using the service and to making the service as environmentally sustainable, profitable, and successful as possible. To enable faster creation of successful and sustainable MaaS-services, MaaS-research should be studied and collected to find out what system features are supported by the MaaS-research. Answering the following research question will provide a list of detected system feature-requirements supported by the narrative literature review fulfilling the Design Science Research Activity 2, "Define the objectives for a solution" (Peffers et al., 2007). The resulting list of system feature-requirements should be capable to being utilized in creating an effective MaaS-service, in case where MaaS-service would be developed following the third activity of Design Science Research-process, "Design and Development". Due to these goals, a following question was formed:

RQ4: What system features are supported to be implemented by the MaaS-research?

3.2 Research process

This thesis was written as a narrative literature review following the guidelines created by Green et al. (2006). Narrative reviews are created with intention to synthesize the available material on a topic and to provide conclusions from the available evidence. Successful narrative reviews should present information that is written using the elements required by the narrative reviews, be well structured, synthesize the available material about the topic and convey a clear message. (Green et al., 2006.)

The elements required from narrative reviews follow those of scholarly articles, consisting of title, abstract, introduction, methods, discussion, conclusions, acknowledgements, references, tables, figures and figure captions (Green et al., 2006). This thesis mainly follows this structure, while also adding chapters relevant for establishing background of the research (Chapter 2) and the creation of list of system features fit for MaaS-services (Chapter 5).

The literature review started with searching for relevant articles. The search was done by searching from Scopus-, IEEE Xplore- and ACM Digital Library-databases. The

search for primary articles were done in the September 2021, with the search term "Mobility-as-a-service". The guidelines of Green et al (2006) specify that the used search terms for the literature review allow the author to retrieve all the relevant studies, while allowing the author to focus the effort (Green et al., 2006). The search term used in literature search was intentionally kept broad due to the research questions requiring wide range of information, ranging from critical issues affecting the success and sustainability of the MaaS-services, to the issues affecting the users' intention to use the MaaS-services. This approach was made possible by the MaaS-concept being relatively young, which kept the number of search results manageable for the research process. In addition to the initial searches from the databases, secondary studies were found during the research by using the reference lists included in the primary studies. The research materials were managed throughout the writing process with open-source reference management software Zotero (Zotero, 2022).

For the study selection process, inclusion- and exclusion-criteria were created following the instructions provided by Green et al. (2006). The selection criteria are used in describing on what criteria the studies were included or excluded from the research. Using the criteria enables the author to keep the text focused and eliminates bias occurring with the author excluding the studies only by the criteria and because of them agreeing or disagreeing with the study. (Green et al., 2006.) The first used criteria was the language. The studies were included if the studies were in Finnish or in English due to writer's language capabilities. The included publications could be conference proceedings, journal articles, book chapters or workshop articles. The included studies must have had a full-text available to be used during the research process. As last inclusion criteria, the studies were required to discuss the MaaS-concept either as a topic of the study or in relation to the study's topic. During the search process, due to the nature of writing master thesis, all the inclusion and exclusion decisions were done by a single person. As this could lead to mistakes in the selection process, the inclusion criteria were used liberally, with studies being excluded only after long deliberation. While this approach increased the number of included studies, this approach diminished the possibilities for wrongful exclusions from the thesis. The used inclusion- and exclusion-criteria are available in Table 1.

The search with search term "Mobility-as-a-service" provided 586 studies as initial results. The first exclusion-stage was done in regards with the topic of the studies. The first studies passing this stage were made on decisions on the titles and abstracts. The studies about MaaS-concept or the ones with relevant information for MaaS-services were let through to the following stage. The rest of the studies were investigated more in depth by going through full texts where available. This approach ensured that no relevant studies would be left in this stage by mistake. Despite using a liberal approach to the inclusion-criteria, these criteria excluded 215 studies. Many of the excluded studies discussed transportation and mobility solutions with passing reference to MaaS-concept, such as mentioning them as one of the emergent changes in transportation sector alongside autonomous vehicles. In the end, this stage excluded 215 papers, with 371 studies going to next stage.

Table 1. The research inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
The publication should be available in • English • Finnish	The publication is available only in other languages
The publication may be: • Conference proceeding • Journal article • Book chapter • Workshop article	The publication is not one of the included research types.
Full-text available for research	Full-text not available
The publication is related to the Mobility-as-a-service (MaaS) concept.	The publication is not related to MaaS-concept or is only mentioned in passing fashion.

During the next stage the inclusion- and exclusion-criteria were applied against the studies. This stage excluded 63 studies from research and left 308 studies for next stage.

The last stage before starting the literature review was the availability. All the studies were checked for whether the full texts would be available for research. This stage left out 76 studies, leaving 232 studies left for literature review. The selection process is represented in Figure 1, where N represents the studies found relevant after each step in the process.

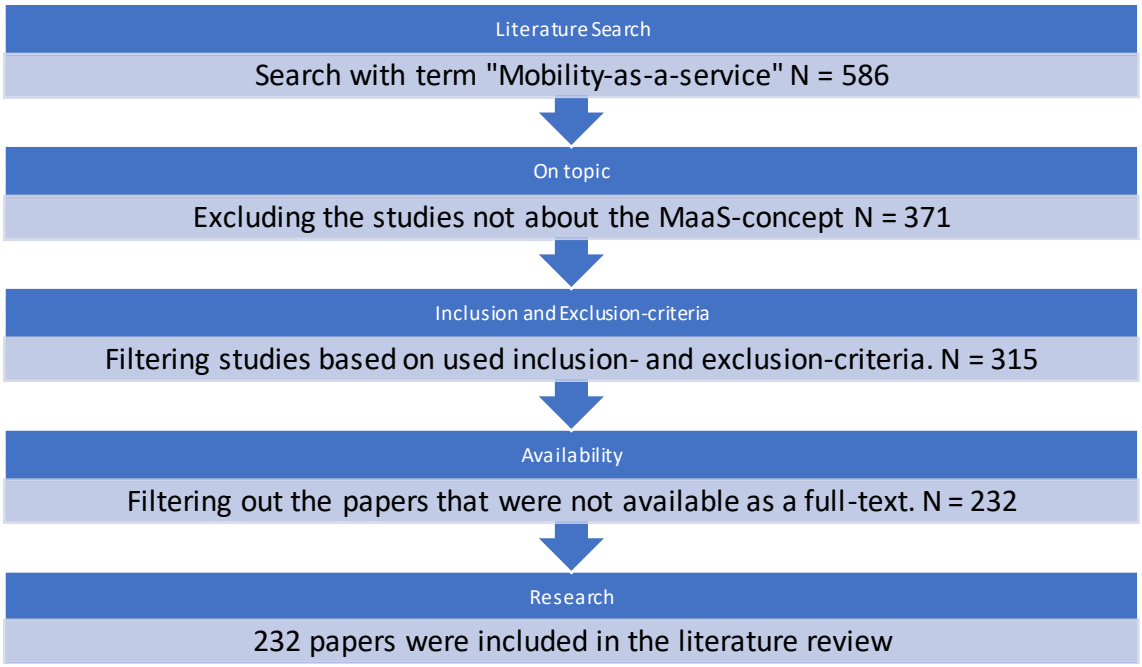

Figure 1. Research selection process represented as flow diagram

Following the search-process, the data synthesis and the resulting literature review was done by manually and systematically reading through all 232 studies in three rounds done between October 2021 and May 2022. The studies were categorized in the reference manager Zotero based on their general themes following the suggestion of Green et al (2006) and were later utilized in writing the literature review. The results of the data synthesis were used in answering the research questions of this thesis. The research questions are answered based on the created narrative literature review, with the fourth question being answered as a list of system requirements relevant from the viewpoint of the two first stages of DSR process, Problem identification and motivation and Define the objectives for a solution (Peffers et al., 2007).

4. Literature review on MaaS

In this chapter the results of the literature review are presented. The chapter contains information about the current MaaS-services, ride-hailing, MaaS stakeholders, the users of MaaS-services, how the MaaS-initiatives are governed, what effects the emergence of MaaS-concept is likely to create and how different contextual factors are affecting the MaaS-services.

4.1 MaaS-services

MaaS-concept has been tested in various cities around Europe in small field trial and pilot studies. Some of the more notable early examples of the MaaS-services which have since been grown into active services are the Swedish UbiGo (Strömberg et al., 2018; UbiGo, 2021) and Finnish Whim (MaaS Global, 2021). Outside of the view of personal transportation, MaaS-services have also been in use as Corporate MaaS providing the company's workers with transport solution to be used within the workplace and for transportation inside and outside the workplace (Hesselgren et al., 2020; Zhao et al., 2020), and has also been proposed to be used to provide sustainable travelling for the tourists for tourist-attractive areas, such as the Alpine regions of Milan (Signorile et al., 2018).

MaaS-services are usually available through the use of smartphone applications (Esztergár-Kiss et al., 2020), and generally require internet access for mobile use of the services (Alonso-González et al., 2020). MaaS-services are sold as mobility bundles with predefined access to different transportation modes with specified level of service. These MaaS-bundles are sold as either subscriptions or as a pay-as-you-go option. (Ho et al., 2018.) The most common transportation modes included in MaaS-services include public transportation, car sharing, bike sharing, ride hailing, taxi and car rental services (Reck et al., 2020).

MaaS-systems can be categorized into five different levels based on their level of integration. Single separate services with no integration with other services are level 0-services. Level 1-services do have integrated information, providing the users with centralized information imported from other data sources within one service. Level 2-services provide the users with booking and payment-integration, making it possible for the users to plan, book and pay for their whole trip within one application on pay-as-you-go-basis. Level 3-services integrate bundling, subscriptions, and contracts within one service, providing the user with comprehensive alternative transportation packages. The last level, the Level 4, means the integration of societal goals, with the system being integrated with the goals such as reducing private car ownership and having more accessible life in mind. (Sochor et al., 2018.)

The number of different MaaS-services is steadily rising, with 31 different services having been launched and with 29 being operational around the world by 2020, with around four new operators launching their services each year. While majority of these services are still relatively small in terms of market penetration, with all but three of the services having less than one million downloads in Google Play store, the service with

the largest covered area, Moovit, was able to get significant market penetration with more than 50 million downloads at the Google Play store. Majority of the MaaS-services have been operating in Europe, with the rest of the services operating in USA, New Zealand, Taiwan and Canada. Majority of the existing services are MaaS-systems with Level 1- and Level 2-services, with only 3 of the existing services being evaluated on the level 3-integration level. None of the MaaS-services in the market had Level 4-integration within the system. (Esztergár-Kiss et al., 2020.)

While the increased interest in MaaS-systems and continuous emergence of new MaaS-services shows that MaaS-concept itself is emerging and taking its own place in the transportation markets, the growing number of MaaS-services does not come without its own issues. The adding number of competing MaaS-services is fragmenting the MaaS-markets, making the usage of MaaS-services more complex for their users and leading to uncertainty for which companies will be the most likely leading MaaS operators in the area (Cruz & Sarmento, 2020). The promise of MaaS-concept of providing individual freedom and instantaneous mobility has also been noted to inherently work against reducing congestions and traffic emissions. While MaaS-services offer various transportation services, MaaS-services tend to offer multimodal door-to-door mobility services for their users. As the other service offering such services called ride-hailing has been suggested to lower the usage of public transportation, there is a notable worry that inclusion of shared vehicles in MaaS-services could have similar effect and reduce the use of public transportation. (Pangbourne et al., 2020.)

4.2 Ride-hailing

Ride-hailing is a service where a user who wants to make a certain trip can be matched with a driver who is willing to take the user through their trip with the driver's own private car (Tirachini, 2020). While ride-hailing is not one of the services that are seen to be integrated directly with MaaS-services, they are one of the first digitalized mobility services that have gained a major foothold in the personal transportation and share notable amount of similarities with the MaaS-services while also competing with the integrated approach of the MaaS-services, making their implementations worth looking into with regards to MaaS-systems. Ride-hailing services have two notable market leaders, Uber and Lyft, which share most of the markets for the ride-hailing services. While Uber has published their plans for commitment for being a zero-emission platform by 2040 (Uber Technologies Inc., 2020), the effects of the ride-hailing services on sustainability of the public transportation have been researched thoroughly and have brought mixed results.

Ride-hailing companies in their earlier days did state their objective was to replace public transportation through competing with price and quality. While ride-hailing companies have changed their approach and are now willing to working with city authorities and complement public transportation, the ride-hailing companies are still able to compete on price and disrupt public transportation because ride-hailing companies do not own the vehicles operating their services nor treat their drivers as employees. This approach has enabled the ride-hailing companies to avoid paying benefits and taxes, while using the lower costs to decrease the viability of the taxis and public transportation services. (Wong et al., 2020.)

Ride-hailing has been found to both substitute and complement public transportation, but the more recent studies have shown that the substitution effect seems to be stronger than the complimentary effect. Ride-hailing services are still unlikely to replace

completely the use of the other transportation modes, as their users still often continue using the other transportation modes. Despite this, the more recent research has shown that ride-hailing services are also likely to increase the vehicle-kilometres-travelled, increasing the congestion with the private vehicles in major cities. (Tirachini, 2020.) Ride-hailing has been found to contribute to increase of motorised traffic at the peak times in the cities, with 20 to 40 percent of ride-hailing trips have been found to occur at times of peak traffic (Tirachini, 2020). It is also possible that the ride-hailing is likely to increase the number of trips the users of the service were doing, as in a research with people of major cities of USA, 49 to 61 percent of the ride-hailing trips would either not have been made, or done by walking, biking or using the public transportation. (Clewlow, 2017).

While ride-hailing services with their current implementation trajectory are not entirely comparable with the MaaS-services and have not so far been included as integrated transportation mode in any of the current MaaS-systems, the research into their implementations do give some concerning examples of what could possibly go wrong if the MaaS-implementations are not planned and governed well enough to bring the best possibilities out of the transportation changes. While ride-hailing services have been claimed that they could be used alongside public transportation services by using them as complementary first mile/last mile-type of service to retain the passengers within public transportation (Tirachini, 2020), ride-hailing could also end up substituting the use of public transportation and incentivize the users to go on additional trips on which they would have not gone without easy access to the transportation-services.

4.3 MaaS stakeholders

As the MaaS-initiatives represent a large change for the transportation services around the area where the initiatives are realized, the MaaS involves a lot of different stakeholders, who all could play an important role in MaaS-partnerships. For instance, two workshops held in United Kingdom and Hungary involved MaaS-stakeholders including city and local government and public transportation authorities and shared mobility companies, such as car-sharing, bike-sharing and car-pooling companies (Polydoropoulou, Pagoni, & Tsirimpa, 2020).

From the perspective of MaaS-service development, two of most central stakeholders are MaaS-operator and MaaS-integrator. The MaaS-operator is the provider of MaaS-services, and enables the users to seamlessly plan, pay and use different transportation services through single interface. MaaS-integrator mediates the offerings of transportation services providers to MaaS-operators through activities such as technical integration, contract management and financial clearing. (Smith et al., 2018.) The MaaS-operator acts as the developer of the MaaS-service, and will be required to cooperate with other stakeholders, meeting their needs and requirements to be allowed to integrate their services in the multimodal MaaS-service. The most important stakeholders for the success of MaaS-services are the transportation companies, who act as the provider of the transportation modes included in the MaaS-services (Stopka et al., 2018). Getting the support of public transportation companies is central for MaaS-concept, as public transportation is expected to act as a backbone for the MaaS-services due to people's travelling habits (Matyas & Kamargianni, 2019). Getting the support of the existing transportation market-leaders and other established actors is highly important for MaaS-services, as the cooperation with the local transportation authorities will be key factor in assisting the small MaaS-operations to scale up beyond the niche markets (Fenton et al., 2020).

Outside the stakeholders directly providing services within the MaaS-services, the stakeholders who manage the local infrastructure are integral for the success of MaaS-services. To enable high quality of service for the MaaS-services and to make them attractive for the end-users, the local infrastructure needs to be capable of providing mobile internet access, secure real-time information and secure payment-options for the users of MaaS-services (Polydoropoulou, Pagoni, & Tsirimpa, 2020; Stopka et al., 2018). These requirements outline the importance of the local telecommunications and mobile network companies as the MaaS-services stakeholders. (Stopka et al., 2018.) On the other hand the lack of infrastructure for online ticket sales can act as a barrier for MaaS-implementations. For example, while places like Luxembourg and Greater Manchester already do give their people options to buy public transportation tickets online, the public transportation of the capital of Hungary Budapest relies on paper tickets, which has acted as a barrier for MaaS-implementations (Polydoropoulou, Pagoni, Tsirimpa, et al., 2020).

The public transportation authorities and the national legislators will have a large part in enabling the creation of MaaS through revising the existing legislation and other supportive structures to support the creation of MaaS-services. As the existing regulations may hinder or completely prevent the emergence of MaaS, the regulative issues may present itself as a serious barrier for MaaS-services. As a result, the support of the local public transportation authorities and of the national legislators will be central for the MaaS-services, making them key stakeholders for the MaaS-services.

4.4 MaaS users

The users of MaaS-services are a significant group of stakeholders, whose interest in using MaaS-services is central for the success of the launched services. For the MaaS-services to be able to provide the services required by their users, the developers of the MaaS-service would be required to understand their users, and how different factors, such as the age and level of education, affect their interest and willingness to use MaaS-services.

In the following subsections the users' and user groups' intention to use MaaS-services is explored, the size of the potential userbase is researched and user group-specific design issues are discussed.

4.4.1 Intention to use MaaS

Previous research has identified different factors that do influence the individual's intention to use MaaS. The individual's age has been shown to have a strong effect on the individual's likelihood of adopting the usage of the MaaS-services. The younger people around 18- to 40-year-old are, the most likely early adopters of the MaaS-services, while the older people over 55 years old are less likely to use the MaaS-services. (Caiati et al., 2020; Ho et al., 2018, 2020; Hoerler et al., 2020; Matyas & Kamargianni, 2021; Vij et al., 2020; Zijlstra et al., 2020.) The early adopters are likely higher educated (Ho et al., 2018; Matyas & Kamargianni, 2021; Vij et al., 2020; Ye et al., 2020; Zijlstra et al., 2020), employed (Matyas & Kamargianni, 2021; Vij et al., 2020), and have higher income than the average (Agbe & Shiomi, 2021; Matyas & Kamargianni, 2021; Zijlstra et al., 2020). Having experience from carsharing (Hoerler et al., 2020), using route planners regularly (Fioreze et al., 2019), being a frequent flier, going on many leisure trips, living in dense environments (Zijlstra et al., 2020), owning

a driver's license (Caiati et al., 2020), having intention to reduce car usage and having pro-environmental behaviour also have been shown to make it more likely for the individual to use the MaaS-services (Alyavina et al., 2020; Hoerler et al., 2020). The person's health also does influence the interest on adopting MaaS-services. People with self-declared good health are more likely to adopt MaaS, while the users with moderate or poor health are either slightly negative or strongly negative towards adopting the use of the services. The effects of the poor health are also visible amongst the users of mobility scooters, with them being more negative towards the idea of adopting the use of MaaS. (Zijlstra et al., 2020.)

In terms of user groups, the most likely user groups to adopt the use of MaaS-services are infrequent car users (Ho et al., 2018), students (Matyas & Kamargianni, 2021) and people who use both car and public transportation (Ho et al., 2020). On other hand, the user groups that are less interested in using MaaS-services are the people who mainly travel by walking or by using their bicycle (Caiati et al., 2020; Feneri et al., 2020) and the people who were not able to drive (Ho et al., 2020). The research results regarding the people who use public transportation and their intention to adopt MaaS-services are mixed. Some research studies report that the people who use public transportation are likely to adopt the MaaS-services (Hoerler et al., 2020; Matyas & Kamargianni, 2021; Zijlstra et al., 2020) and are more open to using MaaS-service than the people who mainly travel by using private cars (Hoerler et al., 2020), but other research studies do show otherwise, with the current public transportation users being not particularly open for adopting MaaS (Ho et al., 2018, 2020), or being willing to pay less than their average monthly mobility costs for the MaaS-services (Agbe & Shiomi, 2021).

The research has noted that the users are not willing to pay for the MaaS-services as much as their current mobility costs are (Agbe & Shiomi, 2021; Alonso-González et al., 2020; Liljamo et al., 2020), and want to pay less than the costs of providing the transport services (Liljamo et al., 2020; Mulley et al., 2020). It has been found that the price of the MaaS-subscription is the main influencer in the people's MaaS-subscription decisions (Caiati et al., 2020). Because the users are not willing to pay for the services as much as their existing mobility costs, it has been suggested that if the MaaS-services are to be widely adopted, the services would need to be able to lower the users' mobility costs through a combination of low subscription fees and mode-specific discounts (Hensher et al., 2021; Ho et al., 2020; Liljamo et al., 2020). The lack of willingness to pay more than the users' current mobility costs is especially difficult issue for the goal of having the MaaS-users lowering the use of their own private cars. The owners of private cars do often underestimate the costs of their private cars, as they only consider the car's operating costs for their assessment of their mobility costs, and ignore other costs such as car's loss of value with time, cost of maintenance and inspections (Maas, 2021; Mladenović & Haavisto, 2021). This underestimation can often lead to situations where MaaS-bundle prices are considered too high against their own assessments of their own mobility costs (Maas, 2021). On top of this, the lack of willingness to pay for the subscriptions is one of the major issues for the future of MaaS-services.

According to the research on the people's willingness-to-pay for the MaaS-services, 17 to 48 percent of the research respondents would be willing to pay for the MaaS-service. Some of the higher percentages were found in United Kingdom (Ho et al., 2018), Finland (Liljamo et al., 2020) and Australia (Ho et al., 2020; Vij et al., 2020), while the smaller results were found in Japan (Agbe & Shiomi, 2021) and the Netherlands (Caiati et al., 2020; Fioreze et al., 2019). While the relatively low willingness-to-pay is an issue for implementing MaaS, it is notable that these research results are only indicative because of the reported limitations in the studies. The study samples could have over- or

under-representation of certain user groups compared to general population of their areas. Of the studies with more positive rates for willingness to pay, some studies reported under-representation of retirees and home keepers while having over-representation of full-time students and unemployed individuals (Ho et al., 2018), while other studies did not include people over 64 years old (Liljamo et al., 2020) or had notably high percentage of people who relied on other transportation modes than private car and did not have a driver's license (Ho et al., 2020). Meanwhile the studies with lowest willingness-to-pay did clarify that their samples were disproportional to their respective areas, with the younger people being under-represented and the older ones being over-represented (Caiati et al., 2020; Fioreze et al., 2019).

As it has been noted that the younger people are more likely to adopt and use the MaaS-services than the older people, the limitations of the research results caused by the over-representation of different age groups can notably skew the results to one way or another. Despite these limitations, these studies can be used as indicative results providing initial view into people's willingness to use and pay for the MaaS-services. As even the most positive study results report that the users are not willing to pay enough to cover the unit costs of providing the MaaS-services, this would suggest that operating MaaS-services would require subsidies or other external funding on top of the payments acquired from the users of the service. The requirement of subsidies and external funding is further emphasized due to profit margins being cut to minimum within the transportation sector (Wolff & Hakanen, 2021), leaving the MaaS-operator to not having many options to be able to provide low enough prices to meet the desires of their potential users. There is a possibility though that the low willingness to pay could be somewhat alleviated with time, as it has been suggested that the better the users understand the advantages and features of the MaaS-service, the less the price will affect the users' intention to use the MaaS-service (Mola et al., 2020). Based on this suggestion, if the users and other potential customers could be communicated well about the benefits of the MaaS-service and could be attracted to try the service with discounted launch prices, the low willingness to pay could possibly present itself as a short-term obstacle for the MaaS-service and make it possible to make MaaS-services profitable in long-term. These discounted prices will not work as an incentive for too long, as it has been suggested that MaaS-services' low price may act as an incentive only during the launch-phase of the service (Mola et al., 2020).

The potential users have been open to digitalized transportation solutions, as shown in a survey with Finnish respondents where 80 percent of the respondents were open to idea that mobility services could be provided and used through a single ticket or application. Over 60 percent of these respondents also believed that transportation's change from the use of private cars towards mobility services would be desirable. (Liljamo et al., 2020.) In similar sense, the younger participants of a Spanish study agreed that well-designed MaaS-service should be able to make a change in their own mobility habits, by giving them personalization options and real-time travel information. It is though notable that the older participants did not agree with this potential for change in their own case. (Lopez-Carreiro et al., 2020.) These results with the lack of willingness to pay brings an interesting picture for MaaS-concept. The potential users can see the value of providing the transportation services through one application and might even see that the use of these services could change their mobility habits but are not willing to pay for these services.

Overall, between the user groups, the public transportation is the most preferred transportation mode for the MaaS-bundles (Caiati et al., 2020; Esztergár-Kiss & Kerényi, 2020; Jang et al., 2020; Matyas, 2020). While this is true, there are still notable

differences in the adoption rate of public transportation mode between the different age groups. Younger people in general are less likely to include public transportation in their MaaS-bundle, while for older people of more than 50 years the public transportation is the most preferred transportation mode (Caiati et al., 2020). There are also differences between the groups in subscribing to highly extensive MaaS-bundles. The MaaS-subscribers who have got themselves more extensive and more expensive bundles are the users with higher income and higher education level (Matyas & Kamargianni, 2021). Meanwhile the students, who have been said to be one of the more likely groups to adopt the use of MaaS-services, are more likely to tend towards subscribing for less expensive bundle-options, which mainly include public transportation and bike-sharing (Matyas & Kamargianni, 2021). In similar sense, while the multimodal users of public transportation have been noted to be positive towards MaaS-services and one of the possible groups of users, they have been found to be less willing to pay for the MaaS-services and preferring public transportation over on-demand transportation services (Alonso-González et al., 2020). As a result it has been said that if the governments would want to go towards more sustainable transportation, there might be a need to lower the fares of the public transportation to attract multimodal users and to retain the current travellers within public transportation (Ho et al., 2018).

As the most likely early user groups to use MaaS-services are younger people in general, MaaS-operators will need to design their services more carefully in terms of affordability. Younger generations tend to have lower purchasing power compared to older age groups, because of which designing the MaaS-service as a high-end product can considerably reduce the number of potential users during critical early phases of the service launch. While the user groups with higher purchasing power are considered as potential users, they are not expected to be amongst the early adopters of the service The MaaS-operators will need to prepare for delays in their income and think of implementing different strategies to attract these potential users to using MaaS-services as early as possible. (Jittrapirom et al., 2020.)

4.4.2 Userbase potential

For the MaaS-services to be able to have any effect on the sustainability of the passenger transportation, MaaS-services would need to be able to attract sizeable number of interested users to keep the services ongoing and profitable. In the following sections, the user interest towards MaaS-services is discussed, and how the level of digitalization could affect the implementation of MaaS-services.

User interest

To understand the level of interest towards adopting the use of MaaS-services, two different research papers by Alonso-González et al. (2020) and Vij et al (2020) presented two studies with generally representative samples of Dutch and Australian population and their interest in adopting the use of MaaS-services. The Dutch paper by Alonso-González et al. (2020) targeted towards the people living in urban areas of Netherlands and was able to cluster the local people into five different clusters. The biggest of the five, the 32 percent of the respondents of “MaaS-FLEXI-ready individuals”, were most likely to cluster to adopt the use of MaaS-services and had very high intention of using pooled on-demand services. The other cluster interested in MaaS are the “multimodal public transport supporters”. These two groups represented 47

percent of the Dutch populace and represent the two user groups who are most likely to adopt the MaaS-services. (Alonso-González et al., 2020.) Vij et al. (2020) found that Australian people can also be clustered into five clusters, from which three are somewhat probable to use MaaS-services. First of these clusters consists of 14 percent of users, who are users of public transportation, taxis and car rental services. Eighty-seven percent of the users belonging to this cluster are highly likely to purchase MaaS-services. The second cluster consists of seven percent of users, who mainly used taxi and car-sharing services. Fifty-one percent of this cluster's users were likely to purchase MaaS-services. The last of the three clusters contains 17 percent of survey respondents, of whom 33 percent were likely to purchase MaaS-services. This last cluster consisted of users of public transportation, ridesharing and taxis. (Vij et al., 2020.)

The user clusters identified in both studies did share some aspects between the clusters. All the user clusters with positive interest towards MaaS-services did have higher education as one of defining features of the user cluster (Alonso-González et al., 2020; Vij et al., 2020). On other end, the two user clusters from Vij et al. (2020) with lack of interest in MaaS and one of the two negative clusters from Alonso-González et al. (2020) generally consisted of older and retired people (Alonso-González et al., 2020; Vij et al., 2020). The two clusters from Vij et al. (2020) with lack of interest in MaaS also included people with lower level of education and who lived in remote areas (Vij et al., 2020).

It is though to be noted that there are notably large user clusters which have little to no interest in buying MaaS-services. The Dutch research had three user clusters of Mobility neutrals, technological car-lovers and anti new-mobility individuals, who did not have positive inclinations towards mobility-integrations or mobile applications. As these two aspects are highly central to MaaS-concept, it is unlikely that these user clusters would end up using the MaaS-services (Alonso-González et al., 2020.). In similar terms, Vij et al. (2020) reported that two user clusters comprising of in total of 63 percent of the participants had near zero average purchase probability for purchasing MaaS-services (Vij et al., 2020).

The research results would suggest that while there is considerable percentage of people who could possibly end up as MaaS-service users, around half of the people are not likely to end up using MaaS-services at this time. While the percentage could still make it possible to launch successful MaaS-services, the relatively low potential for the people to turn into MaaS-users is going to limit any effects the MaaS-services could have for the sustainability of the passenger transportation. While the Australian research did state that one of the user clusters with near zero average purchase probability could be persuaded for buying MaaS-services if the bundle would provide the users with unlimited long distance public transportation with under 230 Australian dollars (Vij et al., 2020), this persuasion would come at the cost of limiting the sustainability and profitability of the MaaS-service.

Digitalization

Outside of lack of interest, another possible issue for MaaS-service implementations is the lack of digitalization and lack of smart devices capable of using the MaaS-applications. In the Dutch research of Alonso-González et al. (2020), it was found that 54 percent of the respondents, consisting of the more technology- and MaaS-oriented people, tended to have 3G-Internet bundles available on their smart devices. Meanwhile the clusters consisting of Mobility neutrals and of anti new-mobility individuals (25

percent and six percent of respondents, respectively) had noticeably less access to 3G-internet, with 72 percent and 43 percent respectively in the corresponding clusters saying they have no access to 3G-internet. (Alonso-González et al., 2020.) Despite the possible issue, the MaaS-stakeholders of Hungary and United Kingdom do not consider the lack of digitalization to be a big issue for MaaS-implementations. Hungarian and British MaaS-stakeholders did not see the poor level of population's digitalization or the existence of significant proportion of people without smart devices or mobile internet as a large issue for MaaS, instead regarding them as weak barrier for realizing the MaaS-system. (Polydoropoulou, Pagoni, & Tsirimpa, 2020.) While it is true that the likely early adopters of MaaS-services have higher technology adoption and so make it possible to implement the MaaS-service in the first place, lack of technology adoption could end up limiting the total userbase of the services. The Dutch research found that lack of technology adoption would be significant barrier for MaaS-usage for the earlier mentioned two clusters of potential users, the mobility neutrals and anti new-mobility individuals. While it would be highly unlikely that the group of anti new-mobility individuals would end up using the service even if they would have the connectivity and technology to use them, the cluster of mobility neutrals, the 25 percent of the respondents of the research, would be a large and difficult customer segment for the MaaS-services to appeal for. This is because while the group's intention to adopt on-demand services is second-highest in the Dutch research, the cluster's lack of technological adoption would work as a significant barrier for them to use MaaS-services. (Alonso-González et al., 2020.)

4.4.3 User-specific design issues

One generally neglected user segment of the MaaS-research are children and young people. Like everyone else, children and young people are active decision makers in their own travel choices with their own specific needs and perceptions. As a group of transportation service users though, they find themselves to have additional disadvantages with travel alternatives compared to adult population. The youth are specifically concerned with the perceived risks of different travel modes and consider the public transportation to be particularly important for themselves. They find themselves vulnerable for violence and harassment while using public transportation, as they perceive that if young people are involved, no one is willing to help them and intervene. The youth also finds the company-branding to be important, as they have stated that they would only use the services from companies they had used before and assessed them to be safe and trusted. (Casadó et al., 2020.) As a result of these issues, the MaaS-services need to have fitting personalization-options for the youth, as they might have their own reservations on using heavily multimodal transportation based on their own lack of experience of different transportation modes or find other transportation modes notably unsafe based on their own experiences. Being able to highlight and save your preferences for different specific transportation companies could also be preferable, as then the users would be able to get the transportation services from the companies they trust to be safe and so lower the barrier of using MaaS-services.

In similar sense, the users could need personalization options due to their own health status. For instance, the inclusion of active transportation modes, such as bike-sharing, can provide the users with active transportation modes with potential health benefits for the users. The inclusion of these services though also means that the service needs to include capabilities for the users to exclude specific transportation modes from being recommended to the user. This is because while active transportation modes could

provide the users with health benefits, not all of the users would be able to use these transportation modes because of possible health issues or accessibility needs. While from sustainability-angle the high usage of public transportation-modes would be highly preferable, public transportation is limited to stop-to-stop principle with highly variable accessibility. At the same time having a lot of transfers from one transportation method to other during the trip will often cause accessibility problems for the users. (Giesecke et al., 2016.) To meet the accessibility needs of the users, the service should provide the users with clear indications of which services and service providers are capable of providing accessible services for their users and possibly include user-operated filters to exclude the services that would be incapable to meet the needs of these users. Users should also be able to sort their trip options on top of lowest price and the least time taken travelled with the least transfers during the trip, to lessen the possible times the impaired users could meet accessibility issues.

While MaaS-concept is usually considered mostly with the idea of taking the passenger from one place to another, users might instead use transportation services for the travel experience itself. People may travel in specific ways for different reasons, such as running for improving health or going by cruise ship for enjoyable travel experience. This means the users might want to personalize their transportation experience based on their wants, as the transportation modes themselves often provide travel experiences while bridging the distance itself. (Giesecke et al., 2016.) The different travel motivations could imply that the MaaS-services will need to include personalization options for the MaaS-services to be attractive for the users of varying interests. One other example of differing motivations are the users who might prefer to travel to work without any transfers despite the longer travel time because doing so they can use part of the travel time for working (Giesecke et al., 2016). While most of the attention to MaaS-services has been given to passenger transportation services, from the user perspective the design of the service needs to give special attention to the users' luggage (Giesecke et al., 2016). If the MaaS-services were to be used as a complementary service for example for the plane trip's first and last kilometres, the system would need to be able to provide information and options to choose transportation modes which allow the user to travel with their luggage to the destination.

4.5 Governance of MaaS-Initiatives

The creation of MaaS-services requires cooperation with multitude of stakeholders and engaging with local politics to have a solid legislative foundation to build a successful MaaS-service. The following section defines the MaaS implementation strategies, talks about legislation and politics around the MaaS-concept and how the emergence of MaaS-services is interacting with other services.

4.5.1 The MaaS implementation strategies

The emergence of the MaaS has been predicted to cause large changes to the ways public transportation will operate, requiring large changes to the roles of the different service providers and forcing the different actors to adapt to the changed markets. The emergence of MaaS-services has been stated to create two new roles into transportation value chain between the transport service providers and the end users, the MaaS-operator, and the MaaS-integrator. MaaS-operators provide the users with a single interface, through which the users can plan, pay, and use the different transportation services. MaaS-integrators assemble and integrate the services of different

transportation service providers through technical integration, contractual management and financial clearing and provides these services to MaaS-operators. (Smith et al., 2018.) These roles can be adopted by the different MaaS-stakeholders depending on the used strategy for MaaS-implementation. Smith et al. (2018) presented in their paper three different development scenarios for the development of MaaS, market-driven, public-controlled, and public-private development scenarios. Market-driven development would be driven by the private actors, absorbing both roles of MaaS operator and integrator. Public sector actors would in this scenario work mostly unchanged, with the new actions being that they would support private actors to sell public transaction tickets, enable the bundling of public transportation tickets with other transportation modes and offer viable deals for the private MaaS operators. In this scenario the public sector would act as enablers, with private actors developing and pushing the use of the MaaS-services. Public-controlled development would see the public sector actors taking the new MaaS-roles and driving and funding the further development of the MaaS-operations. Public-private development scenario would be between the previous scenarios, with public sector taking control of the role of integrator, while private sector actors would take the role of the operator. (Smith et al., 2018.) Both the public-controlled and market-driven development strategies can be seen in the currently existing MaaS-services. Cluster analysis of current MaaS-services showed that the systems can be identified into three clusters, the Level 1-route planners, the private actor driven third party systems, and the public transportation operator driven public systems. (Esztergár-Kiss et al., 2020.)

The idea for market-driven development is the assumption that MaaS would create viable business operations, with the private sector having higher incentives and capabilities for creating services meeting customer needs compared to public sector. Public-controlled development hinges on the ideas that the main purpose for developing MaaS is to facilitate a modal shift from private cars towards other transportation modes, with the public transportation acting as a basis for MaaS and that by controlling the development the public sector can avoid the issues stemming from the conflicting goals of private and public sector actors and develop the systems towards their own needs and goals. Public-private development would work between the two, resulting in lower initial costs for private operators, while preventing the risk of singular MaaS-operators becoming too dominant in the area while also lowering the risks for the transportation service providers becoming too reliant on brokers in similar way to car rental and hotel industries. (Smith et al., 2018.)

Even if the public sector actors would decide that the MaaS-initiatives should be done with the idea of market-driven development, the said actors should keep themselves involved and co-operate with MaaS-service developers where needed if they want to make sure that they will still operate as a transportation-system provider in the future. This is because in analysis of current MaaS-services, only 70 percent of the available MaaS-services included public transportation services (Esztergár-Kiss et al., 2020). The number would suggest that if the public transport actors would act complacent or indifferent towards the private MaaS-developments, private actors could end up making the MaaS-services by themselves without the involvement of the public transportation modes. If such service would end up getting popular, it could possibly attract users of public transportation towards other transportation modes that would not necessarily work according to the sustainability plans laid by the city officials and the public transportation managers. It is also notable that shared mobility services tend to be operating with higher profits compared to subsidised public transportation operators. This could easily raise a situation where it would be financially benefitting for the MaaS-service operator to have the users substitute the usage of public transportation

services for other transportation modes within the service. (Wong et al., 2020.) It has been proposed that to increase the sustainability of the MaaS-services, car- and ride-sharing and other private car-based travel modes should be marginalized in the MaaS-service (Alyavina et al., 2020). If the MaaS-operator would end up changing the MaaS-bundle designs and prices towards the use of the more profitable alternative transportation modes (Wong et al., 2020), it would directly act against the proposed marginalization and directly contribute to the unsustainability of the created MaaS-service.

4.5.2 Legislation and politics of MaaS

As the development of MaaS-services has been found to be prone to develop towards less sustainable end results, companies and public actors have taken different actions to be able to direct the MaaS-development. MaaS-services have been influencing user decisions towards using more environmentally friendly transportation modes by comparing the CO2-emissions of the different available transportation modes, promoting public transportation over other transportation modes or giving the users incentives for their choice to use sustainable transportation. (Jittrapirom et al., 2017.) Other approach to direct the MaaS-development is legislative. For example, it has been proposed that to ensure the best results from MaaS-initiatives in terms of environmental sustainability, the governance would need to implement policies to increase the average occupancy of vehicles, have the people shift from private vehicles to public transport and couple the public transport with transportation modes for the first and last kilometres (Noussan & Tagliapietra, 2020). When making regulations to support the use of MaaS-services, the policymakers need to be careful to avoid undesired effects. While it would be tempting to make regulation clearly favouring MaaS over other transportation modes, this could undermine the users' feeling of freedom in their transportation choices. (Schikofsky et al., 2020.) Instead it has been recommended that legislative actors should focus on communicating the benefits and advantages the use of MaaS-services do provide for the users of the service, as the perceived usefulness of the service has been found to be the users' main driver of intention to use the MaaS-service. (Mola et al., 2020).

One issue for the governance of the MaaS-implementations is the existing legislation and the lack of action of changing the legislative issues. While for example the European Commission has mentioned the opportunities of multimodal transportation services in reaching transport policy goals, the commission's effect on MaaS-development has been limited by lack of directives directly supporting MaaS-concept (Audouin & Finger, 2018). One reason for the lack of regulative changes could be caused by the various actors lacking the motivation and self-interest to create the required regulation changes (Wolff & Hakanen, 2021). While European Commission has been inactive in taking legislative actions, the Finnish government revised Finnish transportation regulations to support the implementation of MaaS-services. Despite the large revisions the actual implementation of the services has still been notably slow (Karlsson et al., 2020). While the Finnish transportation regulations have gained international praise for their standing as a good example for the countries providing foundation for MaaS-services, the Finnish public sector actors themselves consider the law to be unrealistic. The regulations have been criticized as they have not been seen to address the issues in the daily planning and operation of transportation systems, regulations having a uniform approach to MaaS despite the differences between the cities of Finland. The market-based approach of the regulations has also been found to be ill-fitting for the low-density regions which do not have viable market conditions for

the approach to work properly. As a result of these issues, the public sector actors find that while the regulations were created to enable the creation of MaaS-services, they were instead found to be one of major reasons for conflicts during MaaS-implementations. (Mladenović & Haavisto, 2021.)

The two sides of the MaaS-service development, the public and private actors, have been noted to have inherent conflicts about the goals of the resulting MaaS-service. In the interviews with Hungarian and English MaaS-stakeholders the biggest motivation for participating in MaaS-service development for private actors was most often the possibilities for gaining higher market share and higher revenues through the service, while the public sector actors looked for increasing the use of public transportation and gaining higher-quality demand data (Polydoropoulou, Pagoni, & Tsirimpa, 2020). In other interviews the Finnish public sector actors had concerns that if the transportation system is not anymore controlled by the public sector, the system is not anymore designed to answer to societal goals (Mladenović & Haavisto, 2021). These concerns might be legitimate, as it has been suggested that while the Finnish regulations are friendly to new market entrants, they could have long-term challenges in keeping the goals of the MaaS-operators and the surrounding society aligned with each other (Ydersbond et al., 2020). To best avoid these conflicts and for the MaaS-implementations to succeed, the private and public stakeholders should have meetings and discussions and create shared vision for the MaaS-initiatives to resolve issues where possible and reduce the number of issues raising from misunderstandings and different interpretations between the different stakeholders (Karlsson et al., 2020). MaaS-experts have stated that the MaaS should be founded on previously defined mobility strategies and policies in effort to reduce the opposition for the MaaS (Wolff & Hakanen, 2021). This way the existing policies could be used in trying to create shared vision between the stakeholders and frame the MaaS-development as a continuation of previous policies.

This could also make it possible to avoid the issue met in Helsinki, where the adoption of MaaS-services was slowed down because of MaaS-operator having neglected to network with the local politicians, leading to local politicians having a lack of understanding of what MaaS is and what it could do for the local transportation. As a result, the local government lacked vision for MaaS and did not push for the local transportation authority Helsinki Region Transport (HSL) to open their services for the MaaS operators. This would not necessarily have helped much though, as big reason for the reluctance for HSL to support MaaS-initiatives was because of the governance structure of HSL. HSL is led by a board of city council members coming from multiple municipalities. As these city council members had rivalries, competition, and different political views and situations between their municipalities, it would have been unlikely the HSL-board members would have an early agreement for their approach for MaaS. (Audouin & Finger, 2018.) Despite the mistake of lack of networking by the MaaS-operator, the example of Helsinki shows that the internal struggles of the public transportation authorities can also be major issue for MaaS-services. To avoid these issues to their best abilities, MaaS-operators should keep networking with the locally important stakeholders where possible to get support for MaaS-operations, while also preparing for unforeseen issues coming up from dealing with large and complicated organizations. Finnish and Swedish state-level actors have taken different approaches towards MaaS-development. Finland's interest in MaaS has come from the idea of developing cost-efficient transportation sector while simultaneously being able to find new growth industries from the digitalization. As a result of this approach, the Finnish actors have taken a promoter-role, where the Finnish actors prepare fitting legislation, create pilot environments and fund MaaS-related pilots. This approach has limited the

possibilities for Finnish actors to govern the MaaS-development trajectory directly but has enabled the actors to protect their interests through proactively directing the implementations through fitting contracts and funding the MaaS-initiatives. (Mukhtar-Landgren & Smith, 2019.)

Implementing MaaS-systems requires notable funding and as such the MaaS-implementations are in difficult situation. For the MaaS-model to fully grow and get implemented, research results from MaaS-implementations would be required to gain interest and funding from the public and private stakeholders. But these results cannot be gained if there is lack of funding for the MaaS in the first place, limiting the growth of MaaS-concept. (Karlsson et al., 2020.) Finnish and Swedish public actors, Business Finland and Innovation Agency, have funded MaaS-pilots and other MaaS-developments to support the creation of MaaS-services (Mukhtar-Landgren & Smith, 2019; Pangbourne et al., 2020). These public actors have been able to influence the MaaS-development through the funding, as funding agencies have generally required the funded projects to be collaborative with the public sector to receive the funding (Mukhtar-Landgren & Smith, 2019).

Funding MaaS-initiatives could also help small private operators to participate in MaaS-services, as these operators might find it impossible to join MaaS-services in the lack of human and financial resources to manage the new project (Polydoropoulou, Pagoni, & Tsirimpa, 2020). Sweden's interest in developing MaaS-services has come from the interest in increasing the market shares of sustainable transportation modes and public transportation. To enable this change the Swedish actors have taken the enabler-role, where the actors are governing the MaaS-development through soft policy-instruments, while the regional public transportation authorities are aiming to implement the instruments and take charge of the MaaS-development. (Mukhtar-Landgren & Smith, 2019.) Despite these actions, the Swedish MaaS-developments have been hindered by the lack of legislative reforms. The interviews with Swedish MaaS-initiative stakeholders did outline that both the local public transportation authorities and the potential MaaS-operators consider that under current Swedish laws the public transportation authorities are not able to take other roles than the role of provider of traditional public transportation (Smith et al., 2019).

While the Swedish regional public transportation authorities have been trying to take charge of MaaS-implementation by using different policies, as a result of no clear intention for reforming legislation, the Swedish regional public transport authorities have less possibilities and less possible operational roles compared to the Finnish authorities (Mukhtar-Landgren & Smith, 2019). Legislation is an important issue, because it prevents municipalities of organizing public transportation services outside of their own region. Legislation limits the capabilities of municipalities of creating encompassing MaaS-services, as they would be required to negotiate individual contracts with the other municipalities to be able to create a well-functioning public transportation system acting as a backbone within their own MaaS-service. (Mladenović & Haavisto, 2021.) Swedish MaaS-stakeholders have mentioned that, as public actors are not under current laws allowed to restrict or distort the market competition, it is difficult to create long-term partnerships between the public transportation authorities and the different private sector companies. (Karlsson et al., 2020; Smith et al., 2019.) Supporting this view, the Finnish governmental organizations have seen that their role in MaaS is to legislate, make sure that the implementations are going according to the laws and prevent MaaS-service implementations being prevented from happening by different legislative issues (Mladenović & Haavisto, 2021). The views of the stakeholders imply that while the public authorities could see benefits in them having

more control over the MaaS-implementations, they could be inhibited by the existing legislation from doing so. While the Finnish organizations see that their role is to help MaaS-implementations to avoid failures from happening due to legislative issues, the chosen approach also implies that the Finnish organizations are not currently planning on changing the legislation to enable themselves to take more active role in the MaaS-implementations. The Swedish interviewees have mentioned that both the private and public actors involved in MaaS consider and treat the current laws, which are restricting the roles and partnerships, as unchangeable, causing the stakeholders to consider the possibilities only based on the options given by the current legislation (Smith et al., 2019). It is possible that the amount of required legislative changes is discouraging the transportation authorities from thinking the possibilities outside of the current legislation, resulting in lack of innovation and lack of action in implementing MaaS-services.

Designing business models that are viable for all the different actors involved in the MaaS-services has been noted to be particularly challenging in multiple interviews with the MaaS-service stakeholders (Karlsson et al., 2020; Mladenović & Haavisto, 2021; Smith et al., 2020). It is possible that as the users of public transportation are expected to be the first users to adopt the use of MaaS-services, the interest of public transportation-companies to provide their services through MaaS-services would be limited. As MaaS-services could potentially become competitors for the public transportation, while the number of users going from private cars to being users of public transportation through the use of MaaS-services is expected to be largely insignificant in short-term. Because of the inherent risk this could mean for their operations, the public transportation-providers could be unwilling to cooperate with the MaaS-operators. (Jittrapirom et al., 2020.) This lack of cooperation has already been visible in practice, as the interviewed Finnish public sector actors have not been open to giving subsidies or letting the MaaS-operators sell public transportation tickets, unless they would be able to prove that their operations were able to significantly increase the service levels and decrease the use of private cars (Mladenović & Haavisto, 2021). On top of this, the existing legal framework can cause the tickets to be more expensive for the MaaS-operators compared to the ones sold straight to individuals, as has been the case in Budapest. The legislation can also prevent the MaaS-operators from selling discounted tickets, such as student- and pensioner-tickets. (Polydoropoulou, Pagoni, & Tsirimpa, 2020.) The issue over selling public transportation tickets has already been limiting the emergence of MaaS-services, as the Swedish private sector actors have stated that the main reason why MaaS-services have not appeared in West Sweden after successful pilot-tests has been that the external public sector actors have not allowed to sell public transportation tickets through the developed MaaS-services (Smith et al., 2019). As it has been found that users will not subscribe to MaaS-bundles if they do not include the transportation modes they find important in their daily transportation (Matyas & Kamargianni, 2019), and that the public transportation is the most preferred transportation mode in the MaaS-bundles (Caiati et al., 2020; Esztergár-Kiss & Kerényi, 2020; Jang et al., 2020; Matyas, 2020), not allowing the MaaS-services to sell public transportation tickets would cripple chances of success for the MaaS-services.

Preventing the MaaS-operators from selling public transportation tickets could cause the private operators in search of higher revenues and market share to start openly competing against the public transportation and integrate different modes into the service with no regard for the substitution of the public transportation. MaaS-service could for example include ride-hailing services in the MaaS-service, which have been found to be more likely to substitute the use of public transportation than complement their use, with ride-hailing increasing the vehicle-kilometres-travelled and contributing

to increase of motorised traffic in cities during the traffic peak hours (Tirachini, 2020). The difficult search for the business model could end up the private actors to operate against the goals and targets set by the public actors, which is why public actors should be encouraged to cooperate with private MaaS-operators to be able to create a MaaS-service benefitting both the public and private sector.

4.5.3 Beyond mobility services

The MaaS-services may interact with multiple different types of services beyond mere mobility services. The following sections discuss the integration of public transportation to MaaS-services, the possible partnerships and the public and private stakeholders demand for high-quality demand data.

Integration of public transportation

Finnish public sector officials in interviews have had conflicting views on whether MaaS-services would be shifting customers from public transportation to other transportation modes or whether it would bring more customers for the public transportation. Some of the Finnish public sector actors believe that MaaS could bring more users to the public transportation if the MaaS-services were designed with complementary first-mile and last-mile services while providing expanded transportation ticket sales (Mladenović & Haavisto, 2021.). It has also been suggested that public transport agencies should integrate ride-hailing services as a last-mile services in low density-markets where the ride-hailing is not likely to increase congestion to be able to retain passengers and not have them substitute public transportation with the ride-hailing service in their entirety (Tirachini, 2020). On other hand while it has been found that having a subscription to well-designed monthly MaaS-packages do influence the usage of private cars towards reducing monthly car kilometres (Hensher et al., 2021), the potential for the modal shift away from the private cars does not appear to be radical.

The potential users are not willing to pay much for the MaaS-services due to seeing the available mobility packages more as extensions to public transportation-services, and not as a replacement of private cars (Maas, 2021). The convenience and freedom provided by the private cars has been found hard to match by using sustainable transportation modes. Because of this it is possible that the use of private cars is replaced with individual cars provided through MaaS-services, while lowering the associated costs and hassles of owning the car. (Sjöman et al., 2020.)

Because of enjoyability of cars as a transportation mode, the people still have preferred to use modes such as car-sharing, ridesharing, ride-hailing and private cars while using MaaS as a complementary transportation mode (Alyavina et al., 2020). As a result, the users of private cars are expected to adopt the use of MaaS-services at a later date compared to other user groups, limiting the short-term potential of MaaS-services in limiting the use of private cars and reducing the congestion in the cities (Jittrapirom et al., 2020).

It is also possible that in markets with lot of peak traffic, the infrequent users of public transportation might shift towards using more of private cars due to increasing transportation fees and more severe crowding after the introduction of MaaS-subscriptions. As this change would be smaller in off-peak markets with less crowding,

it is still possible that on aggregate the car ownership would decrease after the emergence of MaaS-services. (Hörcher & Graham, 2020.) Results from Finnish survey though give some hope for the MaaS-services reducing the use of private cars in long-term. The survey respondents consisting of Finns aged 18 to 64 answered that if the public transportation connections were good enough for them in their area, 39 percent of respondents would not want or need to own a car. In case where MaaS-service with lower annual costs compared to their current ones would be launched in their area, 58 percent of respondents would not feel the need to own a car. (Liljamo et al., 2021.) While the survey-results emphasize the need for MaaS-service to be able to lower the mobility costs of their users, the results do give hope that emergence of MaaS-services could be able to fulfil one of the goals set for the MaaS-services, to lower the use of private cars.

Partnership with other public services

The interviews with the Finnish MaaS-stakeholders brought up a view that MaaS could be seen as something beyond mobility, and that all the other services that can be bought alongside the mobility services, such as concert tickets, can be considered MaaS (Mladenović & Haavisto, 2021). One possibility for improving the usefulness and profitability of the MaaS-services could be the inclusion of external services in MaaS-services. For example, some of the MaaS-services have provided access for parking services or including municipal services with access for payment and reporting system for breakdowns or disruptions (Jittrapirom et al., 2017; myCicero Srl, 2021). Following this idea, it has been proposed that MaaS-mobility services could be bundled and sold alongside other services, such as mobile phone contracts (Hensher & Mulley, 2021). It could be possible that including MaaS-services alongside mobile phone contracts with internet access could promote and encourage the usage of inherently online-oriented MaaS-services. In similar sense, following the idea where sporting venues have negotiated with local public transportation companies to allow free transportation for the ticket holders during game days (Shoup, 2020), selling tickets to different events combined with MaaS-tickets to the event could possibly be used to lessen the use of private cars and promote the use of sustainable transportation modes among the people going to the event. Partnering with other companies could help the MaaS-services to promote themselves to users of other companies while developing the MaaS-concept itself from niche (Hensher & Mulley, 2021). In the lack of research though, the effectivity of this approach can mostly be only speculated upon and will require further research to be done in the future. Another way the MaaS-operator could possibly improve their own profitability would be to sell data analysis services to other actors. These actors could vary from other mobility service providers to urban authorities or to other private companies such as retailers. (Pangbourne et al., 2020.) While this approach would raise questions about data privacy and could be prevented by the existing regulations, this approach could possibly improve the profitability of the MaaS-services and create viable business models for MaaS-operators. It is though mentioned that different mechanisms related to data ownership could be misused by local MaaS monopolies, preventing the competition from entering the market, enabling the MaaS-operator to raise prices for the end-users, with these raised profits being taken as a profit for the MaaS-operator instead of distributing it to partnering transportation companies (Pangbourne et al., 2020).

Demand for high-quality data

One of the important aspects for designing MaaS-service would be to provide both the public and private sectors actors with high-quality demand data. The MaaS-actors, ranging from private and public transport operators, car rental companies to city government authorities, were invited to MaaS workshops held in Budapest, Hungary and in Greater Manchester of United Kingdom. During the workshops, most of the different actors specified that getting high-quality demand data was important motivational reason for participating in MaaS-system. (Polydoropoulou, Pagoni, & Tsirimpa, 2020.) Providing this data for the stakeholders could be such argued to be central requirement for the design of the MaaS-services. This is because MaaS-services cannot work properly if the majority of the dominant transportation service providers do not join the service. This lack of involvement from the dominant actors would prevent the integrated solution-approach from working as intended. (Smith et al., 2019.) As such, providing to the needs and motives of the different actors in creating and providing high-quality demand data can be considered one of the central factors in creating successful MaaS-services.

It is though notable that the same stakeholders mentioned that one of the biggest operational barriers for MaaS is the companies' unwillingness to share data and the limited availability of application programming interfaces (API). In addition to lack of availability, the available APIs do not tend to use compatible data formats, causing additional difficulties for interoperability of data and collaboration between transportation companies. (Polydoropoulou, Pagoni, & Tsirimpa, 2020.)

Public transportation authorities have brought up that the market-driven and public-private development models imply that the authorities will be less involved in end-user interactions, increasing their reliance on third-party data. Unwillingness to share this information would make it very difficult to make plans and set budgets for the public transportation efforts. (Smith et al., 2018.) Even if the country will have regulations making it mandatory for the transportation companies to provide data and enable third parties to sell public transportation-tickets through APIs free of charge, this does not necessarily help the business case of the MaaS-service. One reason for this is that while the regulations around the APIs have been created, surveillance over service providers has been lacking. The Finnish authority Traficom had taken advising role to the changes, with the sanctions for lack of complying with the regulations starting from spring 2019. This choice led to service providers largely ignoring the regulations, with only a small number of service providers having provided the essential minimum of data to Finnish National Access Point. (Ydersbond et al., 2020.)

Another reason for the lack of helping the business case is that while the new regulations enable the MaaS-services to include large transportation modes to be used through their service, for example the Helsinki Region Transport (HSL) did not pay any commission or compensation for the resellers using the API by 2019 (Ydersbond et al., 2020). When in December 2016 Helsinki Region Transport opened their API, the HSL decided to only open their single-ticket API for a single MaaS-operator working in the area called MaaS Global (Audouin & Finger, 2018). MaaS Global is the company behind the MaaS-service Whim, which launched in November 2017 and operates in Finland in the area of the Helsinki (Ydersbond et al., 2020). HSL's decision to open only a single-ticket API created a large problem for MaaS Global, as they provided the users of Whim-service unlimited access to public transportation through their mobility bundles. This caused the Whim-application to need to book singular public transportation tickets every time the user wanted to use their transportation services

through the application. As singular tickets were not subsidized like the seasonal tickets, this caused additional costs for MaaS Global. While eventually HSL did open their single-ticket API for everyone in April 2018 and API for seasonal tickets in November 2018, between these two years the MaaS-operators could only get access to API causing the operators additional costs, hindering the profitability of MaaS-solutions and slowing down the usage of MaaS-services. (Audouin & Finger, 2018.) Despite the non-payment for online resellers, Helsinki Region Transport did pay commissions for resellers operating in physical sale points. This decision was appealed by MaaS Global, with Transport Safety Agency concluding that there was no discrimination and that pricing scheme negotiation in such way was allowed. (Ydersbond et al., 2020.)

This conflict highlights the importance of the negotiations during initial-phases of MaaS-implementations. The MaaS-operator needs to be able to convince the dominant transportation companies to join a service while getting the companies to share their data with each other, or the quality of the demand-data will suffer in the absence of the major players of the area, limiting the usefulness of the acquired data and adding to the hesitancy of the transportation companies to join the service.

4.6 The Effects of MaaS

MaaS-services are expected to have large effects on the transportation sector, with a large part of the interest in MaaS-services being based on their potential effects on the sustainability of the transportation. In the following sections, the effects of MaaS-services are first explored through pilot studies, how the different payment models will change the effects of MaaS-services, and how the MaaS-subscription bundles could be designed and how these design choices will affect the effects of the MaaS-services.

4.6.1 Pilot Studies

While MaaS-services have been set high forward-looking expectations in solving problems such as congestion, carbon emissions, air pollution and shortage of parking space, these expectations have been noted to lack nuance and empirical support. This nuance has been missing due to ambiguity around MaaS-concept and a lack of empirical studies on MaaS-services in real-life contexts. (Storme et al., 2020.) The lack of empirical studies on the effects of MaaS on the user behaviour has been caused by the low number of MaaS-implementations and their lack of their open evaluations (Strömberg et al., 2018). Within this small group of empirical studies, the Swedish UbiGo (Strömberg et al., 2018) and the Belgian study of Storme et al. (2020) act as early studies exploring the effects of MaaS-services in real-life contexts.

The early MaaS pilot studies suggest that the MaaS-services could have the capabilities for lowering the amount of use of the private cars. A Belgian exploratory pilot study lasting two and a half months trialled a prototype MaaS-smartphone application, which provided the participants with different MaaS-transportation modes with in-application booking and payment (Storme et al., 2020). The participants were recruited from the employees of the University of Ghent, with the pilot study targeting people who were most likely to reduce their private car use with the usage of the MaaS-service. The chosen 100 participants were provided with 150 to 350 euros monthly travel budget depending on their current use of their own private cars, while also asking them to limit the use of their private cars as much as possible. (Storme et al., 2020.) Another study, a Swedish six-month pilot test with a UbiGo MaaS-service, provided 195 individuals of

the municipality of Gothenburg with a prepaid credit-based MaaS-service. The pilot study was conducted with the idea of participants using the service as a part of their own lives with no requests for the use of service. (Strömberg et al., 2018.) The participants of both pilot studies considerably lowered the use of their private cars during the pilot studies. Many of the participants of the Swedish study reported that they had lowered their car use beyond their expectations. The participants stated that having the car ready outside the owners do not even consider other possible types of transportation, and that during study they had realized how well their public transportations systems actually worked (Strömberg et al., 2018.) The Belgian study though did find that while their participants were able to use their cars less, none of the participants were able to fully substitute the car use. This was because while replacing routine commute trips was found to be simple, replacing leisure trips was notably more difficult. Some of the examples given by the respondents were that while for commute there are alternatives, they do need the car for bringing children to their sports activities and that they need their car to help their disabled parents. The private cars were also heavily used within the peoples' own social networks, by chauffeuring the children of the befriended parents or by having the cars being used by participants' partners or adult children. (Storme et al., 2020.)

One notable issue for the use of MaaS-services is the convenience and the flexibility of the private cars compared to the use of MaaS-services. In the Belgian study 46 percent of the trips made on private cars were motivated by the alternatives to private cars being too much of a hassle. The requirement to plan more of their traveling, uncertainty about travel times and having to care less about the traveling modes the users would use could lead the users opt-out of using MaaS-services when the user needs to go to many locations within short time, leading to lack of interest of substituting the use of their private car. While the user could still occasionally use the MaaS-services, their use would be limited to working as complementary service to the private car usage. (Storme et al., 2020.) This issue might not though affect all the MaaS-users as severely depending on their approach and attitude to the alternative modes. In the Swedish UbiGo-study, some of the participants stated that they had not been using their cars as much as the use of MaaS-service required more planning. During this increased planning the study participants had merged their trips, lowered the number of spontaneous trips, or changed their plans on where to meet their friends in the first place. These users did not find the increased need for planning as a negative aspect of the service. (Strömberg et al., 2018.)

It is notable that while the UbiGo-trial had participants who wanted to give up owning a car or wanted to have access to one without having to buy one, neither of these two groups of participants were satisfied with the coverage of the car rental and carpool-services. This unsatisfaction did lead these users to skipping trips or making adaptations to their plans. (Strömberg et al., 2018.) While this could be okay for some of the users, other people might not be willing to change or cut down their mobility needs in lack of having enough access to cars through the services. For instance, the fact that the Belgian participants were not able to stop making trips with the private cars even when they were incentivized to do so raises questions over the substitutive effect of the MaaS (Storme et al., 2020). While the users might be able reduce the use of their cars in general, they would not be able to get rid of their own cars and instead use the MaaS as complementary service alongside their own private car.

As a summary, the two pilot studies suggest that the implementation of MaaS-services could possibly decrease the use of the private cars especially in routine commuting trips. The change would be more limited with leisure trips, as the users could end up using

private cars as a transportation mode mostly because of the alternatives were too much of a hassle to use. In the end, pilot studies suggest that while the MaaS is prone to end up being a complementary service alongside the use of private cars, the services could still be able to lower the use of private cars and possibly lead the users who are willing to do extra planning for their travelling to manage to sell their own cars. For the design of the MaaS-service on other hand, the UbiGo-trial showed that the participants of the trial were unaware of their own preconditions and travel needs and behaviour, leading to the participants being not able to predict their own behaviour changes during the trial. Because of this the MaaS-services should be flexible and let the users change their subscription plans when needed and support the users' behaviour change within the service. (Strömberg et al., 2018.)

4.6.2 Payment models

The payment models that have widely been used and discussed with the MaaS-services are the monthly subscription-model with mobility packages and the pay-as-you-go-model (Esztergár-Kiss et al., 2020). MaaS-services allow customers to purchase bundles of mobility services with defined access to transportation modes with a specified level of service (Ho et al., 2018), with pay-as-you-go model billing the customers periodically based on their use of transportation services and subscription-model having customers pay monthly fees for access to predetermined access to transportation services (Vij et al., 2020). The currently existing MaaS-services most often employ the use of pay-as-you-go payment system, while some of the services have monthly invoice for the used services, and a few services have monthly mobility packages including a mix of different transportation services for predefined prices (Esztergár-Kiss et al., 2020).

In terms of preferring the different payment models, the Hungarian and British managing stakeholders of MaaS-initiatives have specified that in their opinion the MaaS-services should start with the pay-as-you-go model to build the trust between the MaaS-operator and the customers, and implement the subscription packages later on tailored to the seen customer needs (Polydoropoulou, Pagoni, & Tsirimpa, 2020). On other hand the research about the preferences of the users is mixed. While the Australian research by Vij et al. (2020) reported that consumers would prefer pay-as-you-go model twice as much over the bundled subscription model, other research made in Sydney Australia, Tyneside UK and Madrid Spain do give the opposite results with the users preferring subscription model over pay-as-you-go model (Ho et al., 2018, 2020; Lopez-Carreiro et al., 2020). For instance the results of Ho et al. (2020) showed that in Tyneside 45 percent of the participants would adopt MaaS-services, with 32 percent going for subscription-plan and 13 percent for the pay-as-you-go payment (Ho et al., 2020), while the Spanish individuals showed a preference for the subscription-model based on its convenience over the pay-as-you-go-model (Lopez-Carreiro et al., 2020). The mixed results for different payment models require the MaaS-operator to research their own area of operations and try to understand the needs of their own users, possibly through experimenting with different payment models and subscription-bundles in the launch-phase of the service.

Both of the common payment-models have their own issues for the sustainability of the service if the payment models have not been implemented correctly. Using the subscription payment model could have a rebound effect, where the users of the service could feel that they have not been getting the value out from their subscription, leading to users making additional trips to remedy this (Pangbourne et al., 2020). If the

subscription-model would be made with the credit-based model where the subscription provides the users with monthly pre-paid credits for the paid subscription, this issue could be mitigated. This could be done having the users' paid unused travelling credits roll-over to the next payment period so the users would not go on additional trips just for the purpose of using the unused credits (Ho et al., 2020). Including the credit roll-over-feature would not increase the attractiveness of the MaaS-plans (Ho et al., 2018) and reduce profit for the MaaS-provider (Reck et al., 2020), but would provide the users with more flexibility and slightly increase the sustainability of the MaaS-service. With the pay-as-you-go payment model the issue is different. Pay-as-you-go payment model enables the users to maintain their existing travelling patterns, limiting the modal change towards the more sustainable travelling modes and letting the users to replace some of their use of public transportation with Taxis, Uber or car-sharing (Ho et al., 2020).

As it seems that subscription-based MaaS-services would be the best MaaS-option in terms of sustainability, it could be beneficial to implement suitable strategies to increase the MaaS-uptake while simultaneously have the users prefer subscription model over the pay-as-you-go model. A MaaS-trial held in Sydney opted to start with initial pay-as-you-go model during first month, and afterwards implemented new bundle every month. This approach provided the system developers an opportunity to grow user interest within the participants, while simultaneously enabled the developers to trial new options and learn through experimentation with the users. This strategy was found to have the pay-as-you-go model as the dominant payment-model throughout the trial, but also created a monthly change from pay-as-you-go option towards subscription-model. (Hensher et al., 2021.) This approach could also be beneficial because of general lack of the users' willingness to pay for the services. As the people have been largely unwilling to pay enough to meet costs of delivering the MaaS-service, launching a successful MaaS-system is challenging. To find a solution for this issue, it has been proposed that using pay-as-you-go MaaS-system as a way to increase the awareness of people towards the new mobility packages could be beneficial, as the people included in a Finnish study shared the interest in having several mobility services available through one ticket or application and that the shift from the use of private cars towards the use of mobility services should be done. (Liljamo et al., 2020.) While starting with pay-as-you-go system would limit the short-term sustainability effects of the MaaS-services, it would enable a change from private vehicles towards mobility services, raise awareness for the different sustainable transportation modes and possibly in long-term lead the users of the service towards MaaS-subscriptions and substitute some of the use of private cars with provided transportation modes. This approach would also give the MaaS-operators a chance to experiment with the subscription-bundles and implement transportation modes more gradually, enabling incremental launch and learning from the gained data before unsuccessful launch, severe mistakes, or slower than expected uptake of the service can cripple the finances of the MaaS-operator.

4.6.3 Subscription bundle design

Research to the creation of MaaS-bundles based on the city characteristic data acquired from 15 European cities created fitting MaaS-bundles consisting of public transportation, bike-sharing, car-sharing and taxi to support efficient realization of MaaS, while supporting user demand-based usage (Esztergár-Kiss & Kerényi, 2020). Based on the data, public transportation was included in the MaaS-bundle in all of the 15 cities with at least 20 days per month usage. The bundle also included bike-sharing as a pay-as-you-go mode, car-sharing with one free hour per day and with the taxi with

10 to 20 km of free kilometres per day. Comparing these results to the MaaS service Whim, it is notable that Whim includes similar basic package, including unlimited local public transportation, 30 minutes of city bike and car rental and taxi rides within a 5-km radius. (Esztergár-Kiss & Kerényi, 2020.) The similarity of the research results and of the basic bundle of the Whim-application suggests that the research's average results would work as a baseline for the European MaaS-services. This basic MaaS-bundle could act as a basis for the MaaS-bundle structure, which could later on be altered on city-by-city basis based on the city characteristics and acquired demand data gained from the active MaaS-service. While it would seem sensible to create multiple different bundles to target different user groups with different preferences, this might not be as needed as expected. While the users can be clustered into different user groups based on their notably different mobility behaviour, the user groups have hardly any differences between each other in terms of preferred services within MaaS-plans. (Maas, 2021.) This would suggest that the baseline-bundle could be used for most of the users in short-term and medium-term, with no rush for creating alternative bundles if the acquired demand data does not show demand for it.

While it is expected that the use of MaaS-services is able to lower the use of private cars among their users, the inclusion of some of the transportation modes in the MaaS-service would not necessarily lead to users lowering their use of private cars. This is because the MaaS-services can provide access to cars to people, who have not had an access to them previously (Durand et al., 2018). For instance, half of the study respondents in Ghana claimed to have a driver's license, while only less than a quarter of them did own a car. This was suspected to be because the local residents would have wanted to drive cars but could not afford to own one. As a result, 53 percent of the participants did answer that they would intend to use car-sharing services if the services would come to their cities. (Acheampong & Siiba, 2020.)

Similar results were obtained in a survey in London, which showed that while 28 percent of the respondents would use more public transportation if MaaS was available, two percent said they would most likely replace some of their use of public transportation with taxis and 12 percent would replace part of their use of public transportation with car sharing (Kamargianni et al., 2018). While MaaS is still expected to provide net positive results in sustainability of transportation, these results showcase that the effects for the sustainability are nuanced and can be affected both positively and negatively. While not directly applicable to MaaS-services, in research of the ride-hailing services, it has been found that ride-hailing is most likely to substitute the use of public transportation the most in places where the public transportation efforts are inadequate in travel time or travel experience compared to cities with more efficient public transportation (Tirachini, 2020). This raises a possibility, that as with ride-hailing services, car-sharing services included within MaaS-services would be more likely to replace the use of public transportation in places where the users are not happy with the quality of the public transportation provided at the area.

The same effect could be seen in two comparable MaaS-research studies conducted in Sydney, Australia and Tyneside, UK. The public transportation users of Sydney were found to be less likely to adopt the use of MaaS-services than the ones in Tyneside. This was thought to be because Sydney has regulated and subsidised transportation services, while Tyneside has deregulated services with complicated fare structures. As a result the users at Tyneside saw more value in having a MaaS-service with integrated payment model compared to users of Sydney. (Ho et al., 2018, 2020.) These results highlight the need to think through the local context of implementing MaaS-service. Implementing different transportation modes and including them in the MaaS-bundles could have

notably different result depending on the local context and the peoples' satisfaction with their current transportation options. They also highlight that the implementations can have effects in both directions, with the local context moderating the positive or the negative effects of MaaS-implementations in the area.

In similar sense to effects of car-sharing on sustainability, it is possible that faulty design of MaaS-service could also have negative effects for the users' health and wellbeing. Healthier transportation modes, such as walking or cycling, have not been highly prominent in currently existing MaaS-services. As a result, the MaaS' promise of providing door-to-door transportation for its' users inherently works against the idea where individuals should have daily physical activity to maintain their physical and mental health. (Pangbourne et al., 2020.) As there is potential for MaaS to change the users' travelling habits towards less-healthy transportation modes, it would be beneficial for the public sector stakeholders to take initiative and promote the active transportation modes where possible to maintain the health of their citizens. One way to promote the healthier transportation modes would be to include the healthier and more active transportation modes to the basic MaaS-bundle. Over 60 percent of the potential MaaS-subscribers have told that they would be willing to try transportation modes they have not tried before if their MaaS-bundle would include the mode (Matyas & Kamargianni, 2019). While in some research the participants have not been willing to pay for the bike-sharing services (Ho et al., 2020), including bike-sharing services in the subscription-bundles would make their users use bicycles more for their transportation needs (Feneri et al., 2020; Ho et al., 2020). While the earlier mentioned European baseline-model would suggest the user demand for bike-sharing as a pay-as-you-go service (Esztergár-Kiss & Kerényi, 2020), the public sector could possibly use the inclusion of healthier transportation modes in the MaaS-bundles as one of the criteria in defining the amount of funding or subsidies from public sector the MaaS-implementation would receive. Through this the public sector could use their inherent power to influence the MaaS-implementation towards their own needs and towards improving the health of their own citizens.

Research has provided some suggestions for the MaaS-services' design through the user preferences. The users have shown a preference to subscribing to longer 12-month subscription bundles instead of the shorter one- to three-month bundles. This has been explained by the people being used to having long term subscription contracts through other services, such as public transportation season tickets or mobile phone subscriptions. (Caiati et al., 2020.) Including an option for the users to create their own bundles with the transportation of their choosing does not increase the take-up rate of the MaaS-subscriptions, while also opening the possibility for limited modal changes. This option limits the modal change towards more sustainable travelling modes and possibly leads to lower adoption of the service, as the user creates a bundle with their current mobility needs and then does not take the plan because of the high price of the created bundle (Ho et al., 2018). The MaaS-service should though have enough flexibility in the mobility bundles, because otherwise the bundles have significant amount of redundancy leading to users not being interested in adopting the use of such MaaS-bundles (Hensher & Mulley, 2021). While accommodating for the user by letting them make their own bundle is suggested to be non-beneficial, the service will need to include the transportation modes the users do use in their regular travelling. A study where 30 individuals from Greater London were interviewed about their understanding and interest in MaaS-concept. The interviews revealed that the person's own habits play an important role when the person is choosing between the MaaS-bundles. During the interviews the interviewees were immediately thinking about their own daily commutes and the transport modes they otherwise use regularly. This resulted in the individuals

choosing one to three essential travelling modes without which they would not take a MaaS-bundle. (Matyas, 2020.) This leaves MaaS-operators in difficult situation. MaaS-services will need to have bundles including the transportation modes the individual users find essential, but without including too many transportation modes which the individual user would find redundant. At the same time the MaaS-service cannot leave the user to create their own bundles if MaaS-services are to be used in creating modal changes for their users.

4.7 Contextual Factors of MaaS

The effects of MaaS-services are affected by the surrounding contextual factors. In this section the effects of COVID-19, rural areas and cultural factors are discussed.

4.7.1 COVID-19

One unforeseen issue for the development of MaaS-services is the COVID-19. The pandemic caused significant decrease in demand of transportation services, reducing the connectivity of the European Union through the lack of foreign and domestic travelling, while causing operational and financial issues for the transport sector companies (European Commission & Directorate-General for Mobility and Transport, 2020).The start of the pandemic has lowered the usage of public transportation and while it has been expected that the ridership could eventually recover, the recovery will be slow and take longer than expected (Basu & Ferreira, 2021). The pandemic has also caused a change in the attitudes and opinions of people regarding buying private cars, affecting the emergence of MaaS-services. One-fifth of the zero-car households in a survey done in USA found that the pandemic had grown their intentions of buying a private car. Asking from the people who had recently bought private cars, the main reasons for purchase were the uncertainties around the service frequency of public transportation, lack of trust in the safety measures against COVID-19 and the fear of other passengers not following safety guidelines. It has also been mentioned that the pandemic could have caused stigma towards public transportation modes, with the people changing towards transportation modes that are perceived to be safer, leading to increased use of private cars. (Basu & Ferreira, 2021.) As peoples' reliance on private cars has been identified as a strong barrier for MaaS-implementations (Polydoropoulou, Pagoni, & Tsirimpa, 2020), if the COVID-19 pandemic has increased the people's use and reliance of private vehicles, it could have long-term issues for MaaS and reduce the uptake of the MaaS-concept.

While COVID-19 has mainly affected MaaS and public transportation negatively, researchers and European Commission have stated that the policymakers should take the chance created by the pandemic and accelerate the decarbonization and modernization of the transport sector to limit the sector's effect on environment and to improve the safety and health of the people (European Commission & Directorate-General for Mobility and Transport, 2020; Hensher, 2020). It has been proposed that the COVID-19 and the increase in working from home should be taken advantage of to improve transportation sustainability. This could largely be done by allowing the workers to work from home and to have more staggered working hours to avoid the transportation peak hours. This would make it possible to decrease the pressure on the transportation network, decrease travel demand and stop the growing congestion of road network. (Hensher, 2020.) European Commission has though noted that this digital transition would require full support from the transportation actors and significant

investment from public and private sectors (European Commission & Directorate-General for Mobility and Transport, 2020). As the transportation sector has been affected by the significant financial issues during the COVID-pandemic, it is entirely possible that getting the full support and investment towards unproven MaaS-initiatives could be even more difficult than expected because of the effects of the pandemic. While the European Commission has stated that they plan to help in developing MaaS-solutions through their funding instruments (European Commission & Secretariat-General, 2019), it is possible that other actors would not be ready to invest in creating significant changes to their own sector before the uncertainty caused by the pandemic has been cleared.

4.7.2 Rural areas

In the rural areas of Finland, the population size is low and ever-decreasing, the population is getting older and will likely need more of transportation services to take the people to the health services, while public transportation is heavily subsidized and with the demand for transportation services being heavily seasonal (Eckhardt et al., 2018). It is also more likely for the people in rural areas to own a car, travel by car and to be dependent on cars (Hut et al., 2021). As people of over 55 years old, people with moderate or poor health, and the user groups living in remote areas were amongst the users less likely to use MaaS-services (See details in section 4.4.1), the questions over viability of MaaS-services in rural areas should be raised. Due to these issues, it has been suggested that in rural areas the MaaS should have different goals compared to the MaaS-implementations found in cities. While the general goals for MaaS-services have been to lower the usage of private cars, reduce emissions and to increase the use of public transportation, these goals do not apply as they are to rural areas. Instead more appropriate goals for these areas would be to improve accessibility, increase transportation efficiency and to create cost savings for the public sector (Eckhardt et al., 2020). Following these suggestions, the Swedish municipalities have been concerned about low accessibility in their areas, and for this reason these municipalities have been involved in rural MaaS-pilots to appeal for current residents to stay and for new residents to move to the area. Meanwhile limited and shrinking transportation budgets have motivated Swedish regional public transportation authorities to finding new ways to provide cost-efficient accessibility to their people in rural areas in collaboration with other transportation actors, leading to multiple rural MaaS pilots being launched in the last years. (Hut et al., 2021.)

In terms of transportation modes, rural MaaS would operate by using on-demand and sharing services instead of aiming to provide multimodal transportation with the public transportation acting as the backbone for the service (Eckhardt et al., 2020). Some transportation modes, such as ridesharing, face difficulties in rural areas due to their operations not functioning well without a critical mass of users, leaving the service vulnerable to external disturbances. (Hut et al., 2021.)

Two pilot tests were run in two Finnish rural areas with no public transportation in evenings and sparse population with long distances. The pilots were made using mobile applications, which were operated with demand-responsive transport and integrated transport services. The two pilots managed to create benefits on societal level, with reduced emissions and the cost savings for public sector. The pilots also managed to have lower average costs for the customers, have higher occupancy rates of vehicles and improve accessibility around the area. (Eckhardt et al., 2020.) Despite the gained benefits, the pilots also highlighted a major issue for rural MaaS, the lack of

profitability. While both of the Finnish pilot tests managed to gain various benefits, the number of orders and customers were low. Despite being unable to cover the expenses of the pilot, one of the two systems continued to operate after the pilot due to it being in line with the city's strategies. (Eckhardt et al., 2020.) Swedish pilot tests have faced similar issues, with none of the services included in the pilot tests managed to gain a critical mass of users. While this could be partly explained by emergence of COVID-19-pandemic during the pilot tests, rural MaaS-challenges, such as small user base and high share of elderly residents did affect the success of the pilots. (Hut et al., 2021.)

4.7.3 Cultural factors

Introducing MaaS-services in areas with different cultures can have notable differences on the effects the emergence of MaaS does have on the local transportation. While in Europe the MaaS-concept has often been developed by the central governments with the idea of reducing the number of car trips made and enhancing the quality of the public transportation (Cruz & Sarmento, 2020), these intended effects are not guaranteed. There is a worry that in areas with public transportation first-culture, such as Asia and Europe, the emergence of MaaS could cause a modal shift from public transportation towards personalised shared modes (Wong et al., 2020).

As an example of the Asian MaaS-development, in Indonesian cities the online motorcycle taxis called "online ojek" have emerged as an example of a quickly growing MaaS-service. Ojek-trend was started in 2015 by the launch of a mobile application of a local Indonesian ride-hailing company Go-Jek. An online survey with 307 users from the capital of Indonesia Jakarta pointed out that the emergence of online ojek-services has quickly changed the travelling patterns of the respondents, with most of the respondents used online ojek services more than seven times a week, and with online ojek becoming the dominant transportation mode for 59 percent of the respondents. The sudden rise of online ojek was made possible by the people's lack of satisfaction in other transportation modes, with people finding the bus-services inefficient and slow and possibilities for walking cumbersome. Compared to these services, the users of online ojek services found them to be more time-efficient than alternative transportation modes and reported to be using less time while commuting than the other Jakartan commuters. At the same time the pricing of ojek-services were found to be competitive with other transportation modes, with prices ranging from being cheaper than other modes to around 50 percent higher than the price of the bus trip, while also being almost three times cheaper than taking a taxi for the same route. (Suatmadi et al., 2019.) The lack of satisfaction in public transportation has been suggested to cause higher adoption of alternative transportation modes.

Similarly, research conducted in Southern Ghana had 53 percent of the surveyed respondents likely to use car-sharing services if these services would be launched in their cities. This was claimed to be because the users of public transportation were unsatisfied with the travel comfort and speed provided by their public transportation, with 70 percent of the users of public transportation being unhappy with their transportation experiences. (Acheampong & Siiba, 2020.) It is possible that the lack of satisfaction coming from having less developed public transportation services in the area could make the MaaS-service development riskier in these areas from an environmental viewpoint. Launching MaaS-services in these areas could make them more likely to replace the use of less-satisfying public transportation-services, and through this contribute to increasing congestion and traffic emissions.

While the Go-Jek-services' expected main user group were the people from middle class switching away from using private cars (Van Mead, 2016), the majority of the service's actual users are those of lower income. As a result of this online ojek is not replacing the use of private cars of the higher income users and is instead replacing the use of the transportation modes more often used by these lower income users, such as the use of public transportation services. While ojek-services could potentially lower their users' carbon footprint through the lower fuel consumption of the ojek-services' motorcycles compared to cars, ojek-services replacing public transportation services combined with ojek-drivers driving to pick up the users before the trip itself is prone to causing negative effects for the sustainability of the service. (Suatmadi et al., 2019.) On top of this, there is the possibility that the launch of convenient transportation service could create additional transportation demand. For example ride-hailing services have been found to induce trips that would have not been made without the availability of the ride-hailing services (Tirachini, 2020). The research of Suatmadi et al. (2019) did assume that availability of online ojek-services would only replace previously transportation modes one to one without creating additional demand for transportation services, leaving the possibility that this assumption leaves some of the additional demand out from the calculations, possibly making online ojek-services more likely to contribute to increasing traffic emissions than expected (Suatmadi et al., 2019). To be able to avoid the growth of traffic emissions, the government has been encouraged to increase tariffs per kilometre for online motorcycle taxi services while limiting the use of these services through limiting the number of drivers by new regulations (Hidayatno et al., 2020).

In private car first-areas, such as North America and Australia, the emergence of MaaS-services is not expected to change the local culture and have the users change to use public transportation in masses (Wong et al., 2020). The MaaS-development in USA has mainly been managed by the local government, with the main focus being on car sharing-services and on creating new business models and improving the utilisation of private cars (Cruz & Sarmento, 2020). Despite the differences in approach, it is expected that the MaaS-services of North America and Australia would be capable in having the users change from using private vehicles to using other shared transportation modes, decreasing the rate of private vehicle ownership and lowering the level of congestion on the roads (Wong et al., 2020). This is because while ride-hailing research has shown that in countries such as Chile, Brazil and China ride-hailing is first substituting taxis and public transportation as transportation modes, in USA it is most often replacing the use of private cars (Tirachini, 2020). This would mean that while the modal change in USA towards public transportation would be limited, the modal change would more likely be environmentally sustainable and avoid the existing public transportation users to start using other transportation modes.

5. Proposed MaaS-features

In this chapter a list of research-supported MaaS-service features is presented, following the research done during the literature review.

5.1 General service design

As some of the main interests for public sector to support MaaS-implementation is to reduce car dependency and to lower the use of private cars (Jittrapirom et al., 2020), the created MaaS-service should be designed to aim for these interests to gain essential political support and access to public transportation-services. This means that the MaaS-operator would need to aim to develop a level 4 MaaS-service, which represents the integration of societal goals. Essential part of Level 4-services is the constant balancing between the demands of transportation services providers and MaaS-operators against the requirements to run a profitable business. (Sochor et al., 2018.) It is to be noted that in order to do this, the MaaS-operator will need to act as a pioneer, as none of the currently existing MaaS-services have been integrated on the level 4 (Esztergár-Kiss et al., 2020).

One example of the difficulties comes from integrating public transportation-services. Integrating public transportation-services into MaaS-packages may prove to be difficult, as public transportation-services are often done with non-flexible price models, while MaaS-service should be perceived as a flexible and unified service. To avoid issues stemming from this, the MaaS-operator should aim to integrate public transportation itself, instead of integrating already existing structures, such as single use tickets or monthly cards. (Sochor et al., 2018.) To add on the complexity of integrating the services, there are already examples from Sweden and Finland, where the local MaaS-operators have not been allowed to sell public transportation tickets at all (Smith et al., 2019), or without the MaaS-operators being able to prove their operations would increase the service levels or decrease the use of private cars (Mladenović & Haavisto, 2021). Also to gain the political support for selling public transportation tickets, the MaaS-operators should also be able to prove that the pricing of public transportation-services within MaaS-services would be revenue-, tax- and price-neutral compared to the direct sales of the public transportation-tickets (Sochor et al., 2018). Meanwhile as the local legislation can prevent the MaaS-operator from selling discounted student- and pensioner-tickets (Polydoropoulou, Pagoni, & Tsirimpa, 2020), addressing the issues of the public stakeholders while creating a MaaS-service attractive to the end users while having profitable business model may prove to be difficult. All of this would though be needed and expected from the MaaS-operator to be able to create mutually beneficial Level 4 MaaS-services.

The issue also exists towards the private stakeholders, which would want to increase their revenues, visibility and market shares through joining the MaaS-service (Polydoropoulou, Pagoni, & Tsirimpa, 2020). This means that while MaaS-operator will need to decrease the use of cars to appease for public stakeholders, they would also need to create a profitable business model for their partnering transportation service providers. While it has been proposed that car-sharing, ride-sharing and other private

car based transportation modes should marginalized in the MaaS-services to increase the sustainability of the MaaS-service (Alyavina et al., 2020), this would need to balanced out with being able to create a profitable business model for MaaS-operator and their partnering transportation service providers. MaaS-operator could be able to increase the profitability by cooperation with external partners. MaaS-services could be bundled and included alongside external services such as concert tickets (Mladenović & Haavisto, 2021), parking services or other municipal services (Jittrapirom et al., 2017; myCicero Srl, 2021) mobile phone contracts (Hensher & Mulley, 2021), or to provide free transportation during sport game days (Shoup, 2020). While generating profits for the service, including municipal services and providing free transportation during game days or events would also be in the interests of the public stakeholders, as they could provide the public stakeholders with additional value from the MaaS-service, help with the sustainability of the transportation system, and could potentially help the MaaS-operator with negotiating over the possibility of including public transportation as a transportation mode.

5.2 Features

This chapter contains information about the central features brought up by the literature review, that will have significant effects on the design of the MaaS-service. Fifty-one features have been extracted from the literature, and these have been grouped into six categories (see Table 2). These features are detailed and listed in the following sub-sections and in tables.

In the tables within the following sections, the following notation has been used. “Requirement ID” field represents an identifier for the feature; the identifier is formed by an abbreviation and a number. The abbreviations are listed in Table 2. The “Requirement” field contains the name of the requirement. The “Description” field contains the description of the requirement, and references to the research supporting the feature. Table 2 contains all the abbreviations used in chapter 5.

Table 2. The abbreviations used in the tables of chapter 5

Abbreviation of requirement	Full name of requirement
GC	General Concept
PBD	Payment and Bundle Design
PER	Personalization
URA	Usability, Reliability and Accessibility
DPM	Data Privacy and Management
SF	Service and Functionality

5.2.1 General concept

MaaS-services can be available through a mobile application or a website or a travel card often connected to the mobile application or website (Esztergár-Kiss et al., 2020), For the purposes of this study, the following system features are made for mobile application or a website accessed from a mobile device.

Route planner is a central feature of a MaaS-service. The integration of travel information to the application makes the created application into Level 1- MaaS-application (Sochor et al., 2018). By using the route planner-feature, the user would be able to get support for finding the best-fit trip for the needs of the user (Lopez-Carreiro et al., 2020; Sochor et al., 2018). The route planners are also notably important when the user is unfamiliar with the trip. If the user is unfamiliar with trip option, the users might feel increased perception of uncertainty related to trip's transfers and discourage the users from picking this trip option. The information provided by the route planners includes information about the transfers, lowering the user's uncertainty about choosing the trip and enables the user to take the trip. (Lopez-Carreiro et al., 2020.) Decreasing this uncertainty also enables the service to create modal shifts between the transportation modes, with the users being less uncertain about the trip details. Due to their central nature for MaaS-services, route planner-features should be implemented in the proposed MaaS-service.

Table 3 contains two general design requirements for the MaaS-service, the requirement to have the service accessible through mobile devices, and the inclusion of route-planner feature.

Table 3. The general design requirements for the MaaS-services

Requirement ID	Requirement	Description
GC-01	Accessible through mobile device	The created MaaS-service should be accessible through mobile devices, either as a mobile application or through a website. MaaS-services are often available through the use of mobile applications or websites (Esztergár-Kiss et al., 2020). 80 percent of respondents have at least somewhat agreed that mobility services should be possible to be combined and used through a single ticket and an application (Liljamo et al., 2020). Offering bundled transportation services through mobile applications have been shown to have relatively high willingness to pay for the potential users (Guidon et al., 2020).
GC-02	Route planner-services	A feature for the users to plan their trip through the available map and other included route planner-features. Integral service in the centre of MaaS-service. Services including route planner-services can be considered as Level 1-MaaS services. (Sochor et al., 2018.) Would help with route optimisation, providing the users with most efficient routes based on their chosen criteria. Enables the users to choose previously unfamiliar trips (Lopez-Carreiro et al., 2020.), enabling the modal shift between the transportation modes.

5.2.2 Personalization options

The users of MaaS-services could disfavour some of the available transportation modes, due to number of factors. The users could safety concerns towards some of the transportation modes, with users not feeling safe to ride a bike, drive in their cities or to use car-sharing services (Matyas, 2020). Due to the perceived lack of safety, the users of MaaS-service might want to choose the transportation services of the companies the users themselves perceive to be safe and trustful. This feature is notably important for the youth, who as a user group are particularly concerned with the perceived risks of the different transportation modes. To make the youth more comfortable with using the MaaS-service, the service will need to include options to choose the transportation companies and the transportation modes the youth themselves trust and have previous experience with. (Casadó et al., 2020.) The users might also want to exclude certain transportation modes according to their own needs. The user's health status and needs for accessibility might cause the user to want to exclude certain transportation modes from their trip results (Giesecke et al., 2016). This could include reasons such as not being able to use bike-sharing services, not being able to do long distances of walking during trip transfers or requiring transportation modes accessible with a wheelchair. Some of the user groups with special needs, such as families and pet owners, might also prefer not to use some of the transportation modes due to lack of information of the features available within the transportation mode (Matyas, 2020). The differing travel motivations and need for luggage space could also act as reasons excluding certain transportation modes. The user might need to work during the trip, excluding transportation modes such as bike-sharing. Other possibility is that the user might be returning home from shopping or from a longer trip and requires luggage space, that is not included in some of the transportation modes or in the services provided by some specific companies (Giesecke et al., 2016).

Third issue was that due to the users' previous bad experiences, the users are not any more willing to use the specific transportation modes. The users also could prefer to use their own bikes and cars instead of the ones accessed through car and bike sharing. (Matyas, 2020.)

Users might want to exclude some trips based on the number of transfers included in the trips. This could be because the user needs to work during the trip, the increased number transfers increasing the number of accessibility issues, or just wanting to have less transfers because of wanting convenience from the trip itself. (Giesecke et al., 2016.) The system should also include filter based on required walking time during transfers to attract users of private cars, as they place high value on the required walking time and are more willing to pay to have no transfers during compared to users of public transportation (Kim et al., 2021). As the time-efficiency of the transportation mode has been one of the factors driving the users for modal change between the transportation modes (Suatmadi et al., 2019), the users might also want to be able to sort the available trips according to the total time taken by the trip. Other beneficial sorting option would be to be able to sort the trips by their price. While this would not be important for the users with extensive MaaS-bundles, this option could drive the usage of MaaS-services amongst the pay-as-you-go users. The table 4 contains nine personalization design requirements for the MaaS-services.

Table 4. The personalization design requirements for the MaaS-services

Requirement ID	Requirement	Description
PER-01	Choosing the transportation company	A feature letting the user choose a specific transportation company for their trip. Users might want to choose the services of transportation companies they perceive to be safe and trustful (Casadó et al., 2020).
PER-02	Choosing preferred transportation modes	A feature letting the user choose specific transportation mode for their trip. Users might prefer different transportation modes based on their perceived safety (Casadó et al., 2020),
PER-03	Excluding specific transportation modes	Feature to exclude specific transportation modes from the trip search results. Users might want to exclude specific transportation modes offered to them based on their perceived safety (Casadó et al., 2020), health status, accessibility, differences in travel motivations or the need of luggage space (Giesecke et al., 2016). Could meet one of the main interests for public stakeholders to support MaaS-services, to improve the public accessibility (Jittrapirom et al., 2020).
PER-04	Filtering offered trips based on number of required transfers	Feature to filter the trip search results based on the number of required transfers. Users might want to limit the number of transfers due to accessibility issues rising from the transfers or from needing to work during the trip (Giesecke et al., 2016). It has been shown that if proposed travel using public transportation doesn't have transfers, they are more likely to use public transportation as a transportation mode (Feneri et al., 2020). Could meet one of the main interests for public stakeholders to support MaaS-services, to improve the public accessibility (Jittrapirom et al., 2020) Users of private cars are willing to pay more to avoid transfers during their trip (Kim et al., 2021).
PER-05	Filtering offered trips based on the amount of walking during transfers	Feature to filter trip search results based on the required walking during the trip transfers. Filter to offer trips based on walking time during transfers should be offered to attract the users of private cars (Kim et al., 2021).
PER-06	Sorting the available trips based on time taken	Feature to sort the trip search results based on the time taken by the trip Being more time-efficient transportation mode has

Requirement ID	Requirement	Description
		been one of the factors driving the users towards using the more time-efficient transportation modes (Suatmadi et al., 2019).
PER-07	Sorting the available trips based on price	Feature to sort the trip search results based on the price of the trip. The option to sort the available trips by price is important for the Pay-as-you-go-users, and would enable them to make savings using the MaaS-service, possibly substituting the use of other transportation modes with MaaS-services
PER-08	Personalized route recommendations	Feature to recommend routes based on their travelling needs, mobility habits and travel history. End-users have stated that the application should recommend routes for the user based on their needs, mobility habits and travel history (Polydoropoulou, Pagoni, & Tsirimpa, 2020).
PER-09	Personalized trip recommendations	Feature to recommend trip based on the user's wishes. End users have asked for mode recommendations based on their desires and activities. User could input their desires for their trip, for example wanting to save money or see more of the city, with the system giving recommendations for the user based on their inputs. (Polydoropoulou, Pagoni, & Tsirimpa, 2020.)

5.2.3 Usability, reliability and accessibility

Despite the general idea that high usability would make the MaaS-service more attractive for the users, as the use of MaaS-service itself is not the end goal of their users and instead acts a tool to satisfy their mobility needs, the ease of use does not have direct impact for the user's intention to adopt the use of the MaaS-services. Despite this, the ease of use affects the user's intentions to adopt the services through affecting the perceived usefulness of the service, which does have an effect on intention to adopt the use of the services. (Mola et al., 2020.) These results signal that the MaaS-service should be designed to be easy to use, but that having easy to use MaaS-service will not be a success on its own, instead requiring the users to find the use of the service highly useful. Besides ease of use, there are also other usability attributes that are relevant for MaaS design. In this regards, functionality, reliability, and accessibility (Inal et al., 2020; International Organization for Standardization, 2010, 2011, 2014; Lauesen, 2005) will ensure that on one hand the service and system are useful and fulfil the user needs, and on the other hand that the service and system are designed for addressing various needs such as those of children and elderly in an equitable manner.

In terms of functionality, the MaaS-service should provide a variety of information through the service. Providing real-time information about the transportation options has been noted to be important for the users (Lopez-Carreiro et al., 2020;

Polydoropoulou, Pagoni, & Tsirimpa, 2020; Stopka et al., 2018), with this information being expected to keep the users engaging with the MaaS-service and having the inactive users to re-engage with using the service (Harrison et al., 2020). Providing information of passenger-crowding could enable the users to avoid congestion and crowds, and enable the transportation service providers to improve the efficiency of the transportation network and the quality of the transportation services (Lopez-Carreiro et al., 2020). Receiving information about the urban pollution levels could be important for users using the active transportation modes, and has been a requested feature by the health-conscious users of ages 45 to 70 years old (Lopez-Carreiro et al., 2020). Information of available route facilities would be highly relevant information for the users depending on their used transportation modes. This information would include facilities such as gas stations, electric charging points and water fountains. (Lopez-Carreiro et al., 2020.) MaaS-service should also include information about the vehicle conditions, such as do the transportation modes have charging points, air-conditioning or priority seats (Lopez-Carreiro et al., 2020). Having this information available would make transportation more accessible to different user groups with special needs, as these users would not avoid the use of these modes due to not having information about all the available features (Matyas, 2020).

The MaaS-service should be able to provide reliable service, as this has been noted to be particularly important for the end-users (Polydoropoulou, Pagoni, & Tsirimpa, 2020). To create and main the trust of the customers, the MaaS-service will need to include quality control mechanisms to make sure that the information provided through the MaaS-service is of high-quality (Sakulyeva, 2020). To make the MaaS-service attractive for the potential users, the MaaS-service needs to be able to provide secure payment-services available for the users. The MaaS-service should also provide support for locally popular payment-systems, such as the Oyster-card used in London (Polydoropoulou, Pagoni, & Tsirimpa, 2020.). While enabling purchases, the MaaS-service will need to be able to verify that the user has a valid driver's license before letting the user purchase transportation modes such as car-sharing. This feature should be made as simple and intuitive as possible, as the users' annoyance with complicated administration can act as hindrance for some of the transportation modes (Matyas, 2020). The service also will need to be able to verify if the user eligible for user group-specific discounts, such as receiving a student-discount.

The MaaS-services should aim to provide accessible services, with focus on user groups as the youth and the elderly. The youth find themselves vulnerable for violence and harassment, and are concerned for their own safety while using the different transportation modes (Casadó et al., 2020). On other hand the elderly might require heavier emphasis on accessibility, with the possible health concerns limiting their capabilities on using the different transportation modes. To improve these issues, the MaaS-services will need to include a variety of system features from personalization, service- and accessibility-categories. The Table 5 contains 12 design requirements relevant for usability, reliability and accessibility of the MaaS-services.

Table 5. The identified design requirements relevant for usability, reliability and accessibility of the MaaS-services

Requirement ID	Requirement	Description
URA-01	Real-time information about the transportation-options	The MaaS-service should provide the users with real-time information about the available transportation options. Providing users with real-time data about the transportation options has been emphasized as important factor for the end-users. (Lopez-Carreiro et al., 2020; Polydoropoulou, Pagoni, & Tsirimpa, 2020; Stopka et al., 2018) Could help with having the users to continue using the application and with having the inactive users to re-engage with the application (Harrison et al., 2020).
URA-02	Real-time information about passenger-crowding	The MaaS-service should provide the users with real-time information about the passenger crowding. Could provide the users information to help them avoid congestion and crowds. Could be useful for transport service providers to enhance the network efficiency and the quality of the provided services. (Lopez-Carreiro et al., 2020.)
URA-03	Real-time information about urban pollution levels	The MaaS-service should provide the users with real-time information about the urban pollution-levels. MaaS-service should provide information about the urban pollution-levels when using active transportation modes such as bike-sharing. Has been a requested feature by health-conscious people aged 45 to 70. (Lopez-Carreiro et al., 2020.)
URA-04	Information about route facilities	The MaaS-service should provide the users with information about the route facilities. The MaaS-service should provide the users with information about the route facilities relevant for the used transportation modes. These facilities would be things such as gas stations and electric charging points for car users and water fountains for cyclists. (Lopez-Carreiro et al., 2020.)
URA-05	Information about the vehicles used for transportation	MaaS-service should provide the users with information about the vehicle conditions. This information would include information such as do the vehicles have charging points for smartphones, existence of air-conditioning, availability of priority seats (Lopez-Carreiro et al., 2020), and accessibility features of the vehicles.

Requirement ID	Requirement	Description
		Would prevent the user groups with special needs, such as families and pet owners, avoiding the use of transportation modes due to lack of information about all the available features (Matyas, 2020).
URA-06	Secure payment-options	The MaaS-service should have secure payment-options. Providing secure payment-options has been identified as the most important criteria for success in making the application attractive for end-users in terms of offered services and potential benefits (Polydoropoulou, Pagoni, & Tsirimpa, 2020).
URA-07	Local payment-system	The MaaS-service should support locally popular payment-options. If the MaaS-service's area of operations already has had their own payment system for transportation-services, the system should support their use with the MaaS-service. For example, this would mean that when operating in London, the MaaS-service should support payment by Oyster card. (Polydoropoulou, Pagoni, & Tsirimpa, 2020.)
URA-08	Provide reliable service	The MaaS-service should provide the users with reliable service. Providing users with reliable services has been noted to be extremely important criteria for the end-users (Polydoropoulou, Pagoni, & Tsirimpa, 2020). Creating and maintaining the trust of the customers requires guaranteeing the quality of the information with quality control mechanisms (Sakulyeva, 2020).
URA-09	Checking out required licenses	MaaS-service should be able to check for valid driver's license before letting the user use transportation modes requiring driver's license, such as car sharing. Users' annoyance with complicated administration can be a hindrance for some of the transportation modes (Matyas, 2020).
URA-10	Checking out user discounts	MaaS-service should be able to verify that is the user eligible for different user group-specific discounts provided by the different transportation services providers, such as student-discount.
URA-11	Accessible services to the youth	Provide accessible services to the youth. The youth are concerned with perceived risks of the transportation modes and find themselves vulnerable for violence and harassment when using public transportation (Casadó et al., 2020). To meet for the youth's safety concerns, the MaaS-services will need to include a number of features to make the MaaS-services accessible for the youth. These

Requirement ID	Requirement	Description
		features are as follows: • PER-01: Choosing the transportation company • PER-02: Choosing preferred transportation modes • PER-03: Excluding specific transportation modes • SER-01: Company-branding
URA-12	Accessible services to the elderly	Provide accessible services to the elderly. The elderly should be provided with accessible transportation-services, so the possible health concerns would not limit the use of MaaS-services. To create more accessible MaaS-services for the elderly, the services should include the following features: • PER-03: Excluding specific transportation modes • PER-04: Filtering offered trips based on number of required transfers • PER-05: Filtering offered trips based on the amount of walking during transfers • URA-05: Information about the vehicles used for transportation

5.2.4 Payment features and bundle design

The two prominent payment models for MaaS-service, MaaS-bundle subscription and pay-as-you-go, should both be implemented within the MaaS-services. The users' interest between the different payment models varies heavily between the potential users of different countries, requiring the MaaS-operators to do research about their own area of operations and their potential customer base. The managing stakeholders have stated that MaaS-services should start from small with pay-as-you-go model to build trust between the MaaS-operator and customers and to gain user data to use in creating MaaS-subscription bundles (Polydoropoulou, Pagoni, Tsirimpa, et al., 2020). Having support for this payment model also would increase awareness towards MaaS-bundles (Liljamo et al., 2020). Subscription-based payment model should be supported, as they have been shown to influence the use of private cars towards reducing monthly car kilometres (Hensher et al., 2021). The support for the subscription-based payment model would be done with MaaS transportation bundles. MaaS-service should include multiple bundles, so the users would be able the choose bundles including their most essential transportation modes (Matyas, 2020), while decreasing the number of redundant transportation modes due to redundancy reducing user interest towards subscribing for the MaaS-bundle (Hensher & Mulley, 2021).

Including a significant number of transportation modes into the MaaS-service could increase the development costs of the MaaS-service due to complexity of the APIs while complicating the negotiations with transportation service providers because of the

competition between the providers (Reck et al., 2020). To avoid this issue, the MaaS-operator might prefer to add only the most requested transportation modes in the early phases of the service. As potential users have not been willing to subscribe for MaaS-services if they do not include the transportation modes the users use the most in their daily transportation (Matyas & Kamargianni, 2019), the MaaS-service should aim to include the transportation modes most used in local context. In European context the research suggests the most relevant transportation modes to be public transportation, bike-sharing, car-sharing and taxi (Esztergár-Kiss & Kerényi, 2020). Public transportation is the most preferred transportation mode for the potential users (Caiati et al., 2020; Esztergár-Kiss & Kerényi, 2020; Jang et al., 2020; Matyas, 2020), and including it in MaaS-service could help with one of the main interests of public stakeholders to join the MaaS-service, increasing the use of public transportation-services (Polydoropoulou, Pagoni, & Tsirimpa, 2020). Car-sharing services should be included, as the users of car-sharing and other on-demand services have outlined as likely users of MaaS-services (Alonso-González et al., 2020; Vij et al., 2020). Including bike-sharing services could enable students to adopt the use of MaaS-services, with them being likely to subscribe for MaaS-bundles containing public transportation and bike-sharing (Matyas & Kamargianni, 2021). Including bike-sharing in MaaS-bundles could possibly improve the health of the MaaS-users, as over 60 percent of potential subscribers have said they would willing to try transportation modes they haven't tried before if they were included in their bundles (Matyas & Kamargianni, 2019), and with users stating including the bike-services would have them use bicycles more for their transportation needs (Ho et al., 2020). Taxi-services are used by older users for longer distance trips (Esztergár-Kiss & Kerényi, 2020), suggesting their inclusion to improve the MaaS-adoption by the older user groups.

European MaaS-services should have a baseline MaaS-bundle including public transportation with at least 20 days per month, bike-sharing as a pay-as-you-go mode, car-sharing with one daily hour and taxi with 10 to 20 kilometres per day (Esztergár-Kiss & Kerényi, 2020). This baseline-bundle could then be modified and adapted to the local context after the service-launch with the use of the local demand-data. MaaS-research also supports the inclusion of both cheaper and more expensive bundle-options. Including cheaper bundles would cater for students and multimodal public transportation users, who have been less willing to pay for extensive MaaS-services (Alonso-González et al., 2020; Matyas & Kamargianni, 2021). On other hand including more expensive options would make it possible for the users of higher income and education to subscribe for more expensive bundles (Matyas & Kamargianni, 2021), possibly improving the profitability of the MaaS-service. The MaaS-service could also include a variety of specialized bundles. The end-users have agreed that MaaS-services should offer flexible bundles for the needs of local citizens, tourists, families, companies, friends and school-going children (Polydoropoulou, Pagoni, & Tsirimpa, 2020).

Research has suggested that it would be recommended to start the MaaS-service in smaller scale, starting with pay-as-you-go payment model, and keep on adding new bundles and options based on the information gained from the customer data. Starting with pay-as-you-go payment-model and continually implementing new MaaS-bundles based on customer data would enable the MaaS-operator to grow user-interest and learn through experimentation with their users. This approach would make pay-as-you-go initially the dominant payment-model, but also have users change monthly to using MaaS-bundles. (Hensher et al., 2021.)

In effort to offer bundle-customization for the users, the users could be offered to include singular transportation modes as bundle-addons (Mulley et al., 2018). Offering add-ons in limited fashion would not complicate the process for choosing MaaS-bundles too much, would offer customization for the users and enable them to add some singular transportation modes without which people would not adopt the use of MaaS-services. In lack of significant research for this feature, it would not be recommended to try to implement this immediately in the MaaS-service, instead it would be better to trial it out in smaller scale and make decisions about the feature based on feedback the MaaS-operator would get from the users.

In implementing the subscription payment-model, the subscriptions should be created with use of credit-system. With the credit-system, the users would receive the monthly transportation services included in the MaaS-bundle as predefined number of transportation credits. Using credit-based subscription system would allow the service to avoid the sustainability issue, where the user would go on additional trips due to them feeling they have not gained enough value from the service (Pangbourne et al., 2020). Further improving sustainability, these credits should be allowed to rollover to next payment-period, so the users would not go on additional trips just to use their expiring bundle-credits (Ho et al., 2020).

Users could be offered discounts for the MaaS-bundles. For example the application Reach Now has been providing their users with discounts for public transportation-services on days with particle pollution- warnings (Schulz et al., 2021). Discounts could be used to support more sustainable travelling by having higher discounts available for more sustainable travelling modes, and could be used in negotiations to gain government subsidies for reduced emissions and car ownership (Reck et al., 2020). Elsewhere though it has been suggested that discounts should only be used during the MaaS-service's launch phase, as they are expected to act as incentive for MaaS-adoption only during the launch-phase (Mola et al., 2020), and could be perceived as external manipulation if they were to be permanently offered for first time users (Schikofsky et al., 2020). The MaaS-operator could include the use of rewards as another incentive for the users. Providing loyal users with rewards for continued use would motivate users to keep on using the application. These rewards could be provided by partnering companies, ranging from free transportation tickets to free coffee at select cafes. (Harrison et al., 2020.)

Table 6 contains 17 system requirements regarding the payment and bundle design of the MaaS-service.

Table 6. The payment- and bundle-design requirements for the MaaS-services

Requirement ID	Requirement	Description
PBD-01	Pay-as-you-go (PAYG) payment-model	Supporting pay-as-you-go payment-model. Managing MaaS-stakeholders have stated that MaaS-services should start with pay-as-you-go payment model to build trust between the MaaS-operator and customers and to gain user data to use in creating MaaS-subscription bundles (Polydoropoulou, Pagoni, & Tsirimpa, 2020). Supporting PAYG-model would increase awareness towards MaaS- mobility packages (Liljamo et al., 2020).
PBD-02	Subscription-bundle payment-model	Supporting subscription-bundle payment model. Having a subscription to well-designed monthly MaaS-bundles has been shown to influence the use of private cars towards reducing the monthly car kilometres (Hensher et al., 2021).
PBD-03	Including the most integral transportation modes	Include the most integral transportation modes in the MaaS-service. As the users are not willing to subscribe for MaaS-bundles if they do not include the transportation modes they use most in their daily transportation (Matyas & Kamargianni, 2019), including the transportation modes used most often by the users is essential for the success of the MaaS-service. The most integral transportation modes are included in the European baseline-bundle (Esztergár-Kiss & Kerényi, 2020). These transportation modes include: - Public Transportation (PBD-04) - Car-sharing (PBD-05) - Bike-sharing (PBD-06) - Taxi-services (PBD-07)
PBD-04	Transportation mode: public transportation	Provide access to transportation mode: public transportation. The public transportation is the most preferred transportation mode for the potential users of the MaaS-services (Caiati et al., 2020; Esztergár-Kiss & Kerényi, 2020; Jang et al., 2020; Matyas, 2020). Public transportation was also included in the European baseline-bundle (Esztergár-Kiss & Kerényi, 2020). Including them as transportation mode could help meeting one of the main interests for public stakeholders to join MaaS-services, to increase the usage of public transportation (Polydoropoulou,

Requirement ID	Requirement	Description
		Pagoni, & Tsirimpa, 2020).
PBD-05	Transportation mode: car-sharing	Provide access to transportation mode: car-sharing Car-sharing was included in the European baseline-bundle (Esztergár-Kiss & Kerényi, 2020). The users of car-sharing and other on-demand services have been outlined as people likely to adopt the use of MaaS-services (Alonso-González et al., 2020; Vij et al., 2020). May increase the usage of cars through giving access to private cars for people who have not had access previously (Durand et al., 2018).
PBD-06	Transportation mode: bike-sharing	Provide access to transportation mode: bike-sharing Bike-sharing was included in the European baseline-bundle (Esztergár-Kiss & Kerényi, 2020). The inclusion of bike-sharing in MaaS-bundle would enable MaaS-adoption by the students, who are likely to subscribe to smaller MaaS-bundles consisting of public transportation and bike-sharing (Matyas & Kamargianni, 2021). With over 60 percent of potential MaaS-subscribers willing to try transportation modes they have not tried before if they were included in the bundle (Matyas & Kamargianni, 2019), and with potential users saying that the inclusion of bike-sharing services in the MaaS-bundle would make them use bicycles more for their transportation needs (Ho et al., 2020), the bike-sharing services could be included in the MaaS-bundles to influence the usage of bike-sharing to improve the health of the users of the MaaS-service. Including bike-sharing as a free transportation mode would increase the use of bike-sharing (Feneri et al., 2020), influencing a modal change towards healthier transportation modes.
PBD-07	Transportation mode: taxi-services	Provide access to transportation mode: taxi-services Taxi-services were included in the European baseline-bundle (Esztergár-Kiss & Kerényi, 2020). Used by older users, for longer distance trips (Esztergár-Kiss & Kerényi, 2020).
PBD-08	Multiple transportation bundles	Support for multiple subscribable transportation bundles. MaaS-service will need to include multiple subscription-bundles for users to be able to choose bundles including their most essential transportation modes (Matyas, 2020) while decreasing the number

Requirement ID	Requirement	Description
		of redundant transportation modes from the bundle (Hensher & Mulley, 2021).
PBD-09	Including a baseline-bundle supported by research	Include a baseline-bundle following the research of Esztergár-Kiss and Kerényi (2020). Research done by Esztergár-Kiss and Kerényi (2020) supports the use of baseline MaaS-bundle, consisting of public transportation with at least 20 days per month usage, bike-sharing as pay-as-you-go mode, car-sharing with one daily free hour and taxi with 10 to 20 kilometres per day (Esztergár-Kiss & Kerényi, 2020). Research supports the use of this bundle as a baseline to be used for European MaaS-services.
PBD-10	Inclusion of less expensive MaaS-bundles	Include less expensive MaaS-bundles Students and multimodal public transportation users have been less willing to pay for extensive MaaS-services (Alonso-González et al., 2020; Matyas & Kamargianni, 2021), supporting the creation of smaller MaaS-bundles consisting mainly of public transportation and other inexpensive transportation modes.
PBD-11	Inclusion of extensive MaaS-bundles	Include more extensive MaaS-bundles. Inclusion of more expensive and more extensive MaaS-bundles would make it possible for higher income and higher education level users to subscribe for more expensive bundles (Matyas & Kamargianni, 2021), improving the profitability of the service. Could lessen the benefits of transportation modes such as bike-sharing, with the users subscribing for more expensive MaaS-bundles being more likely to use other more expensive transportation modes (Feneri et al., 2020).
PBD-12	Inclusion of specialized bundles	Include specialized bundles aimed for different specialized user groups. MaaS end-users agreed that MaaS should have flexible packages offering solutions for different needs. These needs vary from the needs of the local citizens, tourists, families, companies, friends and children going to school (Polydoropoulou, Pagoni, & Tsirimpa, 2020). These bundles could for example vary in terms of length, number of people served with single purchase and included transportation modes compared to the common MaaS-bundle.
PBD-13	MaaS-bundles with credit-system	Creation of MaaS-bundles with credit-system, where the users paying for bundle-subscription get the number of monthly credits specified in their

Requirement ID	Requirement	Description
		bundles to be used for specified MaaS-services. Would help in avoiding the sustainability issue with unlimited use of MaaS, where the user would go on additional trips due to feeling they have not otherwise gained enough value from the service (Pangbourne et al., 2020).
PBD-14	Credit roll-over	Enable roll-over of paid transportation-credits for the next payment-period. Would make the MaaS-service more sustainable by not having the users go on additional trips just to use the expiring credits before the end of payment period (Ho et al., 2020).
PBD-15	Support limited bundle customization through singular addons	Support the bundle customization through offering singular addons MaaS-services could offer limited bundle customization through letting users choose singular transportation mode as a bundle addon (Mulley et al., 2018).
PBD-16	Launch-phase discounts	Have support for launch-phase discounts. Discounts should only be used during the launch-phase, as they are expected to only act as an incentive during the launch-phase of the MaaS-service (Mola et al., 2020) and may be perceived as external attempted manipulation if they are permanently offered for first time users (Schikofsky et al., 2020).
PBD-17	Reward-system for loyal users	Feature providing the loyal users with rewards for continued use. MaaS-service should provide the loyal users with rewards for their continued usage to motivate them to keep on using the application to improve the profitability of the MaaS-service. Rewards could be for example free transportation tickets or services provided by associated sponsors e.g. free coffee at cafes. (Harrison et al., 2020.)

5.2.5 Service requirements

Because one of the main motivations for the transportation service-providers to join the MaaS-service is to gain high-quality demand data (Polydoropoulou, Pagoni, & Tsirimpa, 2020), the service would need to be capable of generating this data and giving the cooperating companies easy access to this data. The requirement to gain high-quality demand data is though complicated due to recent emergence of new data privacy regulations, such as the European General Data Protection Regulation (GDPR). If the MaaS-service requires a registration, the service would need basic information such as user's name, contact information, age, and gender. On top of this, more specified information could be required, such as preferred transportation modes, driver's license

and financial information. When this user information is combined with the travel data gained through the MaaS-service itself, the companies possessing this information can create detailed idea of the users. (Cottrill, 2020.)

For making registration simple for the users, MaaS-operator could want to implement Single Sign On (SSO) systems into their MaaS-service. These SSO services would be provided by e.g., Facebook or Google, through which the users could use their existing Google- or Facebook-accounts to register into the MaaS-service. While these services would improve the convenience of the MaaS-service, their inclusion will inherently raise questions for the user data and it's transferability between the companies. (Cottrill, 2020.) If the MaaS-operator would want to implement SSO systems, it would be highly recommended to pay close attention to the user data and that the SSO-implementation would follow the requirements of the GDPR. (Cottrill, 2020.)

Due to GDPR and related privacy requirements, it has been suggested that the MaaS-operator should codify six specific key practises into their MaaS-agreements: MaaS-operator should develop a clear, understandable, and consistent language for giving consent, adequately representing the practises on the relevant parties. Privacy by Design principles should be incorporated in the system architecture, ways to minimise data collection should be determined, a Data Protection Officer should be hired and consistent practises for users to request the removal of their own data should be established together with methods for enforcing compliance across the involved parties. (Cottrill, 2020.)

Privacy by design means that the companies possessing personal data to process it for other purposes should implement appropriate technical and organisational measures to implement data-protection principles to meet the privacy requirements set by the GDPR regulations and to protect the rights of the users (General Data Protection Regulation, 2016). GDPR-regulations specify two specific examples for such measures. First example of the two, Pseudonymisation means the act of processing personal data so that the personal data cannot anymore be specified to specific user without the use of additional information. The second example, the data minimisation, means that the used data is relevant and only limited to what is necessary for purposes the data is processed. (General Data Protection Regulation, 2016.) These two examples are already being followed by existing MaaS-services.

As a reaction to the GDPR-regulations, the MaaS-service Whim updated their privacy policy on May 24th 2018, a day before the enactment of GDPR. The resulting privacy policy of the MaaS-service Whim specifies that their service pseudonymises and encrypts personal data and specifies the reasons what all the data the services collects is used for in the service. In addition to these actions, Whim's privacy policy also specifies that their service uses industry standard security mechanisms to protect the collected data, with all the personal data being protected by firewall and by physical and software-based access controls. Whim also uses Payment Card Industry Data Security Standard Level 1 certified payment providers and have a process for regularly testing and evaluating the effectiveness of the measures ensuring the processing security. (Cottrill, 2020.)

Based on the GDPR-regulations and the example provided by Whim, MaaS-services should use pseudonymisation and encryption to protect the users' personal data and have processes to test and measure the effectiveness of the processing security. MaaS-operator should also follow the recommended six key security practises.

Table 7 includes the eight recognized data privacy and management requirements for the MaaS-services.

Table 7. The data privacy and management requirements for the MaaS-services

Requirement ID	Requirement	Description
DPM-01	Providing the Transportation service-providers with high-quality demand data	Support the creation and delivering of demand-data to MaaS-stakeholders. To attract the transportation providers to operate within the MaaS-service, transportation service providers will need to be provided with one of their main motivations for joining MaaS-services, gaining access to high-quality demand data (Polydoropoulou, Pagoni, & Tsirimpa, 2020). The personal data contained in the demand data will need to be processed to meet the requirements of the GDPR. (See requirement DPM-02)
DPM-02	System architecture made with Privacy by Design-principles	MaaS-service should be created following the Privacy by Design-principles. The MaaS-service should be designed and created with Privacy by Design-principles to meet the requirements of GDPR-regulations (Cottrill, 2020). (See Requirements DPM-03, DPM-04, DPM-05, DPM-06 and DPM-07)
DPM-03	Provide a way for users to give and withdraw consent for using their data in the MaaS-service	Enable the user to give and withdraw their consent for using their data in the MaaS-service. GDPR-regulations require the companies to obtain consent from the user before processing the user data. The request of consent will need to be presented in consistent, clear and easily accessible language. (Cottrill, 2020.) Withdrawing consent will need to be as easy as providing consent (Cottrill, 2020; General Data Protection Regulation, 2016).
DPM-04	Data pseudonymisation	The user personal data should be pseudonymised. The personal data contained by the MaaS-operator should be pseudonymised, meaning that the data should be processed so that the specific user cannot be recognized without using additional information. This should be done to meet the requirements of the GDPR-regulations and to protect the rights of the users of the service. (General Data Protection Regulation, 2016.) Would follow the example set by the MaaS-service Whim (Cottrill, 2020).

Requirement ID	Requirement	Description
DPM-05	Data encryption	The user personal data should be encrypted. The personal data should be encrypted to protect the security of the users, following the example set by the MaaS-service Whim (Cottrill, 2020).
DPM-06	Data minimisation	The user personal data should be minimized. The collected personal data is relevant and limited to data necessary for the purposes they are processed for (General Data Protection Regulation, 2016). Personal data which is no longer necessary in for the purposes they were collected or processed shall be erased without undue delay (General Data Protection Regulation, 2016). Personal data that has been collected prior to user withdrawing their consent shall be erased (General Data Protection Regulation, 2016).
DPM-07	Regular evaluation of data processing security	The data processing processes should be regularly tested and evaluated. MaaS-operator should have a process for regular testing and evaluation of the effectiveness of the measure ensuring the security of the data processing (Cottrill, 2020).
DPM-08	Personal data removal	Enable the user to remove their personal data. MaaS-service should include a consistent way for their users to request the removal of their data (Cottrill, 2020).

The MaaS-service should include a way for the users to access their transportation tickets through the service, so the users would be able to show their tickets during ticket inspections. The users and the MaaS-stakeholders have both stated that the MaaS-service should support the use of Quick Response (QR) code scanner or Near Field Communication (NFC) in verifying the validity of the MaaS-tickets. In addition, the users have requested support for accessing the MaaS-tickets as a printout, as this would work as a backup-option for moments such as when their mobile phone battery would be running low. (Polydoropoulou, Pagoni, & Tsirimpa, 2020.)

The user interface of the MaaS-service could emphasize the company-branding of the different transportation-service providers in effort to create visibility for the transportation companies. Through this feature the created MaaS-service would be able to serve for one of the interests the private companies have for joining the MaaS-service, gaining visibility for the company (Polydoropoulou, Pagoni, & Tsirimpa, 2020). The MaaS-service should also support the use of notifications, as these could be used to warn the users in case of delays, traffic accidents and changes in service (Polydoropoulou, Pagoni, & Tsirimpa, 2020).

The following Table 8 contains the three previously described service and functionality-requirements.

Table 8. The service and functionality requirements for the MaaS-services

Requirement ID	Requirement	Description
SER-01	Company-branding	Emphasize the branding of the transportation companies in the service UI. The MaaS-service should emphasize the company-branding of the transportation-service providers, as this could create visibility for the transportation companies and as such meet one of the main interests to join the MaaS-services, to gain visibility for the company through joining the service (Polydoropoulou, Pagoni, & Tsirimpa, 2020). Would be relevant feature for the youth, who would only be willing to use the transportation services from the companies they have used before and assessed them to be safe and trustworthy (Casadó et al., 2020).
SER-02	Access and verifying of MaaS-tickets	The MaaS-service should be able to let the user access their own tickets through the MaaS-service to be able to show the tickets to ticket inspector during ticket inspections. MaaS-stakeholders have supported access to MaaS-tickets through MaaS-application or through smartphone wallet (Polydoropoulou, Pagoni, & Tsirimpa, 2020). MaaS-stakeholders and end-users have supported the use of Near Field Communication (NFC) and/or Quick Response (QR) code scanner in verifying the validity of MaaS-tickets (Polydoropoulou, Pagoni, & Tsirimpa, 2020). While unsupported by the managing stakeholders, the end-users wanted the application to support accessing the tickets through print-outs as a backup-option for cases such as having mobile phone battery running low (Polydoropoulou, Pagoni, & Tsirimpa, 2020).
SER-03	App notifications	The MaaS-service should support the use of notifications MaaS-service should have notifications in case of delays, traffic accidents and changes in service (Polydoropoulou, Pagoni, & Tsirimpa, 2020).

6. Discussion

In the discussion chapter the research questions of the thesis are answered.

RQ1: Are MaaS-services capable to decrease the number of private vehicle kilometres and to lower private car ownership?

MaaS-services seem to be capable in decreasing the number of private vehicle kilometres when launched in areas with sufficient number of transportation modes available for the MaaS-service to fulfil the users' mobility needs. The users of the two pilot studies have reported being able to lower the use of their private cars (Storme et al., 2020; Strömberg et al., 2018). Users were able to substitute their routine car trips with MaaS-services but did have more trouble substituting their more irregular leisure trips (Storme et al., 2020). Using MaaS-services requires more travel planning from their users compared to using private cars, which can have their users either merge their trips (Strömberg et al., 2018), change their travel plans or cancel their trip altogether (Storme et al., 2020; Strömberg et al., 2018). Depending on the users' attitudes and situation, the increased travel planning might not be considered negatively (Strömberg et al., 2018), but could turn off some users from using MaaS-services. Major motivation for using private cars during the studies were due to alternatives being too much of a hassle, requiring the users to plan more, endure more uncertainty about travel times and requiring the users be more open about the used transportation modes, leading the users to use private cars during trips with multiple stops in short time. Because of these reasons the MaaS-services would not be able to have the users completely substitute the use of private cars, instead operating as a complementary option alongside the private cars. (Storme et al., 2020.)

Different contextual factors and recent events may have additional effects on change from private cars. The COVID-19 pandemic may have hindered the change away from the private cars, due to the pandemic increasing people's uncertainties towards the safety of using public transportation (Basu & Ferreira, 2021). The people's satisfaction in the local public transportation also plays significant part in reducing private car kilometres. Introducing MaaS-services with access to carsharing-services in areas where the people are not satisfied with their current transportation solutions or do not have access to cars could have the people substituting their use of public transportation in favour of private cars, increasing the usage of cars and the number of kilometres driven by private cars (Acheampong & Siiba, 2020; Durand et al., 2018). The modal change would also be limited in rural areas, where the lack of profitability is hindering the MaaS-services, with the MaaS-pilots not managing to cover the expenses from the pilot tests (Eckhardt et al., 2020; Hut et al., 2021).

The surrounding transportation culture does also have an effect on the use of private cars. If the MaaS-service is launched in areas with public transportation first-culture, there is a possibility that the service might replace the use of public transportation with the personalized transportation modes available in the launched MaaS-service. On other hand, in private-car-first areas it is unlikely that the launch of MaaS-service areas will cause a significant number of people to change to using public transportation, but the

launch will more likely have environmentally friendly effects on transportation (Wong et al., 2020.).

Another significant aspect is the local user demographics. For example in dense areas (Zijlstra et al., 2020) where the population is younger (Caiati et al., 2020. Ho et al., 2018. 2020. Hoerler et al., 2020. Matyas & Kamargianni, 2021. Vij et al., 2020. Zijlstra et al., 2020.), higher educated (Ho et al., 2018; Matyas & Kamargianni, 2021; Vij et al., 2020; Ye et al., 2020; Zijlstra et al., 2020), and has higher income (Agbe & Shiomi, 2021; Matyas & Kamargianni, 2021; Zijlstra et al., 2020), the population is more likely to be early adopters of MaaS-services. The most likely user groups to adopt the use of MaaS-services are infrequent car users (Ho et al., 2018), people who use both cars and public transportation-services (Ho et al., 2020) and students (Matyas & Kamargianni, 2021), suggesting that the MaaS-services could be capable in lowering the car ownership amongst the infrequent and multimodal car users. Opposite of this, the more remote areas (Vij et al., 2020) with older (Caiati et al., 2020; Ho et al., 2018, 2020; Hoerler et al., 2020; Matyas & Kamargianni, 2021; Vij et al., 2020; Zijlstra et al., 2020) and less healthy (Zijlstra et al., 2020) population the people would not be as inclined to adopt the use of MaaS-services, limiting the potential for modal change away from private cars in areas with population consisting of older and less healthy population.

The payment models also have an influence on the type of modal change from private cars. Pay-as-you-go payment-model enables their users to maintain their current travelling patterns, limiting the modal changes away from private cars to more sustainable travelling modes (Ho et al., 2020). While having subscription to well-designed MaaS-bundle has an influence towards reducing monthly car kilometres (Hensher et al., 2021), the subscription payment-model can have its own issues in lowering the number of private car kilometres due to issues in the service design. The users might do additional trips if they feel they have not had enough value from their subscription (Pangbourne et al., 2020) or they could use their unused transportation credits before their expiration (Ho et al., 2020). These issues though can be solved with different system designs, such as the use of credit roll-over-feature (Ho et al., 2020). A large issue for the subscription model to reduce the private vehicle kilometres is the users' lack of willingness to pay for MaaS-bundles. For the users to sign for MaaS-bundles, the price of the MaaS-bundles would need to be lower than the people's existing mobility costs due to people's lack of willingness pay more than their existing mobility costs (Agbe & Shiomi, 2021; Alonso-González et al., 2020; Liljamo et al., 2020). While the need for low prices also affects the pay-as-you-go payment-model, it raises complicated issue for lowering the ownership of private cars with the use of subscription-bundles due to users' underestimation of costs of private cars. The owners of private cars often underestimate the costs of their private cars by ignoring costs such as car's loss of value with time, cost of maintenance and cost of inspections (Maas, 2021; Mladenović & Haavisto, 2021). Due to this the prices of MaaS-bundles may be considered too high against the people's assessments of their own mobility costs (Maas, 2021), and may limit the extent of reducing private car kilometres to be gained from emergence of MaaS-services.

RQ2: What are the central factors affecting the environmental sustainability of the MaaS-services?

The central factor affecting the environmental sustainability of the MaaS-services is the cooperation between the different MaaS-stakeholders towards attracting and serving large user groups to using MaaS-services on a regular basis.

MaaS represents large changes to the whole transportation sector, with its emergence being capable of changing the whole transportation market. The private and public sector actors have inherent vision conflicts about MaaS, with for example public sector actors looking for increasing the use of public transportation services (Polydoropoulou, Pagoni, & Tsirimpa, 2020) and providing public accessibility (Jittrapirom et al., 2020), while private sector actors are looking for different kinds of financial benefits, such as increasing revenue for the companies (Polydoropoulou, Pagoni, & Tsirimpa, 2020). Public sector actors have been concerned about that if they were to lose the control of transportation system, the system would not anymore be designed to serve the public interests (Mladenović & Haavisto, 2021). Public transportation has been found to be the most preferred transportation mode in the MaaS-bundles (Caiati et al., 2020; Esztergár-Kiss & Kerényi, 2020; Jang et al., 2020; Matyas, 2020), with it being regarded as the backbone for MaaS-services (Matyas & Kamargianni, 2019). If the public and private sector actors would not manage to cooperate, the MaaS-service would easily be facing issues due to MaaS-service not being able to sell public transportation tickets (Mladenović & Haavisto, 2021), having the sold tickets be more expensive, not being able to provide student- and pensioner-discounts (Polydoropoulou, Pagoni, & Tsirimpa, 2020) or even would not be able to provide public transportation-services in the first place (Smith et al., 2019). This could mean that the MaaS-services would not be able to be profitable and cease to exist or could end up being profitable through competing with public transportation-services. In this case the MaaS-service would be created in pursuit of highest possible profits and attracting the users of sustainable transportation modes towards more profitable and less sustainable transportation modes (Wong et al., 2020).

One way to solve these issues would be to deeply cooperate with private actors and create a shared vision for MaaS through a number of meetings and discussions (Karlsson et al., 2020). Another way to solve the issues would be by regulative actions. As finding profitable business model for MaaS-services has been noted to be particularly difficult (Karlsson et al., 2020; Mladenović & Haavisto, 2021; Smith et al., 2020), giving public funding for MaaS-development could be used to influence the MaaS-services to serve public interests (Mukhtar-Landgren & Smith, 2019) by for example requiring the inclusion of healthier and more sustainable transportation modes to gain funding or subsidies for their services. Other option would be to implement policies supporting MaaS-services by for example coupling public transportation-services with other transportation modes as first and last kilometre-services (Noussan & Tagliapietra, 2020). In terms of payment-models, it would be preferable to support the adoption of the subscription model due to subscription to MaaS-bundles influencing a modal change towards reducing private car kilometres (Hensher et al., 2021). The pay-as-you-go model enables the user to maintain their current travelling patterns, limiting the modal changes and the improvements to sustainability of the transportation system (Ho et al., 2020). While the subscription model has its own issues in terms of sustainability such as the users taking additional trips to either feel they have got enough value from their subscription (Pangbourne et al., 2020), or to use their unused pre-paid credits (Ho et al., 2020), these issues can be circumvented with clever design using features such as credit roll-over feature (Ho et al., 2020).

RQ3: What are the most critical factors affecting the success of MaaS-services?

The most critical aspects for the success of the MaaS-services are the issues with achieving profitable business model, the users' lack of willingness to pay for the services and the cooperation between the stakeholders.

Getting all the stakeholders involved and cooperating within the MaaS-service is essential for the MaaS-services, due to many of these stakeholders acting as the transportation service-providers within the MaaS-service. While public transportation-services have been found out to be the most preferred transportation modes for the potential users (Caiati et al., 2020; Esztergár-Kiss & Kerényi, 2020; Jang et al., 2020; Matyas, 2020), getting the support from the established local transportation market actors is highly important for MaaS-services due to them acting as a key factor in scaling up the MaaS-service from niche-markets (Fenton et al., 2020). The stakeholders of MaaS-services have set goals for MaaS-service that conflict with the goals of other stakeholders, requiring compromises to be made between the stakeholders. While the private and public stakeholders do have common elements in their goals, such as receiving high-quality demand data (Polydoropoulou, Pagoni, & Tsirimpa, 2020), the public sector actors generally do aim for substituting the use of private cars with public transportation (Jittrapirom et al., 2020; Polydoropoulou, Pagoni, & Tsirimpa, 2020), while private sector actors are more concerned with gaining financial gains, such as increasing their market share and revenues (Polydoropoulou, Pagoni, & Tsirimpa, 2020). This creates a difficult situation where the MaaS-operator will be required to find a compromise between improving the sustainability of transportation-system and the profitability of the MaaS-service, while keeping both public and private stakeholders satisfied and involved in the MaaS-service. The cooperation issues also extend to regulations. Without gaining the support of the local legislators, MaaS-service may face legislative restrictions ranging from legislation restricting long-term partnerships with public actors (Karlsson et al., 2020; Smith et al., 2019) to not receiving funding or subsidies, or to having problems selling public transportation tickets varying from being unable to sell pensioner- or student-tickets (Polydoropoulou, Pagoni, & Tsirimpa, 2020), having the tickets be more expensive (Audouin & Finger, 2018; Polydoropoulou, Pagoni, & Tsirimpa, 2020), not receiving commissions (Audouin & Finger, 2018), having access to only limited types of tickets (Audouin & Finger, 2018), to not being able to sell the tickets at all. .

One of the most critical issues for the success of MaaS-services is the users' lack of willingness to pay for MaaS. Research suggests that 17 to 48 percent of research respondents from various countries would be willing to pay for the MaaS-services (Agbe & Shiomi, 2021; Caiati et al., 2020; Fioreze et al., 2019; Ho et al., 2018, 2020; Liljamo et al., 2020; Vij et al., 2020). The users are not willing to pay for MaaS-service as much as their current mobility costs are (Agbe & Shiomi, 2021; Alonso-González et al., 2020; Liljamo et al., 2020), with some of the studies suggesting the costs not covering the costs of providing of these services (Liljamo et al., 2020; Mulley et al., 2020). The lack of will to pay as much as their current mobility costs is also affecting the modal change from private cars to public transportation. The owners of private cars do also underestimate the costs of their cars by ignoring factors such as loss of value and maintenance fees, which is further disincentivizing the users from getting rid of their own private cars due to costs of MaaS-services being compared to underestimated costs of private cars (Maas, 2021; Mladenović & Haavisto, 2021). While it has been suggested that low willingness to pay could be later alleviated by communicating about the benefits and features of the MaaS-services (Mola et al., 2020), the price of MaaS-subscription is the main influencer in the users' subscribing decisions (Caiati et al., 2020). If MaaS-services would be to be widely adopted, they should be able to lower the users' mobility costs through actions such as having low subscription fees and by using mode-specific discounts (Hensher et al., 2021; Ho et al., 2020; Liljamo et al., 2020). If the MaaS-service is to achieve widespread adoption, have a modal change from private vehicles to public transportation and to lower the car ownership while

being profitable for the operating company, it is likely the MaaS-service will need to be given subsidies or other external funding to support the service.

RQ4: What system features are supported to be implemented by the MaaS-research?

The literature review research has resulted in a list of 51 system feature-requirements categorizable into six different categories: General Concept, Payment and Bundle Design, Personalization, Usability, Reliability and Accessibility, Data Privacy and Management and Service and Functionality. General Concept-category contains two requirements relevant for the general concept of the MaaS-service, Payment and Bundle Design has 17 requirements to implement effective payment- and subscription bundle-design for the MaaS-service, Personalization has nine requirements to provide the users with personalized MaaS-service, Usability, Reliability and Accessibility has 12 requirements relevant for improving the usability and accessibility of the created MaaS-service, Data Privacy and Management contains eight requirements relevant for maintaining data security and Service and Functionality has three requirements relevant for providing better service and functionality through the service. Table 9 contains the created list of the detected 51 system-feature requirements.

Table 9. The detected system features supported by MaaS-research

Category	Detected requirements
General Concept	• GC-01: Accessible through mobile device • GC-02: Route planner-services
Payment and Bundle Design	• PBD-01: Pay-as-you-go (PAYG) payment-model • PBD-02: Subscription-bundle payment-model • PBD-03: Including the most integral transportation modes • PBD-04: Transportation mode: public transportation • PBD-05: Transportation mode: car-sharing • PBD-06: Transportation mode: bike-sharing • PBD-07: Transportation mode: taxi-services • PBD-08: Multiple transportation bundles • PBD-09: Including a baseline-bundle supported by research • PBD-10: Inclusion of less expensive MaaS-bundles • PBD-11: Inclusion of extensive MaaS-bundles • PBD-12: Inclusion of specialized bundles • PBD-13: MaaS-bundles with credit-system • PBD-14: Credit roll-over • PBD-15: Support limited bundle customization through singular addons • PBD-16: Launch-phase discounts • PBD-17: Reward-system for loyal users

Category	Detected requirements
Personalization	• PER-01: Choosing the transportation company • PER-02: Choosing preferred transportation modes • PER-03: Excluding specific transportation modes • PER-04: Filtering offered trips based on number of required transfers • PER-05: Filtering offered trips based on the amount of walking during transfers • PER-06: Sorting the available trips based on the time taken • PER-07: Sorting the available trips based on price • PER-08: Personalized route recommendations • PER-09: Personalized trip recommendations
Usability, Reliability and Accessibility	• URA-01: Real-time information about the transportation-options • URA-02: Real-time information about passenger-crowding • URA-03: Real-time information about urban pollution levels • URA-04: Information about route facilities • URA-05: Information about the vehicles used for transportation • URA-06: Secure payment-options • URA-07: Local payment-system • URA-08: Provide reliable service • URA-09: Checking out required licenses • URA-10: Checking out user discounts • URA-11: Accessible services to the youth • URA-12: Accessible services to the elderly
Data Privacy and Management	• DPM-01: Providing the Transportation service-providers with high-quality demand data • DPM-02: System architecture made with Privacy by Design-principles • DPM-03: Provide a way for users to give and withdraw consent for using their data in the MaaS-service • DPM-04: Data pseudonymisation • DPM-05: Data encryption • DPM-06: Data minimisation • DPM-07: Regular evaluation of data processing security • DPM-08: Personal data removal
Service and Functionality	• SER-01: Company-branding • SER-02: Access and verifying of MaaS-tickets • SER-03: App notifications

7. Conclusions

In this thesis a narrative literature review was conducted to study the effects of the MaaS-concept and to what extent will the MaaS-services be able to contribute to reducing private vehicle kilometres and to increasing the share of sustainable transportation modes following the goals set by the Finnish government. Using the narrative literature review method, the thesis answers the following research questions: Are MaaS-services capable to decrease the number of private vehicle kilometres, What are the central factors affecting the environmental sustainability of the MaaS-services, What are the most critical factors affecting the success of MaaS-services and What system features are supported to be implemented by the MaaS-research? The results of literature review were used to create a list of system features supported by the MaaS-research, fulfilling the first two steps of the Design Science Research Methodology.

According to the literature review, existing research suggests that MaaS-services would be capable in reducing private vehicle kilometres, but the capability to reduce private vehicle ownership would be limited with MaaS-services operating as a complementary option alongside the private cars. Reducing private vehicle kilometres and car ownership is affected by recent events and contextual factors, with COVID-19, people's satisfaction in local public transportation, level of people's access to cars, living in dense or rural areas and surrounding transportation culture all affect the level of change acquired from launching MaaS-services. To enable MaaS-services to make a modal change away from private cars, the potential users would need to adopt the use MaaS-services. Using subscription payment-model as dominant payment-model against the pay-as-you-go payment-model would enable further changes away from using private cars, with pay-as-you-go payment model enabling the user to maintain their current travelling patterns, while subscribing to well-designed MaaS-bundle has an influence towards reducing monthly car kilometres. The level of MaaS-adoption is heavily influenced by the local demographics, with younger, higher educated with high income people being more likely to adopt the use of MaaS-services, leading to areas with such demographics being more likely to be affected with modal changes through MaaS-services. MaaS-services would need to pay less than the people's current mobility costs and be able to compete with underestimated costs of private cars to increase MaaS-adoption and to have people reduce the number of kilometres travelled with private vehicles.

The central factor affecting the environmental sustainability of MaaS-services is getting the MaaS-stakeholders to cooperate in attracting and serving users to regularly using MaaS-services. The MaaS-stakeholder have inherent vision conflicts and largely differing goals, making cooperation between the stakeholders difficult. If MaaS-service would not be allowed to include public transportation services, the MaaS-services could end up chasing highest possible profits, attracting the users of sustainable transportation modes towards more profitable and less sustainable transportation modes, decreasing the sustainability of the MaaS-service. These issues could be fixed by creating a shared vision through meetings and discussions or through regulative actions, such as giving public funding to MaaS-development against requirements serving public interest or by making policies supporting MaaS-services.

The most critical factors for making successful MaaS-services are the issues achieving profitable business model, the users' lack of willingness to pay and the cooperation between the stakeholders. Getting all the stakeholders to cooperate is essential due to these stakeholders acting as transportation service-providers for the MaaS-service. The MaaS-operator will be forced to make compromises between the stakeholders to keep them involved with the MaaS-service, to be able to include their transportation modes in the service, receive funding or subsidies from public sector, not face additional difficulties in selling tickets and to avoid regulative issues preventing long-term cooperation. The users' willingness to pay is one major issue for success of MaaS-services. Seventeen to 48 percent of research respondents are willing to pay for MaaS-services, with the users not willing to pay enough to cover the costs of providing the transportation services. If MaaS-services are to be widely adopted and create modal change towards sustainable transportation while being profitable, they are required to lower the users' mobility costs and likely will require to be given subsidies or other external funding to support the service.

The research into MaaS-service system feature-requirements provided 51 system feature-requirements suitable for implementation within MaaS-services. The requirements can be categorized into six different categories: General Concept, Payment and Bundle Design, Personalization, Usability, Reliability and Accessibility, Data Privacy and Management, and Service and Functionality. These system requirements can be used in developing an initial prototype-version of the MaaS-service.

7.1 Limitations

A limitation of the research is the used search term "Mobility-as-a-service". While by using this search term, one could find the studies directly related to MaaS-concept, there is a possibility that one could have been able to get more relevant information for system design by for example designing a mobile application for public transportation-companies and involving users and stakeholders in the design process. There is also a possibility that as the MaaS-concept itself was created in 2014, the search was not necessarily able to find all the relevant research material from before this time. Another possible limitation is due to the research nature as a master thesis. All the inclusion and exclusion decisions were done by a single person, which could possibly have led to mistakes being made during the study selection process. To counter this, including papers into study has been done liberally, with each exclusion being done after long deliberation. Despite this the possibility for mistakes still exists and may act as a limitation for the thesis. Another limitation is the used focus on MaaS-research. While by concentrating on MaaS-literature, the author was able to identify many features directly relevant for MaaS-services themselves, the list of system features could be further improved by going through research on usability of mobile services. Going through this research would have been able to include more technical system requirements, that would improve usability and accessibility of the created services.

7.2 Implications for research and practice

This research gives a few directions for future research and development. The literature review yielded that there are several studies researching MaaS, but there is a shortage of pilot studies experimenting with MaaS solutions in real environments. Every aspect identified as desired feature or requirement for MaaS could be researched in depth as to its impact on MaaS design and user adoption. While the created list of system features is based on previous MaaS-research, there is a possibility that as this thesis only follows the first two stages of Design Science Research process, the list of system features could lack some of the required features or that some of the included features would not necessarily work in MaaS-service like the previous research has suggested. This means that the results from this thesis could be extended in future by following through the Design Science Research process and developing a MaaS-service following the created list of system features. Creating an actual MaaS-prototype system would make it possible to find out deficiencies in the list of system features and enable further iterations of the list to be created and utilized in creating real-life MaaS-service. The list could also be improved and extended upon by studying usability- and accessibility-research, and using the gained knowledge for improving the list of required system features and detailing the existing ones with details relevant for usability and accessibility. Furthermore, the topic of MaaS design can be studied and approached from the perspective of service design and participatory design to include users' perspectives more strongly in the early phases of the MaaS system design and development.

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