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Faculteit Bedrijfseconomische Wetenschappen

master in de handelswetenschappen

Masterthesis

Technological and business challenges for Mobility as a Service (MaaS): An application to Belgium

Floris Lisabeth

Scriptie ingediend tot het behalen van de graad van master in de handelswetenschappen, afstudeerrichting ondernemerschap en management

PROMOTOR :

Prof. dr. Stephan BRUNS

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Voorwoord:

Als student Handelswetenschappen aan de Universiteit Hasselt heb ik deze masterthesis geschreven om dit jaar mijn master in de Handelswetenschappen – Ondernemerschap en Management te behalen. Na een intensief laatste jaar aan deze universiteit heb ik MaaS (mobility as a service) bestudeerd en onderzoek verricht naar het potentieel van MaaS als toepassing in België. Graag zou ik mijn promotor Prof. dr. Stephan Bruns willen bedanken voor de uitstekende ondersteuning en begeleiding gedurende deze masterproef.

Bovendien wil ik de gehele faculteit BEW aan de Universiteit Hasselt bedanken voor de fijne ervaringen, de kennis en vooral het praktijk gericht- en hardwerkend karakter dat aan deze Universiteit gesmeed wordt. Ten slotte wil ik nog mijn familie, vrienden en vriendin bedanken voor de permanente steun gedurende mijn studiecarrière.

Floris Lisabeth, Universiteit Hasselt, Juni 2022

Samenvatting:

De wereldbevolking zal naar verwachting tegen 2050 met nog eens 3 miljard groeien, dit brengt veel stedelijke problemen met zich mee die opgelost zullen moeten worden (Buhaug en Urdal, 2013). Eén van deze problemen is stedelijke congestie. Stedelijke congestie leidt tot een toenemende hoeveelheid uitlaatemissies en heeft een verwoestend effect op de lokale luchtkwaliteit (Grote, 2016). Een duurzamere aanpak zoals het implementeren van een MaaS-systeem (Mobility as a service) zou onze mobiliteit kunnen verbeteren en de opgebouwde druk in deze overbelaste stedelijke gebieden kunnen wegnemen. MaaS is een groeiend concept dat in beperkte gevallen heeft aangetoond dat het mensen toegang kan geven tot meerdere vormen van complementair vervoer (Sochor et al., 2016). Dit zou kunnen leiden tot een kleinere koolstofvoetafdruk, betere luchtkwaliteit en minder auto-ongelukken. Het zou ook het gebruik van auto's in privébezit kunnen verminderen, hetgeen veel extra maatschappelijke voordelen met zich meebrengt, zoals minder parkeerbehoefte en minder congestie (Smith et al., 2020).

MaaS is een one-stop online ICT-interface met een intermodale reisplanner (een reisplanner die verschillende vervoerswijzen kan combineren) die in realtime werkt en overal ter wereld kan worden geraadpleegd (Enoch, 2018). MaaS kan profiteren van zowel een abonnementsdienst als een pay-as-you-go-model. Het kan worden aangeboden door vele soorten spelers, zowel privaat als publiek. Tevens kan het worden gebruikt om milieu- of maatschappelijke voordelen te creëren (Smith et al. 2020). Een MaaS-exploitant streeft ernaar de optimale combinatie van vervoerswijzen voor elke reis aan te bieden door inzicht te verwerven in de netwerkomstandigheden en de voorkeuren van de gebruiker in real time (Lebas en Crutzen, 2021). Bij nieuwe diensten/technologieën is het regelgevend kader niet altijd duidelijk. Zeker bij openbaar vervoer is er zelden sprake van een economisch voordeel en wordt het vooral gesubsidieerd door overheden. Het combineren van meerdere vormen van vervoer moet in essentie toegankelijker en dus goedkoper worden gemaakt dan de huidige vervoersalternatieven (Smith et al. 2020). De huidige MaaS-pilots zijn kleinschalig; daarom is het een uitdaging om de gegevens goed te analyseren en toe te passen op een wereldwijde schaal. In 2009 stelde de Belgische vervoersdienst vast dat in Vlaanderen, pendelaars meer dan vier miljoen uren verloren door vast te zitten in files (Van Acker, 2011). Bovendien wordt in Vlaanderen een vierde van elk woon-werkverkeer met een privéauto afgelegd. Het gebruik van privéauto's is onhoudbaar en heeft gevolgen voor mens, gezondheid en klimaat (Van Acker, 2011). Dit opent een interessante weg naar het MaaS framework

Deze Masterproef onderzoekt twee onderzoeksvragen:

1. Wat zijn de technologische en zakelijke uitdagingen van MaaS?
Deze masterthesis beschrijft opportuniteiten die een MaaS systeem kan bieden. Daarnaast identificeert het potentiële uitdagingen bij het adopteren van een MaaS dienst/ontwerp. Deze obstakels zullen worden gegroepeerd in twee primaire categorieën: enerzijds technologische en

anderzijds zakelijke uitdagingen. Dit om de effectieve implementatie van een MaaS-systeem te kunnen garanderen.

2. Kan het Belgische Mobiliteitsecosysteem MaaS toepassen?
Na onderzoek van de potentiële uitdagingen tijdens de implementatie van MaaS, zal een checklist worden opgesteld. Deze zal helpen identificeren of de benodigde kritieke elementen aanwezig zijn om een MaaS-systeem te implementeren. Deze checklist zal MaaS valideren in de Belgische Mobiliteitsomgeving.

Deze masterproef maakt voornamelijk gebruik van literatuur geschreven in de laatste 5 jaar. MaaS is een nieuw systeem, dus verdere studie is nog vereist. Daarnaast werd er ook gebruik gemaakt van MaaS-testcases en pilotstudies. Dit bracht een aantal theoretische beperkingen en praktische uitdagingen aan het licht. Verder hielpen ze bij het identificeren en beschrijven van de implementatie-uitdagingen van MaaS.
Het Literatuuronderzoek bestaat uit 4 hoofdstukken:

- De waarde van MaaS
- Duurzaamheid van MaaS
- De zakelijke uitdagingen van MaaS
- De technologische uitdagingen van MaaS

Aan de hand van de bevindingen uit het literatuuronderzoek werd een checklist opgesteld om de tweede onderzoeksvraag te beantwoorden: "Kan MaaS worden toegepast op het Belgische mobiliteitsecosysteem?". Deze checlist helpt de huidige opportuniteiten te identificeren, welke intrinsieke elementen ontbreken, waar extra investeringen nodig zijn en de praktische haalbaarheid van de implementatie van MaaS in België.

De checklist is een uitbreiding van het negen-principes model (Jittrapirom, 2017). Voornamelijk, de negen sleutelprincipes van MaaS (jittrapirom, 2017), de zeven obstakels van MaaS (Smit, 2019) en de vijf belangrijkste beleidsprincipes voor de succesvolle inzet van MaaS (jittraprirom, 2020) komen aan bod. Deze modellen vatten de uitdagingen en opportuniteiten uit de literatuur samen. Deze informatie wordt verder in de checklist geïntegreerd. Uiteindelijk zal de checklist een uitgebreide versie vormen van de negen sleutelprincipes (Jittrapirom, 2017), gevolgd door een Ja/Nee vraag voor hun aanwezigheid en een andere Ja/Nee vraag om na te gaan of de principes erkend worden en er een indicatie is voor de toepassing hiervan in de toekomst. De toepassing van MaaS in België zal aan de hand van deze checklist worden gecontroleerd op de negen essentiële principes. Daarnaast zullen uitdagingen en obstakels worden geïdentificeerd. Een recente Belgische studie zal de basis vormen voor deze toepassing (Lebas en Crutzen, 2021), evenals een pilotproject dat momenteel in België loopt (MaaS - Mobility in Brussels Is Moving Forward, 2022).

De resultaten van de eerst onderzoeksvraag zijn als volgt: Om binnen het MaaS-ecosysteem te gedijen, moeten publieke en private entiteiten samenwerken. Het traditionele vervoersbeleid en de regelgeving moeten opnieuw worden geëvalueerd en vereenvoudigd. Daarnaast zijn er onvoldoende API's en dataformaten voor het aantal transportbedrijven dat MaaS nu al wil gebruiken. Verder is het belangrijk dat een commercieel levensvatbare mobiliteitsoplossing zoals MaaS rekening moet houden met bestaande discrepanties en hiaten in de markt. Als antwoord op de tweede onderzoeksvraag werd de gemaakte checklist toegepast. Deze is gebaseerd op 9 basisprincipes waaraan moet worden voldaan met volgende resultaten:

1. Integration of frictionless transport modes: Nog niet aanwezig
2. Tariff option (Pay as you go / subscription): Nog niet aanwezig
3. One dynamic platform: Nog niet aanwezig
4. Multiple actors that cooperate closely: Aanwezig
5. Use of technologies that improve current ICT conditions: Nog niet aanwezig
6. Demand orientation and increase validity of MaaS: Nog niet aanwezig
7. Registration requirement: Aanwezig
8. Personalization: Nog niet aanwezig
9. Customization with the aim to continuously improve digital infrastructure and collect data: Aanwezig

Na het toepassen van de checklist werden volgende kernzaken bevonden: De Belgische infrastructuur voor openbaar vervoer laat niet toe om een effectief MaaS-systeem te ontwerpen. België moet eerst zijn mobiliteits-ecosysteem herstructureren. Bovendien is er nog geen duidelijk economisch model dat een voordelige prijsstelling oplevert voor de consument.

Er is behoefte aan een solide IT-oplossing in België. Deze is nog niet aanwezig; momenteel vertoont ze een verhoogde kans op cyberaanvallen en het verliezen van gevoelige gegevens. Binnen Belgie is De MIVB de enige organisatie die een openbaar MaaS-model ondersteunt, met als argument het algemeen welzijn en inclusie van de bevolking. Er is nog geen overeenstemming over een uniform businessmodel in België.
Het optimale businessmodel van het Brussels hoofdstedelijk gewest is een hybride aanpak waarbij het de doelstellingen en stromen controleert om de kwaliteit van de dienstverlening te verzekeren. Toekomstige pilotprogramma's zullen onderzoeken welk model het meest geschikt is in België en de meeste gebruikersgerichtheid en servicekwaliteit zal opleveren.
België heeft voldaan aan drie van de negen sleutelbeginselen voor MaaS-integratie: “Multiple actors that cooperate closely”, “Registration requirement” en “Customization with the aim to continuously improve digital infrastructure”.

Voor de resterende sleutelprincipes zijn er nog aanpassingen en verbeteringen noodzakelijk. Er waren echter duidelijke aanwijzingen dat er een goed begrip is van het belang van de negen sleutelprincipes. De belangrijkste opdracht zal erin bestaan om de technologische en infrastructurele uitdagingen aan te pakken die een verbetering vereisen en uiteindelijk noodzakelijk zijn om het

volledige potentieel van MaaS te kunnen benutten. Om Maas volledig te kunnen integreren met daarnaast de grootste kans op slagen, moeten de voordelen voor de consument en het gebruiksgemak centraal staan.

Door de ontwikkeling van MaaS en de afhankelijkheid van technologie moet de bestaande checklist wellicht worden geactualiseerd om er nieuwe eisen in op te nemen. MaaS is gebaseerd op vervoer; het vervoerslandschap zal alleen nog maar meer veranderen in de nabije toekomst. Daardoor zal MaaS kunnen profiteren van de ontwikkeling van transferknooppunten, zelfrijdende voertuigen en modulaire vervoerssystemen. Echter, deze veranderingen kunnen de checklist wel minder accuraat maken. MaaS is van plan het transportsysteem te reorganiseren zodat het gebruik van privévoertuigen afneemt. Vanwege de nieuwheidsfactor en het gebrek aan proefstudies zijn de gevolgen op lange termijn van MaaS moeilijk te voorspellen.

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1. Introduction

1.1 Motivation

In the past decades, there has been an ever-increasing trend in the global population; much of our global population has and still is migrating to live in cities. Furthermore, this migration to cities is not slowing down, and this phenomenon could cause enormous disruption in those cities on multiple levels. For the people migrating to the inner cities, moving to a big city has always been seen as an economic improvement. In addition to this, the global world population is expected to grow by another 3 billion by 2050, creating many urban problems that need solving, transport being one of them (Buhaug and Urdal, 2013). Previous research done in multiple countries has shown us that a lower income is closely tied to less frequent travelling, which is essential in more significant urban areas (Murakami & Young, 1997).

However, with this increase in population, more and more people are likely to enter the middle class and could express a desire to buy a car. It has been seen as a symbol of freedom for many years. Therefore, this could become an issue as this development could cause severe pressure on the current urban infrastructure that would not sustain this sudden increase in road vehicles (Bouton et al., 2015). During peak hours, congestion puts enormous pressure on the urban infrastructure. Primarily, the inner parts of urban areas suffer from the consequences of congestion. Urban congestion results in an increasing amount of tailpipe emissions. These emissions are being produced whilst being in slow traffic, resulting in a growing amount of greenhouse gasses and consequently has a devastating effect on the local air quality. Furthermore, the transport systems in these urban areas are not built to carry such an overwhelming wait of vehicles (Grote, 2016).

In addition to looking at recent data (Fig. 1 and 2) provided by the European environment agency (EEA), there is an apparent reason to consider alternative transport solutions to privately owned cars. A good choice, even if it were only for the environmental benefits. Almost 72% of greenhouse gas emissions in transport are produced by road transport (Fig. 1). If we then further analyse this data by looking at (Fig. 2), we can conclude that of that 72%, almost 45% is caused by car emissions. A more sustainable approach like implementing a MaaS system could improve transport and release some build-up pressure in these overly congested urban areas. It could also have an environmental impact.

The main objective of this dissertation is to analyse and provide a comprehensive literature review of what MaaS is, how it is currently applied and how this system and the compatible technology is evolving. Afterwards, create a checklist that includes the important principles for implementing an effective MaaS system based on the challenges associated with the creation of MaaS and the policies that should be enforced in order to deploy MaaS successfully. In addition, investigate the viability of MaaS as an alternative mobility solution in Belgium by applying the created checklist to the mobility

ecosystem in Belgium and defining its inherent limitations. In addition, it could express itself with application suggestions/improvements stated at the conclusion of this dissertation.

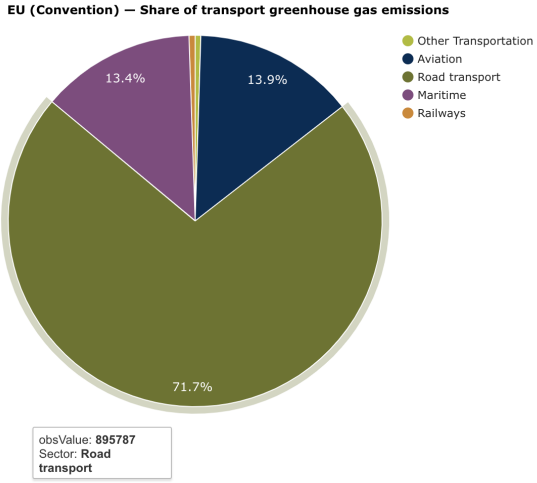

Fig. 1: EU Greenhouse Gas Monitoring Mechanism all transport

Notes: Dark green shows that Road transport accounts for 71.7% of greenhouse gas emissions. Dark blue shows the 2nd biggest polluter at 13.9%, being Aviation. Purple shows the 3rd biggest polluter at 13.4% being Maritime transport. Source: EEA (2020)

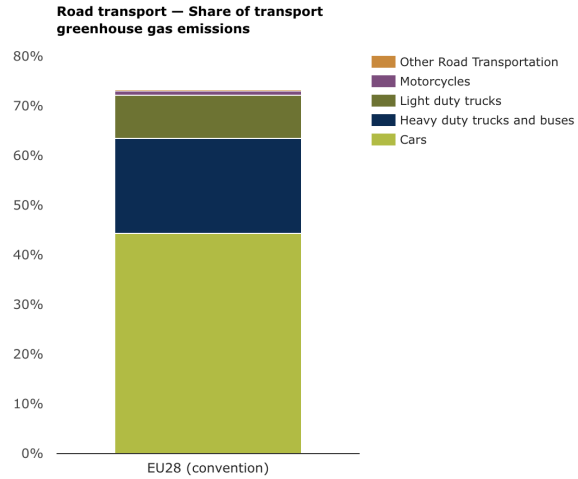

Fig 2. Share of road transport greenhouse gas emissions

Notes: Cars in light green account for ~45% of all road transport greenhouse gas emissions. Dark blue shows heavy-duty trucks and buses accounting for ~20% of road transport greenhouse gas emissions. Source: EEA (2020).

1.2 What is Mobility-as-a-Service (MaaS)?

MaaS is a growing and developing concept that has, in limited cases, shown that it can give citizens access to multiple forms of complementary transport (Sochor et al., 2016). Therefore, also making the use of public or shared transport easy and more attractive. As a potential benefit, this could affect the use of privately owned cars, bringing out a lot of extra societal benefits such as reduced parking needs and congestion, especially in the inner cities. This could result in a smaller carbon footprint, improved air quality and fewer car accidents. There could also be an extra societal benefit; applying MaaS could make transport more accessible and productive, thus creating more economic opportunities and helping its population grow on the socio-economic ladder (Smith et al., 2020).

However, what is MaaS now specifically? Holmberg et al. (2016) state that MaaS is still a developing concept with no clear universal definition. However, Enoch (2018) was able to narrow the basics of a MaaS system down with the following definition: "MaaS is a one-stop online ICT interface that includes an intermodal journey planner (which can combine different modes of transportation such as car-sharing and car rental) that operates in real-time and can be accessed from anywhere in the world. Customers may either pay as they go or pre-pay for a 'service package' in advance, depending on their requirements, using a single payment interface like that seen on smartphones. MaaS is a booking system that covers all stages of a journey from start to finish." In this master thesis, this definition will be used as the benchmark to explain, deconstruct, and apply MaaS as a concept.

In addition to the definition given above, in 2017, KPMG suggested we see MaaS as a newly provided service rather than a newly created technology (KPMG, 2017). This said, MaaS brings together a whole range of already existing forms of transportation, such as car and bike-sharing, public transport, and apps like; Bird, Lime and Uber. Consequently, the prospects of MaaS will lay in its usability and applicability of combining all these services in a platform that is easy to use and fits in a framework of new policies that will support this innovative service (Smith et al. 2020). MaaS is generally integrated via an app or platform. The MaaS topology suggests that it acknowledges four levels of integration (fig.4): information, booking and payment, mobility packages and policy (Sochor et al. 2018). To simplify MaaS at its essence, we could describe MaaS as: "A type of service that through a joint digital channel enables users to plan, book and pay for multiple types of mobility services" (Smith et al. 2020). As a booking and payment system, MaaS can benefit from both a subscription service and a pay-as-you-go model. Furthermore, MaaS can be provided by many types of players, being private or public and being used to create environmental or societal benefits (Smith et al. 2020).

MaaS involves integrating all mobility services accessible in a given area, including public transport (e.g., bus, tram, metro, train) and private players' shared modes (e.g., car-sharing, car-pooling, bicycles, scooters). In reality, the MaaS operator seeks to offer the optimal combination of transport modes for each journey by understanding the real-time network conditions and user preferences (Lebas and Crutzen, 2021). MaaS, furthermore, has different levels of integration (Lebas and Crutzen, 2021). A visual idea of the MaaS concept will be explained in the table below as well as the

different levels of MaaS integration that will be explained. (fig 3. And fig 4.) (Lebas and Crutzen, 2021)

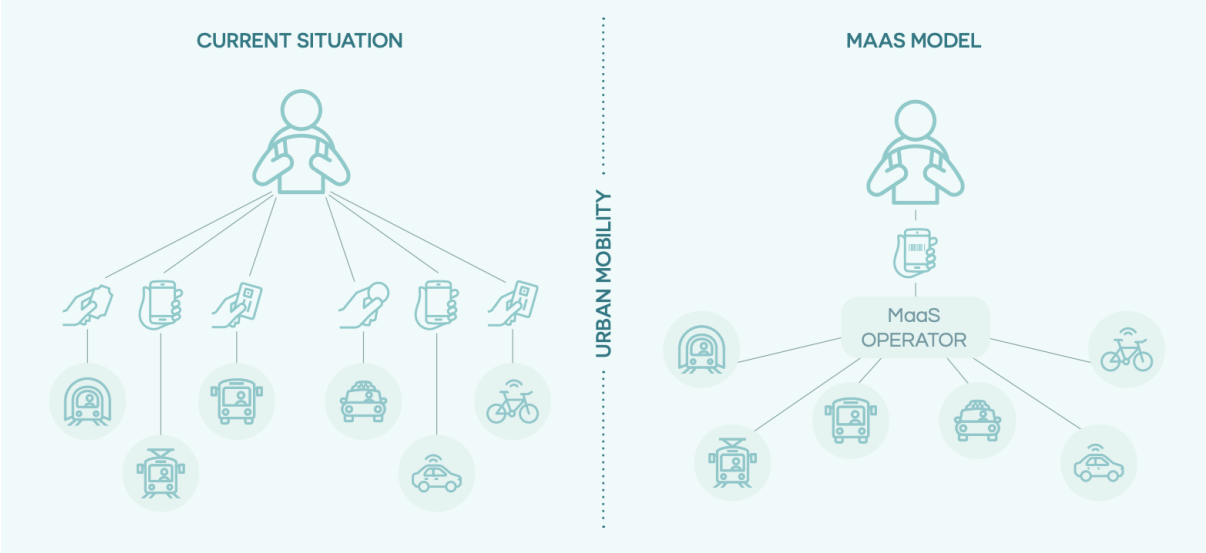

Figure 3. Visual concept representation of MaaS. Source: (Lebas and Crutzen, 2021)

NOT CONSIDERED AS MOBILITY AS A SERVICE		MOBILITY AS A SERVICE		
LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
NO INTEGRATION	INTEGRATION OF INFORMATION	INTEGRATION OF BOOKING & PAYMENT	INTEGRATION OF SERVICES	SOCIETAL INTEGRATION
Services are provided separately for different means of transport.	Travel information is provided by (multimodal) travel planners.	Users can find, book and pay for their trips, regardless of the means of transport, through a single point of service.	Transport services are integrated through passes, bundles or packages. At this level, MaaS offers an alternative covering all daily mobility needs.	Supply and demand are now associated with societal objectives such as reducing car use or promoting habitability in cities.
E.g. The user has a monthly ticket for public transport, an app for each shared mobility service and must compare the travel information on all these different channels.	**E.g.** The user has a public transport season ticket, an application for each shared mobility service, but can plan their journey through a single platform that compares the different alternatives.	**E.g.** Users have a single platform on which they can plan their journey and compare mobility alternatives. They can also book individual journeys through this platform.	**E.g.** The user has a unique platform on which they can plan their journey and compare mobility alternatives. They have a monthly pass giving them unlimited access to public transport, shared bicycles in the city and a number of shared taxi and electric scooter routes.	**E.g.** In addition to level 3, the user receives bonus points that are converted into vouchers or discounts if they choose more environmentally friendly modes of transport.

Figure 4. Different levels of integration. Ranging from level 0-1 (Not considered MaaS) – level 2-4 (considered MaaS). Source: (Lebas and Crutzen, 2021)

1.3 Current MaaS applications

The concept of MaaS is evolving rapidly; more specifically, it is being implemented and rapidly growing in the Nordic countries where current research is being done trying to study the business, institutional and technical effects of MaaS. These studies show promising results and could imply that although MaaS is a sustainable business model when applied/misdesigned, it could also generate a harmful environmental impact. In addition to this, in 2014, "UBIGO" became one of the first MaaS concept services to be piloted in Gothenburg, Sweden. In 2016 the finish Maas-service "MaaS.Fi" was brought to life to extend its reach outside the finish borders and expand globally. On a European level, the implementation and growth of MaaS have also been widely supported thanks to organisations like the MaaS Alliance, that was founded in 2015. For many countries, the public sector is still analysing which role they could or should play in the MaaS ecosystem (Holmberg, 2016).

MaaS is an innovative system that could bring many improvements to many of the transportation issues we struggle with today. However, there are some regulatory questions we should keep in mind. Who will be the governing entities behind MaaS, and who will implement the appropriate policies? With new services/technologies, the regulatory framework is not always clear. With public transport, there rarely is any economic benefit or surplus produced and it is primarily subsidised by governments. How will MaaS affect this current system? Combining multiple forms of transport should, in essence, be made more accessible, and thus cheaper than existing means of transport (Smith et al. 2020).

The current MaaS pilots have been on a small scale; therefore, it is challenging to analyse the data correctly and apply it to a global scale. It is currently not feasible to estimate the impact on society and generate enough knowledge about the different forms of MaaS application (Smith, 2020). Besides the MaaS projects currently running, new and innovative technologies enable the further development of MaaS. Sony revealed in 2020 that it was developing a blockchain-based database that would allow for MaaS operators to facilitate MaaS systems. This shared database would enable seven million-plus users a day to anonymously record and share their travel data and revenue allocation. Sony worked together with the Dutch government to test out this new software, successfully amassing information within the blockchain and making it possible to access and utilise that data in a MaaS system, scaling the concept of MaaS with big data (SmartCitiesWorld news team, 2020). New technologies are enabling the further growth and development of MaaS systems; most of these projects have been primarily concentrated in the northern European countries. These are relatively small countries with a manageable population. MaaS projects today are about gathering immense amounts of data and correctly analysing this data, providing the customer with an A-Z overview of different transport options, routes, and the total cost of this journey via an efficient and easy to use medium.

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

Fig 5. Example of a MaaS project and its Tariff options by MaaS application "Whim" Helsinki
Notes: Whim to go: pay as you go. Whim urban: subscription with add-ons. Whim unlimited: all-in subscription with unlimited free rides. Source: (Whim, 2022)

1.4 The mobility ecosystem in Belgium

In 2009 the Belgian transport department found that in Flanders (the northern part of Belgium), commuters lost over four million hours being stuck in congestion on the Flemish roads (Van Acker, 2011). (Fig.4) shows the growth in the usage of private cars, busses, trains, trams, and metro vehicles. We can see that although there is a slight increase in public transport usage, an enormous portion of the population still uses their private car as the primary means of transport (Van Acker, 2011). Looking at the whole of Belgium, it is estimated that in Flanders, 11% of the population uses a bike as a regular means of transport compared to Brussels and Wallonia, here the percentage is a lot lower at 1% and 2%. In Flanders, one-fourth of every commute is done to get to work or school (Van Acker, 2011). The usage of private cars is unsustainable, affecting time, health, and climate. This opens an exciting pathway toward the MaaS framework. Corporate entities and schools could apply the MaaS system to offer a more sustainable form of transport to their employees/students.

The research done on MaaS systems in Belgium is minimal. Therefore, it will be interesting to look at the current international projects and models and try to see what the right market fit could be for these models in the Belgian mobility ecosystem. In particular, explore the current limitations of these models and the inherent risks they bring when applied to Belgium's infrastructure. At the current timing, this system, and the technology with which it is applied is still very much in its infancy. Hopefully, this explorative dissertation will bring some of its potential to life when applied to small, highly polluting countries like Belgium. Moreover, they result in ways to tackle these limitations and their inherent risks.

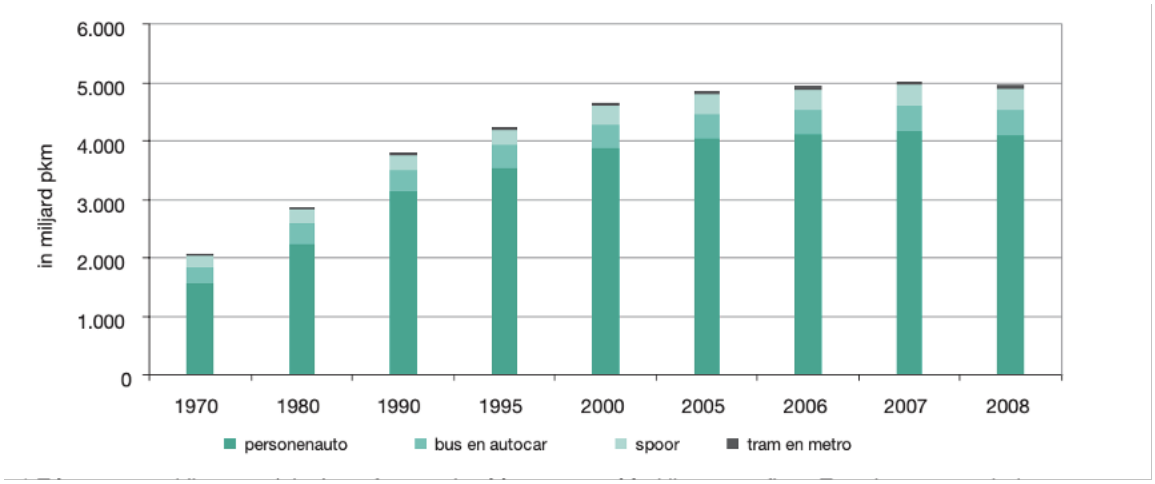

Fig 6. Growth usage Private cars

Notes: Dataset from 1970-2008 showing the growth in the number of kilometres driven expressed in billion. Dark green showing the increase in the number of cars. Green is showing bus and vans. Light green shows rail traffic. Black is showing tram and metro traffic. Source: Van Acker (2011)

1.5 Research questions and methodology

The research questions assessed in this Master thesis can be split into two parts:

1. What are the technological and business challenges for Mobility as a service (MaaS)?
This Master thesis aims to create a framework that identifies the inherent opportunities and needs for a MaaS system to be put into place. For this reason, it is crucial to identify the potential challenges that can occur when applying a MaaS service/design in a specific setting. These challenges will be divided into two main branches: the technological challenges, focusing mainly on the already available technology and the technological advancements needed to implement such a system effectively. On the other hand, concentrating on the business challenges, focusing on private or publicly available resources and particular business challenges that need to be tackled to ensure the successful implementation of a MaaS system.

2. Can MaaS be applied to the Belgian mobility ecosystem?
After analysing the various issues that may arise during the implementation of an effective MaaS system, a framework will be developed to simplify them. This will serve as a tool for identifying the inherent basic and advanced needs required to effectively implement a MaaS system. This framework will serve as the basis for validating the use of MaaS inside the Belgian mobility ecosystem.

To answer the first research question a literature review was done.
The literature used for this Master's thesis focuses on recent research, mostly studies done in the last five years. MaaS is a new system, so current research is necessary with its rapidly changing nature. In addition to the literature, some test cases and pilot studies for MaaS were utilised in this Master's thesis. This aided in comprehending the theoretical constraints and uncovered new practical

limitations not mentioned in the academic literature. These were especially helpful for identifying and describing a number of challenges while implementing a MaaS system.

Before evaluating the challenges, it was necessary to explain why MaaS is an essential subject of study and why there is a need for further research. This is explained in the introduction.

The literature research contains four chapters:

2.1 The value proposition of MaaS
2.2 MaaS as a sustainable transport system
2.3 The business challenges of MaaS
2.4 The technological challenges of MaaS

To gain a deeper understanding of the current ecosystem around MaaS, the research also examined MaaS legislation and regulations alongside existing frameworks. It is crucial to comprehend the present legal structures and opportunities around MaaS, primarily motivated by sustainability.

To answer the second research question, "Can MaaS be applied to the Belgian mobility ecosystem?" was done by creating a checklist using the data collected in the literature review. This checklist was then applied to Belgium. The first part focuses on developing a Checklist for assessing the viability of a MaaS system in a specific country. It will aid in identifying the current assets available, what intrinsic assets are lacking, where additional investment is required, and the practicality of implementing MaaS.

The checklist will be an adaptation of the nine key principle model (Jittrapirom, 2017).
The literature review focuses on identifying shared constraints and prerequisites for the application of a MaaS system. In addition to reviewing the literature, we will examine MaaS from a business perspective by developing a business model canvas based on data collected in the literature review. The business model canvas will aid in a more thorough evaluation of the requirements for a well-organized MaaS system and help identify some of the key elements necessary for the further development and implementation of MaaS. Additionally, three models will be examined: The nine key principles of MaaS (jittrapirom, 2017), the seven challenges of MaaS (Smit, 2019), and the five most crucial policies for the successful implementation of MaaS (Jiitrapirom, 2020). These models will provide an excellent summary of the challenges and opportunities identified in the literature. The ultimate objective is to integrate them into the checklist. This checklist can then be applied to different countries and regions to determine if the correct elements are present. The checklist will be created as follows: an adaptation of the nine key principles (Jittrapirom, 2017) followed by a Yes/No question for the presence of those key elements and another Yes/No question to indicate the principles are acknowledged. and will be implemented in the future.

This checklist will be applied to Belgium to see whether the nine key principles are present. Furthermore, the challenges or current obstacles will be identified. The basis for this application to Belgium will come from a recent research study done in Belgium (Lebas and Crutzen, 2021).

2. Literature review

2.1 The value proposition of MaaS

The literature agrees that the benefits of MaaS are heavily reliant on technology and thus have the potential to accelerate its growth as well as solve multiple urban mobility problems (Enoch, 2018; Smith and Hensher, 2020). While there are also arguments that MaaS is seen as a method that could drastically impact the economic structure around mobility where MaaS would mostly offer multiple economic improvements (Smith and Hensher, 2020). Outside of these realms, others suggest that the benefits of MaaS are primarily found in its promised value towards sustainability. Where MaaS could offer many benefits to our environment in the long term, the environmental benefits will mostly start to be noticeable in the long term and will not be as significant in the short-term view (Sarasini, 2020). MaaS business models may generate a variety of sustainable value, and practitioners should focus on identifying ways to capture that value, either directly via revenues or indirectly via other economic advantages. Additionally, they should grasp the trade-offs between environmental sustainability and accessibility. Further, it was suggested that a thorough understanding of how business models can generate sustainable value would not only improve the sustainability of transportation systems but will also enable practitioners to advocate for MaaS in broader contexts, thereby legitimising the concept and establishing enabling conditions for its growth (Sarasini et al., 2017).

To further add on the previously discussed environmental benefits and economic advantages, Arias (2020) adds that all sharing services are urged to promote electric mobility, which may also reduce noise and air pollution. The majority of businesses seemed to offer door-to-door mobility, which increased their marketability and attractiveness as a feasible option to driving. In Madrid there are three station-based services (Bicimad, Ubeeqo, and Respiro); nonetheless, certain constraints must be set. If shared mobility services continue to flourish and overcome Madrid's last-mile challenges, MaaS has the potential to become the city's new mode of transportation. MaaS will continue to grow in popularity due to the fast growth of mobility applications and the resulting need to consolidate them onto a single platform. The present state of Madrid may assist authorities, transit providers, and other stakeholders in better appreciating the city's potential: MaaS (Mobility as a Service) is becoming increasingly prevalent in Madrid as a result of the fast growth of niche enterprises (Arias, 2020).

While some studies argue that MaaS’s propositions are mostly about capturing extra economic value or the more long-term sustainability effects. Others believe that one of its biggest propositions is to move privately owned vehicles out of the current mobility ecosystem, with a rapidly increasing elderly population this would fill in a gap where much-needed transport solutions should be found (Enoch, 2018; Li, 2017).

In addition to the literature about the benefits of MaaS (Smith and Hensher, 2020; Sarasini, 2020; Enoch, 2018), a different study (Li, 2017) suggested It's not only young individuals who may benefit from MaaS; it can also play an essential role in satisfying the travel demands of an elderly population. Furthermore, MaaS may be the appropriate solution when self-driving vehicles are widely available on the market. Using Autonomous MaaS (A-MaaS), the business claims will be an excellent alternative to owning a car while simultaneously leveraging the benefits of automated vehicles (Li, 2017).

To learn more about this phenomenon (MaaS), Enoch (2018) reviewed the available literature. Additionally, factors that impact societal and individual mobility needs were also examined. He stated that one of the critical aspects of MaaS is that it is a one-stop online ICT interface that includes an intermodal journey planner (which can combine different modes of transportation such as car-sharing and car rental) that operates in real-time and can be accessed from anywhere in the world. Customers may either pay as they go or pre-pay for a 'service package' in advance, depending on their requirements, using a single payment interface like that seen on smartphones. MaaS is a booking system that covers all stages of a journey from start to finish.

Many factors contribute to change, but technology is the most important one. To further understand MaaS, "crowdsensing," in which a considerable number of users' personal-level data is gathered via sensing devices such as cell phones and then used to promote community well-being, is a new technology. The rise of self-driving automobiles is causing a significant shift in how transportation is provided in the future at the governmental level. So, in response to public concern about climate change, energy security, and poor air quality, governments have increasingly turned to "encouraging" citizens not to drive whenever possible, whether via increased gasoline costs or a ban on cars in city centres. The firms that supply intermediate modes of transportation are likewise seeing a significant shift in the way they do business. Traffic deaths are on the rise as a consequence of a growing number of old individuals who are unable to drive, as well as younger people who are more barred from automobile ownership and usage due to more complex driving exams and rising insurance rates, as well as attitudinal issues. As a result of economic concerns (including but not limited to the global financial crisis), consumer demand, job levels, and purchasing power have all changed (Enoch, 2018).

Smith & Hensher (2020) provided the basis for the study of MaaS policies by introducing a framework that identified elements of MaaS policies that should be addressed. An empirical evaluation of the "Transport for New South Wales's MaaS policy program" was done and published to illustrate how the framework may be applied. The transportation literature was enriched in two ways by this article. Writers began by improving their understanding of MaaS and its differences from existing practice. First and foremost, they helped improve our understanding of how the public sector may aid in creating and the diffusion of innovative technology. A transition perspective can be used to understand the development and distribution of MaaS from a public sector perspective to transform personal mobility from (mostly) fragmented to (more) polycentric, to reap public benefits by altering them in a more integrated and coordinated way. Considering things from the standpoint of changes,

MaaS is not a new mode of transportation nor a new transportation paradigm, and this is the most crucial point to make here. MaaS, on the other hand, is being developed and disseminated because of the need to gradually alter the personal mobility system so that transportation services and different modes of transportation are better aligned. People who utilise serviced modes of transportation rather than non-serviced modes are expected to benefit from a broader range than those who use non-serviced methods. This means that as we learn more about the MaaS phenomenon, the conception of MaaS will need to be reworked. Scholars and practitioners may use an easy-to-use instrument to identify synergies and misalignments between MaaS policy efforts and what is required in order to facilitate and manage MaaS' expansion and diffusion (Smith & Hensher, 2020).

Sarasini et al. (2017) studied whether MaaS business models are likely to be beneficial in the extended value run. This value goes above and beyond the standard "profit norm" ingrained in business structures and organisations regarding sustainability. The objective of this paper was to give a new and comprehensive view on how the MaaS model may generate long-term value that might be used by MaaS practitioners to develop new MaaS services, as well as to serve as a springboard for further study into the issue. There are numerous sorts of sustainability benefits that may be produced in the context of MaaS business models, and the authors evaluated several techniques for capturing this value. The kinds of sustainable value mentioned seem to be related to the mobility and data service components of MaaS business models and the transportation system's resource efficiency. While this is by no means a complete list, it may serve as a jumping-off point for further inquiry.

More profound knowledge of these qualities and their impact on long-term success should serve as the bedrock of MaaS business models. Additionally, the data showed a collection of future-oriented opportunities for sustainable value generation via resource efficiency improvements, which the researchers explored. To make these potentials a reality, practitioners from various sectors must collaborate in novel ways to promote the adoption of environmentally friendly vehicle technology and the recycling of recyclable materials. The objectives were intended to be long-term in character rather than short-term. Sarasini (2020) adds to the value proposition of MaaS by stating

Sochor et al. (2018) presented a MaaS topology as a tool to facilitate further debate of MaaS, allowing for comparison of different services, comprehending MaaS's possible implications, and promoting the incorporation of societal goals into MaaS services as a result of their research. The authors analysed existing definitions based on a review of the literature. The findings of an expert session aimed at identifying key traits and, as a result, distinguishing service offers are discussed in this study. MaaS topology and its implications, on the other hand, were highlighted as an important tool for boosting dialogue, a better understanding of barriers and enablers at various phases of MaaS development, as well as a better grasp of MaaS topology and its implications. On the other hand, MaaS topology and its implications were identified as an essential tool for enhancing discussion, a better understanding of barriers and enablers at various stages of MaaS development, as well as

making it easier to implement MaaS (for example, by creating action plans that are specific to the desired MaaS level and its objectives).

Hybrids between levels are possible, and matching services to levels is always a matter of interpretation; for example, is multimodal public transportation with a journey planner and some level of integrated ticketing/payment regarded a level of public transportation, or not? Rather of providing a comprehensive and static definition of MaaS, this topology was created to facilitate discussion, comprehension, and comparison of various service kinds, their feasibility and effects, and the feasibility and consequences of each. As a result of the topology, a number of tactical, operational, and reflective measures might be devised to aid in the transition to a long-term transportation system based on the MaaS technology platform (Sochor et al., 2018).

Both definition and exploration were the objectives for Kamargianni & Matyas (2017) when they developed their concept of MaaS and explored an all-encompassing design approach for the MaaS ecosystem. They created the MaaS concept and proposed a MaaS ecosystem, in which the roles and duties of each player were specified. The MaaS ecosystem was developed through personal interviews and focus groups conducted with the different parties involved. It was via the implementation of this all-encompassing approach that the MaaS concept was established and identified areas that needed more inquiry to help in its fulfilment. According to the authors, ensuring that all public transportation modes in the city are available via a MaaS provider is more accessible if the transportation authority is the service provider, they argue. The fact that most cities' transportation authorities are responsible for authorising or purchasing all other forms of transportation means that obtaining their participation in the MaaS service would be easier, and the service would be more accessible as a result. Furthermore, since public transportation authorities are often also transportation regulators, the MaaS concept may be implemented in a shorter period. It is possible that diversifying and expanding the functions of public transportation authorities may prove to be too difficult and that it will take years to accomplish. The bureaucracy of transportation agencies, like that of many other government agencies, may act as a barrier to the adoption of new technology. It's also conceivable that public transportation authorities lack the motivation or are obligated by law to develop MaaS services that may significantly enhance the overall travel experience.

The primary purpose of MaaS is to make intermodal and multimodal journeys for customers as seamless as possible from start to finish. As a result, the approach that has been implemented has proved to be user centric. An integrated mobility service provider collects all of the transportation operators' services in this method, emphasising that MaaS is more than simply an integrated mobility service; it is a complete reorganisation of mobility supply, with the MaaS Provider at its core. Additionally, it may be given to customers via a single digital platform, highlighting the importance of information and communications technology (ICT) and information technology infrastructure (IT infrastructure) in the operation of MaaS systems (Kamargianni & Matyas, 2017).

Ditmore & Miller (2021) developed models for adopting MaaS that go beyond the public sector based on the public sector approach. Because of this, it was noted that a universal strategy would not provide the same results as a system suited to each region's specific needs. To promote the usage of shared modes of transportation, a policy driven MaaS Operating Model is necessary. Because of the fast-changing nature of transportation, control mechanisms must be put in place well before fully automated (single-occupant) vehicles become the norm. To do so, it is necessary to establish control mechanisms as soon as possible. Public institutions would be better positioned to keep up with technological advancements if a clearly defined framework was implemented. When allowing developers to engage in requirements debates, innovation is likely to be stimulated since it will be easier to match technology with impending laws rather than the other way around. Whether official or informal, collaborations between the public and private sectors become more critical in this scenario.

According to the author, models that allow for the ideal balance of individual and societal benefits should be investigated in the future. When users fully realise the real influence of MaaS on society and individuals, it is conceivable that their behaviour may alter due to this realisation. Increasing the amount of research into the underlying causes for individual choice in multimodal consumption would allow MaaS providers to grasp market acceptability better. With the aid of MaaS, it is possible to enhance the user experience. On the other hand, prioritising the best possible user experience above social good is a poor approach. MaaS solutions at the forefront of policy will soon become the standard, opening us to a new window of opportunity to assess their efficacy and make changes to upcoming initiatives (Ditmore & Miller, 2021).

2.2 MaaS as a sustainable transport system

There are several ways in which MaaS might help enhance environmentally friendly transportation, according to Jang et al. (2021). A stated portfolio experiment was agreed upon to better understand people's preferences for MaaS. When consumers sign up with MaaS, they may choose from various modes of transportation. A reduction in consumer dependence on personal automobiles and even a delay or abandonment of car ownership are expected due to advanced technology being used to book, schedule, and pay for door-to-door transportation services, leading to improved environmentally friendly modes of transportation.

Jang et al. (2020) found that MaaS may either help or hurt the transportation system's long-term viability because of its capacity to facilitate seamless transfers across forms of transportation. The monthly cost, time commitment, and pricing systems for transportation modes tied to specific MaaS bundles all play a role in determining membership fees for the new service. On the one hand, drivers who already own cars may switch to MaaS and choose package choices that include just public transit and active modes of transportation. Packages that include vehicle rental and car-sharing options are available to current public transit and slow mode users. Applied to Belgium they could make way for Corporate MaaS schemes that would take the place of the current unsustainable corporate car

scheme alternative. The scale of these two transitions, as stated above, will ultimately decide the influence of MaaS on the transportation system's long-term survival. MaaS may have a negligible impact on improving sustainable transportation networks, but there are other compelling reasons to implement the plan anyway. The quality of public transportation, the cost of parking, and other factors affecting traffic congestion and access to parking lots will need to be investigated further (Jang et al., 2021).

Considering MaaS as an environmentally friendly form of transportation, Alyavina et al. (2020) explored the factors that impact adoption and the likelihood of it being successful. While MaaS seems to be an appealing method, it does not appear to result in the necessary behavioural change to the extent that transportation-related sustainability issues may be resolved. It is convenient and enjoyable that people who utilise public transit opt to go by vehicle. They do so with little consideration for the environmental consequences, and as a result, they feel compelled to keep their existing driving habits. Because public transportation lags far behind the private automobile in terms of acceptance and intended use, even when combined with shared-use mobility options, it is necessary to overhaul these services and their general design in tandem with steps to encourage people to leave their automobiles at home, according to the World Health Organization. For the time being, MaaS can only give potential users the ease of "applied" access, which may reduce the cognitive load associated with planning and going to their destination. Users are not prepared to pay for rapid access since it only allows them to quickly access services that do not suit their needs and, as a result, do not meet their expectations, according to the survey.

As an alternative to competing with the convenience of a private automobile, MaaS provides consumers with a way to be a part of an effort to build a more sustainable, livable, and socially inclusive future through the creation of a multimodal transportation option that is more environmentally friendly. Users should be encouraged to use MaaS responsibly through the use of tax credits or other financial incentives, as well as through awareness, information, and social engagement campaigns designed to make the concept more familiar to them and emphasise its importance in terms of sustainability if used responsibly, among other methods. People's attitudes toward private cars must be changed if MaaS is booming, which is a difficult task. As a result, policymakers and mobility providers should encourage responsible MaaS use, promote public transportation as the backbone of the system, and use public engagement exercises and trials to introduce people to the concept while simultaneously demonising private car ownership and use (Alyavina et al., 2020).

2.3 The business challenges of MaaS

When Polydoropoulou et al. (2020) looked into MaaS from a business point of view, they did workshops and in-depth interviews in Budapest, Greater Manchester, and Luxembourg. Data gathered during the research process led to a complete assessment of the MaaS ecosystem and identified three MaaS leaders in the field. Models for MaaS business models have been made on the Osterwalder canvas (business model canvas) to show how MaaS operators can create, provide, and

collect value for their customers. Public and private organisations need to work together and compete to succeed in the MaaS ecosystem. Partners in a MaaS collaboration, such as mobility service providers, public transit authorities, and regional governments, were always the most important. Also, the systems' of innovation approach was used to look for both positive and negative factors that could help people use MaaS and possible solutions.

Regulators might make it hard for MaaS operators to use commercial tactics (like low-cost tickets and bundled services) to stay competitive if they do not allow them to do so. Traditional transportation policy and regulations must be re-evaluated and changed to make MaaS technologies easier to use. Another problem is that there aren't enough APIs and data formats for all the different transportation companies working on the project to make it easy for people to use the scheme. To make it easier for data and API feeds from various MaaS providers to work together, policymakers should set standards for collecting, managing, and sharing data.

As a result, authorities should consider giving money to transportation operators who want to get involved in this field. Regarding infrastructure problems, it was found that flexible tickets and electronic transactions were not yet available in some places due to technical issues. However, MaaS is very dependent on these two variables to work correctly. Existing technologies should be used to make public transportation networks more efficient, and new ticketing ideas should be encouraged. There should be access to data and API feeds in all areas where MaaS is expected to be used. This includes data and API feeds. Several parties in the MaaS ecosystem were also crucial in the study. The public and private sectors should work more closely together (public transportation authorities, providers, and municipalities). Privately held businesses also have to deal with this. To get the most value and promote their businesses in a very competitive market, private MaaS companies should work together and compete with each other to do so. It can only be beneficial to MaaS if the people who use it work together getting the most out of this innovative system (Polydoropoulou et al., 2020)

Lebas & Crutzen (2021) conducted early research on Belgian municipal mobility representatives' interests and views about MaaS, its implementation, and its management. According to the authors, the adoption of MaaS is seen differently across cities because of the differences in local cultures. Two things stand out regarding the public and private sectors' respective roles: first, all interview participants agree that the public sector should facilitate or coordinate the implementation of mobility services, and second, private operators should provide these services themselves except for public transportation. In addition to the lack of resources and experience inside cities, this technique is driven by a desire to implement policy goals. However, two patterns appear when it comes to managing systems: most cities have no clear preference for one, but those that do prefer a hybrid model in which the public or at least some parties are involved in the administration of a franchised solution.

There may have been some prejudice in the interviewee's perspective for each city. At the level of the role played by this individual in this scenario, this prejudice is justified. Secondly, the authors

concentrated on local governments and public-private partnerships in our research (Public transport operator). To complete this particular case and develop a comprehensive vision for MaaS management and governance, it will be necessary to incorporate additional stakeholders' perspectives in the future, such as private transportation operators, regional governments, MaaS service providers, and users. There are several reasons why the authors chose the 10 locations they did for this research, including the fact that MaaS is now concentrated in metropolitan regions with an appropriate density of mobility services (Lebas & Crutzen, 2021)

Li and Voege (2017) argued that MaaS is plagued by user perspectives, legislative frameworks, and commercial models. There are concerns about the mobility industry's competitiveness, which might have severe ramifications for innovation and small and medium-sized businesses if MaaS is implemented on a European or global scale (SMEs). A few vast corporations might soon dominate the worldwide MaaS market. A proper regulatory framework must be in place to enable the adoption of MaaS and the benefits of MaaS to passengers while also prohibiting unfair competition.

The commercialisation of mobility through the service package model demands the purchase of services by customers, even if MaaS is meant to promote more environmentally friendly habits. The ability of private businesses to generate a profit is intrinsically related to their use of these services. MaaS, as a result, has the potential to increase mobility among those who have the financial resources to do so (and have paid in advance). It is an idea rather than a fixed product when it comes to offering services to clients, according to Pangbourne et al. (2018). Even if customised services offer conceptual features, MaaS is being promoted as a complete solution that can alter how cities organise and manage their transit. To back up their claim, the authors gave a short history of the MaaS concept's evolution and an account of its formation in early sites of innovation for integrated MaaS platforms. There was also a discussion on the threats that corporate models offer value to important policy goals like congestion reduction and climate change mitigation; Furthermore, they examined the dangers of relying on a limited number of creative service providers, as well as the potential consequences of innovative services on present transportation and social services. We may see an increase in exclusion due to increased vulnerability to cyberattacks, increased reliance on digital technology, and a consequent reduction in access to transportation (Pangbourne et al., 2018).

MaaS is often described as both technologically pessimistic and too optimistic about the consequences for society as a whole. MaaS marketing as "mobility on the whim" promotes the false promise of individual unrestrained freedom that fails to acknowledge that current problems with traffic congestion, air and noise pollution, and greenhouse gas emissions are large-scale problems resulting from the aggregate impact of our individual activities, with a wide distribution of mobility habits. To achieve more desirable and inclusive social outcomes, the government’s engagement in the design goals, pricing structures (including subsidies), coverage, and consumer protection of MaaS developments is critical to success. This might lead to opportunities to overcome long-standing roadblocks to providing integrated transportation services. As an additional option, outsourcing mobility coordination and relying less on government coordination and steering in favour of MaaS

sounds like a recipe for disaster that is impossible to undo. While some have suggested that technology lock-in may be disastrous, there is no apparent option between laissez-faire and government-led regulation. It is possible to address consumer concerns while the technology is still developing in a proactive or even participatory way by fostering conversation about the proper role of the government in satisfying people's fundamental mobility requirements (Pangbourne et al., 2018).

During a field operational test (FOT) done by Sochor et al. (2015) in Gothenburg, Sweden, 195 persons used UbiGo to navigate the city for six months. The combination of public and private transportation alternatives resulted in an innovative type of joint mobility that contributed to Sweden's societal goal of reducing reliance on personal automobiles. Three stakeholder groups—users (FOT participants-customers), commercial actors (mobility brokers and service providers), and society—were polled utilising a triangulation approach to data sources and data collection procedures to understand their perspectives better. The relevance of concepts like transportation smorgasbords, reduced vehicle ownership, and more excellent pre-trip planning was shown. It was discovered that several anomalies existed, including a lower level of automotive use than anticipated, disparities in revenue models between the mobility broker and service providers, administrative inefficiencies in the back office, and issues with the smartphone platform.
Several routes were deemed impractical, and new car-sharing stations were required to alleviate the situation. A total of 93 per cent of participants expressed satisfaction with their travels, and 97 per cent said that they would use UbiGo again in the future. First and foremost, a commercially viable mobility solution must take into account present market mismatches and gaps. The study indicates that in order to generate fully integrated solutions, public and private actors must work closely together, and at least three stakeholder perspectives, often at conflict with one another, must be considered. New business models are necessary to ensure integrated urban transportation networks (Sochor et al., 2015).

One of the largest challenges for MaaS will be the need to help policymakers better understand the complexity of the MaaS idea, Arias (2020) made significant contributions to building a more robust literature foundation in pilots undertaken outside of the Nordic nations. During this study, Spain was the focus of attention. Multi-Level Perspective was utilised to identify rising shared mobility operators and their service characteristics to establish how this affects MaaS developments at the niche level. According to the report, more than 30 services are available in Madrid, with an estimated total fleet of more than 30 thousand vehicles run by 29 unique businesses. Users and authorities alike are becoming more interested in MaaS because of this dynamic ecosystem of mobility options, making it harder for customers to navigate through different applications. Even though at least three ongoing MaaS initiatives in the city (Respiro, Ubeeqo, and Bicimad), do not cooperate. The existing state of partnerships adds validity to what other authors have identified as one of the most significant obstacles to the practicality of MaaS: a lack of adequate governance structures for MaaS.

2.4 The technological challenges of MaaS

When looking at the technological challenges that emerge in the study about MaaS systems in Madrird Arias (2020) found the following: to build a single MaaS app in Madrid, the research findings showed little or no coordination between the many parties involved. MaaS efforts that were still under development in Madrid do not enable consumers to plan, pay, or use mobility services via a single mobile application. For example, to add to the current research surveys or structured/semi-structured interviews may be used to acquire primary data from shared mobility operators, furthermore, the already existing database keeps constantly evolving. There are several benefits to studying how shared mobility services affect Madrid's outlying areas and their overall mobility patterns (Arias, 2020)

It is unclear what the critical aspects of MaaS are and how they may be handled, according to Jittrapirom et al. (2017), who describes the concept as vague. Even though various MaaS systems have been implemented throughout the world, there is no systematic assessment methodology to characterise each technique's unique characteristics. The authors produced a list of attributes resulting from this, which they then used to describe different MaaS systems and existing uses. Because of the service's primary characteristics, travel demand modelling, supply-side analysis, and business model design were all studied. They established the current state-of-the-art in various industries to ensure that MaaS is supplied with the necessary enhancements.

Given the novelty and fuzziness of MaaS, establishing what MaaS is and how to apply it may be a challenging task to do. Even though there is a great deal of variation in attributes such as personalisation, customisation of tariff options, and platform aggregators, specific patterns can be observed among the schemes considered (for example, modes included in the services; real-time information; trip planning; and booking and ticketing) (GPS, E-ticket, and E-payment). Specific programs seemed to provide additional features such as trip cancellation notifications and personal schedule synchronisation, among other things. Several distinguishing elements may be identified in case studies, including factors that may influence a traveller's decision and the existence of extra services, such as freight transportation or municipal services, among others. These characteristics may be advantageous to the proposed framework; however, further case studies are required to evaluate if they are essential components or advantages of MaaS or not. The findings of this study contributed to the definition of MaaS, the description of appropriate schemes, and the establishment of a framework for future research in all three areas.

Additionally, research and activities that use mobility as a service may find this valuable. Other schemes may be included in the description framework to further increase the analysis's quality. This will allow for the discovery of even more contrasts and similarities and the distinctive characteristics of the services (Jittrapirom et al., 2017).

A multidisciplinary approach to MaaS development and deployment was necessary, as Zhao et al. (2020) acknowledged. Four viewpoints, including service design (SD), business model (BM), travel

attitude and behaviour (TrA&B), as well as system effects, were used to identify hurdles to MaaS development and deployment (SI). These difficulties were explored by looking at them from three perspectives (individual, organisational, and social). For this, a systems thinking approach was used throughout the investigation. Corporate Mobility as a Service (CMaaS) was the MaaS variant examined in this study.

This article's knowledge and suggestions for MaaS stakeholders were quite helpful. Researchers found that while creating and implementing hurdles, they must look for cross-cutting relationships across different types of barriers and look for patterns in those relationships. Some of the difficulties you're encountering maybe only be symptoms of more severe issues that need care. To design, develop, and implement effective service systems at all phases of their evolution, MaaS must also be seen as a complex socio-technical system. All stakeholders, including people who will use the system, must be taken into account while creating a plan, and the consequences of the system must be assessed. This study demonstrates why it is critical to integrate several disciplines and stakeholders in identifying obstacles and the facilitation of the adoption of MaaS systems. It is expected that similar problems would arise in developing MaaS systems at a bigger city or regional scale, even though this study focused on the corporate segment of MaaS.

The report's authors welcome further discussions and continuous assessments of obstacles inside MaaS systems to bring other perspectives to the debate. Further research is also required to fully comprehend MaaS hurdles and look for any connections between the challenges. Further testing and experimentation are needed to enhance MaaS development. For MaaS to reach its full potential benefits and capabilities, it is vital to understand how systems expand over time and appropriately record these dynamic changes (Zhao et al., 2020).

Platform-based businesses that make extensive use of data are among the most valuable businesses in today's digital world. As more devices and equipment get connected to the internet and interact with one another, the value of data production such as this will grow even more in the future. According to Kostiainen & Tuominen (2019), there are numerous major concerns among various stakeholders about moving toward a more integrated and inclusive sustainable transportation service. The authors included the most significant social problems and roadblocks that remain in the way of attaining a fully comprehensive and integrated vision of MaaS to broaden the discussion beyond a solely technical approach. They emphasized how investigating socioeconomic difficulties might help clarify the perspectives, worries, and anxieties held by various stakeholders, which aided in the MaaS concept's adoption. Based on information from national and European research efforts in the sector, this study concluded the evolution of the MaaS idea and practices in Finland.

Many people believe that a clear definition of the "MaaS vision" has yet to be formed, and that different people have different ideas of what it involves. People have very diverse ideas about what "user-first" means and where the line should be drawn between a broad vision for all users and specialized transportation services in order to achieve the requisite level of coordination and connectedness. Even if they all profess to be fans and proponents of MaaS, it has become a

contentious topic when addressing the roles and obligations assigned to various public and private organisations. The introduction of ride-hailing services has had a range of repercussions on traffic and public transportation, according to people who have used them. MaaS solutions, for example, may play a big role in influencing the future of mobility by setting pricing systems that favor on-demand services more when public transportation is less capable. To reduce the environmental cost of MaaS, systematic and accurate participatory design of the service's provisioning might be used, and this is an area where research is most urgently needed in the MaaS context. Clarification of various stakeholders' roles, ownership or management of customer relationships, and access to and ownership of usage data and statistics are also required to aid multiple parties in making the most of understanding user needs and behavior and applying that knowledge, for example, in traffic planning and user-centric service design, among other areas (Kostiainen & Tuominen, 2019).

As Tomaino et al. (2020) have pointed out, Transportation is a perfect location for examining how individuals behave when they are buying. Ultimately, the authors sought to stimulate additional research into the numerous psychological components of MaaS, such as concerns of control, consumer identification, community, and perceived costs, to assist the service in realising its full potential. The significance of MaaS for individuals and society as a whole has been highlighted. Touted as a feasible alternative to the current restrictive and inefficient method, the novel concept of centrally managed mobility platforms (MaaS) has attracted significant investment, with the prospect of soon seeing broad adoption. For MaaS to flourish, consumers must abandon the status quo, which is the present transportation system. The status quo is likely the most significant hurdle to adoption. MaaS designers should use market research to develop solutions that make the transition as enticing and straightforward as possible for customers.

Identifying and removing psychological barriers that prevent the widespread adoption of new transportation technologies such as MaaS platforms is crucial as new transportation technologies such as MaaS platforms gain popularity. However, MaaS highlights how new technology may be used to improve other critical areas of transportation, such as safety and efficiency, via simulations. As a whole, transportation psychology study is regarded as a valuable tool for building transportation systems that provide substantial benefits to consumers (Tomaino et al., 2020).

According to research conducted by Es ztergár-Kiss et al. (2020), the applications' payment capabilities, personalisation skills, and capacity to deliver all of MaaS's characteristics have development potential in the future. Every day, it is possible to see an increase in the number of operators. MaaS suppliers, whether public or private, have not yet established themselves as market leaders. Clusters were developed, each with its traits and development routes. The group of route planners uses a variety of transportation modes and provides a diverse range of services. While the Third parties category mainly consists of private MaaS service providers, the Public systems category primarily consists of public MaaS service providers. MaaS providers and regulators may profit from this in-depth analysis by gaining a better grasp of the market's typical features as well as its potential development pathways in the future.

In the business sector, third-party MaaS services are often owned and run by corporations; however, public-sector MaaS services are increasingly popular. Benchmarking studies have been conducted on the MaaS industry, and three primary business models have evolved. In a free market system, it is customary for an independent third-party operator to be in charge of the operation of the Third parties. MaaS operators that utilise the Public Systems solution created and overseen by national authorities are subject to several restrictions. While route planners prefer to concentrate their efforts on a single place with a solid local following and minimal competition, the solutions they provide are more widely applicable.

The market for MaaS is expected to develop at a stable rate. MaaS services may likely be made available in certain places, which might result in new income models for operators and new possibilities for consumers in those locations. Present and future MaaS operators and regulators will be able to better comprehend the typical features and growth routes of the MaaS business as a result of this comprehensive data gathering and analysis.

3. MaaS: key concepts and models

This dissertation aims to create a Checklist-based framework to assess the specific resources needed to implement a fully functioning MaaS system. Therefore, we will use the Business model canvas to assess what the essential working assets need to be to have an optimal system put in place. The literature will provide the information to fill in this business model canvas and get a clear overview of its different assets. Furthermore, within this business model canvas reported in Table 1 the nine key concepts of MaaS will be discussed (Jittapriom, 2017). Additionally, to the nine fundamental principles, in Table 2 a list of challenges will be used that could impair the development of MaaS (Smit, 2019); these challenges were created based on the Netherlands. The Netherlands is geographically similar to Belgium regarding the distance between cities and urban centers and infrastructure. Therefore, it will be a great asset to apply the framework to Belgium. These will also be used in assessing the needs and appropriate actions to limit the effects of these challenges. The checklist-based framework will then be applied to our use case, "Belgium". We will analyse the inherent resources and market fit and apply the framework to see the potential for this system.

3.1 The business model canvas

Within the Business Model Canvas not every segment will be essential in aiding to create the checklist-based framework. To create the framework, it is essential to state the specific needs required to build an optimal Mobility as a Service system. The following segments within the Business Model Canvas are crucial: Key partners, Key resources, Channels, Key activities and the Customer segment. The business model canvas will be based on the literature and the business model prototypes created by Polydoropoulou (2020). How MaaS will evolve is still uncertain and will depend on multiple evolving factors like IT, mobility trends and the openness to completely restructure our behaviour towards a more sustainable form of transport by new disrupting mobility solutions (Sprei, 2018). Therefore, this business model canvas is just a model that helps to give a business overview of MaaS.

Key Partners: Within MaaS, there is a constant exchange between its actors. These actors interact with each other to provide MaaS's primary Value Proposition. These key partners consist primarily of mobility service providers: public transport, making most of the already available shared infrastructure, private mobility providers like a rental car, taxis, and vehicle-sharing services to extend the public offering and add the factor of flexibility. Local governments and authorities facilitate the scalability and adoption of MaaS and grant an exchange between private and public mobility providers. The final key partner is the owners of transport infrastructure, roads and parking, which aid and facilitate transfer points, where users can easily switch between nodes. Parking spaces and carpool areas are crucial within this model. Furthermore, adjusting the current road infrastructure to aid in these transfer points.

Key resources: What are the crucial resources a MaaS provider needs to make the system work efficiently. It needs Human resources as one key resource. The personnel to bridge the other

essential digital and physical resources, where the digital resources mainly consist out of IT/Tech/big data pools with information regarding customers and transport and the physical resources out of infrastructure needed to run the MaaS system being: the website/application and information systems around it.

Channels: How do MaaS providers communicate with their customer segment and allow them to fully utilize MaaS systems. The primary channels are the APP and website to establish communication between the MaaS provider and the user. The customer service can be integrated in the app or website, but it will mainly be used for planning, booking and paying for the planned trips. Via social media new customer can be acquired. The key partners could be used as a medium for promotion and communication with new users.

Table 1. Business Model Canvas MaaS

<table>
<tr>
<td rowspan="2">KEY PARTNERS
-Local Private mobility partners: car rental: Hertz, Europcar, Avis. Car sharing, Rental (e)bikes, steps, scooters. ETC. Taxi providers.

-Local Public mobility partners: De lijn, MIVB, Velo, Mobit, NMBS.

-Local Governments: Federal, Flemish, Wallonian

-Owners of transport infrastructure: roads, parking</td>
<td>KEY ACTIVITIES
-Customer support

-Creating a mobile interface to plan, book and pay for multimodal transport

-Creating and merging big data pools

-Booking and trip planning

-Ticketing and payment

-Marketing

-Gathering customer data

-Marketing</td>
<td rowspan="2">VALUE PROPOSITION
-Sustainability benefits

-One platform that merges all transport forms public/private (multimodal transport) and makes it easy to plan, book and pay for your personalised travel.

-Reduce congestion

-Optimize Private/corporate mobility expenses</td>
<td>CUSTOMER RELATIONSHIP

-Focus on customer support with personalised assistance</td>
<td rowspan="2">CUSTOMER SEGMENTS

-Private users: local population, students, ederly etc.

-Tourists

-Commuters: Corporate MaaS</td>
</tr>
<tr>
<td>KEY RESOURCES
-
Website/application
-IT/TECH/BIG data
-Mobility experts, engineers, IT, business analysts, Etc.</td>
<td>CHANNELS
-APP
-Website
-Social Media
-NFC providers
-Advertisement via key partners: Car rental providers</td>
</tr>
<tr>
<td colspan="3">COST STRUCTURE
-Investment in creating and running the service (app, website etc.)
-Investment in further expansion of infrastructure
-Personnel
-Merging and acquiring transport assets
-Marketing
-Customer service</td>
<td colspan="3">REVENUE STREAM(S)
-Subsidies government
-Revenue from APP
-Public and Corporate MaaS subscription models
-Pay as you go
-fees paid by mobility providers</td>
</tr>
</table>

Key activities: The Key activities within a MaaS service involve the primary and evident ones: Booking and trip planning, ticketing and payment, customer support, creating and maintaining the digital interface to use the MaaS service. Less obvious but equally important are gathering customer data and processing it; this to aid customer support and enhance user experience and create and

merge big data pools to optimize the services provided. The last crucial key activity would be marketing to create more awareness and reach more users. Effective marketing will aid in expanding the user pool and generate more valuable data to improve the MaaS service.

Customer segment: MaaS's three main customers are private users, tourists and corporate clients. Tourists are non-frequent users of MaaS and have seasonal fluctuations, so it is in a different segment than the private users, primarily out of the local population. Tourists have different needs, so MaaS systems and their offerings need to be adjusted towards these needs. The corporate segment is also of incremental value for the practical application of MaaS lots of governments support corporate public travel incentives to limit congestion in urban areas.

3.2 Nine key concepts of MaaS

To establish the checklist-based framework for this dissertation, the following model will be used as one of the building blocks. This model discusses the nine principles of MaaS (Jittrapriom, 2017). The author summarized the essential features that should be evident when implementing such a system in practice based on a literature review discussing definitions of MaaS while looking at essential new mobility services and ideas. This model was created out of the abundance of definitions about the novelty concept of MaaS and should provide a clear foundation of its core principles. MaaS was bought to life to change the behaviour of its users, reducing car ownership being one of them (jittapriom, 2017)

Table 2. Summary of MaaS's nine key concepts (Jittrapirom, 2017)

Core Characteristics	**Description**
Integration of transport modes	One purpose of MaaS schemes is to encourage people to use publicly available transport by combining multi-modal transportation and allowing users to choose and simplify their multimodal journeys.
Tariff option	Two alternative tariff options could be offered by a MaaS: one being a monthly subscription and the other being a payment option that allows users to pay for specific mobility usage.
One platform	MaaS is based on a digital platform that gives end-users access to all the services and information they need for their trips.
Multiple actors	the MaaS ecosystem is based on interactions between several sets of actors: mobility demanders, transportation service providers, and platform owners. Other actors can help further improve the efficiency and scalability of the service
Use of technologies	To allow MaaS, a variety of technologies are combined: a laptop or smartphone; a internet connection which facilitates digital ticketing and payments services as well as communication between various devices and platforms

Demand orientation	User-centric MaaS initiatives are required. To meet the needs of the consumer, providing the most efficient and comfortable mobility alternative.
Registration requirement	Users must register for an individual or household account, which will aid in the further customization of the user account, as well as the optimization of services supplied.
Personalization	Personalisation of transportation options is a big factor within Maas because MaaS platforms must be user centric. Based on the end-profile, user's specified preferences, and previous actions, the system makes unique recommendations and tailor-made solutions.
Customization	Customisation enables the consumer to tailor the transportation options to their specific requirements, enhancing customer satisfaction and retention.

3.3 Seven challenges for MaaS

The second model that will be used as a foundational piece for our checklist-based framework. The list of challenges defined by Jittrapirom (2018) was chosen for this study. The authors of this study did a literature review and conversation with a group of MaaS experts, making this one of the most recent and comprehensive lists of challenges concerning MaaS. The following summary of the framework Table 2 created by Smit (2019) by use of a delphi model to establish and prioritize the majority of the hurdles, constraints, and facilitators of MaaS efforts, focusing on public and private actors. These challenges are a great summary of the main technological and business challenges discussed in the literature review.

Table 3. MaaS's seven challenges (Smit, 2019)

Challenge	**Description**
Limited public budget	MaaS is a novel concept, a significant amount of funding is required for testing and development. Lack of government financial incentives is a barrier.
The insufficient physical transport structure	The current transport infrastructure is intended for today's mobility, which includes public and private transportation. Because multimodality is a crucial feature of MaaS, transfer points should be constructed so that passengers can quickly transition between two modes of transportation.
Lack of an appropriate business model	Companies will need an effective business model as an assurance to begin utilizing MaaS systems, hence a lucrative business model is required. There are currently none, owing to the fact that they are so dissimilar to conventional business structures.
Existing public transport concession	A concession specifies the conditions under which a public transportation provider can operate in a given area. In many countries public transportation is

	arranged by government-issued concessions, which last for a long period and do not specify any MaaS option (yet).
Existing ICT conditions	Existing ICT conditions may be impeding MaaS development. Because there is a lack of shared real-time data and other ICT-related features
Limitations informal regulation regarding finance and operation	The current mobility governance is a hinderance, because a national MaaS system totally transforms the way mobility is organized and requires a lot of new governance.
Perception of the limited value proposition of MaaS service by important actors	Many businesses are invested in MaaS, while some remain sceptical and cautious. One of the reasons could be that they simply do not believe MaaS is a viable answer to mobility issues.
Low appreciation of MaaS by potential users	There haven't been many MaaS pilots done so far. The present traveller is mostly oblivious of MaaS, whether they were effective or not. People who already possess a private car and enjoy its conveniences may be less open and receptive to MaaS.

3.4 The five policies and their conditions for successful implementation of MaaS

A panel of experts was asked what they thought were the most important policies for the successful implementation of MaaS and their related conditions. The consensus was that the implementation of Pilot projects is by far the most important policy that should be implemented. This is linked to the necessity to monitor and assess the Maas pilots' effects thoroughly. The group recommended that the institutional context be improved by enacting supportive laws and eliminating tax incentives for leasing company cars. Close coordination between key actors and stakeholders was repeatedly identified as the most critical factor for success. According to experts, this is directly tied to providing a lucrative business opportunity. In addition, the panel recommends the establishment of a national contact point for sharing knowledge about transport platform operation, such as applicable norms and practices, to make MaaS participation easier for mobility service providers in a given country.

Table 4. Summary of the necessary policies and their corresponding conditions to ensure the successful implementation of MaaS ranked by importance, (Jittrapriom, 2020)

Policy	**Condition**	**Description**	**Importance**
Pilot projects and experimental learning	Collaboration between key actors and stakeholders is essential.	Pilot projects allow for 'learning by doing,' which is an effective way to gain knowledge and minimize overall uncertainty. (must be an interesting business opportunity)	Essential
Improve physical transport infrastructure	Pilot schemes that have been operationalized successfully	By making use of pilot schemes the physical transport and infrastructure can be tested and improved	Essential

Clearer roles and responsibilities	Mobility data availability and standardisation	During pilot projects necessary data should be collected to help create role structure.	Very important
Improve digital infrastructure and data collection	Actors and stakeholders will find this to be an appealing business prospect.	Data collection and improving of the digital infrastructure are interesting business opportunities because of the ROI potential.	Important
Prioritize MaaS in High level planning and policy documents	Pilot schemes that have been operationalized successfully	MaaS should be taking into account during high level planning and the creation of new policy documents and legislation.	Important

4. Framework

This checklist is based on the "Nine MaaS Principles" (Jittrapriom, 2017). Despite the fundamental ideas of Jittrapirom et al. (2017), MaaS is still relatively new and, as a result, not thoroughly acknowledged. Nonetheless, many academics and politicians admit that MaaS requires numerous stakeholders to modify their behavior (i.e., reduce their car ownership) and include new technologies (Jittrapirom et al., 2017). The innovation involves both public and private actors and is therefore susceptible to misunderstandings among them (Jittrapirom et al., 2017).

All principles are introduced with a Yes/No question indicating whether they are already inherently available in the country or not. In this Thesis, every essential feature or principle will be thoroughly examined and enlarged with the use of the literature review done in chapter 2. This checklist will then be supplemented with challenges and opportunities identified in the current literature that will help with achieving this important principle. The result of the checklist would include a discussion of the essential points to attain. And the specific challenges mentioned for every principle should be taken into account, when setting up a MaaS system.

To speak of an all-inclusive MaaS system every principle must be met. Moreover, without certain principles it is impossible to meet the necessary requirement to meet the next key principle.

Table 5. Checklist MaaS based on the 9 principles of MaaS.

Checklist MaaS	**Present**
Integration of transport modes	Yes/No
Tariff option	Yes/No
One platform	Yes/No
Multiple actors	Yes/No
Use of technologies	Yes/No
Demand orientation	Yes/No
Registration requirement	Yes/No
Personalization	Yes/No
Customization	Yes/No

4.1 Integration of transport modes

Key idea:

"One purpose of MaaS schemes is to encourage people to use publicly available transport by combining multi-modal transportation and allowing users to choose and simplify their multimodal journeys (Smit, 2019)."

One of the core principles of MaaS is multi-modal transport. And therefore, the first element to be fulfilled in the checklist is the availability and or integration of Multimodal transport. The use of multiple transport options is essential to the existence of MaaS. Furthermore, by merging multi-modal transportation and allowing users to select and simplify their multimodal journeys, MaaS schemes aim to encourage individuals to use publicly available transit. This key idea is further confirmed within the literature as MaaS's value is there to eradicate the extensive use of privately owned vehicles (Enoch, 2018; Li, 2017). MaaS enables customers to contribute to the development of a more sustainable, livable, and socially inclusive future through the development of an eco-friendly multimodal transportation choice (Alvavina, 2018).

Other authors found that the frictionless movement between multimodal transport was one of MaaS's key areas. MaaS's major objective is to make customers' intermodal and multimodal journeys as frictionless as possible from start to finish. Consequently, the deployed strategy has been shown to be user centered (Kamargianni & Matyas, 2017). Additionally, Sochor (2018) identified the following question: "Is multimodal public transit with a trip planner and integrated ticketing/payment considered public transportation, or not?" The key idea behind this question was to ease people in understanding and transitioning into a MaaS environment. Where the ultimate aim is to learn from the debate and help transition into a long-term transportation system based on MaaS.

Challenges and opportunities:

MaaS providers would have a better knowledge of market acceptability if they undertook more research into the underlying causes of multimodal consumption preferences (Ditmore & Miller, 2021).

To aid in the adoption of MaaS, among other methods, users should be encouraged to use MaaS responsibly through the use of tax credits or other financial incentives, as well as through awareness, information, and social engagement campaigns Challenges and solutions; designed to familiarize them with the concept and emphasize its significance in terms of sustainability when used responsibly. If MaaS is to flourish, people's attitudes toward private automobiles must be altered, which is no easy undertaking. Therefore, policymakers and mobility providers should support responsible MaaS use, promote public transit as the system's backbone, and use public engagement exercises and trials to introduce people to the concept, all while demonizing private automobile ownership and use (Alyavina et al., 2020).

In addition to the literature above, Smit (2019) identified the following challenges that need to be taken into account:

Table 6. Biggest challenges for MaaS when applied to the integration of transport modes. The challenges model (Smit, 2019)

Challenge	**Description**
Limited public budget	MaaS is a novel concept, a significant amount of funding is required for testing and development. Lack of government financial incentives is a barrier.
The insufficient physical transport structure	The current transport infrastructure is intended for today's mobility, which includes public and private transportation. Because multimodality is a crucial feature of MaaS, transfer points should be constructed so that passengers can quickly transition between two modes of transportation.
Lack of an appropriate business model	Companies will need an effective business model as an assurance to begin utilizing MaaS systems, hence a lucrative business model is required. There are currently none, owing to the fact that they are so dissimilar to conventional business structures.
Existing public transport concession	A concession specifies the conditions under which a public transportation provider can operate in a given area. In many countries public transportation is arranged by government-issued concessions, which last for a long period and do not specify any MaaS option (yet).

Adaptation to the principle:

One of the key elements that MaaS offers is the frictionless movement between multi-modal transport. Thus the principle implemented in the checklist will be defined as "Integration of (frictionless) transport modes"

4.2 Tariff option:

Key Idea:

"Two alternative tariff options could be offered by a MaaS: one being a monthly subscription and the other being a payment option that allows users to pay for specific mobility usage."

As described in fig 2. (Whim, 2022) there are 2 tariff options: The "mobility bundle" and "pay-as-you-go" are the two pricing options offered by the MaaS platform for accessing its mobility services. In exchange for a monthly fee, the package contains a set number of kilometres/minutes/points that can be utilized on various forms of transportation. The pay-as-you-go model charges subscribers based on their actual use of the service.

Depending on their needs, customers may pay as they go or pre-pay for a "service package" using a single payment interface similar to that seen on smartphones. MaaS is a booking system that encompasses the entirety of a journey, from beginning to end (Enoch, 2018)

Challenges and opportunities:

The literature doesn't state any challenges or opportunities to these problems. As these tariff models are already proven models in today's society. Used in a multitude of services.

Adaptation to the principle:

The tariff option discussed in the literature (Enoch, 2018) and available in an example MaaS pilot application (Whim, 2022) offers specifically 2 tariff options: Pay as you go or by means of subscribing to the service. Hence, the reasoning to add this to the principle in the checklist. Tariff option (Pay as you go/Subscription**).**

4.3 One platform:

Key idea:

"MaaS is based on a digital platform that gives end-users access to all the services and information they need for their trips."

A primary element of a MaaS system is that it allows users to manage their mobility on a single platform. This is expected to be a digital platform where a traveller can access all the necessary information, including planning, booking, ticketing, payment, and real-time information (Smit, 2019).

Challenges and opportunities:

According to research conducted by Es ztergár-Kiss et al. (2020), the payment capabilities, personalization skills, and ability to supply all MaaS characteristics have future growth potential. It is feasible to observe an increase in the number of operators every day. Arias (2020) discovered the following when examining the technological problems that emerge in the study regarding MaaS systems in Madrid: for the development of a single MaaS app in Madrid, there was little or no coordination between the various partners.
Although, users and authorities are becoming increasingly interested in MaaS due to the dynamic ecosystem of mobility alternatives, which makes it more difficult for customers to move between

applications. Due to the rapid growth of mobility apps and the consequent necessity to integrate them into a single platform, MaaS will continue to gain popularity. (Arias, 2020)

Adaptation to the principle:

The platform that MaaS offers combines a wide range of mobility options. Users and authorities are becoming increasingly interested in MaaS due to the dynamic ecosystem of mobility alternatives (Arias, 2020). The dynamic factor that MaaS offers and that generates a lot of interest from various stakeholders is a determining factor in the sustainability of the platform. The following adaptation will be made to the principle in the checklist: One (dynamic) platform.

4.4 Multiple actors:

Key idea:

"The MaaS ecosystem is based on interactions between several sets of actors: mobility demanders, transportation service providers, and platform owners. Other actors can help further improve the efficiency and scalability of the service"

Multiple parties are involved in the development and utilization of a MaaS system. Some of them are involved with the digital platform: mobility service consumers, mobility service providers, and a party that maintains the platform. Other parties, such as government entities, are also involved (Smit, 2019).

Challenges and Opportunities:

The literature identified that success depends on close collaboration between important players and stakeholders. This is a huge economic prospect, say experts. The panel also advises establishing a national contact point for sharing knowledge about transport platform operation, such as applicable standards and practices, to enable MaaS participation easier for mobility service providers. (Jittapriom, 2020)

Policymakers and mobility providers should support responsible MaaS use, promote public transportation as the system's backbone, and use public engagement exercises and experiments to expose people to the concept, while condemning private car ownership and use (Alyavina et al., 2020). Furthermore several policies could accelerate the further growth and interest in MaaS by appealing to multiple actors. Jittapriom (2020) identified several policies that with the right conditions could help open up opportunities for MaaS.

As described in the summary of the necessary policies and their corresponding conditions to ensure the successful implementation of MaaS ranked by importance, (Jittrapriom, 2020). The following policies should be implemented for the successful implementation of MaaS.

Table 7. Policies for successful implementation of MaaS (Jittrapriom, 2020) when looked at the multiple actors.

Policy	**Condition**	**Description**	**Importance**
Pilot projects and experimental learning	Collaboration between key actors and stakeholders is essential.	Pilot projects allow for 'learning by doing,' which is an effective way to gain knowledge and minimize overall uncertainty. (must be an interesting business opportunity)	Essential
Improve physical transport infrastructure	Pilot schemes that have been operationalized successfully	By making use of pilot schemes the physical transport and infrastructure can be tested and improved	Essential

Adaptation to the principle:

One of the conditions for one of the essential key policies that need to be implemented is the collaboration between key stakeholders and stakeholders (Jittrapriom, 2020). Furthermore, the literature (Jittapriom, 2020) confirms that close collaboration between stakeholders is a key factor for the effective implementation of a MaaS system. Thus, the following adaptation will be made to the principle in the checklist: Multiple actors (that cooperate closely).

4.5 Use of technologies:

Key idea:

"To allow MaaS, a variety of technologies are combined: a laptop or smartphone; an internet connection which facilitates digital ticketing and payments services as well as communication between various devices and platforms"

Numerous technologies are used because MaaS is built on a digital platform. This would require end-users to utilize a computer or mobile device. A wide area of connected technologies, including mobile internet networks and GPS, are necessary for the functionality of the platform.

Additionally, e-payment services are required to ensure the payment of the application. Furthermore, emerging technologies such as the Internet of Things and blockchain may ease the introduction of MaaS (Smit, 2019)

Challenges and opportunities:

According to the literature, simulations illustrate how MaaS can be used to improve other crucial aspects of transportation, such as safety and efficiency. Overall, transportation psychology research is viewed as a helpful resource for designing consumer-beneficial transportation systems (Tomaino et al., 2020). In addition to the opportunities in a case study done in Madrid, Arias (2020) discovered the following: for the development of a single MaaS app in Madrid, there was little or no coordination between the various partners. MaaS will always really on different actors and parties so before the use of technology can be discussed the different technological actors must be identified and willing to collaborate. Furthermore, in the literature, they analyzed the risks of relying on a small number of creative service providers, as well as the potential effects of innovative services on existing transportation and social services. Growing vulnerability to cyberattacks, increased reliance on digital technology, and the resulting decrease in access to transportation may lead to an increase in exclusion (Pangbourne et al., 2018).

A clear challenge identified in the literature is the following (Smit, 2019)

Table 8. ICT challenges (Smit, 2019)

Existing ICT conditions	Existing ICT conditions may be impeding MaaS development. Because there is a lack of shared real-time data and other ICT-related features

Adaptation to the principle:

One of the main challenges when it comes to the development of MaaS is that the existing ICT conditions may be impeding MaaS development. Therefore, it is important MaaS is implemented in a way that helps the current ICT conditions improve. The growing risk and vulnerability to cyberattacks add to the main reasons the current ICT conditions need to improve (Pangbourne et al., 2018). The following adaptation will be made to the principle in the checklist: Use of technologies (that improve current ICT conditions).

4.6 Demand orientation:

Key Idea:

"User-centric MaaS initiatives are required. To meet the needs of the consumer, providing the most efficient and comfortable mobility alternative."

MaaS is centred on offering the highest quality service to consumers. The ideal service would consist of providing consumers with the most effective and convenient mobility alternative (Smit, 2019).

MaaS has three main customers: private users, tourists and corporate clients. Tourists are non-frequent users of MaaS and have seasonal fluctuations, so it is in a different segment than the private users, primarily out of the local population. Tourists have different needs, so MaaS systems and their offerings need to be adjusted toward these needs. The corporate segment is also of incremental value for the practical application of MaaS. a lot of governments already support corporate public travel incentives to limit congestion in urban areas.

Challenges and opportunities:

MaaS aims to make intermodal and multimodal journeys seamless for customers. The resulting strategy is user-centric. An integrated mobility service provider collects all of the transportation operators' services in this way, highlighting that MaaS is more than just an integrated mobility service; it's a total reorganisation of mobility supply, with the MaaS Provider at its centre. Customers may receive it via a single digital platform, demonstrating the relevance of ICT and IT infrastructure in MaaS systems (Kamargianni & Matyas, 2017).

The demand orientation also involves around the commercialization of mobility as a service through the service package model requires the purchase of services by clients, despite the fact that MaaS is intended to promote more eco-friendly behaviors. Profitability of private companies is integrally tied to their utilization of these services (Pangbourne et al., 2018).

Challenges identified in the literature that need to be taken into account (Smit, 2019)

Table 9. Challenges for MaaS (Smit, 2019), looking at demand orientation.

Perception of the limited value proposition of MaaS service by important actors	Many businesses are invested in MaaS, while some remain sceptical and cautious. One of the reasons could be that they simply do not believe MaaS is a viable answer to mobility issues.
Low appreciation of MaaS by potential users	There haven't been many MaaS pilots done so far. The present traveller is mostly oblivious of MaaS, whether they were effective or not. People who already possess a private car and enjoy its conveniences may be less open and receptive to MaaS.

Adaptation to the principle:

A challenge that inhibits the further development of MaaS is that some potential stakeholders and customer remain sceptical and cautious, because of the lack of validity that MaaS offers as a viable transport alternative. This can be done by implementing more pilot studies as the current traveler

might not be aware of MaaS as an alternative (Smit, 2019). The following adaption will be made to the key principle in the checklist: Demand orientation (and increase validity of MaaS).

4.7 Registration requirement

Key idea

"Users must register for an individual or household account, which will aid in the further customization of the user account, as well as the optimization of services supplied."

Users must register for an individual or household account, which will aid in the further customization of the user account, as well as the optimization of services supplied (Smit, 2019)
It is necessary to create an account to collect data and maximize personalization options tailored to the user.

Challenges and opportunities

When it comes to registering for accounts. GDPR-laws and usage of data should always be taken into account. The ability to personalize the account to the user and collect data to optimize the user experience are big opportunities that can make or break an application. Furthermore, the registration requirement is a necessity to meet the personalization requirement discussed in the next paragraph.

4.8 Personalization

Key Idea:

"Personalisation of transportation options is a big factor within Maas because MaaS platforms must be user centric. Based on the end-profile, user's specified preferences, and previous actions, the system makes unique recommendations and tailor-made solutions."

Since MaaS is centered on the traveler as an individual, mobility options can be customized. The traveler could specify their preferences and receive a customized mobility option in response. Therefore, travel history might be utilized for this purpose (Smit, 2019).

Challenges and opportunities:

Given MaaS's novelty, defining it and using it may be difficult. Even if personalization, pricing options, and platform aggregators vary widely, certain trends may be detected among the schemes analyzed (such as modes included in the services, real-time information, trip planning, and booking and ticketing) (GPS, E-ticket, and E-payment). Specific programs offered features like trip cancellation notifications and personal schedule synchronization. Case studies may include aspects that influence

a traveler's decision and added services, such as freight transport or municipal services. Further case studies are needed to determine if these traits are essential to MaaS or not (Jittapriom, 2017) According to Es ztergár-Kiss et al. (2020), applications' payment, personalization, and MaaS delivery capabilities have growth potential.

4.9 Customization:

Key idea:

"Customisation enables the consumer to tailor the transportation options to their specific requirements, enhancing customer satisfaction and retention."

When a consumer chooses a mode of transportation, they should be given the opportunity to modify their selection so that it better suits their preferences and requirements (Smit, 2019)

Opportunities and challenges:

In a pilot study done for UbiGo the following information was identified in the literature opening up the discussion about the importance of close cooperation by different stakeholder. It was found that 93% of travelers were satisfied with UbiGo, and 97% indicated they'd use it again. A commercially effective mobility solution must consider market mismatches and gaps. According to the study, public and private actors must work closely together and consider at least three stakeholder perspectives, which often conflict. Urban transportation networks need new business models (Sochor et al., 2015).

As described in the summary of the necessary policies and their corresponding conditions to ensure the successful implementation of MaaS ranked by importance, (Jittrapriom, 2020). The following policies should be implemented for the successful implementation of MaaS.

Table 10. Policies for successful implementation of MaaS (Jittrapriom, 2020) when looked at customization.

Policy	Condition	Description	Importance
Clearer roles and responsibilities	Mobility data availability and standardisation	During pilot projects necessary data should be collected to help create role structure.	Very important
Improve digital infrastructure and data collection	Actors and stakeholders will find this to be an appealing business prospect.	Data collection and improving of the digital infrastructure are interesting business opportunities because of the ROI potential.	Important

Adaptation to the principle:

Customization is one of the key principles of MaaS, however, customization should have a specific purpose to further improve MaaS development. An important policy that should be implemented is the improvement of the digital infrastructure and data collection, this policy is interesting as it provides business opportunities as well as provide considerable ROI potential (Jittrapriom, 2020). The following adaptation will be made to the key principle in the checklist: Customization (with the aim to continuously improve the digital infrastructure and collect relevant data)

4.10 Conclusion

The checklist for the successful implementation of MaaS identifies some strong points. To facilitate a MaaS system not necessarily the principle but more importantly, the existing challenges that come with the implementation of that principle should be met. Certain policies should be put in place before MaaS can be fully adopted and understood. Nonetheless, some opportunities were identified that could make the adoption of MaaS worthwhile, not only creating societal benefits but also creating economic opportunities and a total restructuring of the transport system we know today.
Seven out of the nine key principles were slightly modified to further increase the probability of a fully functioning MaaS system. These adaptations were identified in the currently existing literature and should make the key principles more concrete.

With every technology there is an adoption process, for MaaS this is the same. MaaS is currently in an early adaptor phase. Because of its novelty factor and it not being fully adopted yet. When analysing the "Technology adoption life cycle" (Moore, 2013) (fig.5). One of the conditions for the adoption of MaaS stated by Moore (2003) in the literature is the mass adoption and acceptance of the concept. Furthermore, meaning that almost all challenges that exist within the sphere of MaaS need to be resolved by implementing new policies and adopting new technologies. First, these critical challenges need to be addressed before MaaS is able to make a real impact and cross the "Chasm".

In addition to the above the literature identified the following, Moore (2003) observed a psychological gap between 'Early markets' and 'Mainstream markets'. First-group clients are dreamers, and second-group customers are pragmatists, he says. Visionaries try new technologies first. They'd test promising, creative technology. Pragmatists only engage after trying to reduce risks. Moore's chasm concept is predicated on the tendency of pragmatic customers and organizations to adopt new technologies when they see others doing so (Dube, 2017).

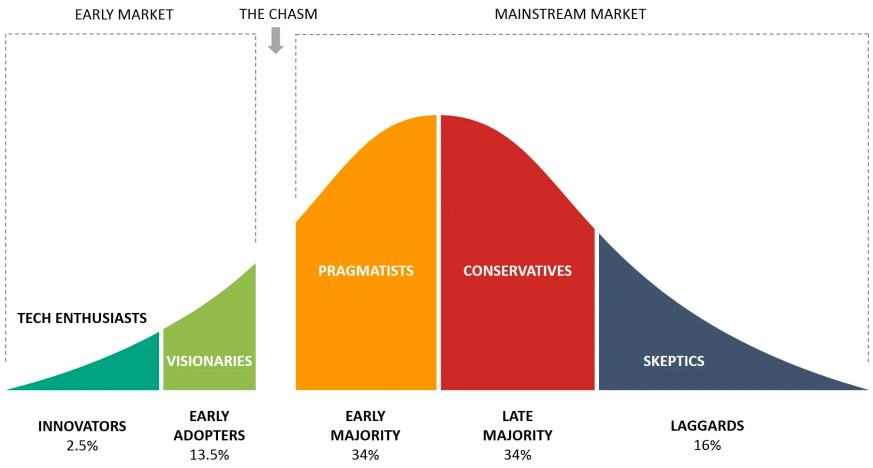

Figure 7: Moore's technology adoption lifecycle

Source: (Crossing the Chasm in Technology Adoption Life Cycle EXPLAINED, B2U, 2020)

5. Applying the checklist to Belgium

The application of the checklist will be done by collecting data from the research of Lebas and Crutzen (2021). Antwerp, Arlon, Bruges, Brussels, Charleroi, Ghent, Hasselt, Liège, Louvain, Mons, Namur, and Wavre were selected as the subject of this exploratory study. The decision to concentrate on "bigger" cities derives from the need for a sufficient concentration of transportation services. They conducted semi-directive interviews with nine territorial representatives. In addition, they conducted interviews with the four public transport companies in Belgium: STIB/MIVB, TEC, De Lijn, and NMBS/SNCB. Since public transit is regarded the backbone of MaaS systems, their perspectives and insights are crucial for completing the local representatives' assessment, since they have a different perspective on mobility management and governance. The following areas were discussed in the interviews: stakeholder engagement, data availability and transparency, profitability and investments, physical infrastructure, regulation, and inclusivity. This is the most recent study done in Belgium that provides data relevant to the application of a MaaS system in Belgium.

Considering the interest for MaaS in Belgium the paper (Lebas and Crutzen, 2021) says the following: In Belgium, the federal, regional, and municipal levels share the responsibility for mobility and digitalization. The regions that hold most of these competencies have shown their strategic interests for MaaS with varying degrees of enthusiasm. In its Intelligent Transport System (ITS) action plan issued in January 2019, the Flemish Region identifies MaaS as one of six priority clusters. In Wallonia, the Regional Mobility Strategy issued in May 2019 mentions MaaS. In the Brussels Capital Region's (BCR) Good Move strategy, the deployment of a MaaS service is specified as a specific goal. The September 2020 coalition agreement clearly states that "the government, in partnership with federated organizations, would design a framework for providing mobility as a service." (Lebas and Crutzen, 2021). Thus, showing there is a strategic plan in place for the further deployment of MaaS. Because of the way Belgium is split into multiple governance parts, there is no indication for a unified national MaaS project.

Table 11. The modification of the Checklist, the checklist identifies whether the nine fundamental characteristics of MaaS that permit complete implementation are present or if there is an indication for future potential.

Checklist MaaS	**Present**	**Indication for future implementation**
Integration of frictionless transport modes	Yes/**No**	**Yes**/No
Tariff option (Pay as you go / subscription)	Yes/**No**	**Yes**/No
One dynamic platform	Yes/**No**	**Yes**/No
Multiple actors that cooperate closely	**Yes**/No	**Yes**/No

Use of technologies that improve current ICT conditions	Yes/**No**	**Yes**/No
Demand orientation and increase validity of MaaS	Yes/**No**	**Yes**/No
Registration requirement	**Yes**/No	**Yes**/No
Personalization	Yes/**No**	**Yes**/No
Customization with the aim to continuously improve digital infrastructure and collect data	**Yes**/No	**Yes**/No

5.1 Integration of frictionless transport modes in Belgium?

Pertaining to the physical infrastructure Lebas and Crutzen (2021) identified the following: All interviewees recognize the need to expand the variety of modes so that supply can meet demand. In addition to its creation, it must also be maintained. In addition to vehicles, all interviewees discuss the requirements of urban and regional planning that favour soft modes, such as separated bicycle lanes and secure bicycle parking.
In addition to soft modes, they propose urban planning that facilitates the easy transition between the means of mobility available in the area, especially via multimodal exchange hubs or the generalisation of transfer nodes. Sharing-capable intelligent physical infrastructures, such as sensors and terminals, are also part of infrastructure (Lebas and Crutzen, 2021)

To successfully establish a system the use of frictionless transport modes is a necessity. The interview identified some of the challenges but also the opportunities when it comes to restructuring the current transport infrastructure. Belgium already has an established public transport infrastructure, so MaaS is possible. But to create an effective MaaS system with the highest chance of full adoption, translating to higher customer satisfaction and ease. Which is one of the main points previously identified in the literature. The availability of transfer nodes and restructuring the current infrastructure are still points to improve on. There is an intent and acknowledgement that Belgium needs restructuring so that opens up a path towards the possible integration of a MaaS system.

5.2 Tariff option (Pay as you go / subscription)

The first proposed feature is the interoperability and standardisation of data in APIv format in order to facilitate communication between the various apps, the integration of the various mobility services, and ultimately tariff integration (Lebas and Crutzen, 2021)

Four interlocutors (Brussels, Ghent, Leuven, STIB/MIVB) view the absence of a clear economic model as a fundamental barrier to an efficient operationalization. The interlocutor from the city of Ghent believes that an efficient economic model should be devised for MaaS operators, but it must be ensured that they do not have an excessive amount of influence over private and public transport service providers (Lebas and Crutzen, 2021)
The representative of the city of Bruges notes the necessity to build an economic model that ensures a favorable pricing for the citizen, failing which there is a risk that MaaS will not be adopted.
The city of Leuven believes that the business case will be feasible only when MaaS technologies are adopted on a broader scale (Lebas and Crutzen, 2021)

Tariff options are already present within the Belgium economy and have proven to be used by foreign MaaS applications like "Whim" (fig 3.). One of the main challenges issues with the application of MaaS in Belgium is the absence of a clear economic model and the necessity to build one that ensures favorable pricing for the user (Lebas and Crutzen, 2021). Although, there is still the absence of a clear business model, the understanding of the different stakeholders in Belgium of the importance of data and the use of it to ultimately integrate tariff options, is a positive indicator.

5.3 One dynamic platform

Four cities (Charleroi, Ghent, Hasselt, and Liège) and the BCR (Brussel capital region) insist that MaaS must be developed inclusively. To expand beyond early adopters, these platforms must be open and readily available to everybody. MaaS must be user-friendly to prevent the digital divide among a portion of the population, particularly the elderly (Lebas and Crutzen, 2021).

When looking at the individual responses from the capital regions themselves concerning the platform to develop MaaS further in Belgium, the following responses were given:

Antwerp was the first city in Belgium to use MaaS in 2018. It has chosen the model of private operator management. Since the launch of the Smart ways to Antwerp program in 2015, the city has built a Mobility marketplace and a framework for MaaS operators to establish themselves (Lebas and Crutzen, 2021).

The representative of Charleroi would prefer the Walloon Region to be in charge of establishing and coordinating this type of application due to its competencies, while respecting a territorial approach by emphasizing mobility possibilities in the user's local area (Lebas and Crutzen, 2021).

Hasselt would argue for a hybrid management strategy, which is prevalent in the province of Limburg. The Region would play a role in the development of a unified Flemish vision for Smart Mobility and serve as an economic driver, including the expansion of public-private partnerships (Lebas and Crutzen, 2021).

Depending on the region that was asked, the consensus drives towards the creation of a centralized platform that would help to further develop MaaS in Belgium, Flanders, or the Walloon region. This is logical as the Walloon region, Brussels and Flemish regions have different public transport authorities so the argument for a hybrid system makes sense, where all these entities could cooperate with the private sector. Furthermore, four cities (Charleroi, Ghent, Hasselt, and Liège) and the BCR insist on inclusive MaaS. These platforms must be open to everyone to extend beyond early adopters. MaaS must be user-friendly to prevent the digital divide among the elderly.
We can conclude that there is a vision to implement MaaS in an inclusive way opening up to the possibility of integrating one dynamic platform.

5.4 Multiple actors that cooperate closely

As the first prerequisite discussed in the study (Lebas and Crutzen, 2021). Collaboration with stakeholders: The first criterion proposed is collaboration amongst the several levels of MaaS participants.

Initially, five cities (Antwerp, Bruges, Charleroi, Liège, and Namur) emphasized the need for increased collaboration within the administration. This applies to interdepartmental mobility cooperation within the administration and to coordination with city PTOs (public transport) and police (Lebas and Crutzen, 2021).
Second, four cities (Charleroi, Hasselt, Liège, and Leuven) underlined the necessity for more collaboration between the various levels of power: these cities believe that MaaS must be implemented at the metropolitan or province level for it to become a reality.
In five cities (Antwerp, Hasselt, Namur, Leuven, and Charleroi), the local police department is responsible for parking enforcement (Lebas and Crutzen, 2021).
The City Pass combines public transportation travel in and around the cities of Antwerp, Charleroi, Ghent, and Liège on a single ticket (NMBS/SNCB, n.d.).
UITP is an international organization comprised of public transport authorities, operators, policymakers, research institutions, and demand/supply services.
The Belgian MaaS Alliance is a public-private community dedicated to advancing MaaS in Belgium (Lebas and Crutzen, 2021).

The BCR (Brussels capital region) adds the need to strengthen collaboration and trust between public and private mobility actors in order to better understand one other's requirements. The spokesperson of the city of Antwerp feels that public authorities must adopt a business attitude in

order to persuade more private mobility operators of the added value of MaaS in terms of sales, as they fear that the rivalry may be too fierce (Lebas and Crutzen, 2021).

The eight cities and the BCR have assigned the public sector a coordinating and facilitating role. The following actions have been mentioned specifically: Bring service providers to the table and encourage collaborations and exchanges (Lebas and Crutzen, 2021).

There is a clear indication that with the incentives like the City Pass there is some level of close cooperation present between stakeholders. However, the acknowledgement that further close cooperation and exchanges between different stakeholders are necessary was also mentioned. This insight will only benefit the further development of MaaS in Belgium as a fully operational national system.

5.5 Use of technologies that improve current ICT conditions:

The city of Namur has highlighted the need for a robust IT solution, with the possibility of a group of municipalities financing it (Lebas and Crutzen, 2021). The city of Leuven believes that the business case will be feasible only when MaaS technologies are adopted on a broader scale.

When discussing the role of the public and private sector, it is important to distinguish between the two. The private sector has a role in deploying and supplying ICT solutions, whereas the public sector should function as a facilitator or coordinator in the development of MaaS, according to the majority of opinions (Lebas and Crutzen, 2021).

The eight cities and the BCR have assigned the public sector a coordinating and facilitating role. The following actions was mentioned specifically:
Position itself as a testing ground to facilitate the development of future technologies (Lebas and Crutzen, 2021).

When it comes to the use of technologies, the data provided in the paper (Lebas and Crutzen, 2021) confirms that there is a need for a robust IT solution, answering one of the technological challenges where it is mentioned that a growing risk and vulnerability to cyberattacks is one of the main reasons the current ICT conditions need to improve (Pangbourne et al., 2018). Also, the role of the public and private sectors was discussed, where the private sector is responsible for deploying and supplying the ICT solutions and the public sector should test and facilitate the ICT solutions provided. Indicating, that there is a willingness to improve the current ICT conditions by the use of technologies. However, these technologies are not yet present.

5.6 Demand orientation and increase validity of MaaS

MaaS must be user-friendly to prevent the digital divide among a portion of the population, particularly the elderly (Lebas and Crutzen, 2021).

The representative of the city of Bruges notes the necessity to build an economic model that ensures favourable pricing for the citizen, failing which there is a risk that MaaS will not be adopted.
The selection of a management model is a difficult decision. The responder believes that a hybrid or private model would be more suitable for the city due to a lack of human and financial resources to provide a good ratio of service quality to customer cost (Lebas and Crutzen, 2021).

A pilot project in BCR is using a hybrid management model with STIB/MIVB as the MaaS platform operator. For the BCR representative interviewed, the ideal management model is a hybrid approach in which the BCR preserves data to monitor objectives and flows to ensure quality of service, inclusion, accessibility, and modal share assessment follow-up.

The TEC:
Although the interlocutor lacks a definitive opinion, he believes that the hybrid approach would be the most user-friendly for citizens (Lebas and Crutzen, 2021).

De Lijn:
While some private MaaS operators may be attempting to sell as many trips as possible, regardless of the form of transportation used, De lijn mentions that this could be a factor that could slow down Belgium's modal shift. When looking at the operational side of MaaS, the optimal operational size would be regional or even federal, as citizens typically work in a different city than where they reside (Lebas and Crutzen, 2021).

STIB and MIVB:
The STIB/MIVB spokesperson justifies the role of a public MaaS platform by emphasizing public benefit and inclusivity (e.g., the requirements of disabled individuals). This is in contrast to private models which aspire to be profitable (Lebas and Crutzen, 2021).

The SNCB/NMBS:
The representative believes that the chosen MaaS model must enable users to select the most cost-effective, environmentally friendly, or quickest route based on their preferences (Lebas and Crutzen, 2021).

The idea of user-centricity as a key factor when it comes to demand orientation in MaaS (Smit, 2019), is a returning factor in the data provided above (Lebas and Crutzen, 2021). What model should be chosen and the effects on the consumer are also widely mentioned (NMBS, STIB, TEC, BCR and Bruges). Only the STIB believes that a public MaaS model, whilst mentioning the public benefit and inclusivity. The other respondents mention the hybrid model as the most efficient way

for the public to benefit and having the most user-friendly approach. The hybrid model would have more financial resources and flexibility that would aid to the consumer experience (Lebas and Crutzen, 2021).

To increase validity in MaaS it is important to do more pilot studies (Smit, 2019). In the Brussels capital region, there is currently a pilot scheme running. They have also opted for the hybrid model; the BCR's optimal management model is a hybrid approach where the BCR monitors objectives and flows to ensure service quality, inclusiveness, accessibility, and modal share assessment follow-up.

Whilst there is no clear consensus or proven management model. The key factor the respondents mentioned was user-centricity and quality of service. Future pilot schemes will be able to assess which model has the most advantages in Belgium.

5.7 Registration requirement

The registration requirement was not mentioned in the study applied to Belgium. However, looking at the information provided by the pilot project in Brussels "mobility moving forward" (MaaS - Mobility in Brussels Is Moving Forward, 2022). The following was mentioned on the website concerning registration requirements: "This is a test version that will only be accessible to the 2,000 persons who have been selected as testers of the tool. To participate, please click on "Register here!" at the top of the web page."

The pilot project in Brussel has a registration requirement. This coincides with the fulfilment of one of the key principles (Jittrapriom, 2017). This is only one example of a MaaS pilot in Belgium. Although, it does fulfill this necessary requirement. It is important to know this is a small-scale pilot project.

5.8 Personalization

Personalization is a requirement and is mentioned in the paper (Lebas and Crutzen, 2021) as one of the necessary prerequisites mentioned in their study. For users, MaaS provides easy access to a wide range of mobility services through a personalized approach, resulting in increased user comfort, flexibility, and, ultimately, a car alternative (Lebas and Crutzen, 2021).

Personalization is acknowledged when MaaS's potential was questioned in the research paper (Lebas and Crutzen, 2021), as one of the key factors when implementing MaaS, giving an indication of future deployment.

When looking at the pilot project "mobility moving forward" in Brussels (MaaS - Mobility in Brussels Is Moving Forward, 2022). There is no mention or indication to include personalization options. This is a clear gap in the MaaS pilot as personalization is a key factor.

5.9 Customization with the aim to continuously improve the digital infrastructure and collect data

The study (Lebas and Crutzen, 2021) identified that all interlocutors believe, that they must play a role in the development of MaaS in terms of digital awareness,
The study recognized data accessibility and administration as a crucial necessity.
In addition to the BCR, six cities (Antwerp, Charleroi, Hasselt, Leuven, Liege, and Namur) have highlighted data as a crucial necessity (Lebas and Crutzen, 2021)

For the BCR representative interviewed, the ideal management model is a hybrid approach in which the BCR preserves data to monitor objectives and flows to ensure quality of service, inclusion, accessibility, and modal share assessment follow-up (Lebas and Crutzen, 2021).

The first proposed feature is the interoperability and standardization of data in APIv format (software that allows to applications to communicate with each other) to enable communication between the various apps, the integration of the various mobility services, and ultimately tariff integration. In addition to compatibility, the interlocutors emphasize the accessibility and appropriate handling of these data (Lebas and Crutzen, 2021).

The eight cities and the BCR believe the private sector should be responsible for deploying mobility solutions. One of the following explanations for data management was cited: The availability of data pertaining to their services that they can use to optimize and enhance these services (Lebas and Crutzen, 2021).

There is a clear understanding that the use of management of data is crucial for the further development of MaaS. During pilot projects necessary data should be collected to help create role structure (Jittrapriom, 2020). The pilot project in Brussels "mobility moving forward" also mentions the following on their landing page: "Once your trip has been set up, you will get an overview of all types of transport. You can also indicate which means of transport you prefer to use" (MaaS - Mobility in Brussels Is Moving Forward, 2022). This confirms the options of customization will be available in the pilot project. And with the data collected above confirms that customization and data collection are seen as essential parts of further MaaS integration.

6. Conclusions:

In this Master thesis the overall aim was to answer the following research questions:

RQ1: What are the technological and business challenges for Mobility as a service (MaaS)?

To thrive inside the MaaS ecosystem, public and private entities must collaborate. Traditional transportation policy and regulations require reevaluation and simplification. Moreover, when it comes to technological integration, there are insufficient APIs and data formats for the number of transportation companies who are already adopting MaaS. In addition to easing the integration of data and API feeds from diverse MaaS providers, governments should establish guidelines for the collection, management, and exchange of data.

Private MaaS service providers should compete to optimize the system's benefits. Initial research on the interests and perspectives of municipal mobility officials in Belgium found that the adoption of MaaS is seen differently in different cities due to the diversity of local cultures. First, the public sector should promote or coordinate the development of mobility services, and second, private operators, except for public transit, should provide these services themselves. In addition to a lack of resources and expertise within cities, this technique is motivated by the desire to achieve policy goals. When it comes to managing systems, however, two trends emerge: the majority of cities do not have a preference for a particular business model (public, private, or hybrid), while those that do opt for a mixed approach in which the public or at least some stakeholders are involved in the administration of a franchised solution.

To facilitate the implementation of MaaS and its benefits for passengers, while prohibiting unfair competition, a robust legal framework must be in place. There is no alternative to government-led regulation, and technology lock-in could be disastrous. A commercially viable mobility solution must take existing market misalignments and gaps into account. To ensure the integration of urban transportation networks, consequently, new economic models are required. Moreover, when new transportation technologies such as MaaS platforms gain popularity, it is essential to identify and eliminate the psychological barriers that hinder their general adoption.

Social difficulties and obstacles continue to impede the development of a MaaS vision that is totally comprehensive and inclusive. To comprehend how systems evolve over time and effectively record these dynamic changes, additional research is required. In the current digital age, platform-based businesses are among the most valuable companies. The emergence of ride-hailing services has had numerous impacts on traffic and public transportation.

Using market research, MaaS designers should develop solutions that make client migration as attractive and straightforward as possible. Additionally, it is essential to identify and eliminate psychological barriers that prevent the widespread acceptance of new transportation technologies. MaaS suppliers, whether public or private, have not yet established themselves as market leaders.

In addition, authorities may make it difficult for MaaS providers to adopt commercial strategies (such as discounted tickets and bundled services) to remain competitive. To make MaaS technology easier to deploy, established transportation policies and regulations must be reevaluated and adjusted.

RQ2: Can MaaS be applied to the Belgian mobility ecosystem?

A checklist was created to assess the feasibility of MaaS in Belgium. The Checklist is based on 9 key principles for successful MaaS application: 1. Integration of transport modes, 2. Tariff option, 3. One platform, 4. Multiple actors, 5. Use of technologies, 6. Demand orientation, 7. Registration requirement, 8. Personalization and 9. Customization.

The MaaS checklist identifies strong points. To facilitate a MaaS system, not just the principle but also the implementation challenges must be overcome. MaaS can't be fully accepted and understood without certain policies. Some opportunities could make MaaS implementation worthwhile, producing societal advantages, economic opportunities, and a total redesign of the current transport system. Seven of the nine main principles were updated to boost the likelihood of a fully functional MaaS system. These changes were recognized in existing literature and should clearly explain the key principles.

When applied to Belgium, Resulting to the following checklist.

Checklist MaaS	**Present?**	**Indication for future implementation?**	**Result:**
Integration of frictionless transport modes	Yes/**No**	**Yes**/No	Not yet
Tariff option (Pay as you go / subscription)	Yes/**No**	**Yes**/No	Not yet
One dynamic platform	Yes/**No**	**Yes**/No	Not yet
Multiple actors that cooperate closely	**Yes**/No	**Yes**/No	Yes
Use of technologies that improve current ICT conditions	Yes/**No**	**Yes**/No	Not yet
Demand orientation and increase validity of MaaS	Yes/**No**	**Yes**/No	Not yet
Registration requirement	**Yes**/No	**Yes**/No	Yes
Personalization	Yes/**No**	**Yes**/No	Not yet
Customization with the aim to continuously improve digital infrastructure and collect data	**Yes**/No	**Yes**/No	Yes

1. Integration of frictionless transport nodes: Not yet.

Frictionless transport modes are required for system success. Belgium's public transit infrastructure doesn't allow MaaS to design an effective MaaS system with the maximum potential of full adoption, increasing customer pleasure and simplicity. Because of a lack of transfer nodes and the need for a complete mobility infrastructural reorganization. Belgium needs to restructure its mobility ecosystem first, which could lead to MaaS integration. The data does reveal that Belgium officials are aware of the need to restructure and the lack of transfer nodes which could be an indication for the future implementation.

2. Tariff options: Not yet.

One of the biggest concerns with MaaS in Belgium is the lack of a clear economic model that provides beneficial pricing for the consumer. Despite the lack of a clear business model, Belgian stakeholders realize the relevance of data and its application to combine tariff possibilities.

3. One dynamic platform: Not yet.

Depending on the location, the consensus favors creating a centralized platform to develop MaaS in Belgium, Flanders, or Wallonia. Wallonia, Brussels, and Flanders have separate public transport authorities, therefore a hybrid system where they can work with the private sector makes sense. Charleroi, Ghent, Hasselt, and Liège insist on inclusive MaaS. To get beyond early adopters, these platforms must be open to all. We may conclude that MaaS will be implemented in an inclusive approach, allowing for one dynamic platform in the future.

4. Multiple actors that cooperate closely: Yes.

The eight cities and BCR have tasked the public sector with coordinating and facilitating. Specifically stated actions: Encourage collaborations and exchanges. with service providers. Transport incentives that allow for the integration of multiple transport options (like Citypass) show some level of close cooperation. This indicates that there already is some form of close cooperation amongst parties. Further stakeholder cooperation and interactions were also acknowledged. This knowledge will help Belgium establish MaaS as a national system in the future.

5. Use of technologies that improve current ICT conditions: Not yet.

There is a need for a solid IT solution in Belgium which is not present yet. With the growing dangers and vulnerabilities to cyberattacks existing ICT conditions need to improve. The role of the public and private sectors is important in Belgium, with the private sector deploying and supplying

ICT solutions and the public sector testing and facilitating them. Indicating a desire to improve ICT through technology. These technologies aren't available yet.

6. Demand orientation and increase validity of MaaS: Not yet.

User-centricity is a big element in MaaS demand orientation.
What model to choose and the consequences for the consumer need to be considered. The STIB is the only organization that supports a public MaaS model, citing public benefit and inclusion. Others say the hybrid model is the most user-friendly and efficient for the public. The argument for a hybrid approach would be that is has more financial resources and flexibility, helping consumers.

More pilot studies are needed to develop MaaS in Belgium. In Brussels, there's a pilot project initiated. The BCR's optimal management model is a hybrid method where it monitors objectives and flows to assure service quality, inclusivity, accessibility, and modal share assessment and follow-up. There is no agreement over an established management model in Belgium yet. User-centricity and service quality are most important when it comes to demand orientation and mentioned by the Belgian officials. Future pilot programs will examine which model is more suitable in Belgium and will facilitate the most user centricity and service quality.

7. Registration requirement: Yes.

Brussels' trial initiative requires signup. This fulfills a key principle and further indicating the understanding to fulfill this key MaaS principle in Belgium. This condition is met. The trial project is small-scale. Yet the condition there is already a registration requirement.

8. Personalization: Not yet.

When applying the checklist to Belgium, personalization is recognized as a major component for deploying MaaS, indicating future deployment. Within the pilot study Brussels' "mobility moving forward". Personalization possibilities aren't mentioned. The MaaS pilot lacks personalization, a vital aspect.

9. Customization with the aim to continuously improve digital infrastructure and collect data: Yes.

All major Belgium cities believe they must play a part in MaaS development in the appropriate management and importance of data. Interoperability and standardization of data in APIv format (software that allows applications to connect) are suggested to enable communication between apps, integration of mobility services, and tariff integration. Furthermore, all cities agreed the availability of service data should be used for optimization and improvement and should be handled by the private sector. Data management is essential for MaaS's development. Pilot programs should collect data to further develop MaaS in Belgium.

When it comes to fulfilling the key principle, the Brussels pilot project "mobility moving forward" lets you choose your preferred mode of transportation (This verifies the pilot project customization options). This data will then be used to improve MaaS development in Belgium. Demonstrating that customization and data collecting are necessary for MaaS integration and are already currently met in Belgium.

General conclusion:

Three out of the nine key principles were already present in Belgium. Seven out of the nine key principles were not. However, there were clear indications that there is a good understanding of the importance of those key principles. Hence, it is likely they will be fulfilled in the future. MaaS is still developing as a concept, and pilot projects are only just emerging in Belgium. These pilot projects are vital and will allow MaaS to further develop in the future. Thereby, they will allow for relevant data collection from these pilot projects that then can be used to further validate the potential of MaaS in Belgium. The key challenge will be to tackle the technological and infrastructural challenges that need improving and are necessary to grasp the full potential of MaaS. If full adoption of MaaS is to happen, the focus on consumer benefits and ease should be the central idea. Only then has MaaS the highest chance of seeing full adoption in Belgium, and will it allow this country to grasp all the societal, environmental, and economic benefits of this innovative system.

6.1 Discussion:

With the evolving nature of MaaS and its reliance on technology, it may be necessary to reevaluate the current checklist in order to incorporate new fundamental requirements. Moreover, MaaS is transport-based; the current transport scene is undergoing a profound transformation. This will have multiple benefits for MaaS; transit can even be altered to suit the MaaS system rather than the individual, such as the introduction of transfer stations, self-driving vehicles, and modular transport systems. However, as a result of these modifications, the framework developed for this master's thesis may become less accurate. MaaS aims to radically rebuild the current transportation system so that nearly no private transportation is required. Therefore, the long-term impacts of MaaS are difficult to anticipate.

7.0 Bibliography

1. Alyavina, E., Nikitas, A., & Tchouamou Njoya, E. (2020). Mobility as a service and sustainable travel behaviour: A thematic analysis study. Transportation Research Part F: Traffic Psychology and Behaviour, 73, 362–381. https://doi.org/https://doi.org/10.1016/j.trf.2020.07.004
2. Arias-Molinares, D., & Carlos García-Palomares, J. (2020). Shared mobility development as key for prompting mobility as a service (MaaS) in urban areas: The case of Madrid. *Case Studies on Transport Policy*, *8*(3), 846–859. https://doi.org/https://doi.org/10.1016/j.cstp.2020.05.017
3. Blockchain platform developed for mobility-as-a-service. (2020, April 30). Retrieved November 15, 2021, from https://www.smartcitiesworld.net/news/news/blockchain-platform-developed-for-mobility-as-a-service--5239
4. Bouton, S., Knupfer, S. M., Mihov, I., & Swartz, S. (2015). Urban mobility at a tipping point. McKinsey Global Institute.
5. Buhaug, H., & Urdal, H. (2013). An urbanization bomb? Population growth and social disorder in cities. Global environmental change, 23(1), 1-10.
6. Crossing the Chasm in Technology Adoption Life Cycle EXPLAINED | B2U. (2020, March 15). B2U - Business-to-You.Com; www.business-to-you.com. https://www.business-to-you.com/crossing-the-chasm-technology-adoption-life-cycle/
7. Ditmore, C. J., & Miller, A. K. (2021). Mobility as a Service Operating Model to Enable Public Policy. Transportation Research Record, 2675(11), 141–149. https://doi.org/10.1177/03611981211026664
8. Daniela Arias-Molinares, Juan Carlos García-Palomares Shared mobility development as key for prompting mobility as a service (MaaS) in urban areas: The case of Madrid Case Studies on Transport Policy, Volume 8, Issue 3, 2020, pp. 846-859
9. Dube, C., & Gumbo, V. (2017). Diffusion of innovation and the technology adoption curve: Where are we? The Zimbabwean experience. Business and Management Studies, 3(3), 34-52.
10. Enoch, M. (2018). Mobility as a Service (MaaS) in the UK: change and its implications. *Government Office for Science, London*.
11. Esztergár-Kiss, D., Kerényi, T., Mátrai, T., & Aba, A. (2020). Exploring the MaaS market with systematic analysis. European Transport Research Review, 12(1), 67. https://doi.org/10.1186/s12544-020-00465-z
12. Göran Smith, David A. Hensher Towards a framework for Mobility-as-a-Service policies Transport Policy, Volume 89, 2020, pp. 54-65
13. Hensher. "Towards a framework for mobility-as-a-service policies." Transport policy 89 (2020): 54-65.
14. Holmberg, P. E., Collado, M., Sarasini, S., & Williander, M. (2016). Mobility as a Service-MaaS: Describing the framework. In Tuesday, February 16, 2016.
15. Jang, S., Caiati, V., Rasouli, S., Timmermans, H., & Choi, K. (2021). Does MaaS contribute to sustainable transportation? A mode choice perspective. *International Journal of*

Sustainable Transportation, *15*(5), 351–363. https://doi.org/10.1080/15568318.2020.1783726

16. Jittrapirom, P., Caiati, V., Feneri, A. M., Ebrahimigharehbaghi, S., Alonso Gonzalez, M., & Narayan, J. (2017). Mobility as a Service: A Critical Review of Definitions, Assessments of Schemes, and Key Challenges. *Urban Planning*, *2*. https://doi.org/10.17645/up.v2i2.93
17. Jittrapirom, P., Marchau, V., van der Heijden, R., & Meurs, H. (2020). Future implementation of mobility as a service (MaaS): Results of an international Delphi study. Travel Behaviour and Society, 21, 281-294.
18. KPMG, 2017. Reimagine Places: Mobility as a Service. Retrieved from KMPG LLP's website. http://kpmg.com/uk/reimagine-maas.
19. Kamargianni, M., & Matyas, M. (2017). The business ecosystem of mobility-as-a-service. Transportation Research Board, 96.
20. Kostiainen, J., & Tuominen, A. (2019). Mobility as a service—Stakeholders' challenges and potential implications. In Towards User-Centric Transport in Europe (pp. 239–254). Springer.
21. Lebas, A., & Crutzen, N. (2021). Mobility as a Service (MaaS): Exploratory study on the governance and the management of projects in Belgium.
22. Li, Y., & Voege, T. (2017). Mobility as a Service (MaaS): Challenges of Implementation and Policy Required. *Journal of Transportation Technologies*, *07*, 95–106. https://doi.org/10.4236/jtts.2017.72007
23. MaaS - Mobility in Brussels is moving forward. (2022, May 22). MaaS - Mobility in Brussels Is Moving Forward; maas.stib-mivb.brussels. https://maas.stib-mivb.brussels/
24. Moore, G. A. (2003). Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers. (3rd ed.). New York: Harper Collins Publishers.
25. Murakami, E., & Young, J. (1997, April). Daily travel by persons with low income. In *Nationwide Personal Transportation Survey Symposium*.
26. National emissions reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism. (EEA) (2020). Retrieved 9 November 2021, from https://www.eea.europa.eu/data-and-maps/data/national-emissions-reported-to-the-unfccc-and-to-the-eu-greenhouse-gas-monitoring-mechanism-17
27. Pangbourne, K., Stead, D., Mladenović, M., & Milakis, D. (2018). The case of mobility as a service: A critical reflection on challenges for urban transport and mobility governance. In Governance of the smart mobility transition. Emerald Publishing Limited.
28. Polydoropoulou, Amalia, et al. "Prototype business models for Mobility- as-a-Service." Transportation Research Part A: Policy and Practice 131 (2020): 149-162. Smith, Göran, and David A.
29. Sarasini, S., Sochor, J., & Arby, H. (2017). *What characterises a sustainable MaaS business model?*
30. Smit, L. (2019). Prioritising challenges to develop Mobility as a Service in the Netherlands using a Delphi study.
31. Smith, G., & Hensher, D. A. (2020). Towards a framework for Mobility-as-a-Service policies. Transport policy, 89, 54-65.

32. Sochor, J., Arby, H., Karlsson, I. C. M., & Sarasini, S. (2018). A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. *Research in Transportation Business & Management*, *27*, 3–14.
33. Sochor, J., Strömberg, H., & Karlsson, I. C. M. (2015). Implementing mobility as a service: challenges in integrating user, commercial, and societal perspectives. *Transportation Research Record*, *2536*(1), 1–9.
34. Tomaino, G., Teow, J., Carmon, Z., Lee, L., Ben-Akiva, M., Chen, C., Leong, W. Y., Li, S., Yang, N., & Zhao, J. (2020). Mobility as a service (MaaS): the importance of transportation psychology. *Marketing Letters*, *31*(4), 419–428.
35. Van Acker, V., Allaert, G., Boussauw, K., Zwerts, E., & Witlox, F. (2011). Mobiel Vlaanderen in een mobiel Europa. *De sociale staat van Vlaanderen 2011*, 311.
36. Whim. (2022, May 9). One app for bus, train, e-scooter, bike, taxi - Whim Helsinki. Whim Helsinki; whimapp.com. https://whimapp.com/helsinki/en/
37. Zhao, X., Vaddadi, B., Sjöman, M., Hesselgren, M., & Pernestål, A. (2020). Key barriers in MaaS development and implementation: Lessons learned from testing Corporate MaaS (CMaaS). *Transportation Research Interdisciplinary Perspectives*, *8*, 100227. https://doi.org/https://doi.org/10.1016/j.trip.2020.100227