An exploration to the impact of on-demand ride sharing services on urban tram systems

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ARCADIS Design & Consultancy for natural and built assets

An exploration to the impact of on-demand ride sharing services on urban tram systems

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Preface

This document considers a research to the impact of potentially disruptive mobility innovations on tram investment policy. Innovation has always fascinated me and the lack of it in traditional sectors, such as construction and public transit maybe even more. Therefore, I am happy to finish my studies from the TU Delft with such a topic, even though my background knowledge on the subject was limited. With this thesis, I finish my Master study in Construction Management and Engineering (CME). I performed this research in a "consultancy role" between Arcadis and Metropoolregio Rotterdam-Den Haag (MRDH). I had my formal supervisor at Arcadis, but I was "employed" to address the problem for MRDH. MRDH is the transport authority of the Rotterdam and The Hague region. Arcadis is a globally operating engineering and consultancy firm. I performed my thesis at the department of rail & public transit, in team asset management.

Without the support and guidance of several people this thesis would not have been established. First, I would like to thank my thesis committee. Many thanks go out to Jan Anne Annema, who helped me from the start to the end with clear feedback, guidance, and enthusiasm. Furthermore, he came all the way to Amsterdam to facilitate my scenario workshop very early in the morning for which I am very thankful. I would like to thank Dimitris Milakis for his honest criticism and sharp questions during meetings that helped me to sharpen my thesis. Bert van Wee I would like to thank for his ability to give precise and meaningful feedback during our sparse meetings. Many thanks go out to Peter Dourlein, who offered me the opportunity to perform my research at Arcadis in collaboration with the MRDH. Moreover, Peter thought me many valuable lessons outside the scope of my research for which I am very thankful.

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Last, I want to thank my friends and family for distracting me on the right and sometimes wrong moments. This made me remember the healthiness of other priorities and gave me fresh energy to continue and finish my thesis research.

Jelle Wins
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Executive Summary

Traditional urban public transit may be on the verge of disruption with the global rise of new mobility services, such as on-demand ride-sharing, car-sharing and MaaS. Since public transit assets are capital intensive and have long lasting technical lifetimes this can be a problem for investment policy and especially for the tram system. This system does not have the speed advantage of the metro and the bus has limited dedicated assets which are more vulnerable to divestment. Digital On-demand Ride-sharing Services (DORS) are a likely suspect to disrupt the tram, because short term diffusion and substitution with transit is plausible according to literature. DORS providers include ride-sourcing, ride-sharing, ride-splitting, microtransit and combinations of them. All match supply and demand of available vehicles/seats using a digital platform with little transaction costs. The main problem is that future development of these services in Dutch cities and their impact on tram investment policy is mostly unknown in literature and practice. Thus, this thesis aims to explore the impact of digital on-demand ride-sharing services' developments on investment policy in the tram system in an urban context. This resulted in the following research question:

"What could be the impact of digital on-demand ride sharing services' developments in Dutch cities on investment policy of metropolitan transport authorities in the tram system?"

To answer this question literature research and a scenario analysis was conducted. The literature research aimed to get an understanding of substitution from tram to DORS in the urban environment to help design the scenario analysis and set a reference point for the scenarios. A framework was developed with input of the scenario analysis in which innovation attributes explaining the adoption of DORS over tram was related to aspects of the urban environment influencing this. The literature research focussed on elaborating the components of the framework and was complemented by five interviews.

It was found that the three major cities (M3) Amsterdam, Rotterdam and The Hague constitute the urban environment. Both tram and DORS operate more efficient in high dense districts, but the tram dwarfs DORS in daily usage. If DORS would diffuse further in the M3 the population variations will segment substitution, while scarcity of space, density, congestion, and policy related to this influence the quality of tram and DORS. Policy is uncertain as no clear standing has been taken by the government considering DORS. Potential growth of other (innovative) travel modes may take share of both systems or help them grow. Tram and DORS can serve anyone for any purpose, but serve different use groups at this time. In general travellers may adopt DORS because it offers door-to-door transportation. This makes it more comfortable, convenient, and faster if the tram connection is not well suited for the trip. However, DORS is less reliable and costs more. Diffusion of DORS may be driven by an emerging need for collaborative consumption, but stalled by the popularity of cycling and materialistic norms. Compatibility of resources may ease adoption of DORS and observability is a major challenge for DORS, especially when compared to the visibility of the tram.

If the urban environment and innovation attributes will remain as elaborated above investments in the tram system will not be affected by DORS as it serves a different market. However, uncertainties in the urban environment and innovation attributes due to the novelty of DORS may lead to a

different outcome within the technical life time of tram assets. A scenario analysis was conducted to explore these uncertainties using the intuitive logics method. In an expert workshop, the critical scenario drivers were identified to differentiate the four scenario plots. The first axis was formed by the development of the sharing economy that either blooms or fails to end the ownership norm. The second axis was formed by government policy that either controls or retreats of mobility provision. The other identified driving forces (AV technology, ICT technology, globalisation, urbanisation, individualism, energy cost, inclusion, and DORS innovative strength) were used to fill the scenario plots.

It was found from the scenario analysis that DORS will grow to a mature travel mode in two scenarios (S1, S2) and substitution from tram to DORS is expected in three (S1, S2, S4). In two (S2, S4) of these they will compete in the entire urban domain, while in (S1) they will be mostly complementary and only compete at line ends. The scenarios only start differentiating in terms of impact after 2020/2025. (S2) may become disruptive with accelerating substitution while the other two (S1, S4) follow a more gradual pattern. Divestments may be a risk for the entire tram network in (S2), while in two scenarios (S1, S4) only investment in weak lines may be risky. Revenues are at risk in (S2) and for some part in (S4). In (S1) DORS can be an opportunity to reduce cost of administrating the tram network. MTA may remain (S1, S3) its role as public transit commissioner or devote funds to other means (S2, S4).

To identify what scenario may unfold in the future indicators of change were found to be monitored by policy makers. These were commercial exploitability of DORS, more sophisticated travel behaviour models that can include DORS and the diffusion of MaaS platforms. Furthermore, developments of AV should be monitored. Not necessarily because this indicates change for the scenarios, but because AV may push each scenario in to the extreme. To address the uncertainty of the scenarios in investment policy three main approaches were discussed. Robust decision making may help reduce the cost of being wrong, but can be too restrictive compared to the risks. The multiple strategies approach can help to anticipate quickly if opportune or risky outcomes of uncertainties unfold, but the benefits should be compared with the effort. The gamble strategy may reduce vulnerability if the gamble is right, but when wrong there will be cost.

In conclusion, the development of DORS can have significant impact on tram investment policy, because substitution to some degree and risk of divestment is probable in three out of four scenarios. Disruptive impact however is probable in only one scenario (S2) and impact is larger for the already low demand corridors and less to non, for the bigger corridors. DORS can be beneficial for tram investments as well. To address this uncertainty a robust and multiple strategy approach can be considered. MTA can also gamble by not considering the scenarios or choose one as truth, but this is not without risks. This thesis contributes to practice by offering asset managers of tram networks tools to address the uncertainty of DORS in investment policy. Its contributions to science are a framework to understand substitution between tram and DORS and an exploration to the impact of DORS on tram investments which has not been done before. The small expert panel is a limitation to this research and it is recommended to validate the results of this thesis amongst a larger group of experts. The developed framework has not been weighted and is recommended as well. Furthermore, other than monetary criteria to assess investments were not addressed and were named as recommendation.

List of Figures

List of Tables

Contents

1. Introduction

Disruptive innovations are notorious for taking over the market at the expense of the established firm. New players and business models are constantly entering the urban transport market since recent years, with Uber as best known. These new services are rising worldwide, but their success on the long term and (disruptive) impact on urban mobility and traditional public transport remain uncertain in science and practice. This can be a problem for local governments, transit companies, tax payers and citizens since investments in public transit are capital intensive, assets last 30 years and infrastructure occupies scarce urban space. This master thesis addresses this gap by elaborating on the impact of these (disruptive) innovations on the traditional urban public transport system. In this introduction, first the problem statement and scope are made apparent. Thereafter, the objectives and research questions of the thesis are defined. Subsequently, the value of the thesis for both science and industry and accompanied by an outline of the main part of the research.

1.1. Problem statement

Traditional public transport in cities all over the world might be facing disruption, as new private players are entering the urban mobility market (Henao & Marshall, 2017), with Uber as most famous. The US based tech company has rapidly expanded its services all over the world. They are most known for offering on-demand taxi and ride sharing services and now start to offer services close to public transport. Other company's services involve e.g. car sharing and Mobility as a Service (MaaS) platforms. These offer seamless access to multimodal transport in packages or pay as you go (Holmberg, Collado, Sarasini, & Williander, 2016). These innovative services are rising in the Netherlands and abroad, but little is known of their success on the long term and (disruptive) impact on urban mobility and public transport (CPB/PBL, 2016; Henao & Marshall, 2017; KiM, 2015b, 2016b).

In history, many examples can be found of disruptive innovations. These are new technologies or business models that change the existing market or establish new markets. Some disruptive innovations take over the existing market without warning, such as Wikipedia for example replacing encyclopaedia (Huang, 2016). In other cases, disruptive innovations can take down the support network, as in the case of the digital camera. The existing market of camera developers largely embraced the new technology, but film producers have mostly disappeared (Klenner, Hüsig, & Dowling, 2013). In general disruptive innovations have the following characteristics, citied from Thomond and Lettice (2002).

- *"It begins its success by meeting the unfulfilled needs of an emerging or niche market.*
- *Its set of performance attributes, highly rated by niche market customers, are not initially appreciated by mainstream markets. Mainstream market customers as well as competitors value different performance attribute sets and therefore view the innovation as substandard.*
- *Niche market adoption enables investment in the product, service, or business model to increase its performance. It can then create or enter new niche markets and expand customer numbers.*
- *Awareness of the product, service, or business model increases, forcing and influencing change in the mainstream markets perception of what it values.*

- *The change in the mainstream market's perception of what it values is the catalyst that enables the innovation to disrupt and replace existing mainstream products, services or business models"* (Thomond & Lettice, 2002).

If the innovative mobility services would disrupt traditional public transit, this could be a problem for transit companies according to KiM (2016b). They may lose customers to the new players putting pressure on their earnings, but transit companies have the possibility to change their business to the new travel modes, just as camera developers embraced the digital camera. However, the dedicated infrastructure used by traditional public transit cannot easily be adapted in case of disruption. Especially urban rail infrastructure is vulnerable, because most innovative travel modes are automotive or road based. If this infrastructure becomes unutilised, this would be a problem for the asset owners of the infrastructure.

In the Netherlands, the asset owners of urban rail infrastructure are the Metropolitan Transport Authorities (MTA). MTA of Amsterdam (MRA) and Rotterdam-The Hague (MRDH) invest around 60% (2016) of available transport budget on maintaining and replacing infrastructure each year according to Mott MacDonald (2017). This budget is state funded and since MRDH alone had an annual budget of €650M in 2016 (MRDH, 2015a), the investments in infrastructure that could be vulnerable to disruption are considerable. The long technical lifetime of rail assets of 20-40 years emphasises this problem, because premature depreciation of assets lead to large one-time costs (Mott MacDonald, 2017). Disruption by innovative mobility providers could cause this depreciation if (parts of) the traditional transit network loses utility. Furthermore, dedicated infrastructure occupies valuable urban space that could be utilised for other travel modes or pedestrians. At the same time, closure of transit lines due to disruption by new mobility providers could be beneficial for investments and city residents if it would reduce overall operating and maintenance cost and clear space without impeding mobility.

Meanwhile, the general goal of MTA is to strengthen the urban competitiveness of the relevant metropolitan region to attract amongst others highly educated people, jobs, investment, knowledge, creative industries, start-ups and multinationals as the clustering of these enable prosperity, growth and innovation (MRDH, 2016; Rijksoverheid, 2014; Weel, Horst, & Gelauff, 2010). Urban transport infrastructure is acknowledged as an important factor of this urban competitiveness as it allows people, goods and resources to move from A to B, influencing production costs and access to labour from an economic perspective (Ewers, 2007; Mullen & Marsden, 2015). Thus, MTA have to continue invest in public transit to live up to their goals while facing uncertainty of possible disruption by the emergence of new innovative mobility services.

1.1.1. Scientific gap

Looking at existing literature that address the uncertainty of disruptive innovations in policy making, Klenner et al. (2013) describe disruptive susceptibility as a means to evaluate the readiness of a market for disruption and identified other forecasting methods: scoring and analysis models e.g. (Rafii & Kampas, 2002), economic models e.g. (Adner & Zemsky, 2005) and scenario and situation analysis e.g. (Kostoff, Boylan, & Simons, 2004). These methods respectively focus on identifying factors for innovations' disruptive potential, simulating diffusion of disruptive innovations in existing markets or developing scenarios for disruptive innovations (Klenner et al., 2013). Nagy, Schuessler, and Dubinsky (2016) have another approach by suggesting a three-step methodology to identify and define disruptive innovations. They state to characterize the innovation to be evaluated, identify what part of the value chain in the existing market they affect and what the differences are between the innovation and the established business model or technology. In the urban mobility market, there are multiple modes that attract different customer types and -purposes in different circumstances and these modes would therefore be affected differently by disruptive innovations in line with Nagy et al. (2016). Therefore, when assessing the impact of disruptive innovations on public transport policy it is advised to address modes individually for different urban circumstances.

For the urban transit market in the Netherlands, KiM (2016b) identified a list of innovations and scored them on change of perceived travel time, effects on current service provider, timescale of probable market penetration, public investment needs and external effects. Although this offers a very valuable base for this research they do not specifically address the effects on the individual traditional urban public transport modes, nor urban dynamics. This offers a research gap to apply one of the methodologies described above to be able to analyse the impact of disruptive innovations on individual modes in the urban transport market.

1.1.2. Scope

To enable an in-depth analysis of disruptive innovations on urban transit that touches the problem stated above and is feasible to perform within the designated time of a master thesis some scoping has been done.

1.1.2.1. Netherlands

The geographic region is narrowed down to the Netherlands, partly because the thesis' author' knowledge and available resources are mainly focussed on the Netherlands. Additionally, the Netherlands is known for their uniquely extensive urban bike use. Therefore, conclusions from a Dutch case will not be easily made compatible with cities in other countries.

1.1.2.2. Tram system

As stated above the impact of disruptive innovations should be considered for individual travel modes, with the vulnerability of investments as main criteria. The tram system is chosen, because it requires dedicated and capital-intensive infrastructure (rail, vehicles and overhead wire), which in case of market disruption cannot easily be used for different purposes or relocated and thus more vulnerable for divestment. Busses and special purpose transport ride on regular roads and the vehicles can ride in any city with little adjustment. The metro system is even more capital intensive and dedicated than the tram, but has a clear speed advantage because it does not mix with traffic and has larger stop distances than the tram system (Van Oort, Van der Bijl, & Roeske, 2015). Therefore, the metro is expected to be less vulnerable for substitution from emerging travel modes. More information regarding the characteristics of the tram system can be read in Appendix A.

1.1.2.3. Digital on-demand ride-sharing services

Disruptive innovations are narrowed down to digital on-demand ride sharing services. The choice is made using the work of Nagy et al. (2016) on identifying disruptive innovations. First, the breakthrough of the innovation should be probable in a city on a reasonable short term to affect contemporary policy. Second, there should be an assumption the innovation can attract customers of the current tram system and third they should be able to operate without the tram system assets to have impact on the asset owner of the tram system. In Table 1**Error! Reference source not found.** this trade-off has been made for innovations derived from KiM (2016b).

Table 1: Choice disruptive innovations

Innovation	Description	Short term breakthrough	Attract customers	Need rail infrastructure
Fully automated rail vehicle (KiM, 2016b)	Train riding without human intervention in all circumstances	Yes, operational in cities abroad	Yes, if this allows higher frequency.	Yes
Fully automated cars (KiM, 2016b; Milakis, Snelder, van Arem, van Wee, & de Almeida Correia, 2016)	Cars driving without human intervention in all circumstances, automation level five.	No, not in a city	Yes, assumedly	No
On-demand ride Sharing services (KiM, 2016b)	Available cars can be tracked real time and summoned on-demand using an App and rides can be shared with up to 14 people with a combinable trip. Payment is automatic via the App.	Yes, already in operation (UberPool, Abel, Bridj)	Yes, assumedly	No
On-demand car sharing services (KiM, 2016b)	Cars can be picked up on-demand for self-use and either returned to a fixed spot or any desired place depending of the service. Payment is only for actual use.	Yes, already in operation (Car2Go, Snappcar, Greenwheels)	Yes, assumedly	No
Mobility-as-a-Service platforms (Kamargianni, Li, Matyas, & Schäfer, 2016; MAAS Global, 2016)	Mobile platforms that offer easy choice, payment by package and access of multiple modalities including tram and other innovations listed in this table without necessarily providing mobility themselves.	Yes, first tests are being executed (Whim) and light versions are in operation (NS business card, mobility mixx)	Directly yes, but indirectly no as these platforms normally do not provide mobility themselves, but rather facilitate it.	Yes, if the platforms want to offer tram service within their package of mobility services.

From Table 1 can be concluded that both on-demand ride sharing services and on-demand car sharing services comply with the criteria. Since, users of on-demand ride sharing services are driven from a to b and do not need to pick up, drive and park the vehicle themselves, this mode is assumed to be more of a substitute for the tram system than car sharing and chosen to be the focus of this research. (Rayle, Shaheen, Chan, Dai, & Cervero, 2014) found in a survey that amongst Uber and Lyft users in San Francisco substitution with public transport (33%) is the highest after taxi (39%) and even higher (43%) than taxi (35%) amongst non-car owners. Since developments of the above innovations seem to go side by side and influence each other, their influence on on-demand ride sharing services will be included in this thesis.

On-demand ride sharing services are offered by numerous different providers with various business models and service levels. SUMC and USDN (2016) categorized all shared modes and from this list, four can be included to the concept of on-demand ride sharing services: ride-sourcing, ride-splitting, ride-sharing and microtransit. More information regarding the characteristics of these services can be read in Appendix A. Not unusually, multiple of these variants are offered by the same service provider and consumers can compare and order them using a single mobile application. All match available vehicles/seats with riders using a digital platform with low transaction costs (Zha, Yin, & Yang, 2016).

Ride-sourcing, ride-splitting, ride-sharing and microtransit are all contemporary offered services. Since we explore future impact of these services, of which none has proven itself sustainably, and considering the rapid introduction of new business models and technology a broad definition of on-demand ride-sharing services is handled in this thesis. This overall concept will be called Digital On-demand Ride-sharing Service (DORS) in this thesis. Digital is added to differentiate the concept from regular taxi's and demand responsive transit (DRT) that offer the same physical service, but have not yet digitalized their product. DORS is defined as a service that operates with a digital platform, which enables on-demand, customized and real-time matching of (multiple) riders with vacant vehicles/ seats that suit their preferences. The following characteristics of DORS are defined:

- Digital platforms matching vehicles/seats with riders in real time
- Vehicles are ordered on-demand: currently in real time, but pre-order, repetitive order, and agenda synchronization are already in the making.
- Vehicles can be human controlled, autonomous, or controlled by anything else.
- Platforms offer customized services for different prices: vehicle size, door-to-door or stop-to-stop, shared with others or private, hurry or no hurry, special assistance for elderly or disabled, etc.
- Road based vehicles with a capacity of 3-12 passengers.
- Vehicles have electric, hybrid, combustion, or other propulsion.
- Platforms cover no line but a complete area: neighbourhood(s), city or urban region.
- Business models can be any: peer-to-peer, business-to-consumer, business-to-business, etc.

1.1.2.4. Investment policy of MTA

This means investment policy in new or replacement of existing major tram system assets, which are the vehicles, rails and overhead wire. These assets are capital intensive for MTA and have a technical life time of up to 30 years (Mott MacDonald, 2017) and therefore, impact of possible market disruption is assumed to be highest for these assets.

1.2. Objectives and research questions

After narrowing the scope and defining the scientific gap, the aim of this master thesis is to contribute to science by exploring the impact of digital on-demand ride-sharing services' developments in an urban context on investment policy in the tram system.

To define an approach to tackle this aim it is first important to consider how investment policy of MTA may be affected by the potentially disruptive developments of DORS on the tram system. MTA are directly involved by subsidizing the exploitation and by legally owning the assets of the tram system (Mott MacDonald, 2017). DORS may affect the exploitation by substitution or feeding demand from or to the tram system, resulting in higher or lower cost. This influence on demand may also influence the assets themselves by giving a reason to alter the tram system asset management. Maybe less or more trams are needed, line segments may be closed or added, or stops will be closed or added as the tram system may move to another stream in the urban mobility market. Therefore, in this thesis it is first investigated whether and for what reason DORS may eat or feed tram demand using disruptive innovation identification methodology. Since, disruptive innovations typically start in a niche market before possibly penetrating the main stream market (Thomond & Lettice, 2002), it is needed to identify how and if this may happen. Thus, the investigation of future impact of DORS on tram demand in an urban context using a scenario study will be the second objective of this thesis. Subsequently, it is investigated how each scenario may impact tram investments and consequently how this may affect investment policy in the tram system. Hence, the main actions of this thesis are:

- Identifying if, how and to what extend DORS currently impact demand of the tram system in an urban context, using disruptive innovation identification methodology;
- Exploring future impact of DORS on tram demand in an urban context, using a scenario study;
- Investigating to what extend DORS may impact tram investments in the future;
- Investigating how MTA may approach these impacts on demand with their investment policy.

This leads to the following central research question:

"What could be the impact of on-demand ride sharing services' developments in Dutch cities on investment policy of metropolitan transport authorities in the tram system?"

To answer the central question, the following sub-questions are asked.

1. To what extend do digital on-demand ride sharing services currently impact tram demand in an urban context?
2. What could be the impact of digital on-demand ride sharing services' developments on tram demand in Dutch cities?
3. What are the implications of this impact for investments in tram assets and what investment policy is recommended for metropolitan transport authorities?

The first two sub-questions could be ordered the other way around as well. In that case the scenarios are developed first and subsequently for each scenario the competitiveness between tram and on-demand ride sharing services will be defined from which the impact can be logically defined in a next step. It is however chosen to keep the above described order, since the competitiveness is highly uncertain and if both systems serve completely different markets there would be no need for scenarios.

1.3. Added value of the proposed thesis to science and industry

Answering the central question should contribute to both science and industry by helping to fill existing knowledge gaps in science and by helping industry to improve their practice.

1.3.1. Science:

The proposed thesis contributes to the science field of disruptive innovations by researching whether DORS may become disruptive to the tram system, which has not been done before to the knowledge of the author. Moreover, the thesis contributes by assessing the future development of DORS in cities in the Netherlands, of which little information is available. Furthermore, by researching the impact on investment policy the thesis also contributes to the field of asset management.

1.3.2. Industry:

For MTA scenarios for future public transport (CPB/PBL, 2016; KiM, 2015a; Voorst, Hoogerwerf, & Potting, 2013) and generic information of the impact of innovations on public transport (KiM, 2016b) are available. However, these studies although unmistakably valuable do not address specific effects on the tram system and are therefore, hard to base investment policy on. By going in depth into the competitiveness of the tram system and DORS now and in the future, this thesis does aim to help investment policy in the tram system by taking away some uncertainty.

1.4. Thesis outline

This thesis will continue with the methodology in chapter two. The literature research, scenario analysis and scenario implications will be discussed. In chapter three a framework for substitution from tram to DORS was developed. Its main components: the urban environment, social system and innovation attributes will be further elaborated in separate paragraphs. Chapter four discusses the results of the scenario analysis. This comprises the identification of key factors and driving forces, estimation of impact and uncertainty of the driving forces, differentiation of the scenario plots and the full scenario plots backed by literature research. In the fifth chapter, the main differences of the scenarios for substitution and investments will be discussed. Moreover, leading indicators of change and possible approaches to investment policy are elaborated. The thesis ends in chapter six with conclusions and recommendations.

2. Methodology

In this chapter, the methodology to answer each of the sub-questions is described. Two main methods have been used to answer the research question in this thesis: a literature study combined with interviews and a scenario analysis. The literature study and interviews were used to answer the first sub-question and to find and elaborate relevant factors that may explain the impact of DORS on tram demand. Factors have been identified from two domains as can be seen in the blue part of Figure 1: the urban environment and innovation attributes. Further information on how the interviews and literature study have been conducted can be read in paragraph 2.1 and the reason the above two fields were chosen to find relevant factors can be read in Appendix B.

Because the problem addressed in this research is a long-term problem due to technical lifetimes of tram assets it is not enough to analyse the impact for the current situation. Since, the future cannot be predicted, but can be explored a scenario analysis method has been executed for this thesis. This comprises the green part of Figure 1 and answers the second sub-question. A result of the scenario analysis was the identification of key factors and these have been used to complement the factors found from literature. Furthermore, the scenario analysis was used to get input for the yellow part in the same figure which answers the last sub-question. How the scenario analysis was executed and used in this regard can be read in paragraph 2.2 and 2.3.

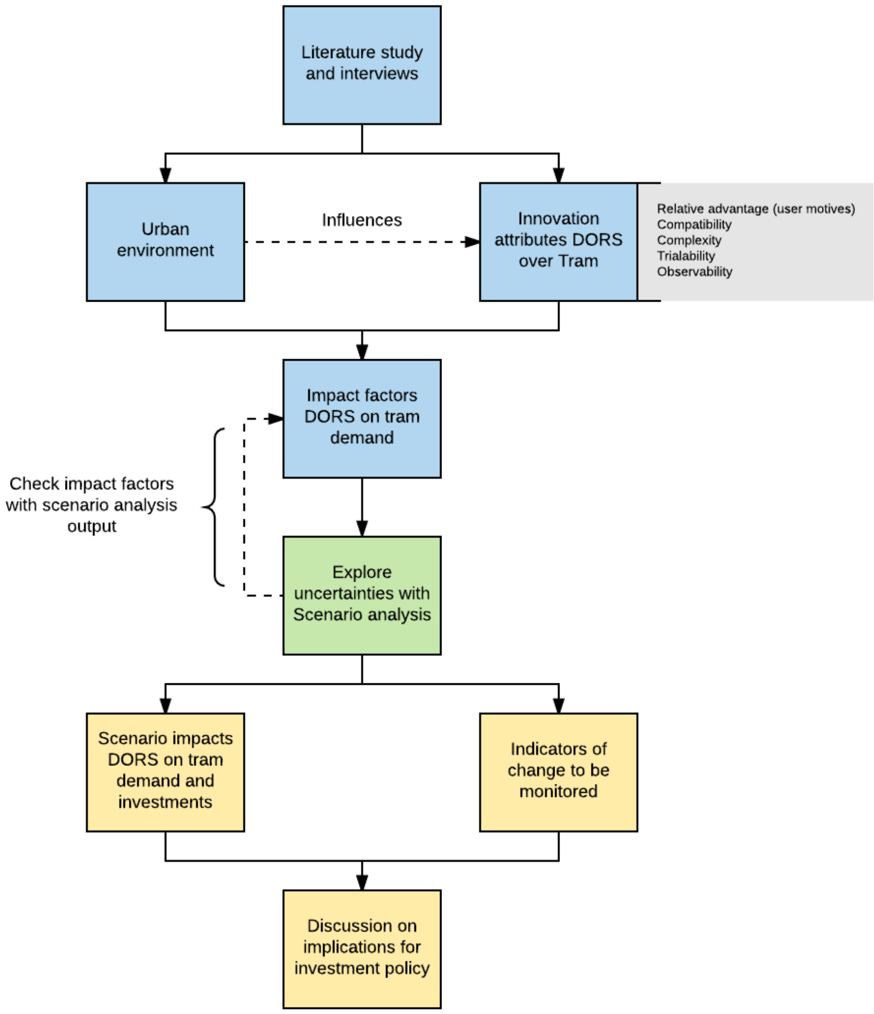

Figure 1: Research model

2.1. Literature study and interviews:

A literature study and interviews were used to answer the question: to what extend do digital on-demand ride sharing services currently impact tram demand in an urban context?

The literature study focussed first on how DORS may impact tram demand. Since our research topic comprises a potentially disruptive innovation within the urban transportation sector both the fields of innovation adoption theory and mode choice theory have been examined by using peer reviewed papers or books found via Google Scholar in Appendix B. The urban environment (paragraph 3.1), social system (paragraph 3.2) and innovation attributes (paragraph 3.3) were found to be relevant and further examined to develop a framework for substitution from tram to DORS. The components of this framework were studied with literature and interviews on their current conditions. From these conditions, the current impact of DORS on tram demand was established. This forms the reference point of the scenario analysis that is elaborated in paragraph 2.2.

For the literature research Scopus, the Library of TU Delft, Science direct and institutions such as PBL, KiM, news articles and websites of service providers are used. The literature study focuses on the urban environment, social system, and the innovation attributes of DORS and for each topic different sources were compared to be able to present a thorough and elaborated picture. The interviews were held to get specific information on operations of the tram and DORS in the Dutch context. A quick search on tram and DORS concepts found that tram is mostly researched within the concept of public transit or BMT and most literature on DORS is from abroad. Thus, the interviews are held to verify if the collected information is accurate and to better understand the specific notions for tram and DORS. The content of the interviews in paraphrased in the main text of this thesis. All interviews follow roughly the same structure: Expertise of interviewee, build environment, usage of the mode, mode choice drivers and forecast/ trends.

Table 2: Interviews conducted for understanding of tram and DORS systems

Topics	Viewpoint	Institution	Position interviewee
Suitable urban environment for the tram, usage of tram within this environment, mode choice drivers to take the tram and forecasts/ trends.	Anonymous*	Anonymous*	Anonymous*
	The Hague tram system service provider	HTM	Senior in the field of tram system condition and development
Suitable urban environment for DORS, Understanding of customers' drive to take DORS over tram and difference between foreign examples of DORS and Dutch urban circumstances.	Research institution in the field of public transport and travel behaviour.	KiM	Senior researcher in the field of public transport and travel behaviour.
			Senior researcher in the field of public transport and travel behaviour.
Understanding of performance and growth of DORS in Dutch major cities, customers' type and drivers served and trends.	DORS provider	Transdev/ Abel	Senior innovation manager

(All elaborated interviews are not included in the appendix of this public thesis; *This interviewee is anonymised to protect his/her corporate interest.)

Five interviews were conducted in total from multiple viewpoints and listed in Table 2. One interview was held with a representative of a ride-sharing service provider in the Netherlands, two with a representative of a research institution and two with tram system service providers. The interviews were held semi-structured to allow discussion and straining of topic if appropriate. To make sure no information is lost; the interviews were recorded with approval of the interviewee. Finally, the results of both cases are analysed on their differences and similarities to define generalized figures of the tram system to be used for the comparison with DORS. All used interviews have been written out and can be read in appendix D.

2.2. Scenario analysis

Scenarios are storylines presenting a picture of possible future states or plausible evolutions from the present to the future. Their advantage over forecasting is that scenarios are generally more creative and flexible. Developing scenarios can help policy makers by evaluating various strategies under a certain scenario or by evaluating a specific strategy under different futures. However, there are many types of scenarios for different purposes and objectives (Bradfield, Wright, Burt, Cairns, & Van Der Heijden, 2005). According to Börjeson, Höjer, Dreborg, Ekvall, and Finnveden (2006) the choice for predictive-, explorative- or normative scenarios depends of the basic question the scenario developer has respectively: *"What will happen?", "What can happen?"* Or *"how can a specific target be reached?"* Our question is a *"What can happen?"* question and therefore an explorative scenario will be set up.

Next step is to choose which scenario building method to use to set up the scenarios. Amer, Daim, and Jetter (2013) reviewed the advantages and disadvantages of both quantitative and qualitative scenario development methods. Because DORS concepts are novel in the Netherlands and abroad, statistic data needed to perform quantitative scenario methods is lacking. Therefore, a qualitative scenario analysis method is suggested. Amer et al. (2013) name three main methods in their paper: intuitive logics, probabilistic modified trends (PMT) methodology and La prospective. From these three options, the intuitive logics method is chosen. PMT requires reliable time series data, which is not available in our case and La prospective is excluded because it is a directed approach and the purpose of our scenario study is not to steer in a desired direction. The advantages of the intuitive logics method are the complete use of future information, the generation of new ideas and the identification of underlying drivers of the future. A disadvantage is that the method strongly relies on the knowledge, commitment and skills of the expert panel that developed them and therefore can be difficult to evaluate scientifically (Mietzner & Reger, 2005). Thus, close attention will have to be paid in selecting the expert panel and the steps followed to develop the scenarios need to be documented carefully to be able to validate the results.

The process followed to develop the scenarios in this master thesis is inspired by the work of Maack (2001) and fourfold: preparation, an expert workshop, elaboration of the scenario plots and validation by the participants of the workshop. The follow up of these activities is illustrated in Figure 2 and the process followed will be further elaborated in the coming indentions. The fifth step: analyse implications will be elaborated in paragraph 2.3.

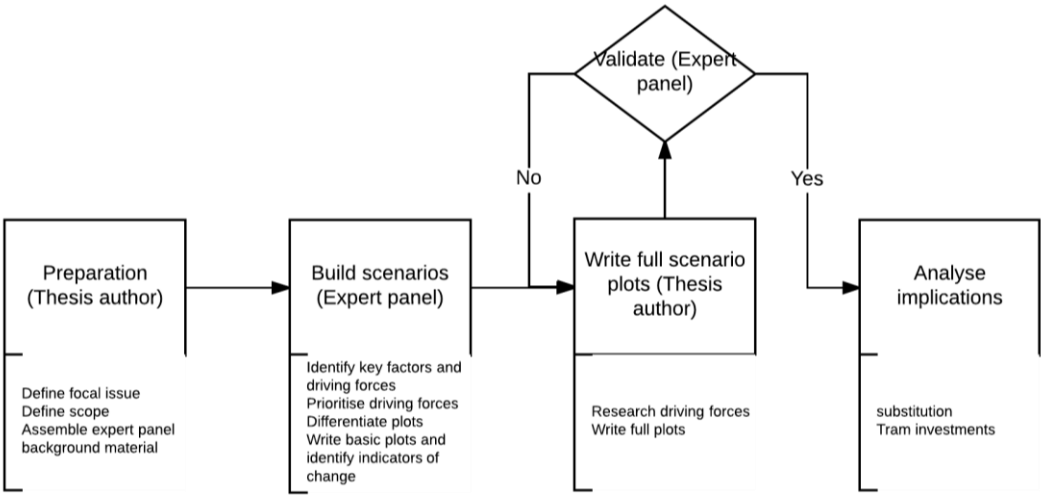

Figure 2: Process scenario analysis

2.2.1. Preparation

According to Maack (2001) first the focal issue needs to be defined and followed by the scope. Next the participant selection, subsequently background material is collected and finally the engagement rules and process of the workshop are described. A fully elaborated description of the preparations done by the author can be viewed in appendix E. In this paragraph, a short version can be read.

2.2.1.1. Focal issue

The first step in any scenario analysis study is to determine the focal issue. This can be a decision or a question that is currently critical to the future of the organization at hand. Maack (2001) argues that to develop a precise focal issue one needs to know what the desired outcome is of both the problem for which a strategy is needed and of the scenario process. Additionally, the timeframe is very important as the main drivers of change for a time horizon of 20 years, may not be applicable for a 5-year project. The problem for which a strategy is needed in this thesis is the question whether MTA should include future developments of DORS in tram investment decisions. The desired outcome of the scenario process is to find a frame of probable impacts of DORS on tram demand and indicators for change to be monitored by MTA. As a time horizon 2040 was chosen, because this corresponds with the time horizon of government reports recently written on the future of public transit in the Netherlands e.g. (MinIenM, 2016a) and (Gemeente Rotterdam & MRDH, 2016). Therefore, the following focal issue was chosen:

To what extent will DORS have impact on public transport demand within big urban regions in the Netherlands in 2040?

Public transport demand was chosen to address instead of tram demand, because this allows MTA to see the impact of DORS on tram in perspective. The tram falls within the concept of public transit and therefore this focal issue is useful to determine the impact of DORS on tram demand.

2.2.1.2. Scope

- Big urban regions (500,000+ inhabitants) in the Netherlands: Amsterdam, Rotterdam and Den Haag.

- By public transport is meant: line based bus, tram and metro.
- DORS as defined in paragraph 1.1.3.

2.2.1.3. Workshop participants

In the preparation phase the five or six participants for the workshop were selected. According to Maack (2001) "Team members should be chosen based on their ability to represent distinct viewpoints on the issue being discussed, be it technical or political… the best scenario teams are diverse". The viewpoints chosen represent the triple helix collaboration of Government, Industry and University, commonly used for developing innovation policy (Stanford University, 2017).

Table 3: Expertise of workshop participants

Viewpoints / bodies of knowledge	Government	Industry	University/ research institution
Urban mobility	1.	1.	2. & 3.
User motives			3.
DORS Technology	4.	5.	
Urban Trends & developments		6.	2.

All viewpoints and bodies of knowledge should be represented by the participants and the following people were invited to attend the workshop, with their expertise shown in Table 3.

1. Marit de Jong, Strategic advisor (Connecting mobility/ Ministry of IenM)
2. Peter Pelzer, researcher and lecturer Urban futures studio, sharing economy, sustainable mobility (University of Utrecht)
3. Peter Bakker, senior researcher collective mobility & social geography (KiM)
4. Martijn van de Leur, Project leader mobility management (Verkeersonderneming/ Ministry of IenM)
5. Quinten Passchier, Manager business development (RMC)
6. Ron Bos, Trendwatcher (SmartUrbanism.org) & Verkeersplanoloog (Den Bosch)

In the end both Peter Pelzer and Quinten Passchier could not attend the workshop at the last moment, but they did review and complement the results of the workshop.

2.2.1.4. Background material

Apart from the focal issue and scope, background material should be presented to the scenario team. Purpose is to help the group to start off with the same basic reference points, while leaving room for creativity (Maack, 2001). Before the workshop the thesis author already found relevant factors for the focal issue by his research conducted in chapter 3. However, to prevent researcher bias and use full creativity it was chosen not to hand these factors to the participants. Instead the factors found by the experts during the workshop will be compared with the factors found by the author. Some general information was displayed during the workshop to prevent discussion about facts. This can be viewed in appendix F.

2.2.2. Building the scenarios

In the half day expert workshop five steps were taken as can be seen in Figure 3, leading to three results elaborated in paragraph 4.1 to 4.3. First the key factors and driving forces were identified (result 1) in a brainstorm and individually assessed by the workshop participants on level of impact on the focal issue and the uncertainty of their future state using Wilsons' matrix (result 2) which can be viewed in Figure 4. Next, the 2x2 scenario matrix was set up using the impact and uncertainty assessment and four draft scenario plots were written (result 3). Finally, indicators for change were discussed to help develop a logical development path for each scenario and write the full scenario plots. The first result was used to compare factors found by the experts with those found by the author in chapter 3 to come to a complemented list of impact factors. The second result was used to differentiate the scenario plots and determine what and how identified driving forces should be included in the scenario plots. The third result was used as a framework to base the full scenario plots on. How the elaborated scenarios were established will be explained in the next paragraph. The entire workshop was audio recorded in full compliance of each participant for the purpose of writing the proposed thesis and the full workshop design can be read in appendix E.

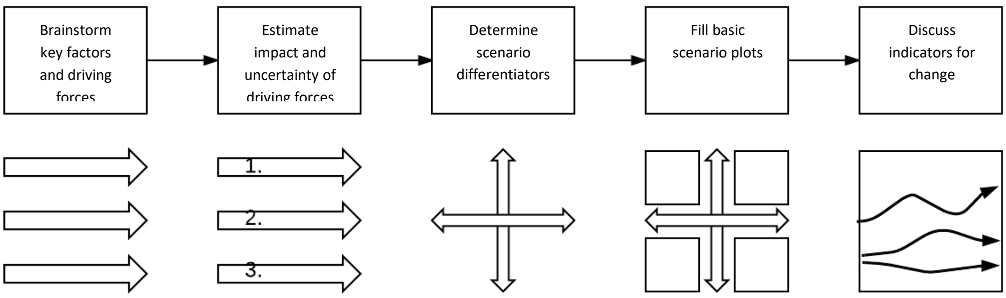

Figure 3: Process scenario workshop

	Degree of uncertainty			
	Low	**Medium**	**High**	***Level of impact***
High	**Critical planning issues** Highly relevant and fairly predictable (can often be based on existing projections). Should be taken into account in *all* scenarios.	**Important scenario drivers** Extremely important and fairly certain. Should be used to differentiate scenarios. Should be based on projections but potential discon-tinuities also should be investigated.	**Critical scenario drivers** Factors and forces essential for success and highly unpredictable. Should be used to differentiate scenario plots and trigger exit strategies.	High
Med	**Important planning issues** Relevant and very predictable. Should be figured into most scenarios.	**Important planning issues** Relevant and somewhat predictable. Should be present in most scenarios.	**Important scenario drivers** Relevant issues that are highly uncertain. Plausible, significant shifts in these forces should be used to differentiate scenario plots.	Med
Low	**Monitorable issues** Related to the decision focus but not critical. Should be compared to projections as scenario is implemented.	**Monitorable issues** Related but not crucial to the decision focus. Should be monitored for unexpected changes.	**Issues to monitor and reassess impact** Highly unpredictable forces that do not have an immediate impact on the decision focus. Should be closely monitored.	Low

Figure 4: Wilson's matrix (Maack, 2001)

2.2.3. Writing full scenario plots

The thesis' author wrote the full-length scenario plots based on the results of the scenario workshop. The basic scenario plots and indicators of change formed the base of the full plots and research on the identified driving forces was used to fill them. All scenarios are composed of a context comprising the end state of urban mobility in 2040, the development path towards this end state and the implications of DORS on public transit demand. After completion, the plots together with the workshop results and scientific backing, were send to each participant for validation of the content. Their reviews were used to improve the work and logic of the author. The next step is to derive implications of the scenarios for the impact of DORS on tram demand and investments. The method used to do so will be elaborated in the next paragraph.

2.3. Scenario implications

As a final step, the impact of DORS on tram demand was evaluated by the author of this thesis for each scenario using the substitution framework developed from the literature study and interviews as a reference point. Elaboration of each factor on current conditions led to an assessment of current impact of DORS on tram demand as illustrated in Table 4. This was done by assessing the operating scale, diffusion of various DORS concepts, competitive relation with the tram, substitution across the network, substitution in time of day/week, and frequency of substitution. Subsequently, it was checked for each criterion what the differences are between the scenarios. This was done in writing and summarised in Table 18. The implications for investment were logically derived from the scenarios, written down and summarised in the same table. Criteria for investment implications were: risk of divestment, risk of revenue loss and the role of MTA. The latter means: where the bulk of MTA investments is allocated to.

Subsequently, the indicators of change derived from the workshop are further elaborated on how and why MTA should monitor them. The scenario specific impact assessment and indicators of change formed the base of the final step of this thesis, which is a discussion on implications of the scenarios for MTAs investment policy in the tram system. In this discussion, the author argued on possible investment policy approaches to address the uncertainty of the scenarios.

3. Understanding substitution from tram to DORS

The aim of this chapter is to understand if and how (disruptive) substitution from tram users to DORS may happen. This is used as background and reference point for the scenario analysis. Both (disruptive) innovation theory and mode shift theory were examined in Appendix B and it was found that factors from the urban environment and innovation attributes may explain substitution. In the scenario analysis key factors were identified as well and compared (paragraph 4.1) with the factors found from literature to come to a complemented list. The factors for substitution and how they relate were put in a framework illustrated in Figure 5. The urban environment is the geographical area in which both tram and DORS operate within Dutch cities and bounds the framework. The innovation attributes are relative to the social system that is subject to adoption of the innovation. This is an individual with certain characteristics, going on a certain trip with certain available resources making a choice between tram and DORS. Both the innovation attributes and the social system are influenced by aspect of the urban environment. These are population composition, land use and availability of other travel modes. Government policy influences the urban environment including all factors related to substitution to some extent.

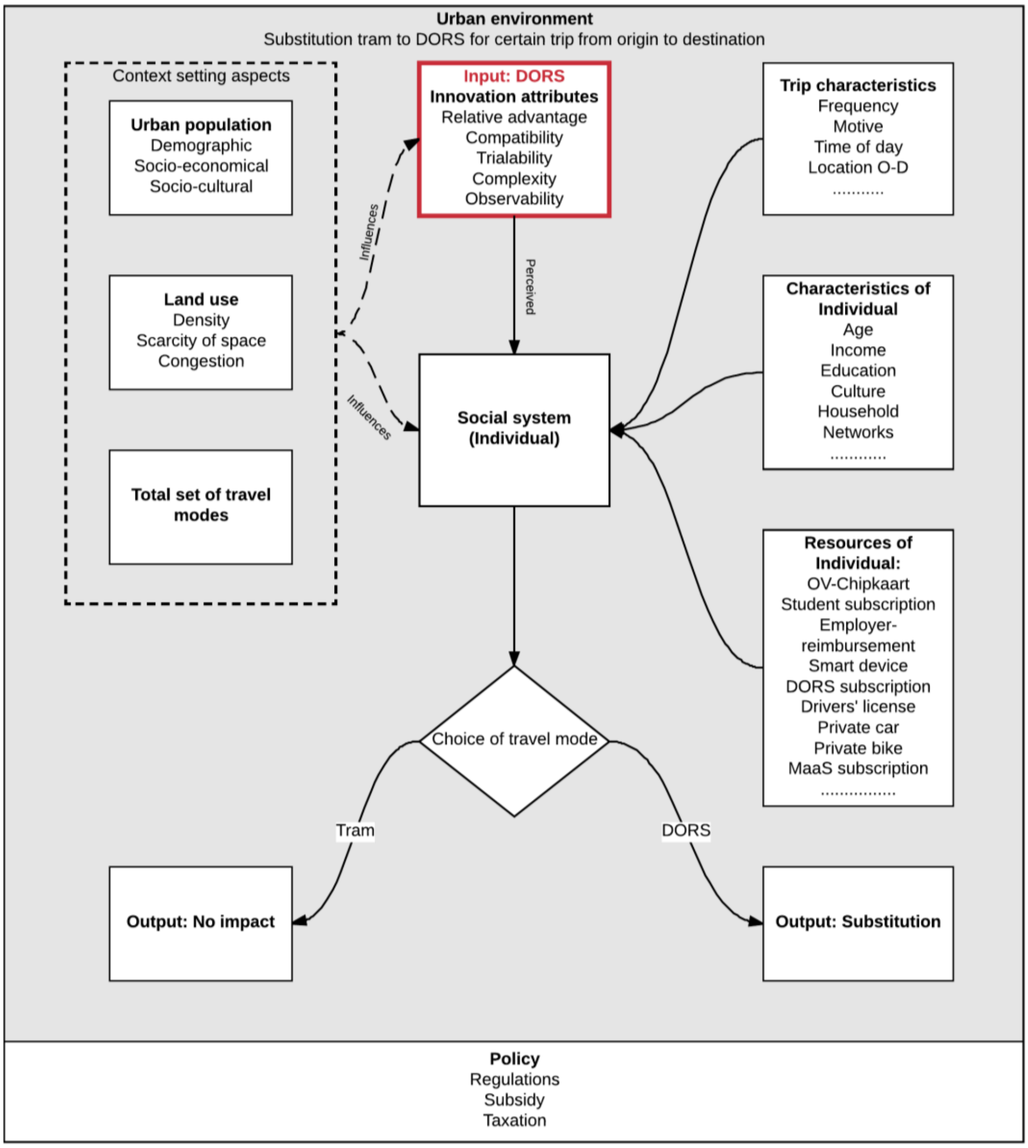

Figure 5: Substitution framework tram to DORS

By elaborating on all components of the framework it was found that the three major cities (M3) Amsterdam, Rotterdam and The Hague constitute the urban environment. Both tram and DORS operate more efficient in high dense districts, but the tram dwarfs DORS in daily usage. Thus, substitution in travel volume is small in the current situation due to the novelty of DORS. If DORS would diffuse further in the M3 the population variations will segment substitution, while scarcity of space, density, congestion, and policy related to this, influence the quality of tram and DORS. Policy is uncertain as no clear standing has been taken by the government considering DORS. Potential growth of other (innovative) travel modes may take share of both systems or help them grow.

Usage of both tram and DORS can be anyone living in a city travelling for any purpose, but they currently serve different markets. Travellers within the M3 may adopt DORS over tram, because it offers more comfort and more convenience when door-to-door and DORS is faster for trips between districts outside the centre. Perceived travel time is also in favour of DORS and when both systems mix with congested traffic DORS has the possibility to deviate its route. Travel costs are far lower for tram however and on a dedicated lane it is faster and more reliable than DORS in case of congestion. High frequency makes the tram more reliable as well for travellers. Further diffusion of DORS may be driven by an emerging need for collaborative consumption, but stalled by the popularity of cycling and materialistic norms. DORS is very easy to use, but may exclude people without smartphones or credit cards. Students and commuters that comprise the majority of tram users may not be inclined to switch if they cannot use their travel privileges for DORS. Observability is a major challenge for DORS, especially when compared to the visibility of the tram system.

The elaboration on the conditions of the urban environment and innovation attributes indicate that DORS and tram currently complement each other as can be seen in Table 4. The small operating scale makes significant substitution across the tram network unlikely. If it occurs it will be concentrated in the evenings and for incidental trips. Therefore, MTA will not have to consider DORS in tram investment policy if this situation sustains. However, it was also found that many factors are subject to uncertainty. Policy has not made up its mind about DORS, while technology may further improve the quality and lower the cost of DORS. Because, tram assets have long technical life times it is necessary to explore uncertainties to be able to answer the central research question of this thesis. This is done with a scenario analysis and the results of which will be elaborated in chapter 4. In paragraph 3.1 the urban environment, related aspects and policy will be further elaborated on current conditions. In paragraph 3.2 the social system and paragraph 3.3 innovation attributes will be studied.

Table 4: current substitution and scenario reference

Substitution	Current situation
Operating scale of DORS	Small
Diffusion of DORS concepts: ride-sourcing, ride-splitting, ride-sharing, microtransit	All four, but mostly ride-sourcing
Competitive relation with the tram	Complements
Substitution from tram to DORS: network	Insignificant
Substitution from tram to DORS: time of day/ week	Evenings
Substitution from tram to DORS: incidental or regular	Incidental

3.1. Urban environment

The operating environment of both systems is summarised in Table 5 and elaborated further in Appendix A. Amsterdam, Rotterdam and The Hague are the cities in the Netherlands with extensive tram systems and DORS operators in their bounds and therefore, the urban environment subject in this thesis. Amsterdam, Rotterdam, and The Hague are the three major cities (M3) of the Netherlands and all have a population of 500,000 – 1,000,000 people. They are the dominant cities within the polycentric city network called Randstad. The M3 are well connected with both public transit and highways and they have a strong magnet function for the surrounding regions, attracting many daily commuters (SER, 2015). Next to a strong interconnectivity between the M3, the cities have well established inner-city infrastructure as well. Furthermore, major cities traditionally house multiple modes for citizens to get from their origin to their destination. The modal split of the M3 can be viewed in appendix C, Figure 16, Figure 17 & Figure 18. Notable are the significant differences between districts within the cities. Biking and walking are overall the most important modes in terms of trips within the M3 and most profound in the centre districts and less in the outer districts. Urban transit usage roughly follows the same path as the slow modes, while car use follows roughly the opposite pattern.

Table 5: Operating environment of tram and DORS in the Netherlands (Appendix A)

	Tram	DORS
Operating cities	Amsterdam, Rotterdam, The Hague, Utrecht	Amsterdam, Rotterdam, The Hague, Eindhoven, Arnhem, Nijmegen
Suitable build environment	High density, mixed use and polycentric city structure	High density and significant city scale
Operating area	Mostly radial set-up of corridors from the outer districts to the centre districts (train station)	Areal coverage of city (districts); first/last mile of transit hubs
Daily usage	150,000 – 250,000 trips (most in centre districts and least at line ends)	Unknown to author, but small compared to tram use (Abel operates with 50 vehicles in 2016)

Both tram and DORS were found to thrive better in highly dense urban areas, although DORS is argued to be exploitable as first/last mile solution in outer districts as well. In the latter case impact on tram demand will be less likely. In these districts, the tram network is less developed and only a small portion of travel volume would be subject to potential substitution. In daily usage, the tram currently dwarfs DORS in the M3. Further elaboration on the operating environment of both tram and DORS can be read in Appendix A.

Within the urban environment the socio demographic composition of the population and land use are considered as aspects of the urban environment influencing mode choice (De Witte, Hollevoet, Dobruszkes, Hubert, & Macharis, 2013; KiM, 2015b). Furthermore, the growth of other (innovative) travel modes can influence substitution from tram to DORS as they may take market share of both and restrict space for DORS to diffuse (KiM, 2016b). Government policy can influence all three aspects named above and arguably travel behaviour itself (Hilbers & Snellen, 2009). These four aspects were studied for their influence on substitution from tram to DORS. All aspects will be further discussed in paragraph 3.1.3 to 3.1.3.

3.1.1. Population:

Age, income, education, cultural origin and other demographic-, socioeconomic-, and sociocultural indicators influence an individual's travel mode preferences. Whether the population influences mode choice or people who prefer a mode tend to live in places where they can use this mode comfortably is up for debate however (Vleugel & Bal, 2016). The major cities are characterized by a relatively large share of 20-40 year olds (millennials) and a multicultural population. About half of the population is foreign of which the majority is of non-western lineage, in the Netherlands overall about 80% is native (OIS Amsterdam, 2016). The demographic build-up of the M3 is not homogeneous throughout the cities as large differences exist between populations of neighbourhoods even in similarly dense urban zones. Because attitudes towards modes are highly individual and can be explained by people's direct environment, resources and living conditions (Geurs, 2014) it is expected that substitution between DORS and tram will be segmented throughout the city districts. Furthermore, the relative importance of demographic-, socioeconomic-, or sociocultural indicators differs across neighbourhoods (KiM, 2015b). Elaborating on what population composition of districts would positively or negatively affect this substitution is complex and would require extensive population research not available to the author. Therefore, it is only acknowledged that substitution degrees will vary among neighbourhoods in the M3, because of differences in age, economic circumstances, and cultural composition of the population.

Households are a relevant aspect as well, they are getting smaller in the Netherlands overall, but more profound in major cities. Families have more affordable space outside the city and single person households have more available activities and friends in the city. Individuals are becoming less part of a traditional community (family, religion, neighbourhood), but maintain various networks instead (Van Dijk, 2012). This phenomenon makes mobility patterns more complex and intensive, because activities are more spread over the city and country, members of households all have their own networks and mobility patterns and trip chaining is more occurring (Nabielek & Hamers, 2015).

3.1.2. Land use/ spatial planning:

Both tram and DORS currently operate in the highly dense centre- and adjacent districts of the M3 (paragraph 3.2.1). High dense districts are often associated with scarcity of space and congestion. Traffic on urban roads is delayed with around 30% on average in the M3 and increasing to 60% during peak-hours (TomTom, 2017). Urban roads cannot easily be widened to expand capacity due to the density of buildings. Especially historic districts were not designed for motorised traffic. Urban streets have to be shared by various and increasing (paragraph 3.1.3) amount of travel modes competing for space. Contemporary policy in the Netherlands is to redirect cars around these districts via large roads to enlarge space for pedestrians, cyclers, and rail transit. Scarcity of space influences the substitution between tram and DORS by the priority both are given respectively. Trams often ride on dedicated lanes and they are well connected to major train stations in the M3. DORS currently shares road space with private cars and are more vulnerable to traffic. For pick-up, drop-off and wait locations they are handled the same as taxis. Changing priority by the government of either tram or DORS would influence the relative advantage of DORS over tram and vice versa for travellers.

Space efficiency is an important argument for governments to grant rail transit priority as it is argued to have a higher corridor capacity than cars. Dings, Kampman, and Janse (2001) state that the corridor capacity of a tramway with a frequency of 30 trams an hour in both directions is about two times higher than the maximum corridor capacity of a road with a typical car occupation of 1.2 person during peak hours. If you would lower the tram frequency to a typical 10-minute schedule however the opposite is true looking at Table 6. Higher occupation rates that could arguably be possible with DORS would increase the people moving capacity of roads. Table 6 however shows an average over an hour, people do not move average and the bulks of people that leave the central train stations in the M3 continuously during peak hours are much easier handled by the tram. Moreover, it is not realistic that all vehicles on a road will be DORS vehicles, thus average occupation rates of 3 or 4 would not be likely for the frequency displayed.

Table 6: Corridor capacity various modes based on (Dings et al., 2001; Koolen, 2006)

	Frequency /h per direction	Frequency /h both directions	Occupation rate	Capacity /h	Space occupation infra in m	Capacity /h /m
Tram dedicated lane 10' schedule	6	12	125	1500	6	250
Tram dedicated lane 7.5' schedule	8	16	125	2000	6	333
Tram dedicated lane Erasmus bridge during peak hours	24	48	125	6000	6	1000
Tram dedicated lane Rokin during peak hours	30	60	125	7500	6	1250
Road 2 lanes normal occupation	1500	3000	1,2	3600	7	514
Road 2 lanes shared vehicle	1500	3000	2	6000	7	857
Road 2 lanes shared vehicle	1500	3000	3	9000	7	1286
Road 2 lanes shared vehicle	1500	3000	4	12000	7	1714
Normal bus dedicated lane 7.5' schedule	8	16	50	400	7	57
Metro dedicated lane 2.5' schedule	24	48	630	15120	8	1890

Urbanisation puts further pressure on urban space and mobility. This trend is forecasted to continue till 2040 for all M3 cities as can be seen in Figure 6. Much of this growth will be within the existing city and close to the centre. As cities have limited space to increase capacity by building more infrastructure, they seek other means to increase capacity. "Smart city" is the catchall concept associated with this. The general notion is to utilise technology and mostly ICT to enable sustainable growth and improve liveability in cities by making more efficient use of existing infrastructure and facilities. This is developed in a bottom-up approach where citizens, businesses and institutions take the initiative and government facilitates, supports, and collaborates (Dameri, 2013). Both the MRA (Amsterdam Smart City, 2017) and the MRDH (THE TIR CONSULTING GROUP LLC, 2016) have programs to encourage smart city initiatives in their respective regions. Whether and in what circumstances DORS, tram or a combination will be perceived as more efficient use of existing space could be an important notion for policy makers in the future.

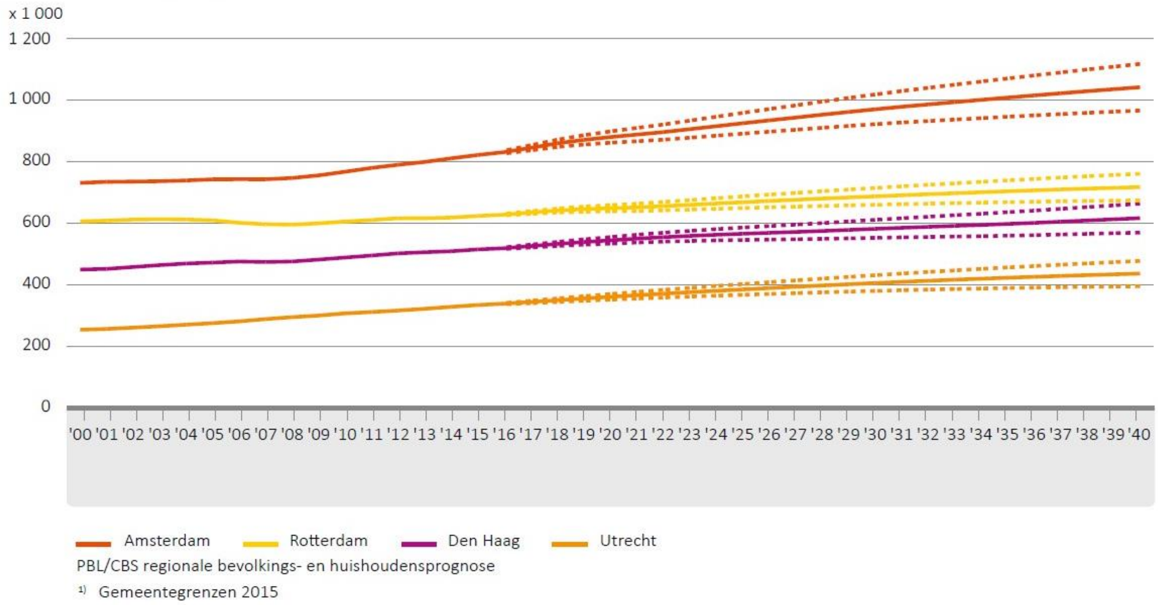

Figure 6: Population growth four largest cities in the Netherlands with 67% forecast interval (Kooiman, Jong, Huisman, Duin, & Stoeldraijer, 2016)

3.1.3. Availability of multiple modes

Many activities in cities can be easily reached on foot, by bike, car and with public transit (De Witte et al., 2013; Vleugel & Bal, 2016). Next to these traditional modes, new private mobility services (Table 7) have entered the playing field in mostly major cities since recent years as earlier described in chapter 1.

Table 7: innovative mobility providers based on (Bouton, Knupfer, Mihov, & Swartz, 2015; Shaheen, 2015)

	Traditional solutions	Innovative mobility services		MaaS platforms
Individual mobility	Private bike ownership	Bike sharing	On-demand short-term bike rentals with the vehicles owned and managed by a fleet operator. OV-fiets	Access to all with personalized subscriptions and travel advice (Whim, Beamrz)
		Bike leasing	Using a bike without hassle of maintenance and it saves you purchase cost. EasyFiets, SwapFiets	
	Private car ownership	Car sharing (peer to peer)	Platform where individuals can rent out their private vehicles when not in use. Snappcar	
		Private lease	Using a car without hassle of maintenance or insurance and it saves you purchase cost	
	Rental Car	Car sharing (fleet operator)	On-demand short-term car rentals with the vehicles owned and managed by a fleet operator. Greenwheels, Car2go	
	Taxi	Ride-sourcing	Ordering a car via on-demand app. App matches rider with driver and handles payment. UberX, Lyft	
Collective mobility	Car pooling	Ride-splitting	Same as ride-sourcing, but allows riders going in the same direction to share the car, thereby “splitting” the fare and lowering the cost. UberPool, Lyft Line, Abel.	
		Ride-sharing	Offers drivers a platform to add passengers to a ride that will already take place and fill seats that would otherwise remain empty. Blablacar, Tooghtr, Beamrz	
	Public transit: Bus, Tram, Metro	Microtransit	Same as ride-splitting, but not door-to-door. Riders are asked to walk short distances to pick up locations to allegedly improve sharing capabilities and vehicle route efficiency. Cheaper than ride-splitting, with the advantage over PT of direct routes and never changing a line. Breng Flex, Via, Chariot, Bridj, Kutsuplus.	

		Private buses	Luxury commuter buses available to employees of selected companies. To free riders from driving to work and allow them to work during commuting time.	

For citizens of the M3 this means more options to get from origin to destination, but many people are still unaware they have these extra options (Bouton et al., 2015). Furthermore, there is limited understanding how customers who have several options might trade off quality aspects of various travel modes (Frei, Hyland, & Mahmassani, 2017). MaaS platforms fill the knowledge gap for consumers by providing them with the travel information for all modes and make switching seamless by enabling access to all with a single subscription (Kamargianni et al., 2016). All in all, the growing number of mobility options in the urban environment means increasing competition for the tram system to attract and maintain customers and for DORS to diffuse. DORS includes the yellow quadrant in Table 7. However, most of the innovative modes are proliferations of the sharing economy (Shaheen & Chan, 2016), just a DORS and their diffusion could strengthen the diffusion of DORS as well (Rogers, 2010).

3.1.4. Policy

The government is the commissioner of public transit and administrates the infrastructure in cities. Multiple government bodies are involved in this and have different responsibilities and interest in urban mobility as can be seen in Table 8. This may result in conflicting interest: e.g. when MTA want to close an underperforming transit line to save operation and maintenance cost, this may be prevented by the municipality that serves the interest of local businesses along the line that are afraid to lose clientele. Furthermore, any expansion of the network requires extra state funding that must be lobbied for. This conflicting interest and the large impact on the environment limit the possibilities to change the public transport network.

Table 8: Responsibility and interest of government bodies

Government body	Responsibility	Interest
State	Funding of public transport operations and infrastructure through BDU: MTA budget for all mobility purposes	Accessible and economically viable major cities; societal beneficial spending of collective funds
Metropolitan transport authority (MTA)	Commissioner of public transport in metropolitan region and asset owner of rail infrastructure; shareholder of TSP	Accessible and economically viable top class metropolitan region; keep operation and maintenance cost within bounds
Municipality	Administrator of public space and urban roads; shareholder of TSP	Serve the interest of city residents and businesses; win elections
Transit service provider (TSP)	Provider of metro, tram and bus transportation under concession of MTA.	Comply with the contractual agreements of the concession and win the next concession.

The concession system of public transit has a large influence on the flexibility of the public transit system as well. Concessions by the MRDH for the tram service in The Hague and Rotterdam are for 10 years and make use of detailed program requirements. In the Netherlands, due to contract legislations, the tram service providers are only allowed to change their schedule once a year (MRDH, 2015b). This gives regular users certainty of service on certain times enabling them to grow a habit and limit search time and effort. On the contrary, this limits the possibilities for learning and improvement of the service providers. With the availability of user data in time and space through the OV-chipkaart system, service providers can effectively monitor the effect that certain alterations in their service has on usage of the system. However, by only being allowed to change once a year they cannot make full use of the available data to customize their service whenever they want to.

In terms of new mobility providers, including DORS the government is still seeking its role. Solutions to provide mobility and improve accessibility in cities are increasingly developed by private parties without government command (MinIenM, 2016b). Such as, smart phone navigation from e.g. Google and TomTom, ride/carsharing concepts and vehicle automation from the automotive and ICT industry. In the Netherlands, the government has recently published two reports from the department of Infrastructure and the Environment with distinctive policy approaches to mobility. “Overstappen naar 2040: Flexibel en slim OV” present a national vision for public transport towards 2040. They anticipate a managing government focusing on a strong collective transit system of bus, tram, and metro in high dense urban regions. Smart mobility- and on-demand mobility solutions are deployed where demand is too low to justify a (existing) collective mobility solution (MinIenM, 2016a).

“Smart Mobility: Bouwen aan nieuw tijdperk op onze wegen” focuses on the rise of ICT and automation in automotive mobility. In this report, they call for a more facilitating and collaborating government instead of managing to give private parties space to further develop and test these innovations in the Netherlands (MinIenM, 2016b). The policy distinction of these reports is not strange as they address two parts of mobility that have mostly separate users on a national scale: namely private individual mobility and public collective mobility. Within major cities these separation is less strong due to congestion, parking policy and better public transport (Bakker, Loop, & Savelberg, 2015). DORS concepts and other innovative mobility concepts alike are a blurring of both, providing private and personalized collective mobility outside the existing concessions. Neither of the two reports acknowledges this blurring and both take position considering DORS from their own perspective only. Whether, DORS will be put in the strict silo called public transit or in the free automotive smart mobility remains to be seen.

3.2. Social system

The social system is an organisation of users by certain characteristics they share (BusinessDictionary, 2017b). In this paragraph characteristics of (potential) tram and DORS usage will be compared to check whether both systems already pool out of the same customer base or if DORS needs to shift its market to have impact on tram demand. Individual characteristics, trip characteristics and resources available to individuals are investigated in this section and summarised in Table 9.

Table 9: use groups, trip characteristics and resources of tram and DORS

Travel mode	Individual characteristics	Trip characteristics	Resources
Tram	Can be anyone	Mostly education/work motive; proximity to tram stop; usage peaks in typical rush hours; 3 km average distance	25% of all BMT kilometres with OV-studentcard; more usage by people without cars
DORS	Can be anyone, but initial target is highly educated millennials	Can be any but mostly social/leisure, in US commuting as well; usage peak in weekend nights; 6-8km average distance (Abel)	Smart phone and bank account; more usage by people without cars

Comparing tram and DORS show that both systems can be used by anyone for any purpose and are more popular among people who do not own cars. Contemporary usage is different however. DORS currently operates in a niche of younger, highly educated users going on social/ leisure trips and the tram is mostly used for work and education related trips. Therefore, when addressing the forthcoming innovation attributes, we need to consider that DORS needs to persuade a broader use group to grow mainstream. The perception of these attributes is a personal matter and will be segmented by different neighbourhoods and social groups. It would be impossible to view the choice between either of the systems from all perspectives, and therefore the matter is approached from a general viewpoint. Thus, the social system is a general individual with certain characteristics, on a certain trip with certain available resources. Specific characteristics of usage are related to the innovation attributes if appropriate. For example, the cost comparison is related to the average distance of tram and DORS trips.

3.2.1. Individual characteristics

According to both Anonymous Interviewee (2016) and Interviewee HTM (2016) users of the tram can basically be anyone living in or visiting the city in which the tram system is operating. Statistics of transit usage in Amsterdam show that usage of public transit is highly heterogeneous, but has a higher share amongst lower incomes and younger people (12-30) (OIS Amsterdam, 2015). Similar statistics can be viewed in Rotterdam and The Hague (OBI, 2015). Lower incomes are more stimulated by the price of transport in their mobility decisions and have less access to cars, which drives them more towards transit (De Witte et al., 2013). In absolute terms however, usage of public transit is higher amongst higher incomes, because they are more mobile than lower incomes (Bakker & Zwaneveld, 2009). Higher usage of transit amongst younger people is related to less car ownership as well.

A few studies have been conducted to user groups of DORS (Circella, 2017; Kooti et al., 2017; Murphy, 2016; Rayle et al., 2014; Rissanen, 2016) and they show a various public, although the younger, highly educated user group is significantly higher than you would expect from the environment. Interviewee KiM (2016a) and Interviewee Transdev (2016) argue that these millennials are the initial target group, but DORS is suitable for anyone.

3.2.2. Trip characteristics

According to Bakker and Zwaneveld (2009) education and work combined count for 63% of bus, tram and metro trips in the Netherlands, while other travel modes have more differentiated motives and a far higher share for social/leisure. Figures of tram usage in Rotterdam (appendix C, Figure 21) show even higher shares for commuting to work (42%) and education (35%). In Amsterdam and less strongly in The Hague, touristic trips are an important purpose for the tram as well (Interviewee HTM, 2016). Anonymous Interviewee (2016) however argues that the situation is more important to consider the tram than the trip purpose of an individual. The tram has fixed lines and only when both origin and destination are near a tram stop, people consider using the tram. The high share of education/ work may explain the usage peaks. These are a sharp morning peak and a broad evening peak (appendix C, Figure 19). The average trip with a tram, ranges between 2-4 km (appendix C, Figure 15).

Usage of DORS is mostly concentrated in social/ leisure trips during evenings. Feigon and Murphy (2016) of the SUMC argues that usage of ride-sourcing currently peaks on weekend nights when transit less viable. Usage of Abel follows a similar pattern with weekend night peaks and flat use during weekdays (Interviewee Transdev, 2016). However, Frei et al. (2017) argues that in America where DORS has been proliferating longer it is broadly used for commuter trips as well and Interviewee KiM (2016a) states that DORS may be used for any purpose. Interviewee Transdev (2016) states that average trips of Abel are around 6-8km, which corresponds with the roughly 5 mile found by (Rayle, Dai, Chan, Cervero, & Shaheen, 2016). Kooti et al. (2017) argues that 50% of 49M trips made with Uber in the US were shorter than 4 miles.

3.2.3. Available resources

Furthermore, available resources matter as well. Litman (2004) argues that subscriptions and employer reimbursement lower the need to switch, because prices of services that are not included are perceived higher. In the Netherlands students can travel for free or with discount with public transit during weekdays or weekends (Rijksoverheid, 2017) and employees can often reimburse cost of transit by their employer. According to Bakker and Zwaneveld (2009) around 25% of kilometres travelled with bus, tram and metro are made by owner of an OV-studentcard and 50% by people who do not own a car. To use DORS an individual usually needs a smartphone, access to internet and a bank account (Westervelt, Schank, & Huang, 2017). Currently only Breng Flex can be used with an OV-chipkaart since it is commissioned by the local transport authority (Stroecken, 2017). In a study by (Rayle et al., 2016) 43% of ride-sourcing users did not own a car against 19% for the population of San Francisco.

3.3. Innovation attributes DORS relative to tram

Now that it is clear in what environment tram and DORS operate, the next step is to get an understanding to what extend and with what motives users may adopt DORS over the tram system. This is done by elaborating the five innovation attributes defined by (Rogers, 2010). These are relative advantage, compatibility, complexity, trialability and observability as perceived by the social system defined in paragraph 3.2.

3.3.1. Relative advantage

“Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes” (Rogers, 2010). It can be expressed in various ways, such as economic profitability or social status. This is mostly determined by the nature of the innovation, but to some degree also by the characteristics of potential adopters. The latter determines which indicators of relative advantage are more important. The innovation DORS is of digital nature matching supply of vehicles/ seats and trip demand in real time.

Sectors where digitalization occurs, cost tend to decrease, while convenience and choice increase. Thus, it is expected DORS will have an advantage in these factors. Looking at literature and interviews show a similar view as can be seen in Table 10. Most advantages found can be considered economic factors instead of emotional factors. However, because the social system is very divers and the relative importance of economic versus social factors can therefore be expected to be segmented we examine both. As economic factors cost, time (perceived), convenience, reliability and comfort will be considered. For the social emotional component we relate to perception and status. Below we will research these factors and how they may translate in a relative advantage of DORS over tram and vice versa.

Table 10: relative advantage DORS over tram

Source	Type	Mode	Relative advantage DORS over tram/ transit
Bakker, 2016	Interview	DORS	Door-to-door, no line change, more comfort against lower price
Tillema, 2016	Interview	DORS	Door-to-door, speed, reliability, more comfort, no line change against lower price
Krumm, 2016	Interview	Ride-splitting (Abel)	Door-to-door, information provision, more convenient, more comfort against lower price
(Rayle et al., 2016)	Journal article	Ride-sourcing	Speed, less waiting time
(Salanova, Estrada, Aifadopoulou, & Mitsakis, 2011)	Journal article	Taxi	Speed, door-to-door, comfort, privacy
(Oerle, 2016)	Magazine article	Ride-splitting (Abel)	Door-to-door, social interaction
(Stroecken, 2017)	Magazine article	Microtransit (Breng Flex)	Speed, no line change

3.3.1.1. Cost

Travel cost play a role in mode choice as consumers are sensitive to changes in price. The degree of this sensitivity depends on several factors, such as user type and trip purpose. Transit dependent riders and commute trips are usually less sensitive, than choice riders and non-commuter trips respectively (Litman, 2004). The fare price differentiation of tram, DORS and taxi are compared in Table 11 and price set against distance is set in Figure 7.

Table 11: fare cost differentiation tram and DORS

Service provider	Base fee in €	Kilometre fee in €	Minute fee in €	Minimum fee in €
Tram (RET, 2016)	0.89	0.137	-	-
UberX (Uber, 2016)*	1.00	1.10	0.25	5.00
Abel (Ecomobiel, 2016)	2.50	1.00 – 2.00	-	-
Breng Flex (Stroecken, 2016)	3.50	-	-	-
Regular Taxi (RTC, 2017)	2.85	2.10	0.35	-

(* Uber handles surge prices when pick-up time is high e.g. 2x initial fare price)

From Table 11 can be observed that DORS providers operate for a price between a regular taxi and public transit and have various business models. The advantage of the UberX business model is that it can balance the supply and demand on peak hours and therefore remain available for users. Schaller (1999) showed that the availability of service increases, when the fare price increases. Uber enables this model by employing only freelance drivers whom can work whenever they want and are therefore drawn to the busier hours. Interviewee KiM (2016a) argues that the downside is that the dynamic fare price may cost customers as they are uncertain of what price they can expect. Abel and Breng Flex have a more favourable business model in these terms, as they offer a flat fare price no matter how busy it is. This can be a problem when demand is high as they may be unable to serve all customers in a reasonable time. This might cost customers as they are uncertain if they can get a service.

What can be observed from Figure 7 is that transit is far cheaper than any DORS mode and the difference increases with the distance. The average trip length of a tram ride is about 3km in a Dutch city (appendix B, Figure 15). For this distance DORS cost only a few euro's more than taking a tram. Whether people may find spending this extra euros for a trip worthwhile will be examined by elaborating on the other quality factors. Another observation that stands out is that taking an UberX with a group of four people costs only slightly more than a tram per person.

The above comparison is made for the contemporary situation and prices may change in the future. In the United States, Uber is experimenting with flat fares and subscription packages. They offer unlimited weekday use for $200 a month (less than subway subscription) for UberPool in Manhattan (Solomon, 2016a) and $20 to $40 subscription packages offering 20 to 40 $3 flat rate trips for UberPool in San Francisco during peak hours. Because drivers are paid for a regular fare price, it seems these offers are more part of an aggressive expansion strategy of Uber and not durable according to Solomon (2016b). Drivers make up the greater part of the exploitation cost of DORS and limit the minimum fare price if they want to earn a decent living. If demand and match efficiency would increase, fare prices may become lower, because more paying people can be moved in a vehicle hour. According to Interviewee Transdev (2016) Abel needs an occupancy rate of two per vehicle hour to operate cost neutral, while Interviewee KiM (2016a) states that six door-to-door ride share trips are the maximum to be feasible in an hour with four being more realistic. It is unlikely however that DORS can reach the price level of transit, unless the driver is eliminated and vehicles drive automatic Interviewee KiM (2016b) or if subsidies would be restrained. The development of automatic vehicles will be handled in chapter 4.4.8.

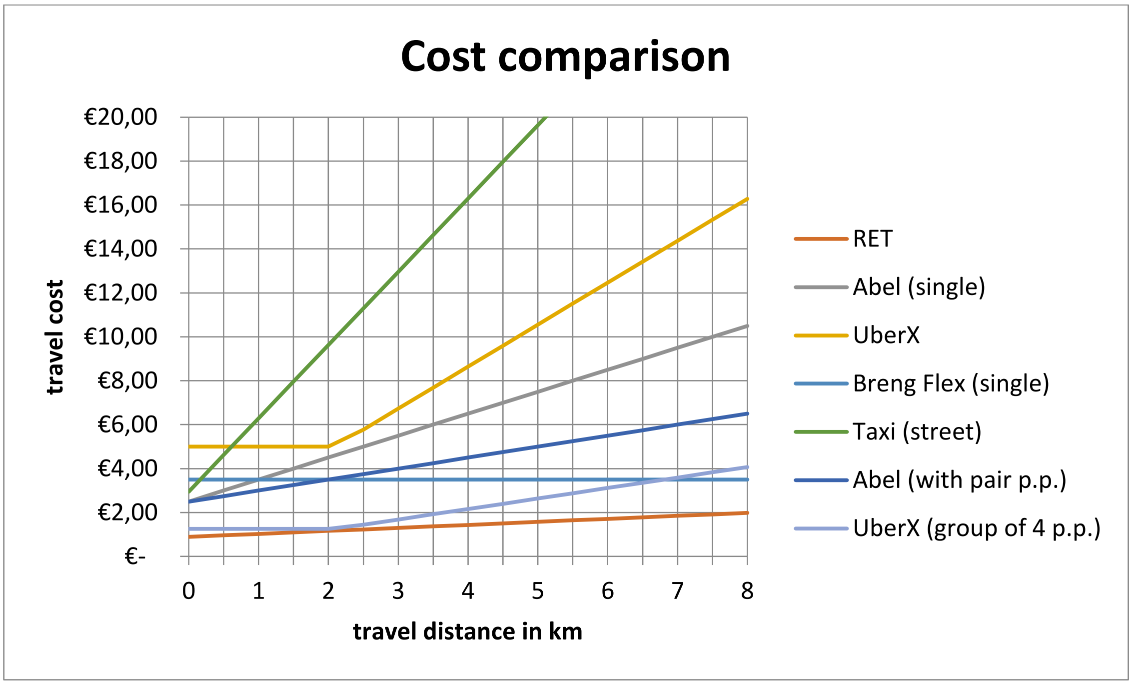

Figure 7: cost comparison DORS and transit with an average speed of 18.5km/h for Uber and Taxi

3.3.1.2. *Travel time (perceived)*

The time component is an important factor for mode choice and may be valued differently depending of the travel motive (De Witte et al., 2013). According to KiM (2016b) perceived travel time can even be considered the most significant mode choice factor. Travel time depends on the distance covered and the average speed and is usually measured from door to door. For this door to door trip the time spend out of the vehicle is considered more important for mode choice than the time within the vehicle (Bakker & Zwaneveld, 2009; De Witte et al., 2013). Trips with tram or DORS require a set of typical steps to complete the door to door journey, which is summed up in Table 12. In this table, all steps are considered from the moment a traveller considers taking either of the modes. The time needed for all these steps are situational, depending on the location of the origin and destination, physical health of the traveller and congestion amongst other things.

Table 12: Travel time components for a trip from a certain origin to destination

Tram (direct)	Tram (indirect)	Microtransit	Ride-splitting	Ride-sourcing
Search time	Search time	Order time	Order time	Order time
Origin wait time*	Origin wait time*	Origin wait time*	Origin wait time**	Origin wait time**
Access time	Access time	Access time		
Waiting time transfer	Waiting time transfer	Waiting time transfer		
Vehicle ride time	Vehicle ride time	Vehicle ride time incl. detour	Vehicle ride time incl. detour	Vehicle ride time
Egress time	Line change time	Egress time		
	Vehicle ride time			
	Egress time			

(*wait time at the origin before moving towards the stop to minimize waiting time at the stop. ** wait time at the origin before the vehicle picks the passenger up at the origin.)

Feigon and Murphy (2016) mapped estimated travel time from a single origin point in the centre of the city to each point in the city with a grid of 0.5 mile for 5pm and 12am (Appendix B, Figure 13). They found that during peak hours transit is the faster option or is roughly equivalent to ride-sourcing, because of road congestion. At 12am congestion is less of a problem and the travel time advantage of transit is more contained. Another study in Chicago by Schwieterman and Pelon (2017) comparing travel times of 2-6 mile trip with public transit and UberPool show that using UberPool does not save time for trips to and from the central business district and therefore transit users would not be inclined to switch. However, for trips originating in outer districts and those linking outer districts time savings of using UberPool increased to 10 and 20 minutes respectively. Considering these two studies it can be expected that travel time between DORS and direct tram trips depend on congestion, while for indirect tram trips using DORS will save time. This was expected by Bakker in an interview with the author as well and users of Breng Flex a microtransit service in the region of Arnhem-Nijmegen named timesaving due to preventing a line change as the main advantage of the service (Stroecken, 2017).

Table 13: expected perceived travel time improvements of DORS compared to traditional transit (KiM, 2016b).

DORS concepts	Actual access and egress time	Actual ride time	Actual wait time	Perceived extra access and egress time	Perceived extra wait time	Perceived extra time due to line change	Perceived extra time due to searching	Perceived extra time due to experience of main journey
Ride-sourcing	■		■	■	■	■	■	
Ride-splitting	■		■	■	■	■	■	
Microtransit			■		■	■		

Travel time is not solely a rational measure as people perceive time differently in different circumstances. According to KiM (2016b) people perceive time for searching, access and egress, waiting, line change and the experience of the main journey longer than the actual time, because they take effort. KiM (2016b) made a comparison between transport innovations and traditional transit on these terms. They found that on-demand services would reduce perceived travel time with 10-40% if door-to-door and 5-10% in the case of microtransit. In Table 13 the perceived travel time indicators that explain the above scores in which DORS may have the advantage over transit can be viewed.

3.3.1.3. Convenience

This factor relates to the perceived effort someone must go through to get to the destination with a certain mode in certain circumstances. This is again relative to the purpose of the trip and very personal (van Hagen & Bron, 2013). Using the tram is completely different from DORS in this regard. The tram rides on fixed lines on fixed times and a traveller can use it if it helps him to get where he wants to, while DORS is an on-demand service.

Transit and the tram included, is more convenient for any traveller that has its origin and destination close to a stop on a single frequent line (Interviewee KiM, 2016a). DORS would not have added value for travellers in these cases he argues. The main inconveniences of using a tram are waiting, access and egress and changing a line, which would be limited in this case. The radial set up of the tram network makes it inconvenient to change tram lines, because it would require a large detour and according to Anonymous Interviewee (2016) people barely change lines or modes when taking the tram. Thus, for DORS to lure tram users out of convenience they need to reduce effort of waiting and access and egress.

According to data acquired by Frei et al. (2017) the disutility of waiting for DORS was perceived half of the disutility of in-vehicle time, while for transit waiting at a stop is perceived 2-3 times longer than in-vehicle time. Thus, waiting at the point of origin is a highly desirable feature of DORS over tram. Not having to access and egress can also be perceived as an advantage of DORS, while having to order the service is a disadvantage. Interviewee KiM (2016a) argues that ordering is in the nature of the innovation and even if it is very easy it may still be perceived as more hassle than simply walking to a tram stop out of habit. Microtransit combines ordering and requires access and egress and thus inherently waiting outside as well. Thus, using this mode would probably not be perceived as more convenient than using the tram by travellers except for trips that require a line change. Ride-sourcing and ride-splitting are door-to-door and can thus be perceived more convenient.

3.3.1.4. Reliability

According to van Hagen and Bron (2013) this determinant for mode choice is related to the trust a customer has the required service is what they expect it to be in a specific situation. Reliability is more important if your travel motive is must compared to lust. The main expressions of reliability are excessive waiting times due to late arrival, and lengthy in-vehicle times, due to traffic or system problems according to Paulley et al. (2006) with the first being more important than the latter for mode choice (De Witte et al., 2013).

For the tram the uncertainty of excessive waiting times is mitigated by a high frequency and good information provision (Interviewee HTM, 2016). A high frequency gives a maximum waiting time on arrival and therefore brings certainty to customers if this maximum waiting time is within their bounds (Anonymous Interviewee, 2016). Good information provision helps because, people are more interested in when the tram actually goes than they are in when it is supposed to go. Real time information provision of the expected arrival time gives travellers the perception of reliability even if the service is not punctual (Interviewee HTM, 2016). This information provision is common practice for DORS providers. The real-time position of available vehicles and estimated pick-up time is transparent for users in the mobile application. When the service is ordered the app shows the route of the approaching vehicle and the driver profile. Driver and rider can contact each other directly via the app if needed (Rayle et al., 2016). Furthermore, the surge pricing of Uber helps maintains the pick-up time of passengers on a stable level, thus increasing reliability of service. However the cost component becomes less reliable (Interviewee KiM, 2016a).

Lengthy in-vehicle times are related to the punctuality of the tram which depends on the degree it mixes with traffic. Trams on dedicated lanes can largely pass by traffic and are therefore a more reliable product for travellers than DORS that must share road space. According to Anonymous Interviewee (2016) trams on dedicated lanes attract more commute travellers for that reason. For trams that mingle with traffic this advantage over DORS disappears. DORS may even have the advantage as it can redirect its route around congested corridors what the tram inherently cannot. Rissanen (2016) states that the Algorithms' ability to monitor traffic throughout the city in real-time to find the optimal route for drivers and provide reliable information to riders of estimated arrival time, pick-up time, and cost is essential. Interviewee Transdev (2016) states that services such as Abel's flexibility and ability to continuously collect data via the mobile applications help it to further improve its reliability. Vehicles can move towards areas of high demand and DORS can anticipate on demand peaks by using historic data to forecast them in space and time. Overall the tram is more reliable, but technological progress of DORS and investment in increasing frequency and information provision of tram could change this in the future.

3.3.1.5. Comfort

Comfort is not a reason to deny a mode, but can be a reason to favour a mode (van Hagen & Bron, 2013). Comfort is not necessary to make the trip, but makes it more joyful. Additionally, comfort influences the perceived travel time of individuals. A highly comfortable journey may make time feel shorter than reality and the opposite is true as well. The difficulty in improving comfort levels of modes is that everyone perceives comfort differently (Bakker, Derriks, & Savelberg, 2011).

The tram has become more comfortable since recent years, with more space to leave luggage and groceries, and platform level floors to ease boarding (Anonymous Interviewee, 2016). According to Frei et al. (2017) these features help transit to become more attractive for a broader use group. Because the tram is a mass transport mode with a fixed network and various user types it cannot comfort everyone's preference. Elderly e.g. may prefer a fine grained network to limit walking distances, while commuters do not mind to walk a little further to a stop if it makes the overall trip faster (Interviewee HTM, 2016). Furthermore, the long technical life time of 30 years limits the adaptation possibilities to changing user needs in terms of comfort. DORS on the contrary is a highly customisable service as users choose their desired service level and pay accordingly. Enjoying the privacy of your own vehicle or walk to the corner of the street to catch a shared ride for lower cost is all possible (Schwieterman & Pelon, 2017).

Punctuality discussed in paragraph 3.3.2.4, influences comfort of the tram (Interviewee HTM, 2016). If a tram is late and rides just in front of the next one, the likely result is one full tram with relatively low comfort levels (people standing) and one empty tram with relatively high comfort levels. The tram cannot easily adjust to unexpected supply or demand variations and therefore tram riders cannot expect to have a seat every time they use it. DORS guarantees users a seat and provides direct and (near) door-to-door transportation, qualities a tram cannot offer. Furthermore, the ride matching system enables both rider and driver to see and rate each other's profile. Additionally, rider and driver can contact one another through the mobile application which may be comfort enhancing (Rayle et al., 2016). The sharing component of DORS can either boost comfort or lower it. People can either enjoy the social component of meeting strange people during a ride or find it uncomfortable. When asking Interviewee Transdev (2016), whether the latter case stops people from using Abel he argues that the low price weighs more and people take the chance of having to share the ride. Thus DORS has the upper hand in terms of comfort, but prices are higher as well. To what extend tram riders find extra comfort worth a few extra euro's remains to be seen.

3.3.1.6. Social emotional component

Relates to the preference and attitudes an individual has to a certain mode, based on his own history, values, norms and environment (De Witte et al., 2013). Bakker et al. (2011) argues that rationally speaking an individual uses or continues to use a mode if it is beneficial to him or her. This implies that the traveller should make a trade off if DORS or tram or any other mode is the right choice for the anticipated trip. To make this choice the traveller needs information, which has to be available and findable. This is a hassle for people and in practice people tend to make choices based on their perception of modes and developed habits. This perception is often bases on incomplete information and differs among people. Travellers with an OV-studentcard or who have their commuting cost reimbursed by their employer have a different perception to the cost/benefit ratio of DORS than those that do not have these resources (Bakker et al., 2011). Furthermore, people that take the tram out of habit will not be inclined to change to DORS, unless DORS serves a need the tram cannot serve that would make them change their habit (Paap & Katz, 2004).

In terms of perception, public transit does not have a good name. It is perceived far more often negatively than cars or bikes especially amongst non-users. They associate public transit with delays and waste of time. Regular and incidental users are more positive towards public transit. An important notion in the comparison with car and bike is that transit has no ownership value and therefore, users are not inclined to justify their ownership. The reason that car captives are more negative towards public transit is because they maintain higher standards towards it. They can be more demanding than non-car owners because they have a good alternative (Bakker et al., 2011).

Like the tram DORS has no ownership value as well, therefore this dimension is not relevant for substitution. Important for the perception of DORS is the category in which you place them. Uber e.g. claims it is an ICT company that enables drivers and riders to match via a platform under the wings of the sharing economy , while others perceive them as a taxi company that tries to bend the rules (Fung, 2017). The reputation of taxi's in Amsterdam is even worse than public transit (Gemeente Amsterdam, 2017), thus in the latter case DORS will have to overcome this paradigm. When perceived as an innovative ICT company it may be adopted more profound by people that enjoy using on-demand services enabled by mobile application technology (Dias et al., 2017). Overall, perception will be a factor in substitution between DORS and tram, but at this point in time it cannot be said what influence it has.

3.3.2. Compatibility

"Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (Rogers, 2010). Often innovations are not viewed singular in this regard. People tend to view them as interrelated bundles of new ideas. DORS concepts are often named under the wing of the ICT enabled sharing economy and access economy, while in the transport world mobility as a service is often related to DORS. The adoption of one innovation within these clusters may trigger the adoption of several others.

3.3.2.1. Previously introduced ideas

An innovation's compatibility with preceding ideas can either boost or slow its rate of adoption. Individuals use old ideas as mental tools to assess new ideas, because they can only deal with an innovation on the basis of the familiar (Rogers, 2010). Acquiring mobility on-demand via a mobile application is different from the operationally driven public transit system, but the concept is not new. Taxis, paratransit and demand responsive transit have been around for many years and DORS only differs from these services by the use of a mobile app for requesting rides and the possibility to share rides (Westervelt et al., 2017). Moreover, on-demand services have been around longer in other sectors, such as music and movies. This compatibility with existing services may help users to get acquainted with DORS.

For MTA compatibility with previous ideas is relevant as well, because they can utilise DORS in their city. They may be tempted to view DORS as a substitute for empty busses and deploy it in a restricted low demand area because that is compatible with the existing idea of public transport. DORS has its main consumer advantage in offering direct, multidirectional door-to-door transportation independent of the location of the user as was argued in paragraph 3.3.1. The latter is also an operating advantage, because it can move towards demand. Implementing DORS only in a restricted area of low demand may impede its attractiveness and was one of the main reasons why Bridj failed in Kansas city (TransitCenter, 2017).

3.3.2.2. Client needs

This relates to the degree an innovation is compatible with a felt need by potential adopters (Rogers, 2010). The most obvious need that DORS serves is door-to-door transportation. Furthermore, consumers can avoid the purchase of a car, while saving cost at the same time by using DORS instead (sharing economy and related economies).

Considering door-to-door transportation, there are three established travel modes in Dutch cities: taxi, car, and bike. DORS is far cheaper than a taxi (paragraph 3.3.1.1) and the main reason for private car owners to use DORS instead is when going for a drink and to save parking cost and hassle according to Henao (2017). Biking is the main mode of travel in Dutch cities however and a major reason the share of public transit in the modal split is relatively small. By biking people get directly to their destination instead of having to access and egress or change lines on public transit (Interviewee KiM, 2016a). DORS has the same advantage over transit, but against a far larger price than biking. However for longer distances and bad weather conditions it may be an attractive replacement (Verlaan, 2016). Thus, it is reasonable to say that the popularity of biking in Dutch cities may limit the need for DORS as a door-to-door travel mode, while DORS has benefits over taxi and car in Dutch cities.

Ride-sourcing, ride-splitting, ride-sharing and microtransit are often related to the evolving sharing economy in both literature and popular press (Shaheen & Chan, 2016). Frenken (2016) describes the sharing economy as the occurrence that consumers allow one another to use their unutilised goods, with or without payment. The sharing economy has a strong relation with three other variants of economy illustrated in Figure 8. The second-hand economy is the occurrence of consumers selling goods to each other (Marktplaats.nl). The product-service economy is the occurrence of consumers renting business owned products (Car2Go). The on-demand economy is the occurrence of consumers requesting a service of a freelancer via an on-demand platform (UberX). DORS concepts do not fall into one of the economies in Figure 8, but can be considered hybrids that allow consumers to choose. UberPool's matching of freelance drivers with consumers can be considered as the on-demand economy, while the pooling passengers that share otherwise unutilised seats is called the sharing economy (Frenken, 2017). Abel and Breng flex are hybrids of the product-service and sharing economy. They offer pooling as well, but operate with a business owned fleet.

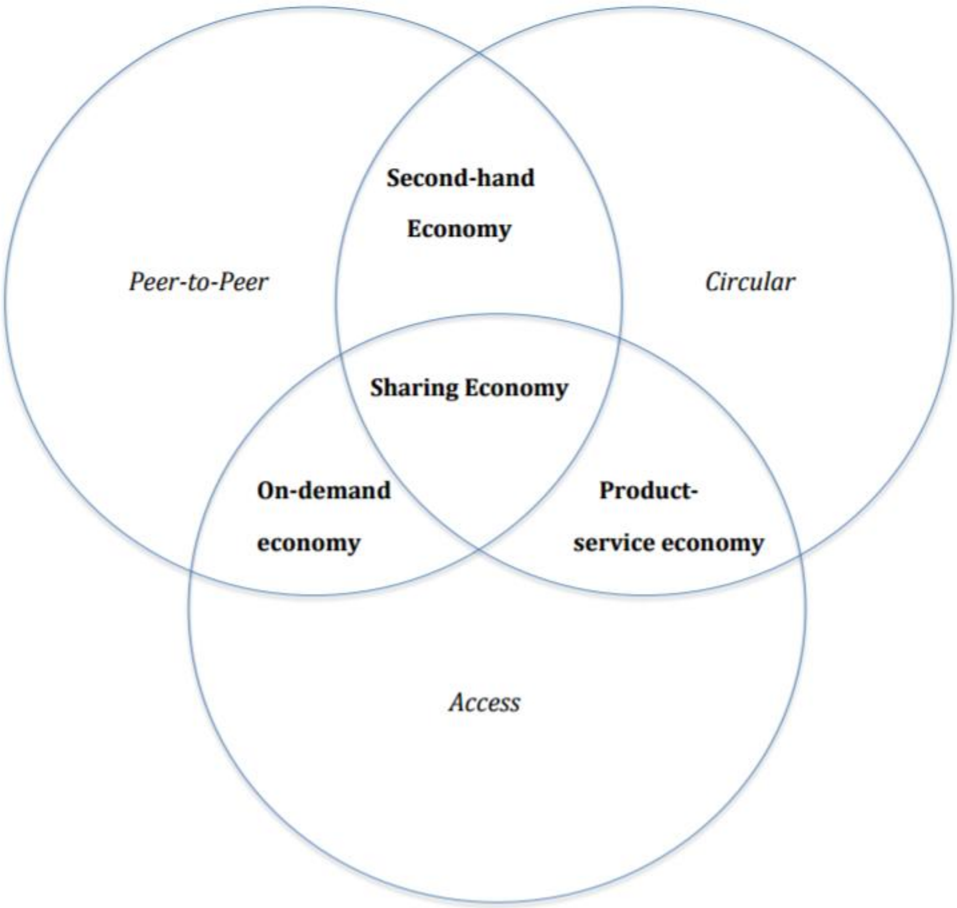

Figure 8: Sharing economy and related types of economy (Frenken, 2017)

Frenken (2017) argues that all four economies in Figure 8 can be considered a subset of what is called collaborative consumption. The need all four provide to consumers is to avoid the purchase of a first-hand consumption good, while saving cost at the same time. This allegedly reduces the total number of goods needed in the economy without giving up on consumer welfare. This implies that the purchase of a private car can be avoided by using DORS, car-sharing and other car access services. An external effect of this is saving of space, as less cars means less needed parking spots that may be rezoned for a different purpose. Moda Living a real estate developer in the United Kingdom recently announced they are offering residents to substitute there parking space for monthly Uber credits. The liberated space will be used to build a fitness or media room offering more value for residents while not impeding their mobility according to (Moda living, 2017).

The growth of the sharing economy is related to three characteristics: companies utilise unutilised supply instead of having to produce supply, sharing saves money for both owner and renter and sharing is self-enhancing. The more people participate on a platform, the more known it gets and the better the product, because choice and proximity of access increase (Frenken, 2016). These characteristics enable fast expansion of services, but also show the need for a critical mass of users and providers that are sufficiently close to each other or other amenities to make sharing platforms work. This makes the urban environment perfect to nourish growth of these sharing companies, including DORS as cities offer scale, density, proximity, amenities and spill over of assets that the sharing economy can leverage (Davidson & Infranca, 2016).

3.3.2.3. Cultural values and beliefs

If an innovation is incompatible with cultural values in the resident country its adoption can be blocked (Rogers, 2010). According to (Barnes & Mattsson, 2016; Piscicelli, Cooper, & Fisher, 2015) a main inhibitor of the sharing economy is materialist cultural norms. Access over ownership is still very hard to except for people who like to own their own cars and other things. Ownership has been the norm for decades and learned cultural values can be deep rooted. According to Vleugel and Bal (2016) there is no consensus if the recent decrease in car ownership among millennials in the Netherlands will sustain. DORS can still diffuse if ownership remains the norm, but car captives will be less likely attracted.

3.3.3. Complexity

“Complexity is the degree to which an innovation is perceived as relatively difficult to understand and to use” (Rogers, 2010). DORS is enabled by ICT technology and can be ordered easily via a mobile application or webpage in real-time no matter where the traveller is in the service area. Ordering a vehicle takes only a few pushes of a button and a user can compare and choose different service levels. Contact information is automatically shared between rider and driver and payment is automated and calculated through GPS. After ordering, a user can see the vehicle approaching and view the expected time of its arrival. In the case of ride-sourcing and ride-splitting a user only needs to get outside of its origin location at the designated time, step into the vehicle and get out at the destination (Rayle et al., 2016). In the case of microtransit a pick-up location needs to be chosen and the app will tell a user when it is time to leave the origin location towards the stop and what directions to take (Rissanen, 2016; Shaheen & Chan, 2016). An overview of the journey made and the calculated cost is visible through the app and the experience of the ride can be reviewed by both driver and rider (Rayle et al., 2016).

The digital nature of DORS enables it to improve the ordering process progressively. According to Interviewee Transdev (2016) data can be collected of people’s behaviour on the application. It can be tracked when people decline a ride and people can easily be asked what they would like as a convenient new feature of the application. Pre-ordering, repeated ordering and synchronisation with a user's agenda are currently piloted by service providers to get people where and when they want to be with little hassle. Therefore, it can be expected that ease of use of DORS will only improve in the future.

3.3.4. Trialability

"Trailability is the degree to which an innovation may be experimented with on a limited basis" (Rogers, 2010). To use DORS an individual usually needs a smartphone, access to internet and a bank account (Westervelt et al., 2017). For those that do, mobile phone apps of DORS providers can be installed and deleted without purchase costs or conditions. This is the case for both riders and drivers. However, digitalization has brought a new form of inequality: the digital divide (Deursen & Dijk, 2011) as not everyone has access to a smart phone or knows how to order mobility with them. According to (Deloitte, 2016) about 87% of the Dutch population (age 18-75) had ready access to a smartphone in 2016. Among the more elderly (55+) an important use group of the tram this was slightly over 75% and this group uses a smartphone the least of all age groups as well. The requirement for owning a smartphone and a credit card could be a barrier to access for low-income individuals as well (Hughes & MacKenzie, 2016). Furthermore, the prerequisite of having a credit card to use Abel was a hurdle for many people to install the app and therefore they included Ideal as well (Interviewee Transdev, 2016). Thus, the required resources can limit the trialability of DORS, but solutions can be found by expanding ordering options.

3.3.5. Observability

"Observability is the degree to which the results of an innovation are visible to others" (Rogers, 2010). According to Barnes and Mattsson (2016) lack of awareness is the main inhibitor for collaborative consumption and (Interviewee Transdev, 2016) names awareness the major challenge for diffusion of Abel in Amsterdam. Where the tram is highly visible and even part of the build environment even if you do not see one riding (Anonymous Interviewee, 2016), DORS is less observable. All vehicles can potentially be used for DORS and they cannot be easily distinguished from a regular taxi. Marketing and new features to address a broader use group help to improve awareness (Interviewee Transdev, 2016). Recent development is the possibility to book Uber and other taxi services using the Google maps mobile application a widely used trip planner (Pals, 2017). This may increase the observability of Uber as a travel mode option for individuals searching transit schedules.

4. Results scenario analysis

In the previous chapter a framework was made of factors that may explain substitution from tram to DORS. By elaborating these for the current situation it was found that substitution is insignificant. Uncertainty surrounds these indicators however and since tram assets have a technical lifetime of up to 30 years in case of the vehicles an exploration of future impact is needed to answer the central research question. Therefore, a scenario analysis was conducted using the intuitive logics method. The methodology can be read in paragraph 2.2 and this chapter continues with the results of the scenario analysis. Four main results will be discussed in this chapter: first the identified key factors and driving forces, second the scoring of the driving forces on impact and uncertainty, third the differentiation of the scenario plots and finally the full scenario plots will be elaborated.

4.1. Key factors and driving forces

The key factors and driving forces that were identified during the workshop by the experts can be viewed in Table 14 and Table 15 respectively. The author of this thesis identified key factors as well and because they were not handed to the experts prior to the workshop to prevent bias, a comparison was made in this paragraph. Goal was to explain differences and to get a complete list to be used for chapter 3, the scenarios and its implications. The driving forces determine the direction and value of the key factors and will be used to differentiate the scenarios. They will be elaborated on in paragraph 4.3 to 4.5.

In Table 14 the key factors found by the expert panel have been related to the factors in the substitution framework of Figure 5 in chapter 3. In general, the factors found by the expert panel could be related to the factors in the framework. First thing that can be observed is that "observability" was not related to during the workshop. This could be because it was not perceived important by the experts or because the designated time of the brainstorm was not enough to establish an exhaustive list. Either way, the author decided to keep this factor in the framework, because it was named as a major quality of the tram system in an interview with Anonymous Interviewee (2016) and named as a major challenge for Abel by Interviewee Transdev (2016). Second difference is the definition of policy. The expert panel identified this as a driving force, while the author initially included it as a factor. The status of policy as driving force was acknowledged by the author, but kept within the framework. Not as factor however, but as aspect that may influence all factors within the framework to some degree. Furthermore, the key factors marked in red were not primarily identified by the author. These were not treated as a separate component of the framework, but included in the one they are related to. The framework in Figure 5 and related content is the complete set of factors that could explain the impact of DORS developments on tram demand in Dutch major cities and is used for the scenario implications.

Table 14: key factors

Key factors identified by expert panel	Notes by expert panel	Related factors in framework
Relative speed and convenience		Relative advantage
Relative comfort		Relative advantage
Relative cost		Relative advantage
Relative perceived status	Differs between districts, communities and individuals	Relative advantage; social system
Segmentation of perception	Trip purpose, districts, ancestry, age	Social system
Urban density	Increases demand for transit and DORS	Land use
District characteristics		Land use and population

Weight of rational quality aspects vs. emotional quality aspects		Social system
Search cost dive towards zero	Driven by ICT technology	Relative advantage; complexity
Increasing efficiency of matchmaking	Driven by ICT technology	Relative advantage
Rise of private mobility providers		Availability of other modes; Compatibility
Need for physical contact to obtain happiness	Is this strived for when traveling? Or is traveling just a means to reach others?	Compatibility; relative advantage
Regulation of DORS		Policy; Relative advantage
Subsidy	For transit and/ or DORS	Policy; Relative advantage
Pricing	Distance- and congestion pricing	Policy
(Electric) bike use	Unique in Netherlands and limits growth of public transit. Also of DORS?	Availability of other modes; compatibility
Sustainability		Relative advantage
Business case of DORS	For what cost?	Relative advantage
Parking regulations		Policy
Ticketing of mobility services		Trialability; available resources
Congestion		Land use
Investment in quality of public transit		Relative advantage
Laws and regulations		Policy

Table 15: Identified driving forces

Driving forces	Note
Urbanisation	
Ageing of population	
Inclusion	e.g. income and digital divide
Leisure time due to Robotisation	
Individualism	Facilitated by ICT
ICT technology	
Government policy	
Cost of Energy	Drive to zero marginal cost of renewable energy and batteries
Development of sharing economy	
Automated vehicle technology (AV)	Both public transit and DORS
(Disruptive) innovation strength	In favour of DORS
Globalisation	Enhances worldwide exchange of technology and experiences

4.2. Estimated impact and uncertainty of driving forces

This paragraph handles the results of the expert prioritization of the driving forces. This was done by estimating the level of impact on the focal issue and the uncertainty of their future state of each identified driving force Table 15. This estimation was done individually to prevent dominance of a single participant and the combined outcome of each individual's estimation can be viewed in Table 16. What can be observed is that the development of the sharing economy (4x) and government policy (3x) are clearly considered as a critical scenario driver. The other driving forces seem to be more scattered around the matrix, but this is hard to comprehend in the visualisation of Table 16. Therefore, the author calculated the average impact and uncertainty as well as the standard deviation. This can be viewed in Table 17 and is used to categorise the driving forces.

Table 16: Estimated impact and uncertainty of driving forces

		Degree of Uncertainty		
		Low	Medium	High
Level of Impact	High	**Critical planning issues:** 2x globalisation 2x ICT technology 1x Urbanisation 1x individualism 1x innovation strength DORS 1x bike use	**Important scenario drivers** 2x AV technology 2x perception of quality aspects 1x cost of energy 1x globalisation 1xurbanisation 1x policy 1x ICT technology 1x rise of private mobility providers	**Critical scenario driver** 4x development sharing economy 3x policy 2x cost of energy 2x AV technology 1x free time 1x inclusion 1x innovation strength DORS 1x perception of quality aspects 1x individualism
	Medium	**Important planning issues** 2x Ageing 1x innovation strength DORS 1x inclusion 1x Urbanisation	**Important planning issues** 1x inclusion 1x quality traditional PT 1x free time 1x cost of energy 1x globalisation 1x innovation strength DORS	**Important scenario drivers**
	Low	**Monitorable issues** 2x Ageing 1x Free time 1x individualism	**Monitorable issues** 1x individualism	**Issues to monitor and reassess impact** 1x status of DORS 1x free time

The criteria for the categorisation all relate to averages and are established in the following list.

- Critical scenario driver: impact and uncertainty >2,5
- Important scenario driver: impact >2,5 and 2< uncertainty <2,5
- Critical planning issue: impact >2,5 and uncertainty <2
- Important planning issue: 2< impact <2,5 and uncertainty <2,5
- Monitorable issue: impact <2 and uncertainty <2
- Monitor and reassess impact: impact <2 and uncertainty >2,5 or >2 if standard deviation >0,5
- Factor: Is listed as a factor and not a driving force in Table 15.

Table 17: average impact and uncertainty scores

Driving force	Impact 1	Impact 2	Impact 3	Impact 4	uncertainty 1	uncertainty 2	uncertainty 3	uncertainty 4	# scores	average impact	standard deviation	average uncertainty	standard deviation	total average	Category
Development Sharing economy	3	3	3	3	3	3	3	3	4	3,0	0,0	3,0	0,0	9,0	Critical scenario driver
Policy	3	3	3	3	3	3	3	2	4	3,0	0,0	2,8	0,4	8,3	Critical scenario driver
AV technology	3	3	3	3	3	3	2	2	4	3,0	0,0	2,5	0,5	7,5	Important scenario driver
energy cost	3	3	3	2	3	3	2	2	4	2,8	0,4	2,5	0,5	6,9	Important scenario driver
perception of quality aspects	3	3	2		3	2	2		3	2,7	0,5	2,3	0,5	6,2	factor
trend from public to private mobility services	3				2				1	3,0	0,0	2,0	0,0	6,0	factor
Inclusion of society	3	2	2		3	2	1		3	2,3	0,5	2,0	0,8	4,7	Important planning issue

DORS innovation power	3	3	2	2	3	2	1	1	4	2,5	0,5	1,8	0,8	4,4	Important planning issue
Globalization	3	3	3	2	2	2	1	1	4	2,8	0,4	1,5	0,5	4,1	Critical planning issue
ICT Technology	3	3	3		2	1	1		3	3,0	0,0	1,3	0,5	4,0	Critical planning issue
Robotics/ free time	3	2	1	1	3	3	2	1	4	1,8	0,8	2,3	0,8	3,9	Monitor and reassess impact
urbanization	3	3	2		1	2	1		3	2,7	0,5	1,3	0,5	3,6	Important planning issue
Individualization of society	3	3	1	1	3	1	1	2	4	2,0	1,0	1,8	0,8	3,5	Important planning issue
perception of status	1				3				1	1,0	0,0	3,0	0,0	3,0	factor
Ageing population	2	2	1	1	1	1	1	1	4	1,5	0,5	1,0	0,0	1,5	Monitorable issue

From Table 17 can be observed that the experts plotted three factors during the workshop. The reason for this could be a miss understanding of the division between factors and driving forces in paragraph 4.2 or the experts rethought the value of the factors and deliberately plotted them. What is interesting is that “Perception of quality aspects” was plotted by three out of four experts and would have been an important scenario driver if considered a driving force.

4.3. Differentiate scenario plots

During the workshop, the expert group choose the development of the sharing economy and government policy as the scenario differentiating uncertainties. The extreme ends of the sharing economy were defined as a situation in which it fully blooms by 2040 and a situation in which the economic model of ownership continues to be dominant in mobility. The extreme ends of the government were defined by a government that desires to be in control of urban mobility on one side and a government that leaves urban mobility to the market and civilians and merely facilitates on the other side.

Plotting the two main uncertainties on two axes leads to four distinct scenario plots that can be viewed in Figure 9. The experts characterised the scenario plots as well during the workshop by naming them and giving a basic description. In the next paragraph, the author takes the next step to derive at the final result of the scenario workshop which are the full scenario plots.

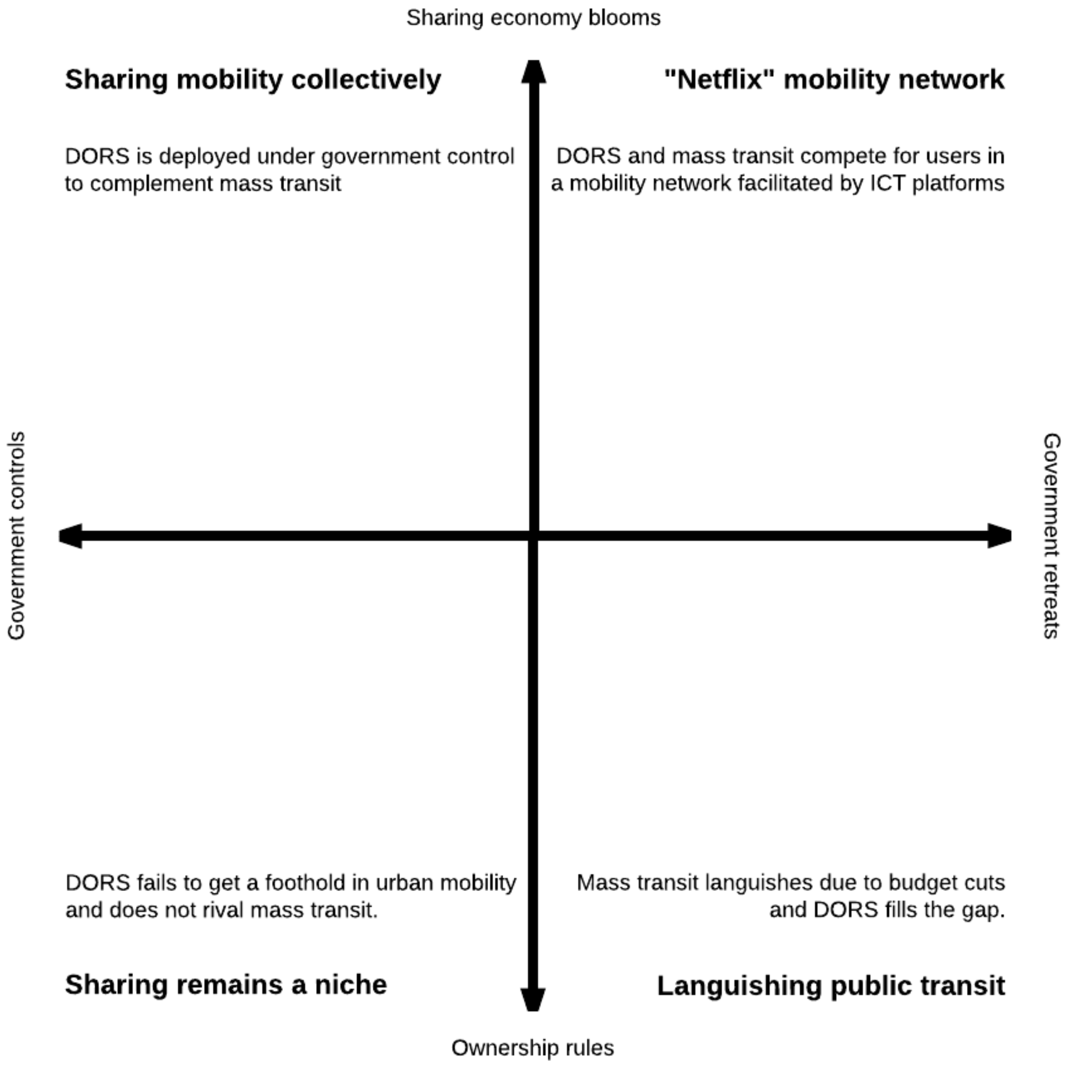

Figure 9: Plotting scenario axes and characterisation of the scenario plots

4.4. Scientific backing scenarios

To write the full plots the author did literature research searching to the driving forces identified by the experts in the workshop (Table 15). This research focussed on defining how they could affect the focal question and what the uncertainty is related to the outcome. Additionally, interactions with other drivers are investigated if applicable and it is explained how the driving force is used in the scenarios. “Ageing” was excluded from research because the expert panel identified it as an insignificant driving force.

4.4.1. Sharing economy:

The sharing economy is one of the differentiating drivers and therefore critical in each of the scenarios. In paragraph 3.3.2.2 client needs, the sharing economy has already been elaborated and therefore only the uncertainty related to the phenomenon is handled here. The main uncertainty in the sharing economy until 2040 related to the focal question is whether people by that time mostly acquire mobility through shared access or through private access.

If the sharing economy comes to bloom there are multiple ways in which this could manifest (Frenken, 2017). One is the assumption that the existing sharing platforms will merge into super-platforms by integrating technologically, organisationally, and financially. These super-platforms provide maximum convenience and seamless consumption by offering as many options and functionalities in as many sectors as possible as a one-stop-shop. Uber, Airbnb, Google, and Amazon are already moving in this direction. The power of these global super-platforms will be so large that governments will shape regulations around the need of these companies, because they are indispensable for consumers (Frenken, 2017). This vision has been used to form the "Netflix network mobility" scenario as governments leave mobility to the market in this scenario. All modes will be accessible through the platforms and many hybrid business models exist. A commuter may lease a car via the platform, take other people with him while traveling to work and offer the same car on the platform to other consumers when he does not need it during the weekend for example. The platform will take a share of each transaction to be profitable. Transit and DORS providers will have to compete for customers on these super-platforms and become completely dependent, such as hotels on booking.com. The super-platforms will have the goal to maximise subscriptions by being as convenient as possible for consumers and do not mind whether DORS, transit or any other mode helps them to achieve this (Holmberg et al., 2016).

If the sharing economy blooms in mobility, but the government seeks control for the benefit of inclusion and scarcity of space, they will regulate the sharing economy to protect their existing interest in public transit. Mobility platforms providing DORS and car-sharing in cities will still grow successful, but they will be put under concession of the government. Only one will be allowed for each city or region and the government will force them to work with a more sophisticated OV-chipkaart system to keep interregional travel seamless. Payment will be automated nationwide by tracking consumer's movement via a smart device and ICT will help users to have all the right information available for their mostly multimodal trips. Within cities the innovative modes will be deployed to maximise use of the existing public transit system, which is not necessary the most favourable for consumers or cost (Holmberg et al., 2016).

If ownership or private access of mobility via leasing remains the norm in society, many DORS concepts will fail. Microtransit and ride-splitting fail to achieve the occupancy rates to be commercially exploitable for a low enough price to become mainstream and either disappear or become more expensive, while operating in niche. Ride-sourcing provides private mobility and will thus remain and consume most of the taxi market. People will still choose for either private or collective modes as their main means of transport and no platform to merge them will be successful in these circumstances. This does not necessarily mean that the sharing economy will not bloom in other sectors of the economy where status and freedom associated with private car use is less important.

4.4.2. Policy:

Policy has already been addressed in paragraph 3.1.4 and therefore we stick to how policy is used to differentiate the scenarios. According to the expert panel the main uncertainty is whether the government feels responsible for mobility provision and takes the managing role by strongly regulating DORS to fit them in existing collective transit networks or take a facilitating role and allow the market and citizens themselves to provide mobility with maybe a few ground rules. A steering government will regulate both price and space for all modes, while protecting existing interest. This implies that DORS will be deployed where traditional transit is less viable (first/last mile) and a nationwide integral pricing system will be implemented. This integral pricing system allows the government to influence travel behaviour over the day, over the modes and quality of separate vehicles by differentiating prices. The OV-chipcard system will have evolved in to an automatic tracking system for usage of all modes, except walking and biking which are free to use. There are limitations to the effectiveness of pricing as people find ways to dodge them if they really want to use their favourite mode. Only one DORS provider will be allowed in each city (only if sharing blooms, otherwise none) and will be commissioned by the government. This implies that peer-to-peer concepts are not allowed if the government steers.

If the government leaves mobility to the market, all DORS business models become possible including peer-to-peer. The government will always have some influence on mobility through spatial planning, although the degree is up for debate. They will still administrate infrastructure and public space, but subsidies to favour certain modes will disappear. This implies transit will become more expensive and of less quality, compared to DORS and other modes. The government will only retreat from mobility provision if liberal parties are in power and if there is a societal development to do so. If the sharing economy blooms, they believe private platforms are better in proving access to mobility for everyone and if ownership still rules, they may feel the downsides of individual transport have mostly disappeared (EV, ICT makes it safer, etc.).

4.4.3. Individualisation/ Network society:

Individualisation is the movement from the old mass society with strong ties towards the multi network society with loose ties. This is fuelled by ICT technology enabling potentially everyone to be connected to the internet and therefore information without marginal cost. Where the mass society relates to the sum of different collective entities (family, neighbourhood, etc.), the network society emphasises individuals connected by networks. The difference is easily explained by considering the change of media. Mostly one-way mass media represents the mass society, such as newspapers and TV channels representing a certain group or vision in society. Social media and e.g. Youtube represents the new interactive media, where individuals have choice to personalize information they want to receive, participate in information provision, and communicate with others about information. As everyone has access to the same information and can freely participate in adding information the traditional knowledge gap between experts and laymen becomes opaque (Van Dijk, 2012).

In transport, this trend is visible with the recent inflow of ICT enabled mobility providers offering personalized choice and the possibility to become part of the mobility provision themselves in a peer to peer system (e.g. UberPOP, Snappcar). Also in mobility, the separation between experts (traditional operators) and laymen (customers) is disappearing. Smart devices can provide real-time information about all options a customer has, no matter where he or she is and give you advice based on this information and your personal preferences or agenda (Goodall & Dixon, 2015). This trend if continued, feeds a need for personalized mobility. Whether this is preferred in ownership or access is uncertain and therefore this trend is strongly related to the sharing economy. DORS is better capable to serve this need than transit.

The network society was identified as an important planning issue by the experts and should therefore be included in most scenarios. In the Netflix network mobility scenario, this trend will help form urban mobility as an open source network itself. Travellers can consume mobility and prosume mobility by offering their own vehicles or parking lots on the network. The subscription they have with a platform is highly personal and may show what they find important (e.g. CO2 free travelling) apart from convenience. In the two scenarios where private access is still important, the network society continues as well, but mobility is not a part of it. Instead nothing can be more personalised than your private vehicle, which helps you move through your networks.

4.4.4. Inclusion:

Inequality in income is a strong factor in the mobility options a person has in a city and in general. Lower incomes rely more on public transport as they cannot afford to purchase a private car (De Witte et al., 2013). DORS concepts are more expensive in use then public transport, but offer some of the benefits a private car has over public transport. Whether low incomes are willing to pay for them is uncertain, but it has the potential to increase their mobility.

Digitalization has brought a new form of inequality: the digital divide (Deursen & Dijk, 2011). E.g. not everyone has access to a smart phone (lower incomes), knows how to order mobility with them (elderly, digibeten) or has access to the internet in every place (tourists). DORS concepts may exclude social groups if there are no other booking methods. Furthermore, DORS works with rating systems and bad ratings may exclude you from the system.

Geographical inequality is also an issue. Where you live, and want to go to in the city depends which options you have, to reach your destination. City centres have good PT connections but limited parking places for private vehicles, while in outer neighbourhoods it is the other way around. Furthermore, Amsterdam and Rotterdam have barriers in terms of major rivers dividing the cities in two, limiting the personal exchange between both parts by walking and biking. DORS is geographically inclusive within its service area as access is not restricted to your location. If you are outside the service area however it is unavailable.

Inclusion is societally desirable, but can be looked up on from two perspectives. Either the individual or community is responsible for inclusion or the government is responsible. The network society trend and government policy accompany this. Inclusion was identified as an important planning issue by the experts and should therefore be included in most scenarios. In the scenarios where government steers, inclusion is secured top down by the government. Transit has always had a social function and inclusion is an important reason to increase transit budgets in these scenarios. In the other two scenarios inclusion is secured bottom up. In the Netflix scenario, this leads to a social system, where volunteers in districts take care of elderly, poor people and handicapped mobility with DORS concepts. The government may subsidise these initiatives if the scenario would move more to the middle according to the expert panel. In the languishing transit scenario, inclusion is less important in society, people take care of their own mobility. DORS is available for everyone, but expensive because the sharing economy failed and therefore not affordable for all people.

4.4.5. ICT technology:

ICT is continuously lowering the transaction costs between especially unrelated people. The internet and mobile applications lower search and contract costs. The apps show all and only the information you need and handles payment automatically online through standard contracts. Integration of GPS, social media and online rating systems bring trust among strangers. At the same time, ICT enables vast big data collection to continuously optimize the matching algorithms and user experience. This trend enhances the sharing economy and the network society, with DORS following suit. Further development of ICT through ever faster internet and storage capacity enables the internet of things, connecting everything with everything, will enhance this trend in favour of DORS over PT (Frenken, 2016). The technology alone however will not lead to more usage of shared modes, there has to be a need that cannot be met by incumbent providers that ICT enables (Paap & Katz, 2004).

ICT technology was identified as a critical planning issue, which means the outcome is important, but predictable and it should be included in all scenarios. In all scenarios ICT continues to grow by Moore's law. Search and transaction cost between unrelated people go towards zero and road capacity is increased by better connectivity and smarter vehicles. However, where scarcity barely exists in ICT it does exist in urban transport. Vehicles and drivers are not unlimited as is road space in major cities. In the scenarios where ownership is still important, there is less space for DORS impeding its availability no matter how developed the ICT behind it is. If the sharing economy blooms there is a societal need to fully exploit ICT technology to match supply and demand of shared vehicles. In all scenarios, it should be possible to pay automatically for consumed mobility, whether through integral government pricing, MaaS platforms or separately for all modes.

4.4.6. DORS provider innovation strength:

Transit service providers are usually under tight long term contractual regulations of transit authorities and other government bodies. Moreover, they must work with fixed infrastructure and vehicles that last 30 years. This impedes both their possibilities and need to innovate their products, but ensures a basic quality for all citizens. However, mass transit providers do get subsidy in return, which allows them to price competitively. DORS is implemented by private companies often as a daughter company of global multinationals in ICT, mobility, and automotive industry or by fast growing disruptive start-ups. Because, their main product is ICT, basically every vehicle can be connected to it and the technology does not have to be adapted to local infrastructure. This allows global data learning and experimentation to improve the service. Additionally, DORS can easier adapt if consumer needs change than mass transit. DORS can be personalised easier, move towards demand and if they work with freelancers it is scalable. This gives them an edge over mass transit providers in the major Dutch cities, who are monopolists and completely specialized companies.

Innovation strength was identified as an important planning issue and should therefore be included in most scenarios. It is included in the scenarios where the government retreats and subsidy no longer influences the competition. In these conditions DORS will have an edge over transit to serve a product with a better rational price/quality ratio.

4.4.7. Cost of energy:

Renewable energy is strongly rising in Europe and the Netherlands alike and have a different cost structure from fossil fuels in terms of marginal cost. Marginal cost are: *The increase or decrease in the total cost of a production run for making one additional unit of an item. It is computed in situations where the breakeven point has been reached: the fixed costs have already been absorbed by the already produced items and only the direct (variable) costs have to be accounted for (BusinessDictionary, 2017a).* After the fixed costs of building a powerplant have been earned back, each Watt of energy produced with fossil fuels requires the purchase of coal, oil, or natural gas, while with renewables the cost of producing a Watt of energy becomes nearly free once the fixed costs have been earned back. This is because solar-, wind- and water power is free and unlimited in supply, although inconsistent geographically and in time. The Bloomberg New Energy Finance (BNEF) state that cost/MWh of solar and wind power is decreasing with 24% and 19% respectively with each doubling of installed capacity quickly gaining on fossil fuels. Cost of batteries needed to buffer the fluctuations of renewable energy follow a similar downward path (Randall, 2016). According to Jeremey Rifkin this trend will continue until energy becomes almost free and abundant. Moreover, renewable energy can be produced by consumers themselves as everyone can buy a solar panel (Rifkin, 2014).

This trend towards nearly free clean energy would have beneficial impact for both public transport and DORS concepts (if electrically propelled (Richardson, 2013)) as operational cost for both DORS and public transport will become lower. The question is how consumers will react if the cost to use an electric car becomes close to zero after purchase or when leased, especially when they produce their own free energy. It would lower the cost of both private and shared access to mobility and if the difference is slim, then what is the benefit of sharing? This will probably lie in the advantage of having access to all modes with little opportunity cost, for a competitive price if the sharing economy blooms.

Cost of energy was identified as an important scenario driver and should therefore be used to differentiate the scenarios. In the ownership rules scenarios, this trend scrutinises the monetary benefit of sharing for consumers, which were already sceptic to the concept in majority. Furthermore, it drives people towards private lease access to vehicles, because it allows them to have continues access to vehicles with the best action radius until the leverage limit is reached.

4.4.8. AV technology:

Vehicle automation is getting a lot of attention lately. Companies from both automotive as tech/ICT industries are rallying to get them on the road. Estimations when fully automated vehicles become a reality in traffic in major cities vary between 2020 and never. A recent study in the Dutch context by professors of Delft university of technology argue that penetration rate of AV level 5 as % of VKT on urban roads will be 0-6% by 2050 (Milakis et al., 2016). Therefore, it seems unlikely that full AV will be a factor for the time horizon (2040) of the scenarios for this thesis. Full AV would reduce cost of DORS significantly as a driver is no longer needed in all circumstances. Lower levels however, already make driving more convenient and safer and allow driverless cars on dedicated lanes and precisely mapped areas, which may have impact on the attractiveness of DORS. In transit, full automation is possible and widely practiced for metros (KiM, 2016b). Automation of trams is not practiced yet and no sources indicate efforts are made to make this possible to the knowledge of the author. For trams on a dedicated lane with few crossings it seems reasonable they can be automated by 2040.

Vehicle automation was identified as an important scenario driver and should therefore be used to differentiate the scenarios. However, the diffusion of automated vehicles in the urban fabric is evenly uncertain in all the scenarios, which makes it rather difficult to differentiate. Policy and the success of the sharing economy do influence how AV technology is used and it would probably enhance each scenario more in to the extreme if it would diffuse by 2040 for road vehicles looking at (KiM, 2015a). Thus, at the end of each scenario it will be discussed how AV might drive each scenario into the extreme as a wildcard.

4.4.9. Globalisation:

The world is becoming ever more connected with global trade and the internet. The global expansion pace of Uber and AirBnB shows that foreign innovations can be implemented across the globe rapidly. Furthermore, many DORS concepts are deployed by start-ups under control of multinationals in the automotive, tech/ICT, and mobility industries. Moreover, DORS attractiveness is determined by the quality of ICT, which enables easy technological exchange and gives them an edge over transit. Transit relies on the network and vehicles for its attractiveness, which is more locally bounded.

Globalisation was identified as a critical planning issue and should therefore be included in all scenarios with the same projected outcome. In all scenarios globalisation enhances the exchange of experiences with DORS. Thus, if the concept fails in places around the world sceptics will be less eager to give it a go in the Netherlands as well. While, if the sharing economy is a success and DORS works well in many cities, both citizens and municipalities would want it in their city too.

4.4.10. Urbanisation:

Urbanisation has already been handled in paragraph 3.1.2 and was identified as an important planning issue, which is highly predictable and medium significant. Therefore, it should be included in most scenarios. In all scenarios, it impedes that scarcity of space and the division of space between the modes becomes a more important policy factor. If the government steers they would make societal cost benefit analyses, whether DORS or tram will be more space efficient in what circumstances. If the government leaves mobility to the market, the platforms would introduce surge pricing differentiated for modes and demand levels to keep their product available. More space efficient modes would get lower surges.

4.4.11. Robotics enables free time:

ICT and robotics are usually deployed to replace human labour and increase efficiency. At the same time jobs are created as well. According to OECD about 9% of current jobs in the developed world is automatable especially amongst low skilled work (Arntz, Gregory, & Zierahn, 2016). The full impact of robotization by 2040 is unpredictable however and what this would do to the competition between DORS and transit even more. Therefore, this trend is not included in the scenarios, but should be monitored closely.

4.5. Full scenarios and development path

With the above research and framework developed by the experts during the workshop the four scenarios below were constructed by the thesis author. Each scenario starts with a description of how consumers access mobility and how DORS and transit would interact in this case. Afterwards a development path is sketched with the two differentiating scenario drivers as a base and complemented with other drivers and factors found during the workshop. In the final paragraph of each scenario the answer is given to the focal question. This is complemented with implications for tram investments and the impact of AV if it would diffuse. The characteristics of each scenario, to see how they differentiate from one another can be viewed in Figure 10.

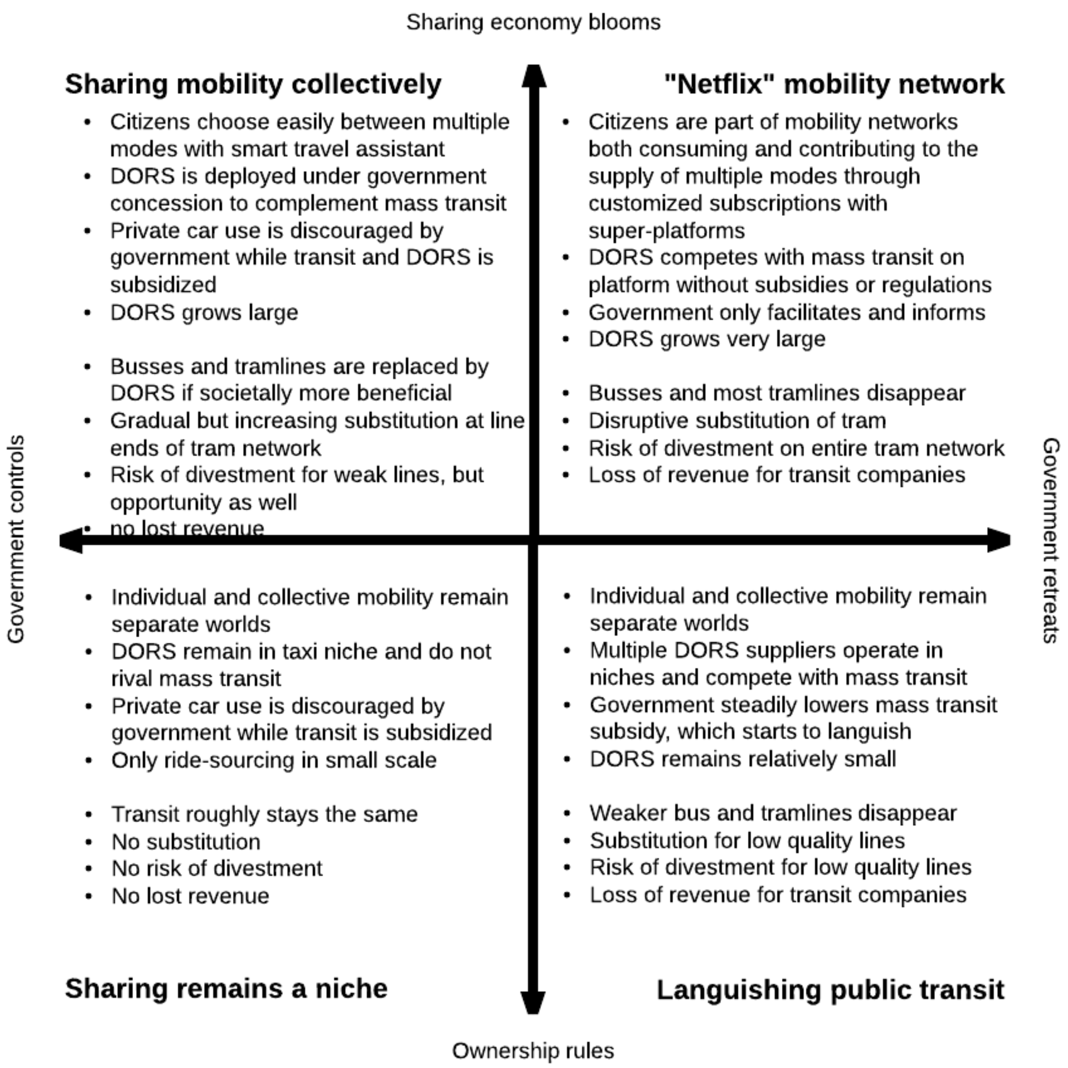

Figure 10: Scenario plots

4.5.1. Scenario 1: Sharing mobility collectively

Back in 2017, some people thought on-demand shared mobility would become the end of public transit, but what a tandem it is now in 2040! All modes have their strong and weak points and a smart travel assistant makes it easy and transparent to compare all options. Biking is favoured on all short distance trips, but other than that there is transit offering fast, frequent, partly automated, and affordable transport to and from the centre. DORS has evolved to a full-grown mode and is preferred for tangent trips between districts, because it saves valuable time. In outer districts, DORS services drive around to take people to the metro and commuters that really need a car make use of private lease while many others carpool. To regulate congestion and travel behaviour the government makes use of differentiated integral mobility pricing via a more sophisticated all mode automated OV-chipkaart system. No matter the mode every traveller pays the government for using the infrastructure per kilometre and hassle with payment while switching modes and ticket controls are over as your smart device automatically registers what mode you have used and via what route.

Sharing is great, but the government sets the rules

Citizens in the developed world had set their thorn against waste long before 2040. Owning stuff that sits idle 90% of the time, such as cars that used to block the space where children now play is a thing off the past. Companies have found value in remaining owner of the products they produce and providing them as a service with the help of ICT, while consumers like the sustainable idea of the sharing economy, it saves money and ICT has made it so easy to have anything available almost instantly.

The government had followed the rise of sharing services with great interest and facilitated all sorts of pilots throughout the major cities, even before 2017. In harmony with the public's growing interest in the sharing economy and technological progress of ICT the scale and popularity of private mobility providers grew extensively. By 2020 many proved to be commercially exploitable and started to eat demand of bus lines apart from private cars. The central government had raised funds for public transit and found this uncontrolled competition between collective modes an undesirable development. Therefore, they made a national law to place DORS and other innovative mobility concepts under concession and regulation of transit authorities, making commercial mobility platforms impossible. Only one provider is allowed for each city and they may cover all districts if they either complement public transit in that district or if it is societally beneficial to replace transit for DORS. In practice, these are the more outer neighbourhoods, where transit is less viable and scarcity of space less of an issue. This regulation of DORS does impede its efficiency and attractiveness and therefore subsidy is required to keep prices affordable.

To strengthen the declining interest in individual car use the government impeded regulations. Parking in centre districts is preserved for shared electric vehicles and integral mobility pricing per kilometre travelled is introduced for all modes except for biking and walking. Pricing differentiations are made to promote shared use and transit over individual car use and discourage people to travel during peak hours to keep the infrastructure available. Because, alternatives are so abundant and convenient and cities have become more liveable with less parked cars, objection to these regulations is limited. Apart from these regulations the government has impeded the sharing of all collected travel data for the benefit of continuously improving accessibility of the city.

Implications DORS for transit:

In this scenario DORS grows to a considerable size, but mostly complements transit. This is due to the government that thrives to deploy DORS in a way it can maximise usage of the existing urban transit network. DORS feeds metro lines in the outer neighbourhoods, connects districts around the centre, replaces existing weak performing tram and bus lines if societally beneficial, but is mostly restricted from covering the bigger tram corridors and centre districts. This means DORS may replace many bus lines and some tram lines. At the same time, this liberates funds to strengthen the bigger transit corridors making them more attractive for travellers, while overlap of the optimised transit network's clientele with DORS's clientele is limited. This overlap will be mostly focussed around line ends of the tram and substitution to DORS is probable in this area. Switching cost are limited due to seamless payment and the fare price will be closer to transit, while reliability/ convenience of DORS will be relatively high due to the large operating scale and related short pick-up times. Because DORS is more attractive for travellers than tram in this scenario the overlapping area may grow over time as consumers or businesses may demand a bigger operational area.

For investments in the tram system this scenario implies that long term investments in underperforming tram lines may be vulnerable. If large capital investments were made in assets of such a line prior to the conclusion that it will be societally beneficial to replace this line for DORS two basic decisions can be made. The line is operated until the assets technical life time ends or the line is closed. This first will prevent depreciation of assets, but inhibit the opportunity to operate the more beneficial DORS for this time and redirect vehicles to other tram lines. In case of the latter, the remaining value of the assets will have to be depreciated, but citizens can enjoy the benefits of DORS and regular maintenance cost can be saved. The degree of depreciation depends on whether vehicles may be used on other lines and whether the infrastructure can be used to redirect other tram lines when maintained. Either way the investment will not serve expected utility. Whether the line ends of the tram network are vulnerable depends on the existence and location of alternative turning circles. These are essential for operations, capital intensive and require much space (Anonymous Interviewee, 2016; Interviewee HTM, 2016). If available at an opportune location it could be an opportunity to close the end segment when DORS eats demand, if not it will probably be more beneficial to continue operations as travel volumes are already low. Overall usage of the tram will grow in this scenario and if anticipated on, the closing of weak lines can liberate funds to further improve bigger corridors or other travel modes.

If AV would penetrate the urban market before 2040 in this world, operating DORS will become far cheaper because drivers can be eliminated and supply is no longer limited by availability of drivers as well. People are already accustomed to the idea of sharing and would therefore not be inclined to use AV for personal mobility. For the impact of DORS on transit, penetration of AV could mean more existing tram and bus lines would disappear. The lower cost will make DORS more favourable in cost benefit analysis if other criteria are not accounted for. Collective mass transit is still favoured as the backbone of urban mobility however and the government will continue to protect its interest via pricing.

4.5.2. Scenario 2: "Netflix" Network mobility

In 2040, the sharing economy has come to blossom in Dutch major cities and mobility is no exception. Consumers like the sustainable idea of the sharing economy, it saves money and ICT has made it so easy to have anything available almost instantly. The ultimate manifestation of this are global mobility platforms that enable a network or internet of mobility in which everyone can consume and prosume mobility to any degree they want. A commuter may lease a car via the platform, take other people with him while traveling to work, rent out his parking lot while away and offer the same car on the platform to other consumers during the weekend to earn money. Car-sharing, car leasing and DORS concepts will have basically merged into a single mode with various service levels and everyone can be both rider and driver. Every vehicle whether car, van, bus, or metro on the network is connected and the platforms match supply and demand for seats and other amenities flawlessly with ICT.

A subscription package allows consumers access to this mobility platform to the degree they wish for, just as a subscription on Netflix allows you access to movies, Spotify to music and almost all other consumer goods on Amazon. To guarantee availability the platforms handle surge pricing to level supply and demand with the availability of infrastructure. Thus, if a consumer mostly travels during peak hours he would run down his subscription package faster than if he would travel mostly off-peak. The opposite is true for prosumers and providers of mobility who can earn more during surge. This surge pricing is differentiated over various modes and geographical locations as well, to redirect people to use e.g. transit if it has spare capacity and they are nearby.

The platforms also advices which mode to take depending on your destination, bundle, whether you want the fastest option, prevent surge, the most sustainable or travel together with friends amongst other things. As different modes, all have their up and downsides in different circumstances and for different trip motives, having access to all of them, whenever and wherever you want to with little opportunity cost is such an advantage for consumers that platforms have become indispensable. Mobility providers whether offering cars, bikes or mass transit are all dependent on the platforms to get any customers and the customers themselves are equally depended.

Self-reliant mobility network on the governments infrastructure

It started when the automotive industry saw the loss of interest in car ownership continue after 2017 in the Netherlands and the developed world and especially in major cities. Joining forces with ICT companies enabled the car manufactures to remain in the urban mobility market by providing fleets of shared vehicles and taxi's as a service and remaining owner. The private mobility providers were helped by the Dutch government, who called out the ambition to become Europe's leading test ground for automated vehicles, electric vehicles, smart mobility, and MAAS solutions after the 2017 elections. They loosened regulations nationwide and facilitated all sorts of pilots and by 2020 the number and scale of providers and business models had grown dramatically in harmony with the growing sharing and access economy. Many had been proven to be exploitable subsidy free in dense urban areas for a reasonable price.

Additionally, when global mobility platforms began to get substantial ground after 2020 with growing popularity and bargaining power, the central government slowly lost the desire to feel responsible for costly collective mobility provision as the market had an instrument to do it. They gradually stopped funding MTA subsidies for exploitation cost of mass transit and only continued to warrant security and maintenance of the bigger corridors if it would prevent gridlock. Mass transit providers no longer had to file responsibility to the government in exchange of a long-term concession. Instead they must compete for customers on fair terms with the new providers on the mobility platforms. The central government allowed MTA and municipalities to use the liberated funds for improving the flow rate of urban roads with ICT technology, and improving the liveability and economic attractiveness of the three major cities. Inclusion is believed to be your own responsibility in the first place, but those with lower incomes may acquire government allowance to be able to access the mobility network and the entire urban region must be covered by the platforms.

Implications DORS for transit:

In this scenario mass transit suppliers will have to compete with DORS providers without subsidies and regulations from the government, but with pricing policy of the super-platforms. The platforms can decide what value modes exchange for on their subscription packages and in what circumstances, just as subscriptions for a mobile phone. They may use flat rates, surge pricing, or allow service providers to price themselves and take a share. Whatever it will be, it can be expected that the price difference between DORS and transit will become smaller due to lacking subsidy and less felt due to subscription. Moreover, cars can be capitalised by consumers, while transit cannot. This gives them an extra incentive to substitute from transit and the citywide trip data collection, small vehicles and freelance drivers allow DORS to be more flexible, customisable, and scalable to demand fluctuations than tram and bus, making DORS more competitive. Metro has an unrivalled speed, reliability and capacity advantage and usage will therefore not be impacted significantly. Tram and bus will struggle however, except for customers with their origin and destination nearby a bigger corridor. They could still favour tram over DORS during peak-hours, because a large corridor with stable demand would still allow a high frequency and travellers can be sure of a spot and bypass congestion with relatively high speed if on a dedicated lane. In all other circumstances consumers will prefer the more flexible modes bike, shared car or DORS.

Major investments in new assets or replacement of existing assets of the entire tram network may be vulnerable in this scenario. Only the bigger corridors that can operate without subsidy may survive. Vehicles may be redirected to the remaining lines, but any investment dedicated to other lines will probably be in vain, leading to large depreciations. In the long run, maintenance cost can be saved and liberated funds can be spend on other means to improve accessibility or liveability of cities.

If AV level 5 will penetrate the urban market before 2040 in this scenario it is interesting what would happen to the network structure of consuming and prosuming. If cars are automated, then capitalisation of using a shared car is no longer possible for consumers, because added value by driving around other people is no longer relevant. AV will take over this network structure to both increase availability and lower prices for using cars as without the need for drivers DORS will become so cheap and abundant that no mass transit mode would be able to compete against it without severe protection of the government. This will largely mean the death of bus and tram similar to the "Mobility as a service" scenario of (KiM, 2015a). Fully automated metro will still have the speed advantage and might survive for that reason.

4.5.3. Scenario 3: Sharing remains a niche

In 2040, nothing has really changed since 2017. The new mobility providers of that time never penetrated the market in the Netherlands and mostly disappeared and the worlds of private and collective mobility remain separate with little exchange of users. Either you are car oriented and live in the outer neighbourhoods of the city or you are transit oriented and live in the centre districts. When traveling towards the centre popularity of park and ride and mostly (electric) cycling has increased, because it has become almost impossible to find a free parking spot as a visitor around the centre in 2040.

No need and no desire for DORS

The sharing economy, who remembers that buzzword of the 2010's? In the aftermath of the global financial crises it seemed revolutionary, but as the Dutch economy began to grow again the dream of sharing slowly diminished. With the rise of ICT, automation and almost free renewable energy, products became so cheap, why would you use someone else's product if you can own or lease one yourself for little more? Moreover, ownership gives you status, freedom, and independency that no service can substitute for, especially if you talk about a car. Because sharing did not come to bloom, ICT companies in cooperation with the automotive industry mitigated their focus on supply and demand matching algorithms and increased their energy in making private car use even more convenient with ICT. In 2040 cars can save hassle by finding their own parking spot in a garage, and on major urban roads you can let go of the steering wheel and spend your time on other things.

The years up to 2040, the central government felt metropolitan transit authorities should have full control over collective urban mobility provision for the benefit of social inclusion. Therefore, they chose to increase budgets for public transit after the 2017 elections and facilitated small scale pilots, mostly in hard to reach areas, for DORS providers to see if they would be beneficial. However, after a few years of testing most pilots stopped by 2020. The termination of Kutsuplus in 2015 and Bridj in 2017 turned out to be no exception. The technology to match rides worked flawless, but demand was too low and scattered to be efficient enough for commercial exploitation in Dutch cities. People favoured the lower price of transit and especially the flexibility of a private bike and car. With subsidies DORS could be exploitable, but the government figured these would be higher than for transit and with no clear societal benefits over transit they chose not to. The digital nature of DORS may exclude social groups and would occupy road space inefficiently, while transit is space efficient, familiar, and accessible for everyone was their reasoning. Commercial ride-sourcing services did remain to serve people with luggage, those going out at night and hard to reach places as they already did in 2017.

Investment in transit let to a partly automated, fine grained and frequent service throughout the major cities by 2040. Although the service has improved since 2017 it has only let to a marginally higher share in the modal split than what would be expected from urbanization and most profound for the city centres. Parking policy sharpened in these areas and cars are mostly redirected around the centre in favour of pedestrians and cyclists. Even the pricing of private car use was implemented leading to a decline of usage within dense congested city districts, but mostly in favour of the (e)-bike for inner city trips, because they offer the same flexibility. The metro grows as well, because commuters can dodge parts of congestion pricing by making use of p&r locations. Districts outside the centre remain the domain of the car and bikes however.

Implications DORS for transit:

In this scenario transit is marginally affected by DORS concepts in Dutch major cities. Only ride-sourcing and sometimes combined with ride-splitting managed to gain ground since 2017, but the price difference is too high and availability too low to lure a significant amount of people from transit to use ride-sourcing. Just as in 2017, DORS only comes close to the fare price of transit when driving groups on short distances. Thus, some demand may be skimmed especially during evenings, but nothing that would worry any transit service provider. The central government liberated extra funds for public transit in this scenario and implemented congestion pricing of private vehicles. Tram usage however still does not grow more than expected from urbanisation, because it is not seen as an attractive alternative for private car or bike use. The tram can only outpace a bike if origin and destination are along the line and therefore does not become more attractive for travellers it did not accommodate already. Private car use does decline within cities due to pricing, but in favour of the (e)-bike for inner city trips, because they offer the same flexibility. The metro grows as well, because commuters can dodge parts of congestion pricing by making use of p&r locations. No investment in tram assets will be in vain due to diffusion of DORS in this scenario.

If AV diffuses before 2040, ride-sourcing would become far cheaper and may become more of an alternative for private car use. Most will keep using it in the private sphere however as status is evenly important and automated or not one still has to wait for a business owned vehicle to arrive impeding freedom and flexibility. Substitution from transit would grow as well, but this is more due to AV than to success of DORS concepts. Similar to “sharing mobility collectively” some bus and tram lines may not be worth operating if AV becomes reality in the city.

4.5.4. Scenario 4: Languishing public transit

In 2040, the private car is back as the preferred mode for everyone in the city, in fact people drive more than ever. It’s cheap, fast, green, and once you get on the major roads you can let go of the steering wheel. Furthermore, it has become basically impossible to have any accident with your car, because of all the ICT and connectivity. Congestion and parking is still a hassle however especially in the centre districts. Thus, for going around the centre and on short distances cycling is the most convenient and if it rains one can take one of those DORS services. It’s a little expensive but very convenient and transit is only an alternative for those living near the lines remaining and prices are higher than they used to be back in 2017. Transit is really languishing, every year more bus and sometimes tramlines close or are only operated during peak-hours. Only the metro has improved which runs automated in 2040 with high frequencies and high speeds.

Mobility is of an individual’s own concern

Sharing never got a major foothold in urban life in 2040, mobility included. The status, freedom, and convenience of having your own car or bike available was never really rivalled by the emergence of ridesharing and carsharing concepts. Back in 2017, people seemed hopeful sharing cars and rides could be the answer to private cars crowding and polluting city streets, but changing one’s behaviour was proved to be difficult with clear advantages missing. By 2020 it was clear that prices to be commercially exploitable were simply too high, while reliability to have a ride or car available at any given moment was too low to persuade people from handing in their private cars. Additionally, the lobby of car owners and the automotive industry proved to be strong to prevent any regulations against private car use.

The central government meanwhile struggled with the rising cost of public transit, its stagnating usage even in the growing major urban regions, and its failure to get polluting cars of the road. Moreover, mobility was believed to be primarily a private concern and the government should facilitate this with infrastructure and not with state subsidized providers. Therefore, they decided to focus more on stimulating electric vehicle diffusion to combat pollution and enhancing flow of urban roads with ICT solutions to combat congestion instead of promoting public transport. Thus, a spiral was formed of continuously decreasing quality (lower frequency, less lines) of the tram system over the years. At the same time, mass transit companies were liberated from regulations on how to deliver mobility to give them space to adapt to the new circumstances and start with innovative mobility concepts themselves.

When electric vehicles became cheaper than internal combustion engine vehicles in integral cost around 2023 diffusion got a huge swing. For the government, this meant that transit lost its sustainability advantage as well. Government funding to MTA for transit exploitation subsidies had become gradually lower already, but this gave the incentive to stop it altogether in the next five years and solely fund the maintenance of infrastructure and security of underground stations. For mass transit companies, this meant increasing prices and closing lines not adding value to the network. This led to coverage gaps of transit in which various DORS providers found their market each serving a niche. For example, companies or business parks that lost a transit connection make deals with a DORS provider to provide mobility for their employees. Most people however will revert to cycling and private car use, because of the languishing transit. Having to order and wait 10 minutes for a DORS vehicle is not nearly as convenient as having your own bike or car available. Moreover, prices are not favourable for DORS, because leasing or owning EVs has become very cheap.

Implications DORS for transit:

In this scenario, the liberated collective transit market will decrease the price difference between DORS and transit, because lost subsidies will have to be covered. Therefore, travel time will become more dominant for rational mode choice. The frequent metro and tram (on a dedicated lane) have a clear speed advantage for travellers going along the line, while for other trips DORS will have the upper hand. DORS’ ICT and data enabled innovation power together with its flexibility will probably give it an edge over transit in most circumstances. However, because DORS is scattered among multiple providers each serving a niche it will be too much hassle for travellers to find out if it is an option for their trip if it is visually or habitually clear transit is available to them. Moreover, most people will substitute the suffering bus and tram for private bikes and private cars making the impact of DORS limited. For incidental trips, it may skim some travel volume of bus and tram, causing it to languish further.

In this scenario tram investments are mostly affected by steadily decreasing state funding, while DORS has only marginal impact. Lack of funds may enforce the closing of tram lines to cut cost or by lowering frequencies. In the first case, any long-term investment made in this line prior to this decision would be in vain. In the latter case, attractiveness of the line will decrease and revenues with it, which could lead to more pressure on budgets in the long run. This will increase substitution to DORS as well.

If AV would reach level 5 by 2040 this will intensify and speed up the languishing of tram and bus until they will mostly disappear. Parking, the main hassle of private car use in cities is no longer a problem, because an AV can drop you off and find its own space. Furthermore, DORS will become far cheaper once automated and becomes an attractive substitute for transit as alternative for those who cannot afford private access to AV. The scenario will become close to the “Fully automated private luxury” scenario developed by (KiM, 2015a) due to AV diffusion.

5. Discussion impact DORS on tram investments

In the previous chapter four scenarios have been presented debating the impact of DORS on urban transit demand for 2040 with special attention to the tram. These scenarios should help science and policy makers to imagine future development, explore the relevant uncertainties and study the consequences for their own merit. The scenarios have many implications, but in this thesis only the substitution from tram to DORS and investment in the tram system have been elaborated. External effects of the scenarios on e.g. accessibility, liveability, the environment have not been included, but can be an interesting subject for future research. In this chapter, the main differences between the scenarios on (disruptive) impact on tram investments are elaborated first. Subsequently, the leading indicators of change to monitor by policy makers are identified. Finally, the implications for investment policy are discussed.

5.1. Main differences between scenarios

After scenarios have been fully developed, policy makers should study their implications for the outcomes being sought by the operation. Investment in the tram system should contribute to accessibility of the city and if many travellers will substitute tram for DORS this investment may be in vain. In this paragraph, the differences between the scenarios are examined regarding possible substitution from tram to DORS and related impact on investments. These are summarised in Table 18 and below the differences between the scenarios will be elaborated in writing.

Table 18: Impact of DORS on tram investments

	S0: Reference point (chapter 3)	S1: Sharing mobility collectively	S2: Netflix network mobility	S3: Sharing remains a niche	S4: Languishing public transit
Operating scale of DORS	Small	Large	Very large	Very small	Small
Diffusion of DORS concepts: ride-sourcing, ride-splitting, ride-sharing, microtransit	Ride-sourcing	All four	All four and hybrids	Ride-sourcing	Not ride-sharing
Competitive relation with the tram	Complements	Complements	Competes	Complements	Competes
Substitution from tram to DORS: network	Insignificant	Line ends, poss. increasing	Entire network	Insignificant	Low quality lines
Substitution from tram to DORS: time of day/ week	Evenings	All day and week	All day and week, but least in peak-hours	Evenings	Off-peak hours
Substitution from tram to DORS: incidental or regular	Incidental	Regular	Regular	Incidental	Incidental
Pace of substitution after 2020/2025	-	Gradual	Fast	-	Gradual
Disruptive?	No	No	Yes	No	No
Risks of divestments in tram network	Insignificant	Weak lines	Entire network, but least for high demand, frequent corridors	Insignificant	Weak lines
Risk of revenue loss	Insignificant	Insignificant	Entire network, but risk of tram serv. provider	Insignificant	Low quality lines, risk of serv. provider
MTA role – majority of investments	Public transit	Public transit incl. DORS,	Smart shared mobility; metro; economic dev.	Public transit	Smart private mobility; metro; economy dev.

Similar to the reference point DORS failed to penetrate the market successfully in "Sharing remains a niche" and no substitution from the tram will occur, but in the other three scenarios substitution from tram to DORS is probable, although the degree varies. In "Netflix Network Mobility", DORS under the wing of global super-platforms will be disruptive to the tram system in Dutch cities. Substitution will occur throughout the network, but least during peak-hours for high frequent tram corridors with a large stable demand (e.g. Universities usually do not change location and fixed lecture schedules induce predictable travel volume peaks). In "Sharing mobility collectively" the tram will be exposed to substitution by DORS as well. In this case however the government controls the operations of DORS through concession to complement the tram network and would limit substitution to line ends or decide to replace an already weak performing tram line altogether. In "Languishing transit", the quality of the tram system declines and substitution to DORS will occur for those lines that cannot uphold an attractive frequency and if lines close than DORS may fill the gap. The operating scale of DORS will be small however in this scenario and substitution thus limited.

The tram will have to compete for travellers with DORS on the entire network in the two scenarios where the market organises mobility, while it is complementary in the others. In all scenarios substitution is more probable in off-peak hours and less for large high frequent corridors with sustainable demand. Only if the sharing economy blooms DORS will be a daily used mode for many people and substitution will be on a regular base. Looking at the time and pace in which substitution may occur, it is observed that until 2020 no significant shift from tram to DORS will happen in all scenarios. After 2020/2025 differences do occur between the scenarios. In both "Sharing mobility collectively" and "Languishing transit" the pace of substitution is slow and gradually. In the first case DORS will grow strongly in line with the self-enhancing characteristic of sharing economy platforms, but once substitution becomes apparent the government regulates operations and further growth of DORS to limit this. However, this may imply that DORS is not available to serve the mobility needs of certain citizens or businesses. If they feel underserved without DORS their lobby may loosen regulations over time and increase the chance of substitution.

In the case of "Languishing transit", budgets for public transit will be steadily decreased up to 2040 and substitution will follow the same pace up worth but not necessary to DORS. This will be in increasing speed, because lower quality transit due to budget cuts will induce less demand and revenue and thus lead to more pressure on budgets as we have already seen happening in the periphery of the Netherlands. The bike, private car, DORS and other innovative travel modes will fill this gap. DORS will become more advantageous than tram over time, but less than bike and car. Substitution will be less gradually in "Netflix Network Mobility". Once business models prove to be commercially profitable and consumers become both aware and convinced by the advantage of DORS a snowball effect may emerge. Diffusion will follow the typical S-curve of disruptive innovation and bus and tram usage may decline relatively fast if transit service providers cannot find an adequate answer to adapt. The exact time when this may occur is unpredictable and whether this scenario or one of the other three becomes reality is evenly uncertain.

Divestment is a risk in three scenarios. In "Netflix Network Mobility" investments in assets of the entire network may be in vain, but least likely for the bigger corridors. In both "Sharing mobility collectively" and "Languishing transit" there is risk of divestment for tram lines with already low demand. This could happen when investments are made for this line and it was not foreseen that in few years DORS is believed to be societally more beneficial leading it to close or when budget cuts enforce its closure respectively. Although substitution occurs in “Sharing mobility collectively” revenues are not at risk as the government prevents this from happening. In the scenarios where the government retreats the tram service providers will face the risk of lost revenue due to DORS developments. This can be restricted to weak lines in “Languishing transit” to volume skimming of the entire network in “Netflix Network Mobility.” The role of MTA is subject to uncertainty in the scenarios as well. If the government seeks control, they will keep spending ~87% of their budget on maintaining and replacing transit assets (60%) and subsidising operations of transit (27%) as they do in 2016 (Mott MacDonald, 2017). In “Sharing mobility collectively” this will include subsidising operations of DORS. If the government retreats from its task of public mobility provision, these percentages will plummet and funds could be devoted to facilitating e.g. electric vehicle diffusion or further enhancing economic activity in the city/ region. It is for MTA and the state to decide what role will best help fulfil their goals.

5.2. Leading indicators for change

During the scenario workshop, the expert group was asked for indicators that would signal if the future will go towards either of the scenarios. According to (Maack, 2001) these indicators should help decision makers monitor changes in the external environment as well as developments of the tram system. The indicators identified by the group were commercial exploitability of DORS, the development of more sophisticated traffic models and the diffusion of MaaS. Apart from that automated vehicle developments should be monitored as this has the potential to drive every scenario further into the extreme if it would penetrate the urban market before 2040.

5.2.1. Commercial exploitability of DORS concepts

There is uncertainty whether on-demand mobility services can be commercially exploitable and for what price. Will consumers find added value in using DORS over traditional transit and are they willing to pay the fare price private suppliers ask for this extra value? Will subsidy be needed to exploit DORS as an attractive system and how would that compare to subsidies needed for traditional mass transit solutions? What are the conditions and success factors that determine the answer to the above two questions? Recent examples show a diffuse image. Kutsuplus in Helsinki (Rissanen, 2016) and Bridj in the USA (Andrew J. Hawkins, 2017) did not make it, while Abel in Amsterdam is expected to run cost neutral in its second year of operation (Interviewee Transdev, 2016) and Uber, Lyft, and Via are booming in New York City (Fitzsimmons & Hu, 2017). Many private DORS providers (mostly American) rely strongly on venture capital to expand their service and operate with low prices. According to (Rajaraman, 2017) they may be part of a bubble called the on-demand economy that is about to burst. In this thesis, we saw that the local urban environment influences the success of DORS and their possible impact on transit. Thus, MTA should monitor and exchange experiences with DORS concepts in other cities, but should encourage pilots in their own city as well. By 2020 and definitely by 2025, it should be clear if and in what circumstances DORS is exploitable. If it is and for such a low price it can compete with private cars and transit, we might be underway towards scenario 1 and 2, while if it is not scenario 3 and 4 will be more likely. Apart from DORS it can be beneficial to monitor the success of other proliferations of the sharing economy in mobility as well, such as carsharing. Innovations under the same umbrella often strengthen each other’s diffusion (Rogers, 2010).

5.2.2. Traffic models

Traditional traffic models cannot yet account for innovative mobility solutions. Sensitivity analyses can be performed, but these take on the perspective that line based transit is always the best solution. It cannot tell whether combinations of DORS, car-sharing and bike-sharing may serve a certain area equally well for lower cost than traditional solutions. No models exist yet to the knowledge of the author to make this comparison. Interesting as well is by what criteria should be decided whether DORS, tram, any other mode or a combination is better in a given area. Scarcity of space will definitely be an important measure in major cities and will be further emphasised by the continuing urbanisation. More space for pedestrians seems to be the desired outcome in this regard, but there is no single answers to this as the tram could save space by its higher corridor capacity and DORS by allowing parking lots to be rezoned. Other criteria could e.g. be inclusion, labour provision, accessibility, pollution, and cost to calculate what is better. More sophisticated traffic models that can handle the above and take smart mobility solutions in to account should be available around 2020/ 2025 as well. Uber and other DORS providers are collecting an enormous amount of travel behaviour and congestion data that would aid the development of such a model. However, they are very protective of their data thus it is uncertain if it would be available for independent research (Frenken, 2017). The outcome of the models will help governments decide whether to take a steering or facilitating role towards urban mobility and would thus indicate the probability of the scenarios.

5.2.3. Diffusion of MaaS-platforms

The emergence of Mobility-as-a-Service platforms that provide seamless access to multiple modes for subscribers by integrating automatic payment and real time travel information across the providers (Kamargianni et al., 2016) is a signpost for scenario 1 and 2 to happen. Currently, there are services that integrate payment for multiple modes via a smart card and monthly invoices, such as Mobility Mixx in the Netherlands and services that provide multimodal real-time travel information, such as Google maps. Whim started a pilot in Helsinki with an application that combines both and allows you to book services of various service providers via the same interface. They offer unlimited public transit and credits for taxis, carsharing and other travel modes within a city region for a monthly subscription (MAAS Global, 2017). By the end of 2017 Whim will come to the region between Amsterdam and Schiphol as part of a concession (Wever, 2017). Google Maps is on a similar track by allowing user to order an Uber or taxi within the application (Pals, 2017). MaaS platforms may be a prerequisite for the global super-platforms of scenario 2 and should thus be monitored. Furthermore, Amazon is taking steps to become a global super-platform by offering a subscription to manage and use various subscriptions of other providers of consumer goods and services on a single platform. The other providers can use Amazon’s servers in return (Perez, 2017).

5.2.4. Penetration of AV into the urban market

Development of AV technology was added as a wildcard to each scenario. AV is not a signpost for either of the scenarios to happen, but should still be monitored. “Languishing transit” and “Netflix network mobility” will become more extreme, leading to the end of trams in favour of shared automated vehicles or private automated vehicles respectively. In “Sharing remains a niche” diffusion of AV could lead to closure of some tram lines, but the government will keep financing transit as long as AV is not available for everyone for the benefit of inclusion. In “Sharing mobility collectively” AV will lead to cheaper and automated DORS and thus more cost benefit analyses will verdict the closure of tram lines in favour of shared automated vehicles. The government continues to protect its interest in the tram if it is more space efficient via pricing in this scenario. Thus, if AV would penetrate the urban market the tram will only survive if the government is willing to pay for it. DORS providers such as Uber and Lyft, the automotive industry and various tech companies are already experimenting with AV (McGoogan, 2017). Furthermore, the Ministry of Infrastructure in the Netherlands recently allowed pilots of AV on Dutch soil (Gersdorf, 2017). Monitoring technical progress of AV within cities would allow policy makers to anticipate on possible change with investments.

5.3. Discussion on investment policy implications

The impact of DORS on tram investments in major Dutch cities by 2040 is uncertain as we saw in chapter 5.1. The main scenario drivers: development of the sharing economy and policy differentiate the impact between zero and disruptive substitution and between complementary and competitive. This leads to the risk of divestment in tram system assets in three scenarios. In two this considers the low demand tram lines, while in one only the biggest tram corridors may survive. What future may unfold can be anticipated on by monitoring the indicators discussed in paragraph 5.2. However, as earlier explained in paragraph 1.1 policy makers or asset managers may not have time to await the future as investments are needed to keep the city accessible. To help policy makers to address the uncertainty of the scenarios in investment policy, three main approaches from Conway (2007) will be discussed: robust decision making, multiple strategies approach and the gamble strategy approach. These strategies are not exhaustive and there might be better strategies if matters outside the scope of this thesis would be considered. The goal is to illustrate to policy makers what the various strategies may offer in this case and not to dictate how they should apply it.

5.3.1. Robust decision making

Hallegatte, Shah, Lempert, Brown, and Gill (2012) discusses multiple approaches to handle investment policy under deep uncertainty. They applied these approaches to climate change uncertainties, but these approaches are not restricted to this field. Hallegatte et al. (2012) argues that in our case if scenarios are equally probable and forecasting is not possible, then robust decision making is advised. The main advantage is that robust approaches evaluate multiple project options, against various uncertainties, including multiple parameters for success. This allows incorporation of multiple views of various stakeholders as robust strategies do not seek an optimum of one variable such as NPV and try to predict uncertainty that cannot be measured. The latter does not allow discussion when there is conflicting interest. A risk of this approach would be being over adaptive to change in relation to the risks leading to higher cost. Being too restrictive, while problems may be urgent is another risk. Three robust strategies suggested by Hallegatte et al. (2012) will be handled in the next indentions.

5.3.1.1. No-regret strategies

These strategies yield benefits in all possible scenarios (Hallegatte et al., 2012). First of all, any investment in tram assets with a technical life time that ends before 2025 should be done if there are good reasons for it. In neither of the scenarios impact is expected to be significant around this time. Secondly, any investment in the bigger high frequent corridors should go through. These run risk in only one scenario and relatively small. Thirdly, the integral reduction of lifecycle costs of the tram system assets without impeding the systems attractiveness would be beneficial in all scenarios. This requires identification and overview of all lifecycle cost apart from maintenance concessions and would make the tram more resilient to changes in the environment, both financially and competitively. Furthermore, this allows policy makers to detect a window of opportunity to close an underperforming line with the least depreciation cost if wanted of course. Fourthly, facilitating pilots of DORS with access to generated data would be beneficial in all scenarios. It offers opportunity to study the external effects and impact on accessibility and travel behaviour independently.

5.3.1.2. Reversible and flexible strategies

The aim of these strategies is to keep the cost of being wrong as low as possible. If an expansion to the tram network would be suggested it can be wise to take the option value into account. According to Hallegatte et al. (2012) this is advised when there is large uncertainty to date, but it can be expected that by postponing the decision some years into the future a better trade-off can be made because there is more information available. This is expected according to the scenarios of this thesis. If DORS business models turned out to fail around 2020 the tram project can still be executed. Although revenue will be missed and the accessibility problem that is to be solved with the project may cost society if the project is delayed. While if the project is immediately executed and scenario 2 unfolds the projected benefits of the tram project will never become reality, while the large investment costs remain. The infrastructure would not easily be removed once it is build, without significant depreciation cost. Thus the option to be able to change course has value and can be included in a cost benefit analysis.

For the same reason, with regular maintenance and replacing existing infrastructure of decent and well operating lines not too much can go wrong. Even if lines close, the infrastructure often remains in the ground. This is for redirecting the tram to keep it operational when large works are done for other parts of the network. This is not very efficient use of space, but if there is limited scarcity this can be understood. Furthermore, stopping maintenance and replacement works altogether for lines with decent utility rates before DORS has proven itself would cost in lost accessibility and it would only be more expensive to restore them. Off course there can be other reasons outside the scope of this thesis to close a tram line, but possible diffusion of DORS as an argument should be handled with care at this time.

Another measure to become more flexible would be through procurement. Why not procure mobility goals instead of performance criteria for separate modes? This allows transit service providers to innovate beyond the traditional modes and no matter the outcome of the substitution between DORS and tram the risk of having to downgrade on e.g. accessibility is mitigated. Financial risks would not necessarily be covered with this.

5.3.1.3. Strategies that reduce decision-making time horizons

Uncertainty increases with time and by reducing the lifetime of investments uncertainty and corresponding costs may be reduced (Hallegatte et al., 2012). Tram vehicles typically have a long technical lifetime of 25 to 30 years (Mott MacDonald, 2017) and reducing this may be beneficial. This would be a less costly initial investment for maybe a little less quality and if DORS would make the tram needless by consumers in the future less valuable years will have to be written off. Additionally, if less quality means the tram are lighter this could be beneficial for maintenance of the tracks.

Furthermore, the developments in automation are not restricted to cars only. Trams may well be suitable for automation as well and if this development comes any time soon and proves beneficial the transition can be implemented faster.

5.3.2. Multiple strategies approach

These strategies involve thinking ahead what would be best to do for each of the scenarios that may unfold to be able to act quickly (Conway, 2007). Once the leading indicators ring their bells and DORS turns out to be commercially exploitable, the citizens are enthusiastic and the state as well it may be too late to think of a plan to adapt. Therefore, thinking ahead about how the tram can still be valuable to urban society in a future with DORS can be beneficial if this is desirable of course. Currently the tram has a one size fits all function in the M3 as it should be accessible for everyone for the benefit of inclusion. The distance between stops should not be too large for the elderly and physically impaired, while it should be fast for commuters as well (Interviewee HTM, 2016). The growth of special purpose transportation shows that it is not succeeding in the first and the average speed of 18km/h (Figure 15 in appendix B) does not display it is achieving the latter either. If DORS would diffuse into a major mode it may be an opportunity for the tram to specialise to remain its value. In chapter three we found that the tram has the advantage over DORS if frequent and riding on dedicated lanes in congested mixed-use areas. Thus, specialising for commuters may be an option, especially because DORS is argued to be suitable to serve the elderly and physically impaired.

Furthermore, in two of the scenarios funds to subsidise the tram will gradually decline apart from possible substitution to DORS. This could lead to closure of lines or reduction of frequency for some tram corridors. What assets and parts of the network may become out of need first? What assets would be most desirable to repel and what choice does a policy maker have? Additionally, if fewer or different trams would be needed in the future than can be foreseen now, what can be done with the surplus? Would leasing of tram vehicles be an option in the future? Asking questions like these and form multiple strategies around them considering the uncertainties could help policy makers to make more informed investment policy decisions. This takes time and effort and policy makers should make the trade off if the risks involved with the uncertainties make the extra efforts worthwhile. In this thesis, no quantitative analysis has been made and its findings can therefore not be directly used for this.

5.3.3. Gamble strategy approach

This strategy would be to choose a scenario that is most desirable or draw a plan that does not consider the scenarios at all and take actions to make it reality (Conway, 2007). This contradicts with the strategies above that are more adaptive. The logic would be that by taking matters in one's own hand, the future can be shaped to one's desire. Directly start lobbying for extra state funding to increase frequencies of the overall tram system or expand the network to become more attractive for travellers could be such strategies. This could arguably limit the market for DORS to diffuse and form a threat. Looking at chapter 3 and the scenarios, this would probably not stop diffusion of DORS however. Its main attribute is that it offers flexible door-to-door transportation, while the tram is inherently fixed. This implies that when not considering cost DORS will be a more attractive option for travellers in most circumstances except for trips along the corridor because access and egress and line changes are routed in the concept of a tram. No matter how frequent or fast the tram will ride, this will not change. If there is a need in society (sharing economy blooms) to have another flexible mode besides or in replacement of the bike or private car, DORS will still diffuse. Furthermore, it may still skim travel volume of the tram system unless restricted by policy. The chance of substitution would be less, but the collective cost for society could be high as well. Before taking such an action, it should be considered if these costs best serve the goals of the policy maker or institution or investing in other means may bring more value for money.

6. Conclusion & Recommendations

This thesis focussed on the rise of innovative mobility providers and their potential to disrupt traditional public transit. Tram assets were found to be most vulnerable for disruption as the tram lacks the speed advantage of the metro and de bus has limited dedicated assets. Tram assets could run the risk of depreciation or disutility which can be a problem for the asset owner, tax payers and city residents. DORS was investigated as disrupter because existing literature showed substitution from transit to be plausible. Scientific literature on potential impact of DORS on tram investments is lacking however. This thesis aimed to contribute to science by exploring the potential impact of DORS developments on investment policy in the tram system in an urban context. A framework for substitution was developed and four distinct scenarios for the impact of DORS on tram substitution and investments were written with the help of an expert panel. Moreover, the implications of these scenarios for tram investment policy were discussed. Overall this led to interesting results and incentives for further research. In this final chapter, the sub-questions and central research question will be answered in 6.1 Conclusion. In paragraph 6.2 reflections and recommendations for future research will be made.

6.1. Conclusion

The central question to be answered in this thesis is: *"What could be the impact of digital on-demand ride sharing services' developments in Dutch cities on investment policy of metropolitan transport authorities in the tram system?"*

This question is divided in sub-questions which will be answered one by one before ending this paragraph with the answer to the central research question.

6.1.1. Answer to the sub-questions

Sub-question 1: To what extend do digital on-demand ride sharing services impact tram demand in Dutch cities?

This depends on the innovation attributes of DORS, the social system subject to adoption of DORS and aspects of the urban environment both tram and DORS are situated in. Within the M3 the impact on tram demand was found to be complementary as both serve mostly different markets at this time. Substitution is insignificant, because the operating scale of DORS is small and substitution is expected to be concentrated in evenings and for incidental trips.

Sub-question 2: What could be the impact of digital on-demand ride sharing services' developments on tram demand in Dutch cities?

To answer this question, key factors and driving forces related to this question were identified and prioritised during an expert workshop. The development of the sharing economy and policy are the critical uncertainties according to the expert panel and drive the potential impact into four outcomes. Differentiation of the scenarios is expected to become significant after 2020/2025. DORS will develop into a mature large-scale mode in two scenarios and substitution from tram to DORS is expected in three scenarios. In one this would be disruptive, with fast substitution across the entire tram network. In the other, substitution will be gradual and limited to the line ends and both systems will mostly complement each other. In the third, substitution to DORS will occur for tram lines that severely decreased in quality due to on-going budget cuts. In the last scenario only ride-sourcing diffuses to take over the taxi market, but this has no impact on tram demand.

Sub-question 3: What are the implications of this impact for investments in tram assets and what investment policy is recommended for metropolitan transport authorities?

In all three scenarios where substitution is expected there is a risk of divestment in tram assets. In the disruptive scenario, the entire network may be at risk, but this is least for the bigger corridors. In the other two scenarios, the risk of divestment is limited to low demand tram lines. In the complementary scenario, the closure of tram lines can be beneficial for investments as well if timed right. Revenue loss was not considered a direct risk for MTA investments according to the scenario analysis. Either the government prevents it or the risk lies with the transit service provider. The main allocation of funds by MTA was also subject to uncertainty in the scenarios. If the government seeks control they will continue spend over 80% on maintenance and operations of public transit, while if the government retreats other means to facilitate accessibility and the regional economy can be utilised.

Regarding investment policy MTA can monitor indicators of change. Commercial exploitability of DORS, more sophisticated travel behaviour models that can include DORS and the diffusion of MaaS platforms were identified by the expert panel as signposts for either of the scenarios to happen. Moreover, developments of AV should be monitored, because this technology may push each scenario into the extreme if it would diffuse. By monitoring these indicators MTA can make more informed investment decisions regarding the impact of DORS developments.

Furthermore, three approaches to address the uncertainty of the scenarios were discussed. Robust decision making was found to help reduce the cost of being wrong and useful to include various viewpoints and uncertainties of a project. A risk of this approach would be being over adaptive to change in relation to the risks or being too restrictive, while problems may be urgent. The multiple strategies approach was argued to be useful to have a plan for each risky or opportune outcome of the main uncertainties. Formulating strategies takes effort however and the value of having multiple ones should be compared with this effort. The final approach would be to gamble by choosing one scenario as truth or do not consider them at all. This might be perceived as making a project less vulnerable to the scenarios and can off course be beneficial if the gamble is right. Being wrong however can have major cost and these should be considered.

6.1.2. Answer to the central research question

"What could be the impact of digital on-demand ride sharing services' developments in Dutch cities on investment policy of metropolitan transport authorities in the tram system?"

DORS was argued to be potentially disruptive to the tram system and investments in its dedicated assets at the beginning of this thesis. However, after developing a framework for substitution and elaborating its components it was concluded that in its current novel state DORS complements the tram system. Tram assets last long however and the found factors are subject to uncertainty. A scenario analysis was conducted to explore these uncertainties and define the impact of DORS on tram demand in 2040. The development of the sharing economy and policy are the critical uncertainties according to the scenario analysis and drive the impact into four outcomes. Differentiation of the scenarios will start slow and become apparent around 2020/2025. In one scenario DORS may become disruptive to the tram, in one it would have no impact, in one it would partly replace a languishing tram and in one it would complement it.

Thus, the problem statement should be more nuanced as disruptive impact of DORS is only probable in one scenario. However, in three scenarios substitution to some degree is probable leading to a risk of divestment. Tram lines with already low demand are most vulnerable for this risk and the bigger corridors with large sustainable demand the least. Revenue loss is not considered a risk for MTA investment. The role of MTA is up for debate in the scenarios and they may consider what role will best serve their mission. To make more informed investment decisions in the tram system and anticipate what scenario may unfold, MTA should monitor commercial exploitability of DORS, more sophisticated travel behaviour models that can include DORS, the diffusion of MaaS and development of AV. Around 2020/2025 the first three indicators are expected to have decreased the uncertainty of DORS' impact on tram demand. Before that time MTA can resort to robust decision making, multiple strategies approach or gamble strategy approach for their investment policy.

6.2. Recommendations

The outcomes of this thesis can be useful for both practice and science. The identified indicators of change can be valuable for those developing policy for tram investments. Furthermore, the implications of the scenarios on tram investments give way on what parts of the tram network may be more, or less vulnerable for divestment. Moreover, the suggested investment policy approaches can be a source of inspiration for policy makers. However, the research in this thesis has several limitations as well. That is because the time limitations to conduct the research required a narrow research scope. Furthermore, the outcomes of the research are subject to large uncertainties due to the explorative nature of the used method and the novelty of the subject. To finalise this thesis limitations and recommendations for future research will be discussed in the next indentions.

6.2.1. The quality of the expert panel

In this thesis, the intuitive logics method was performed to construct the scenarios. The value of this method strongly relates to the knowledge and commitment of experts involved in the scenario workshop. Only four out of six invited experts were present during the workshop and although they had various knowledge backgrounds and viewpoints in urban mobility, having the other two invited experts present during the workshop might have been beneficial to the quality of the results. The results of the workshop were reviewed and complemented by the two absent experts two mitigate this limitation. Furthermore, it needs to be acknowledged that the presence of experts from other knowledge fields or stakeholders could have led to different results or nuances in the scenarios. Therefore, it is recommended to ask several experts with other fields of knowledge, such as transit asset management or innovation theory to validate the developed scenarios. The overall conclusion will get more weight by doing this.

6.2.2. Validation of the scenario implications

The implications of the developed scenarios on tram investments and related policy have been logically derived by the thesis author. For the quality and scientific weight of this thesis it could have been beneficial to ask experts with a knowledge background in investment policy, asset management and public transport to review this analysis by the author. Therefore, this is recommended for future research.

6.2.3. Study external effects

This thesis focussed on the monetary component of tram investment. However, there can be other variables to consider, such as the environment, social inclusion, liveability of cities or interest of local residents and businesses. The effects of DORS on these criteria are not considered in this thesis and are still uncertain to this date. Therefore, it is recommended to study the external effects of the various scenarios. This can help policy makers to understand broader consequences of the scenarios to base investment policy on. To research this, the accumulated data of DORS providers such as Uber would be highly beneficial. However, to this date these private companies are very restrictive with sharing this data by only sharing data for research they fund themselves. This may limit the possibility to study external effects of DORS, but does not mean it should not be done. An alternative for policy makers and researchers could be to start a pilot with DORS themselves to study external effects.

6.2.4. Quantify the substitution framework

The developed framework for substitution in this thesis helps to understand the possible impact of DORS on tram demand. Although the various components have been elaborated, no weighting of their importance has been assigned to them. This may result in policy makers monitoring insignificant factors. A recommendation would therefore be to study the weight and nuances of the quality aspects that explain the relative advantage of DORS over tram in various circumstances. This can be done relative to trip characteristics, characteristics of the individual, resources available to the individual and aspects of the urban environment. A choice experiment may be a suitable method to do this and the framework established in chapter 3 of this thesis can be helpful for this purpose. This can help policy makers and researchers to better understand in what specific circumstances DORS is favoured over tram and how both systems can complement or replace each other. Additionally, it can help to quantify the scenarios. For a choice experiment to work, the population participating in the experiment should have knowledge of the DORS concept. Since DORS is not familiar yet, this should be considered before engaging in this research.

6.2.5. Quantify the scenarios

The outcomes of this thesis give valuable insight in the potential impact of DORS on tram demand. These outcomes are subject to large uncertainties however. Although terms such as disruptive have been used, it is not clear what this actually means in numbers. This limits its direct usefulness to test tram system investments for policy makers, because this would require a quantification of the scenarios by adding a value of substitution from tram to DORS to the scenarios. This quantification could have made the results of this thesis more illustrative and valuable for policy makers. Therefore, it is recommended to quantify the scenarios, because this would allow policy makers to use the scenarios for cost benefit analyses of tram investments. They could test the expected usage of the tram system against the scenarios. To do this a group of experts may be asked to estimate the rate of substitution for each of the scenarios or a computational model can be developed. This should be done with care to prevent estimated figures to be declared as absolute truth.

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Appendix

A. Service characteristics

Tram service:
Electric tram diffusion started in Europe around 1890 and came to Amsterdam (1900) and Rotterdam (1905) as a follow up to the horse tram. Closure started in 1930's and speeded up after Second World War throughout Europe and replaced by motor bus, mainly due to large initial investment as operational costs are comparable. Demand reduced due to private car use. Tram survived in large cities without underground systems, because of its capacity (Costa & Fernandes, 2012). Since late 1980's renewed attention for tram and light rail in the Netherlands starting with the program "OV maal 2" to combat car congestion in the major cities (Baanders, Hoorn, & Waard, 2010).

The oxford dictionary defines a tram as: "A passenger vehicle powered by electricity conveyed by overhead cables, and running on rails laid in a public road" (Oxford University Press, 2016).
Although trams are designed to travel on streets, sharing road space with other traffic modes, most systems include off-street running as well, with a separated strip designated for the tram (Infrasite, 2008). The terms tram, light rail and metro are often interchanged and many hybrid systems exist, but some differences do exist as can be seen in Table 19.

	Tram	Light rail	Metro	Train
Covering area of the system	Small/Medium	Medium	Small/Medium	Large
Connection to environment	Integrated	Integrated	Exclusive/closed	Exclusive
Crossings with other traffic	Many	Several	None	Few
Priority at junctions	Sometimes	Often	NA	Always
Stopping distance	0.2-0.8km	0.4-2km	0.4-2km	2-100km
Train signalling applied	Sometimes	Often	Always	Always
Vehicle capacity	Low	Medium	Medium/high	High

Table 19: Some characteristics of Tram compared to other modes (Van Oort, Van der Bijl, & Roeske, 2015)

In the Netherlands many tram lines share road space at some line segments while riding on a dedicated line on other segments. Therefore, in this thesis both trams sharing road space and trams on a dedicated lane are considered.

The tram service is characterized by a fixed service both geographically and timely. The service is geographically fixed, because it needs dedicated infrastructure (rail and overhead wiring) following fixed routes and stopping at fixed stations. Altering the route or stop location requires physical changes to the infrastructure and thus capital investment. The fixed route characteristic makes the tram attractive for journeys going roughly along these lines and ineffective for destinations perpendicular to the line as they usually require a line change. The use of scheduling by service providers makes the tram system timely fixed and unless a user's starting point and destination is directly next to a stop, the tram service always requires access- and egress time and distance. Recent research shows that people are willing to take longer for access and egress if the tram service is more frequent, as the risk of having to wait an unacceptable time due to missing a tram becomes smaller (KiM, 2016a).

Another characteristic of the service is the durability of the vehicles and infrastructure. The technical lifetime is 30 years and they are used and depreciated along those years. According to (Interviewee HTM, 2016) this is due to a 150 year old habit of manufactures, service providers and transport authorities. Both the dedicated infrastructure and durability of assets limits service providers to adapt to changes in the environment such as user needs. On the contrary, this also gives the service the perception of infinity. People and businesses can count on the fact that the tram will ride today and tomorrow in the same place and time, whether they use the service or not. This gives a sense of trust in their own mobility and accessibility.

The tram operates on a fixed network and therefore depends on the demand conditions along the lines. According to (Anonymous Interviewee, 2016) and (Zelezny, 2014) the tram system is positively affected by a high degree of urban density, mixed urban space and polycentricism. The high density is needed for sufficient demand to fill the tram and mixed urban space enables a more flat-out use during the day as different functions are commonly used on different times of the day. A polycentric city structure balances the tram network by generating bidirectional demand at peak hours. The tram networks in the M3 are shaped around the central train stations. From there the tram lines follow a radial pattern to connect the centre with the residential areas in the outer districts. Within the centre area of the M3 multiple lines are bundled on the same infrastructure increasing its efficiency and enabling higher frequencies in the centre districts compared to the outer neighbourhoods. Most of the usage is concentrated around the centre area as can be seen in Figure 14 in appendix C, while usage in the capillaries is marginal. In daily usage the tram has a sharp morning peak and a broad evening peak in both Rotterdam (Anonymous Interviewee, 2016) and The Hague (Figure 19, appendix C). In The Hague around 250,000 people (HTM, 2016) use the tram daily.

On-demand ride-sharing services

Started in the Netherlands in the 80’s / 90’s as so called shared taxi’s or vans for the elderly and disabled and was broadened to commercial use as well. After subsidy was cancelled only the paratransit service remained heavily subsidized. During operation, it was not a success, because there was a strong resistance against the need to call, not knowing when you arrive, the feeling of going on a detour to pick up other people and sharing the ride with unknown people (Interviewee KiM, 2016a). Recent developments in ICT, internet and mobile communications take these concerns away as they are all made transparent in a smart phone application with the use of roadmaps, GPS, social media and real-time monitoring of traffic and fleet. As 85% of Dutch people owned a smart phone at the end 2015 (TelecomNieuwsNet, 2016) the service is potentially accessible for almost the entire population.

This digital innovation, which we saw earlier in music and film with the likes of Spotify and Netflix, started in the taxi market. Uber introduced digital technology that exposed a new source of supply, while removing demand distortions. The new source of supply came from utilizing private car owners. Instead of being employed by a taxi company that owned a fleet of cars, basically anyone with a vehicle and a smart phone could now become a driver whenever they want to. On the demand side, users no longer had to wait on the street or rely on a central booking office, but could see all available supply on their smart phone and directly book a ride with a driver. This both lowers transaction costs and reduces the information asymmetry between business and consumer, making it easier and more reliable to book a ride against a far lower fare price (Dawson, Hirt, & Scanlan, 2016).

The sharing of rides was the next step in utilizing formerly uncultivated supply. Many rides are booked by individuals leaving three or more empty seats. The digital nature of the product allows a real-time intelligent transport system in which a central server optimizes the routes of all viable vehicles with trip orders in real time. This allows the combining of trips, lowering the price and enlarging availability. After Uber many other followed and currently on-demand ridesharing services come in various ways and are under continuous development. The Shared use mobility centre (SUMC) defined a list of common shared use mobility services. All are demand driven, app based and user centric, but offer different services with different business models and vehicles. Of this list the following can be included in the concept of on-demand ride sharing services (SUMC & USDN, 2016):

Ride-sourcing: Most known form of shared mobility, where so called transportation network companies (TNCs), such as Uber and Lyft use online platforms to connect private drivers with passengers in real time. Smart phone apps are used for booking the ride, rating both driver and rider to enhance security; and automatic, cashless payment. The connection is made with one passenger or a group of people and the price is for the whole car (Greenblatt & Shaheen, 2015). In the Netherlands, UberX is such a service and operates in Amsterdam, Rotterdam, and The Hague.

Ride-splitting: In this form TNCs allow drivers to add extra passengers with similar destinations to a trip in real time, offering both the driver and the rider a better price. Single passengers or pairs can select they would not mind to share the vehicle and pay for 1 or 2 seats instead of the entire vehicle in the mobile application. Next, the technology behind the app searches for other passengers with a similar trip to be combined in the same vehicle under the condition of limited time loss of all passengers as can be seen in Figure 11. The responsibility for combining trips is completely with the TNC and therefore, if it is not able to, the passenger still pays for the seat only. When traveling in pairs you do not pay for 1+1 seat, but the price is only slightly higher than for 1 seat, in order it to be still cheaper than ordering an entire vehicle (Abel, 2016). The service is unavailable for more than two people as they can make better use of a ride-sourcing service. In the Netherlands Abel operates such a service in Amsterdam and the most notable examples abroad are UberPool and Lyft Line.

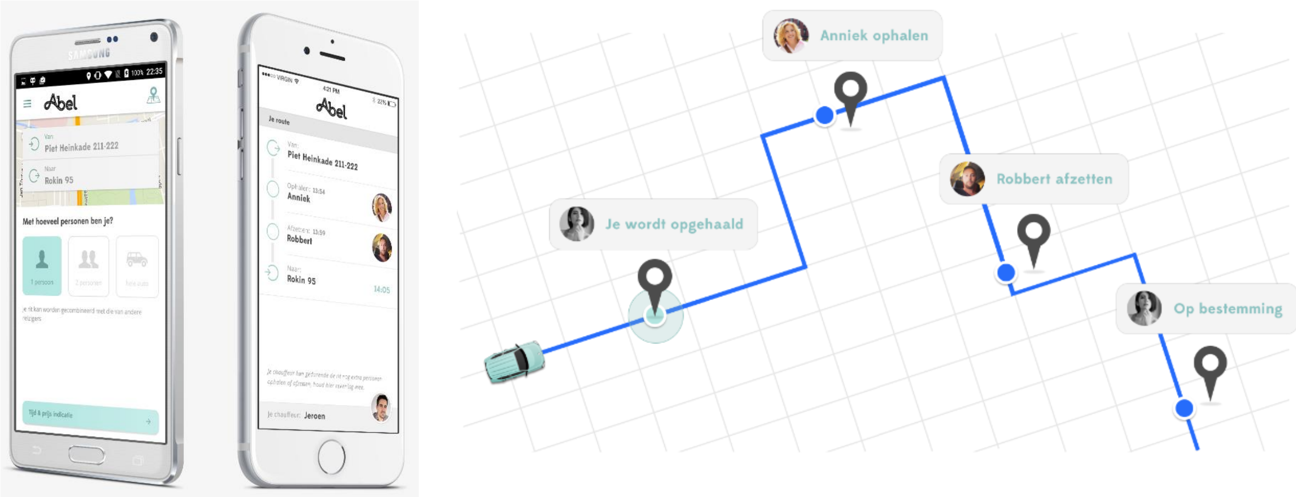


Figure 11: the concept of ride-splitting (Abel, 2016)

Ridesharing/Carpooling: Offers drivers a platform to add passengers to a ride that will already take place and fill seats that would otherwise remain empty. Thus, the difference with ride-splitting is that the driver is not paid for his service, but compensated for (gasoline) costs made. The concept has been around for decades, but has been given new stimulus since the digital age made matching easier (Greenblatt & Shaheen, 2015). The platforms are usually web and smart phone app based and allow users to offer or request rides. The service is in its contemporary form still rather static with long pre-order times as real-time matching is not yet in operation. Extensive research is done however, on the feasibility of dynamic ridesharing for its potential to get cars of the road e.g. by (Gargiulo, Giannantonio, Guercio, Borean, & Zenezini, 2015; Mallus, Colistra, Atzori, & Murroni, 2016; Stiglic, Agatz, Savelsbergh, & Gradisar, 2015, 2016).

Dynamic ridesharing would allow people driving to the supermarket for example to be notified immediately they can pick-up someone else along the way (Meurer, Stein, & Wulf, 2014). Uber is piloting a form of dynamic ridesharing called Uber driver destinations in San Francisco, what Uber drivers can use twice a day e.g. when commuting to work. Drivers can send in their destination and earn some extra cash by picking up anyone requesting a similar ride. Uber is not alone in this development as Lyft their major competitor in the US is offering a similar service (Andrew J . Hawkins, 2015). In general usage of ridesharing at this time is more for intercity commuting and not so much within cities. Whether this will change in the future remains to be seen. Examples in the Netherlands are Blablacar operating throughout Europe (Blablacar, 2016) and Toogethr just started with a Tinder-like concept for companies on the Zuid-as in Amsterdam to encourage their employees to share rides when commuting (Toogethr, 2016).

Microtransit: It is a demand-responsive transport system, which optimizes routes of mini-buses on the base of trip orders of up to 14 customers in such a way that users going in the same direction are directed and picked up by the same vehicle. The system relies on real time information of the traffic situation in the service area and a fast re-optimization time to be able to estimate reliable driving times. The difference with ride-splitting is that the service is not door to door, but they seek a stop and pick-up location that efficiently combines the trips of multiple passengers to save time for all passengers and help more people at once. The pick-up locations are static, making use of existing bus stops plus extra virtual stops for a fine-grained service with short walking distances (Rissanen, 2016). Payment and booking is made for a seat and makes use of similar smart phone app technology as TNCs. Foreign examples are Bridj, UberHop and Chariot in the US and Kutsuplus in Helsinki. In the Netherlands, Breng Flex started operating in the urban region Arnhem-Nijmegen, since December 2016.

Except ridesharing, all the above variants use more or less the same app based technology. Therefore, ride-sourcing, ride-splitting and sometimes microtransit are not unusually provided by the same service provider. Uber for example offers choice between UberX (ride-sourcing), UberBlack (Taxi), UberPool (ride-splitting), UberHop (microtransit), UberDestinations (ridesharing) and UberVan (Taxi for large groups, disabled and movers) to app users if available on their location. In the three biggest cities in the Netherlands UberX, UberBlack and UberVan are available. This variety of services enables users to easily check and compare the alternatives on availability, vehicle type, price, and arrival time and choose the variant that suits their needs. The user chooses where, when and by what to be picked up and dropped off no matter the geographical location or time within the service area. All what is needed is a road for motorized vehicles, a driver with a vehicle, a rider and both need a smart phone application. The service is also flexible in the route it chooses, by continuous monitoring of congestion the application always shows the most favourable route from A to B and the driver is obliged to follow it.

The above are all contemporary offered services and since we explore possible futures of these services, of which no contemporary form has proven itself sustainably, and considering the rapid introduction of new business models and technology a broad definition of on-demand ride-sharing services is handled in this thesis. This overall concept will be called Digital On-demand Ride-sharing Service (DORS) in this thesis. Digital is added to differentiate the concept from regular taxi's and demand responsive transit (DRT) that offer the same physical service, but have not yet digitalized their product.

A service operating with a digital platform, which enables on-demand, customized and real-time matching of multiple riders with vacant vehicles that suit their needs.

The above definition is handled when addressing the overall concept. A lot of research however, focuses on individual services or service types of which we address the following. Ride-sharing is driver centric and attracts mostly intercity/regional rides (driver flexibility), within cities it is similar to ride-splitting and therefore not individually addressed. Ride-sourcing is not actually a shared mode, but because this service has been around longer, more research is conducted on this mode and is offered in combination with ride-splitting, this mode is included. Thus, ride-sourcing, ride-splitting and microtransit are further discussed in the remainder of this thesis and compared with the tram system in the Netherlands. When speaking about the three variants in general the acronym DORS is used.

DORS can be effective in any urban environment in terms of density according to (Interviewee KiM, 2016a), because they cover an area and not a corridor such as the tram system. DORS can move towards demand within the area and does not depend on the density along the line. According to (Hughes & MacKenzie, 2016) higher density of population and jobs is associated with shorter wait time in Seattle, presumably because greater density means more frequent trip requests and would thus attract more drivers and reduce waiting time in an area. (Interviewee KiM, 2016a) argues that in highly dense districts demand is high and potential trip matches as well, while at the same time traffic congestion frustrates operations by increasing travel times. Cities are attractive for DORS, because of the initial target audience of millennials who tend to live there (Circella, 2017). The scale of a city matters as well, as larger cities have more potential users, leading to higher ride combination rates. (Interviewee Transdev, 2016) argues that for this reason a city the size of Amsterdam is needed to commercially exploit a service such as Abel without subsidy. In smaller cities such as Arnhem, DORS concepts may work as well with Breng Flex as the live example. Subsidy however is argued to be necessary in these cases says (Interviewee Transdev, 2016).

The greater the area DORS serves the greater the amount of possible destinations and the more demand it may generate. This should be in balance however with the amount of vehicle supply, because a large area with few vehicles leads to long waiting times and therefore a less attractive system. The sharing of rides improves this, by being able of handling the same demand with less vehicles as recent research on shared taxis in New York showed (Conner-Simons, 2017). MIT developed an algorithm and found that 3000 four person shared taxis could serve 98% of New York taxi demand currently served by nearly 14.000 taxis with an average waiting time of less than 3 minutes.

All in all, usage of DORS in the Netherlands is still on a relatively small scale. Abel operates with about 50 vehicles according to (Interviewee Transdev, 2016). The taxi market is also relatively small in the Netherlands and mostly concentrated around Amsterdam with about 4000 vehicles. Rotterdam comes in second with 1500 and The Hague third with 500 vehicles in operation. Due to the emergence of Uber it is growing fast however (Business Insider Nederland, 2016). (Feigon & Murphy, 2016) of the SUMC argues that usage of ridesourcing currently peaks on weekend nights when transit less viable. Usage of Abel follows a similar pattern with weekend night peaks and flat use during weekdays according to (Interviewee Transdev, 2016).

Appendix

B. Substitution from tram to DORS

At the end of this paragraph we want to understand how substitution from one mobility service to the other may occur to be able to find relevant impact factors. This is investigated from both the field of innovation diffusion and of travel mode choice. According to research of (Paap & Katz, 2004) on anticipating disruptive innovation, substitution may only occur if there is an unmet need in a dominant driver and the current technology in use is unable to meet that need competitively. This can happen if current technology matures relative to the dominant driver or if the dominant driver changes and the present technology cannot fulfil the new needs. The latter may be due to a change in the environment or the former dominant driver reaches a saturation point. (Rogers, 2010) argues in his widely cited innovation adoption theory that the individual's perception of five attributes predict an innovations rate of adoption over the service, product or idea it supersedes. These five attributes are relative economic or social advantage; compatibility with the previous idea, values, norms and user needs; complexity to use the innovation; trialability of the innovation; and observability of the benefits of the innovation.

If one looks at substitution between mobility modes specifically a similar pattern can be observed. (Goletz, Feige, & Heinrichs, 2016) did research on factors that drove mode shifts in Paris, Santiago de Chile, Singapore and Vienna. According to them a mobility trend or mode shift can be explained by both the surrounding conditions and user motives of which the latter is influenced by the surrounding conditions as can be seen in Figure 12. User motives can be further divided into rational- and social-emotional motives. Rational motives relate to quality aspects of modes, such as speed, costs and reliability, where social-emotional motives relate to personal desires and social norms. (Bakker et al., 2011) suggest similar determinants for the use of local public transport in the Netherlands. They argue that external factors and the decision maker's perception of quality aspects of public transport and alternative modes determine mode choice.

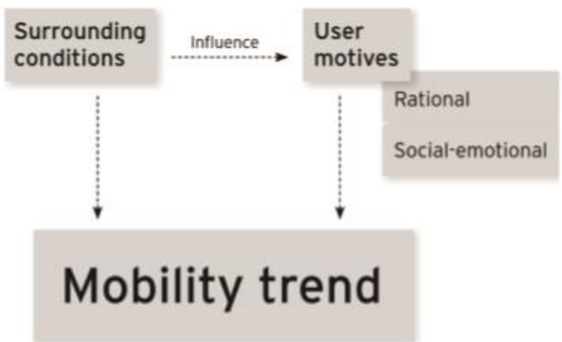


Figure 12: factors that drive a mobility trend (Goletz et al., 2016)

From the above theorem can be concluded that substitution from tram to DORS would be related to aspects from the urban environment and user motives to adopt DORS. The urban environment is investigated in paragraph 3.1 by first researching in what urban area they operate and subsequently what aspects of this environment may influence substitution. The potential adoption of DORS is analysed in paragraph 3.3 by elaborating the innovation attributes of DORS relative to the tram within the urban environment. These innovation attributes should be researched relative to the social system which is elaborated in paragraph 3.2 (Rogers, 2010).

Appendix

C. Figures

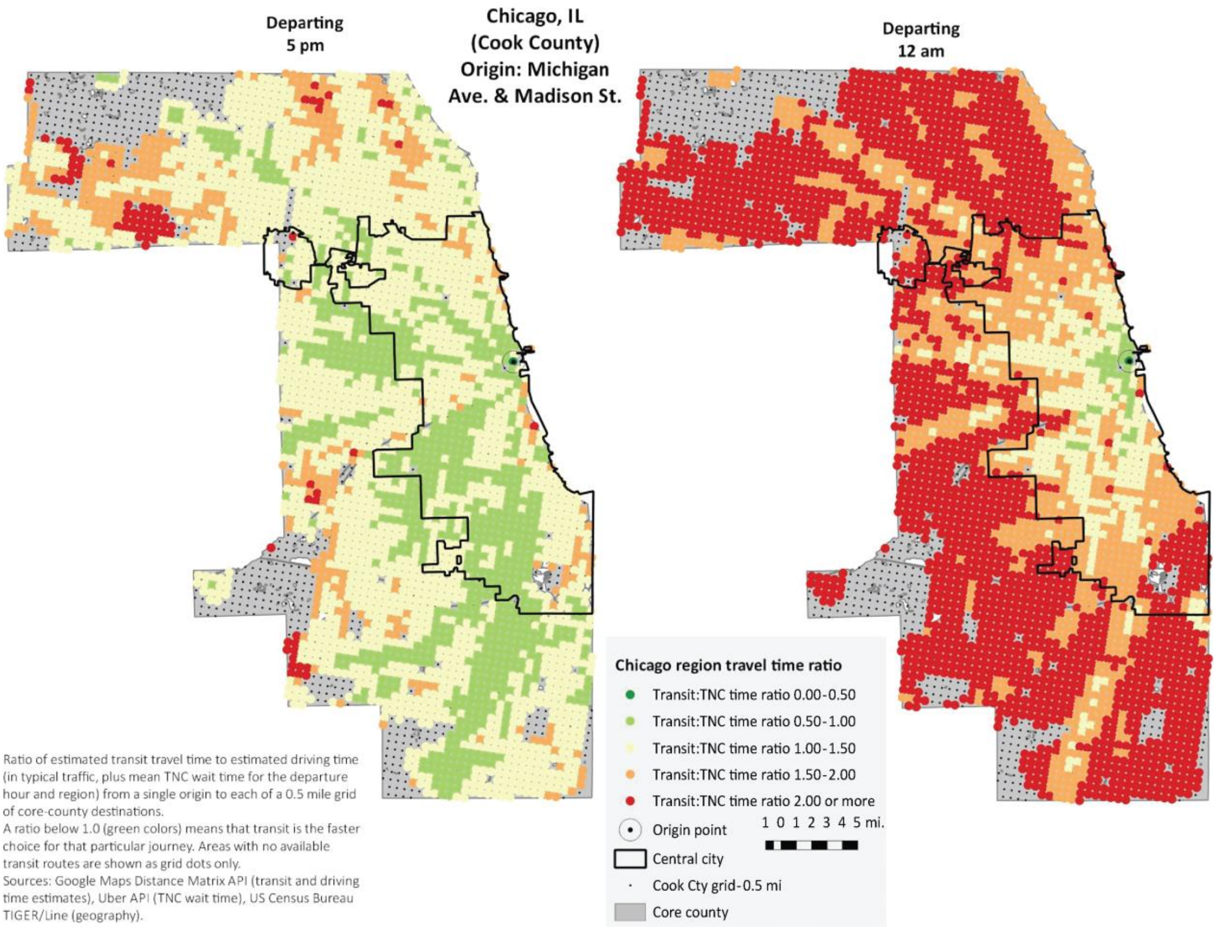


Figure 13: travel time comparison transit and ride-sourcing in Chicago, USA (Feigon & Murphy, 2016)

Figure 14: Picture is anonymised

Figure 15: Picture is anonymised

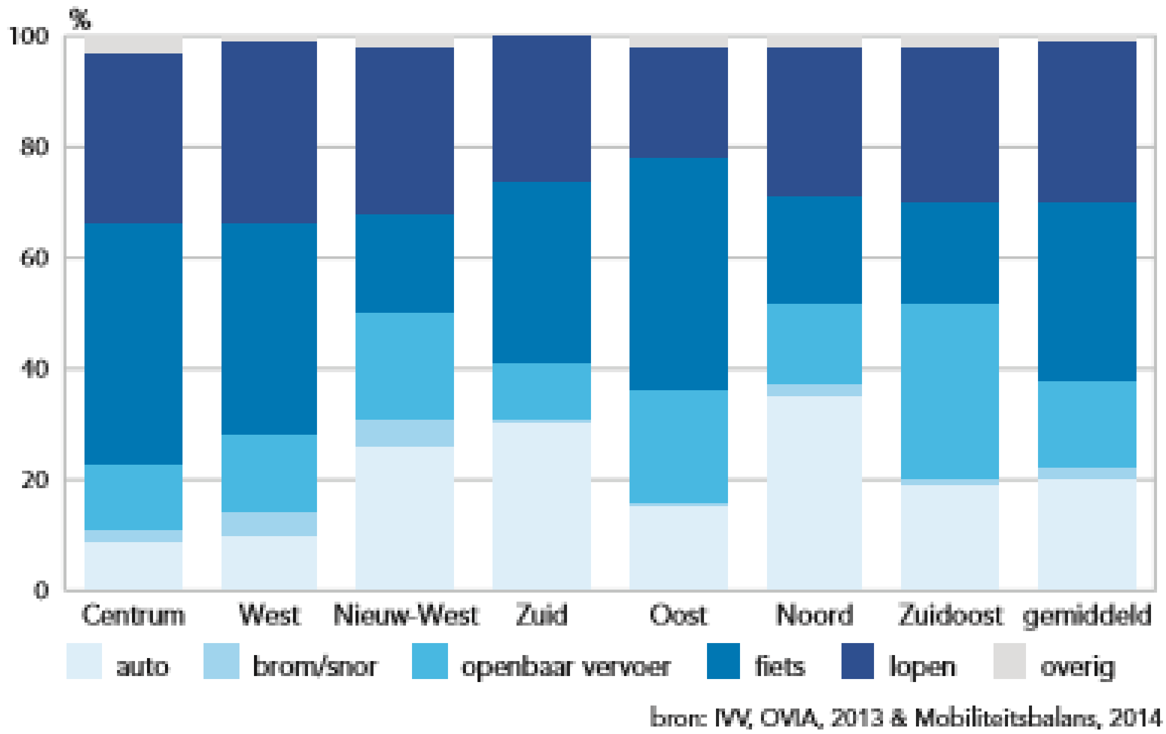


Figure 16: Modal split of Amsterdam 2014

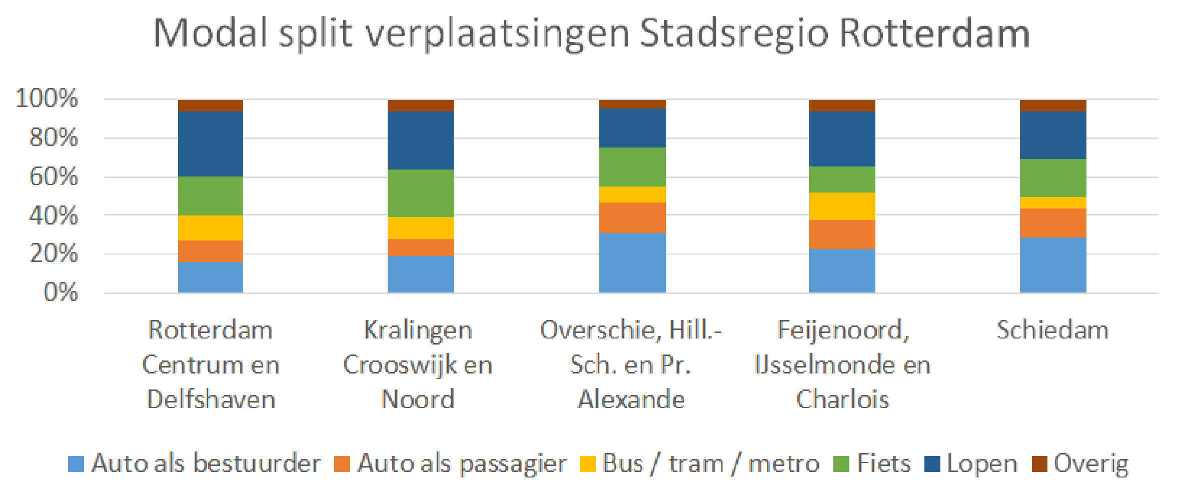


Figure 17: Modal split Rotterdam 2010-2014 (OBI, 2015)

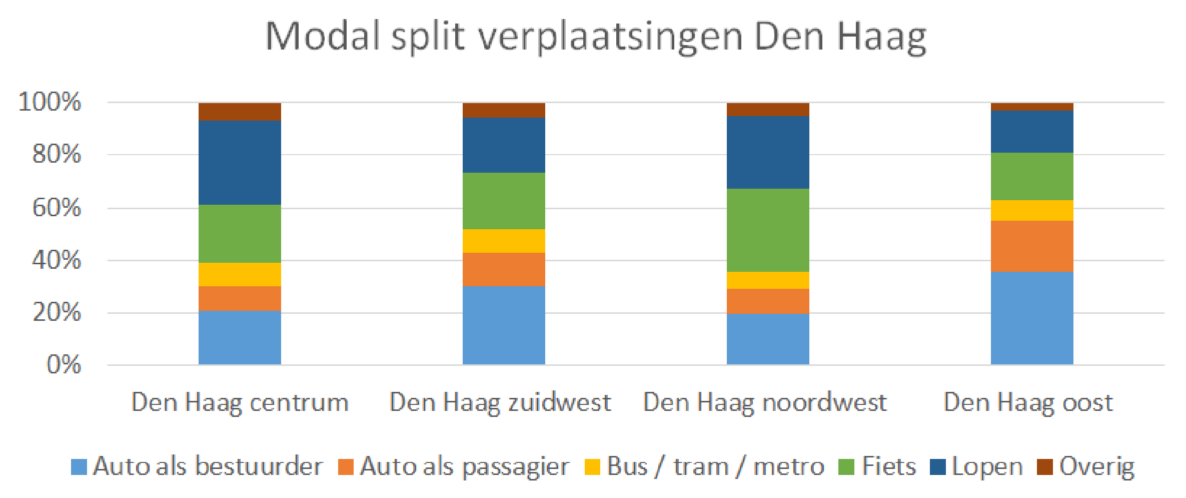


Figure 18: Modal split The Hague 2010-2014 (OBI, 2015)

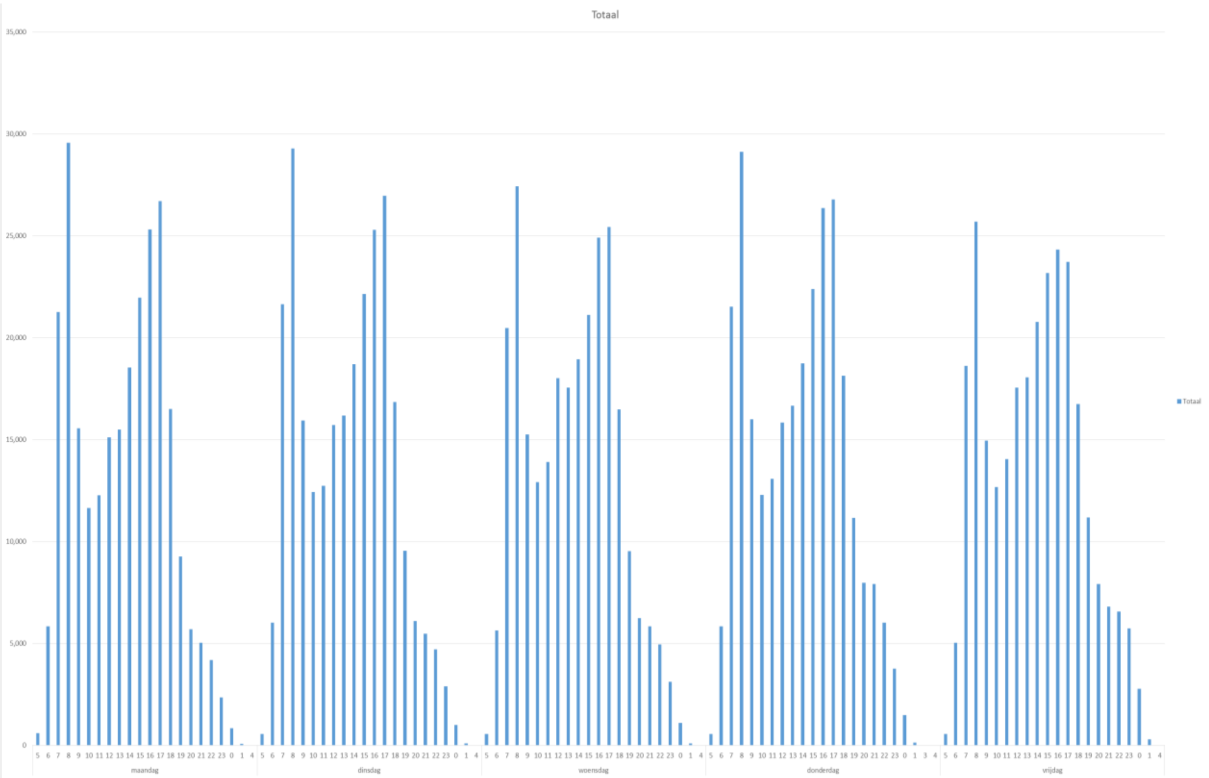


Figure 19: hourly tram use during weekdays in The Hague (source: HTM)

18. U reist nu ergens naartoe, wat gaat u daar doen? * Jaar Crosstabulation

			Jaar						
			2014	voorjaar 2015	najaar 2015	Q1 2016	Q2 2016	Q3 2016	Total
18. U reist nu ergens naartoe, wat gaat u daar doen?	wonen	Count	1425	1375	1195	1091	1249	868	7203
		% within Jaar	29,5%	26,7%	27,6%	26,4%	29,3%	27,5%	27,9%
	werken	Count	1101	1346	1091	1048	1207	786	6579
		% within Jaar	22,8%	26,2%	25,2%	25,4%	28,3%	24,9%	25,5%
	onderwijs	Count	675	596	617	591	495	351	3325
		% within Jaar	14,0%	11,6%	14,3%	14,3%	11,6%	11,1%	12,9%
	winkelen	Count	388	483	339	313	289	274	2086
		% within Jaar	8,0%	9,4%	7,8%	7,6%	6,8%	8,7%	8,1%
	sporten	Count	100	81	97	121	96	65	560
		% within Jaar	2,1%	1,6%	2,2%	2,9%	2,3%	2,1%	2,2%
	bezoek	Count	521	537	468	458	410	351	2745
		% within Jaar	10,8%	10,4%	10,8%	11,1%	9,6%	11,1%	10,6%
	anders	Count	613	727	517	503	514	459	3333
		% within Jaar	12,7%	14,1%	12,0%	12,2%	12,1%	14,6%	12,9%
Total		Count	4823	5145	4324	4125	4260	3154	25831
		% within Jaar	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

Figure 20: travel motives tram user The Hague (source: HTM)

Figure 21: Picture is anonymised

Appendix

D. Scenario workshop preparation

The preparation of a scenario workshop in the intuitive logics method follows a few distinct steps. These are not strict and deviations can be made freely, but following these will lead to a good base for the scenario workshop (Maack, 2001). First the focal issue needs to be defined, followed by the scope, next the participant selection, subsequently background material is collected and finally the engagement rules and process of the workshop are described.

Determine focal issue of scenario analysis

The first step in any scenario analysis study is to determine the focal issue. This can be a decision or a question that is currently critical to the future of the organization at hand. The focal issue should not be too broad to prevent it from drifting to a general description of the future economy for example. At the same time it should not focus on the future of the organization itself or it will be likely that bigger forces are missed during the scenario building that drive the organization in unforeseen directions regardless where it wants to be. (Maack, 2001) argues that to develop a precise focal issue one needs to know what the desired outcome of both the intervention for which a strategy is needed and of the scenario process. Additionally, the timeframe is very important as the main drivers of change for a time horizon of 20 years, may not be applicable for a 5-year project. Below these three questions are handled.

<u>What is the desired outcome of the intervention that needs strategy?</u>

Public transport budgets are in constraint, while the goal of MTA is to improve accessibility of the metropolis sustainably for citizens and visitors. The tram system is in general the most expensive in terms of cost per travelled kilometre, while passenger numbers remain flat. On the flip side, there are very good running tram lines as well and it is a very recognizable product for users, it can move a large amount of people in limited space and it has a social function for the less fortunate. Since, the public transport system is build and maintained with scarce public money and plans are made for 30 years in the future, MTA need to choose in what assets/ services to invest more or less to achieve their goal of improving accessibility.

At the same time a new mode of transport is rising, offering shared on-demand transportation. From the first sub-question we found that these so called Digital On-demand Ride-sharing Services (DORS) mostly complement the tram system. They currently fill a gap for rides where the tram or other urban PT is not attractive due to a required line change, long access and egress distances or low frequencies leading to long travel times. This is typical for trips between urban districts outside the centre (line change) and during off-peak hours (low frequency). For rides where the tram is an attractive option a trade-off is made between more convenience (door-to-door) and comfort for DORS against lower cost for tram. Total travel time is comparable in these cases, although congestion favours the tram on a dedicated lane. Perceived travel time is in favour of DORS however, because it is door-to-door.

The substantial difference in costs make substitution more likely for incidental tram riders than for frequent riders and when people travel in a group (costs can be split). Apart from cost using DORS would require frequent tram riders to change their habit of acquiring mobility. No longer they can learn the schedule and automatically walk to the stop, get on the tram and walk to the destination. Instead they have to order mobility each time they want it, but it comes their way in a few pushes on a button using a smart phone. Whether this is perceived as hassle by incumbent users or fills an unmet need we saw earlier in music and film industry remains to be seen. Instant availability, seemingly unlimited offering and a competitive subscription pricing that characterises other digital innovations such as Spotify and Netflix has not yet come to blossom for DORS.

These services are new however and the ride matching technology is still immature, but improvements in both the supply and demand side can be and are made rapidly due to the digital nature of the product. This may lead to DORS shifting to a bigger part of the mobility market, including transit or they may remain in the taxi niche. All in all we do not know what market segment DORS will serve in the future or how large their piece of the mobility pie will be. We also do not know if they will significantly eat the tram's piece of the pie or of another mode and which part of the piece or in which circumstances. We do know that the level of competition is determined by the extent the market segments of both systems overlap and the relative advantage one system has over the other within this overlapping segment. If this overlap is small it means that DORS are mostly complementary and MTA might want to encourage its implementation to improve overall accessibility. If the overlap is large they may e.g. choose a strategy to shift to a less overlapping segment with the tram, impede regulations on DORS or replace tram lines for DORS. Thus, MTA want to know what the future of DORS may bring to be able to make informed investment decisions in the public transport system including the tram that benefit sustainable accessibility of the city.

<u>What is the time frame?</u>

In recent and coming years policy plans are written throughout the Netherlands for the future of public transport in 2040. There is a national plan for 2040 (MinIenM, 2016a) and the city of Rotterdam is in the process of making a plan for 2040 together with the MRDH (Gemeente Rotterdam & MRDH, 2016) which is the MTA of the Rotterdam-The Hague metropolis. Furthermore, the MRDH and RET together face the decision what type and how many trams to order by 2025 for the next 30 years. This thesis is made in collaboration with the MRDH and therefore, 2040 is chosen as time horizon with an in-between bearing for the implications in 2025.

<u>What is the desired outcome of the scenario process?</u>

The scenarios will be used as a tool to test MTA investment strategy on the possible impact of DORS. In this thesis we look specifically at the tram system and therefore, we want to know what the implications of each scenario could be for tram demand. This impact on tram demand is predominantly measured qualitative in this thesis, because quantification would require an additional step that cannot be executed in the designated time of a master thesis. Recommendations to quantify the results in future research will be given at the end of this thesis.

To measure the impact qualitatively we want to know how the impact found in the first part of this thesis changes due to the scenarios. Therefore, we want to know if DORS would affect: small corridors vs. big corridors, incidental vs. structural, peak vs. off-peak hours and centre districts vs. outer districts. As a result we know the possible implications of each scenario for tram demand. Subsequently, this information will be translated to impact on investment policy in a discussion framework. This gives decision makers a sense of importance of the scenarios and an incentive to use them. Moreover, a strategy is advised how to use them. This may be a robust, flexible, multiple or gamble strategy. These strategies will be explained in chapter 7.

What is the focal issue?

Looking at the requirements for a good focal question explained above it should not be too broad and it should not focus on the own institution. To examine what suits best we investigate three focal questions from broad to narrow, for their ability to lead to the desired outcome elaborated above.

The first option is to ask: **What will mobility look like within big urban regions in the Netherlands in 2040?** This is a broad enough question and both the future of the tram system and of DORS or any other mode for that matter can be placed within this question. Maybe, DORS will thrive better in some futures and maybe in other futures the tram will be more competitive. This does not answer however if DORS has impact on how well the tram is performing, unless development of DORS and tram is considered a factor that shapes future mobility. This is not unlikely, but even so it will be one of many factors. A cross-factor analysis helps, but would only show if there is a relation between tram and DORS, whether it is positive or negative and an estimation of the degree. This gives a generalized image and does not tell you why there is impact and what it drives.

Another option is to make a competitor scenario analysis and look through the eyes of DORS. This type of scenario broadly examines in which market segment the competitor may choose to compete, how it competes and what is seeks to achieve (Fahey, 2003). This could lead to the following question: **What segment of the mobility market will DORS serve within big urban regions in the Netherlands in 2040?** By answering this question one knows what extremes of market penetration DORS can achieve. Moreover, one knows what factors would drive the possible shift of DORS to a more mainstream market from the niche market where it is currently in. Subsequently, one can analyse to what extent the market served by tram found in the first part of this thesis overlaps with the DORS market segments of each scenario. Additionally, one can analyse whether the tram system can adapt to the drivers causing change. In this way one can logically argue what the implications of DORS developments may be on tram demand and one can form a strategy for the tram system to position itself against the DORS scenarios. Another positive is that these scenarios, similar to those that would lead from the first option can be used for other modes as well by MTA. However, this focal issue may miss bigger forces outside the specific future of DORS that may have a far larger impact on tram demand. Therefore, when making strategy from these scenarios it is advised to look at other more general scenarios as well.

The third option is to make the question even more specific to the aim of this thesis: **To what extent will DORS have impact on public transport demand within big urban regions in the Netherlands in 2040?**

This focal issue will lead to worlds where competition can be from fierce to almost non-existing. Because there are two systems in the question the factors involving the impact may consider the quality aspects of either system or what system users may favour in the future apart from other things. By asking for the impact on public transport and not tram, the question remains broad enough to prevent to the participants from focussing too much on factors considering future strategy of the tram, because these may be considered to affect the degree of impact stronger. This would imply a focus on internalities and self-reflection, while the purpose of building scenarios is to map how external forces can affect your case and then self-reflect what strategy is best. Moreover, by focussing on public transport, MTA can put the impact on tram into perspective with the entire system and explore the impact on bus or metro in future research if they would like to. After answering this focal question one knows how the urban public transport system could be affected by DORS and naturally the impact on tram demand can be derived from that.

Looking at the advantages and disadvantages of the three levels of specification of the focal issue elaborated above it is argued that the third option suits best to the desired outcome of both the intervention and scenario process. The implications of the scenarios for tram demand will be measured in terms of: small corridors vs. big corridors, incidental vs. structural, peak vs. off-peak hours.

Define scope

- Big urban regions (500,000+ inhabitants) in the Netherlands: Amsterdam, Rotterdam and Den Haag.
- By public transport is meant: bus, tram and metro. corridor
- DORS: Digital On-demand Ride-sharing Services
    - Digital platforms matching vehicles with riders in real time
    - Vehicles are ordered on-demand: real time, pre-order, repetitive order, agenda synchronization, etc.
    - Vehicles can be human controlled, autonomous or controlled by anything else
    - Platforms offer customized services for different prices: vehicle size, door-to-door or stop-to-stop, shared with others or private, hurry or no hurry, special assistance for elderly or disabled, etc.
    - Road based vehicles with a capacity of 4-14 passengers
    - Vehicles have electric, hybrid or combustion propulsion
    - Platforms cover no line but a complete area: neighbourhood(s), city or urban region.
    - Business models can be peer-to-peer or business-to-consumer

Choose scenario team

"Team members should be chosen based on their ability to represent distinct viewpoints on the issue being discussed, be it technical or political… the best scenario teams are diverse" (Maack, 2001).

- Three viewpoints to be represented
    - Government
    - Market
    - Research
- four bodies of knowledge to be represented
    - Urban mobility
    - User motives
    - DORS Technology
    - Urban trends

Choose scenario team

	Government	Market	Research
Urban mobility	1.	1.	2.
User motives			3.
DORS Technology	4.	5.	
Urban Trends & developments		6.	2.

1. Marit de Jong, Strategic advisor (Connecting mobility/ Ministry of IenM)
2. Peter Pelzer, researcher and lecturer Urban futures studio, sharing economy, sustainable mobility (University of Utrecht)
3. Peter Bakker, senior researcher collective mobility & social geography (KiM)
4. Martijn van de Leur, Program manager mobility management (Verkeersonderneming/ Ministry of IenM)
5. Quinten Passchier, Manager business development (RMC)
6. Ron Bos, Trendwatcher (SmartUrbanism.org) & Verkeersplanoloog (Den Bosch)

Prepare background material
Apart from the focal issue and scope, background material should be presented to the scenario team. Purpose is to help the group to start off with the same basic reference points, while leaving room for creativity. Three general areas are recommended (Maack, 2001).

- Predictable, relevant forces
- Unpredictable, relevant forces
- Sociopolitical information

The summary of (KiM, 2016b), (Weel et al., 2010) and (MinIenM, 2016a) will be available as background material during the workshop. Furthermore, the deep driver framework STEEP will be available for them if necessary with a basic description of each letter of the acronym. The STEEP framework can help to identify the drivers behind the relevant forces of the focal issue and stands for Social, Technological, Economical, Environmental and Political. In Appendix E the background material handed to the participants is displayed.

Workshop process & rules of engagement
The aim of the workshop is to fully benefit of the broad expertise of the participants and come up with four distinct basic scenario plots within 3.5 hours. The workshop includes four parts. First, the organizer will give a presentation to make sure the focal issue is understood by each participant. Second, key factors and driving forces for the focal issue are identified in a brainstorm session. Third, the identified forces and drivers are prioritized using Wilson’s matrix. Fourth, the four basic scenario plots are build and written. Below each step is elaborated in more detail with a time frame and rules of engagement for the participants if applicable.

<u>8.40 – 9.00 Presentation (10min + 5min questions)</u>

The goal of the presentation is to clarify the purpose of the workshop, the process followed, rules of engagement and the tools available to the participants during the workshop. Below the subjects handled in the presentation are lined out with the designated number of slides and time.

- Welcome and outline (1 slide and 1 minute)
- Explain thesis and purpose of scenario analysis (1 slide and 2 minutes)
- Explain focal issue and scope (1 slide and 2 minutes)
- Explain background material (1 slide and 2 minutes)
- Explain process and role facilitator (1 slide and 2 minutes)
- Rules of engagement (1 slide and 1 minute)
- Questions (5 min)

Because 10 minutes is limited time to address the above thoroughly a more elaborated description of the above will be send two weeks prior the workshop to all participants and is available during the workshop itself. The presentation makes sure all participants have the same basic knowledge and understand what is asked from them regardless if they have read the information send to them.

Rules of engagement during presentation:

- Questions should be kept to the end
- Participants are asked if they have questions one by one

Needed resources:

- Presentation screen
- Laptop
- Recording device
- Seats and table for participants
- Writing blocks and pens for participants
- Coffee and tea

9.00 – 10.00 Brainstorm key factors and driving forces (1 hour)

When the focal issue is clear for all participants, the brainstorm session leaded by the facilitator begins. This session starts with identifying key factors for the success of the focal issue. This can be specific events, such as the passage of supply regulation for DORS or general trends, such as increasing digitalization of consumer goods. The session is kicked off with the presentation of relevant forces found by the organizer in preparation of the workshop. These are presented on a big screen visible for everyone and can be read in hardcopy on the table. The factors presented constitute no more than eight words and make clear how they may affect the focal issue. The participants are free to ask the organizer for elaboration on the presented factors if they are not clear during the brainstorm.

After presenting the basic factors, the facilitator asks the participants to discuss the presented factors and to complement the list. For this purpose a flip-over or whiteboard is present in the room. When participants name a factor to be added the facilitator writes it down, below the earlier found factors. Again the factors should not comprehend more than eight words and their effect on the focal issue should be clear. This process will continue for half an hour or when the group feels satisfied. There is no bound for the amount of factors to be identified, but after this first session the group is asked if certain factors may be clustered into one to make it more comprehensive. The next step is to identify the drivers associated with each factor by handling factors one by one and asking participants to discuss which driving forces are relevant. Multiple driving forces may be relevant for a factor. If the group is struggling with finding relevant drivers the STEEP framework can be introduced. This framework is held back to allow creativity and prevent the group from sticking to the framework.

Time frame:

- Process introduction of facilitator (5 minutes)
- Brainstorm key factors (30 minutes)
- Cluster and refine factors (10 minutes)
- Assign driving forces to factors (15 minutes)

Rules of engagement:

- Free engagement between participants
- Organizer can be asked for explanation of factors
- Facilitator needs to pay attention everyone in the group speaks
- Facilitator needs to pay attention group does not argue to long on one factor
- If the group is stuck, the facilitator may interfere and suggest a direction of thought.
- Organizer needs to pay attention to group dynamics for limitations to research.

Resources:

- Presentation screen
- Laptop
- Recording device
- Seats and table for participants
- Writing blocks and pens for participants
- Whiteboard or flip-over and markers
- Background material: focal issue and scope, basic factors, STEEP framework

<u>10.00-10.40 Prioritize driving forces (40 min)</u>

After the key factors and driving forces have been identified the group is asked to estimate driving forces' level of impact on the focal issue and the uncertainty of their future state. This is done individually to prevent dominance of a single participant. The estimation is made by giving both impact and uncertainty a score of low, medium or high. To score the drivers all participants are handed a paper with the following table:

Driving force	Impact	Uncertainty
….		
….		
….		
….		
….		
….		

….		

The participants have 15 minutes to fulfill this task and asked to hand the papers to the facilitator afterwards. The next step is to plot the scores in Wilson's Matrix shown below, which will be printed on a large scale or drawn on a flip-over. Each driver will be given a distinct color that represents a dot sticker of the same color. Next, the estimations are plotted in the matrix using the stickers. This process is executed by the organizer and facilitator while the participants enjoy a 10 minute break.

Degree of uncertainty

Level of impact	Low	Medium	High
High	**Critical planning issues** Highly relevant and fairly predictable (can often be based on existing projections). Should be taken into account in *all* scenarios.	**Important scenario drivers** Extremely important and fairly certain. Should be used to differentiate scenarios. Should be based on projections but potential discon-tinuities also should be investigated.	**Critical scenario drivers** Factors and forces essential for success and highly unpredictable. Should be used to differentiate scenario plots and trigger exit strategies.
Med	**Important planning issues** Relevant and very predictable. Should be figured into most scenarios.	**Important planning issues** Relevant and somewhat predictable. Should be present in most scenarios.	**Important scenario drivers** Relevant issues that are highly uncertain. Plausible, significant shifts in these forces should be used to differentiate scenario plots.
Low	**Monitorable issues** Related to the decision focus but not critical. Should be compared to projections as scenario is implemented.	**Monitorable issues** Related but not crucial to the decision focus. Should be monitored for unexpected changes.	**Issues to monitor and reassess impact** Highly unpredictable forces that do not have an immediate impact on the decision focus. Should be closely monitored.

Note: Shaded areas indicate key focus.
Source: Adapted from Wilson 1989.

After the break the facilitator shows and explains the outcome of plotting the drivers in Wilson's matrix. The group is then asked to discuss which drivers should differentiate the scenario plots. These should have both a high impact and high uncertainty. If there are precisely two drivers that fulfill this requirement, the choosing process is easy. If there are more or less, then some discussion is needed to come to an agreement. The group is given 15 minutes to do so.

Time frame:

- Estimate impact and uncertainty (15 minutes)
- Break / plotting in Wilson's matrix (10 minutes)
- Discuss scenario differentiating drivers (15 minutes)

Rules of engagement:

- Estimation is done strictly individual by the participants
- During break the participants are free within the building

- The facilitator explains which drivers may be used to differentiate the scenario plots for group discussion and prevents the group from focusing on other ones.
- All participants should agree on the chosen drivers
- If agreement cannot be made unanimously, the drivers will be decided by vote.

Resources:

- Recording device
- Seats and table for participants
- Writing blocks and pens for participants
- Whiteboard or flip-over and markers
- Estimation paper for each participant
- Wilson’s matrix printed or drawn
- Colored sticker dots
- Coffee, tea, etc.

<u>10.40 – 12.00 Writing basic scenario plots (1.25 hour)</u>

After the scenario plots have been differentiated it is time to fill them up. We start this process by defining the extreme ends of the two axes. Subsequently, for each plot it is discussed how the two forces interact and what world this would entail. Each world is named one after another and a short 3 sentence description of its end state is written. 25 minutes is designated for this process: 5 minutes to define the extreme ends and 5 minutes for each of the four worlds.

For the next step the group is split in two. Each group takes two scenario plots and works backwards from the earlier defined end states to explore how forces need to interact to reach that point. They can use Wilson’s matrix to fit in the earlier found driving forces and key factors to help them in this process. A paper will be handed with a description how to do this. The result is a general description and rough pathway of each world with bullet points, similar to the example below. After the teams have finished their basic scenarios, they present the worlds to each other and the organizer for questions and feedback. This can help the organizer to write the full scenario plots.

Time frame:

- Define extreme ends (5 minutes)
- Name worlds (20 minutes)
- Fill in scenarios (30 minutes)
- Present worlds (20 minutes)

Appendix

E. Scenario workshop background material

Enkele bevindingen:

Ecosysteem stedelijke mobiliteit is veranderd: meer keuze voor consumenten naast de traditionele oplossingen.

	Traditional solutions	Innovative mobility services	
Individual mobility	Private bike ownership	Bikesharing / bike leasing	
	Private car ownership	Car sharing (peer to peer)	Platform where individuals can rent out their private vehicles when not in use. Snappcar
	Rental Car	Car sharing (fleet operator)	On-demand short-term car rentals with the vehicles owned and managed by a fleet operator. Greenwheels, Car2go
	Taxi	Ride-sourcing	Ordering a car via on-demand app. App matches rider with driver and handles payment. UberX
Collective mobility	Car pooling	Ride-splitting	Same as ride-sourcing, but allows riders going in the same direction to share the car, thereby “splitting” the fare and lowering the cost. UberPool, Abel.
		App based car pooling	Offers drivers a platform to add passengers to a ride that will already take place and fill seats that would otherwise remain empty. Blablacar, Tooghtr
	Public transit: Bus, Tram, Metro	On-demand microtransit	Same as ride-splitting, but not door-to-door. Riders are asked to walk short distances to pick up locations to allegedly improve sharing capabilities and vehicle route efficiency. Cheaper than ride-splitting, with the advantage over PT of direct routes and never changing a line. Breng Flex, Via, Chariot, Bridj, Kutsuplus.
		Private buses	Luxury commuter buses available to employees of selected companies. To free riders from driving to work an allow them to work during commuting time.

Bovenstaand vallen de diensten in het grijs onder vraaggestuurde ritdeeldiensten en worden meegenomen in de scenarios. Consumenten moeten er nog aan wennen en bewust van worden dat ze meer keuze hebben om van a naar b te komen binnen de stad. Momenteel zijn de vraaggestuurde ritdeeldiensten vooral gepositioneerd op en ontdekt door de millenials en smart phone liefhebbende individuen, maar in principe zijn ze voor iedereen even aantrekkelijk. Vooral omdat de aanbieders gepersonaliseerde diensten aanbieden, waardoor je bijvoorbeeld ook met een rolstoel of grote groep terecht kan. In onderstaande tabel is het relatief voordeel van vraaggestuurde ritdeeldiensten weergegeven.

Relatief voordeel van vraaggestuurd t.o.v. lijngebonden OV voor reizigers:

Voordeel vraaggestuurd ritdeel systeem	Nadeel vraaggestuurd ritdeel systeem
Keuze uit service levels die je kan oproepen ongeacht bestemming, waar en wanneer je het nodig hebt ipv dat je locatie, bestemming en de dienstregeling bepaald welke service je wanneer kan gebruiken.	Hogere prijs die bij Uber ook onzeker is van de reistijd en de vraag.
Alle bestemmingen zijn direct en (bijna) deur tot	Beperkte capaciteit bij grote vraag, zowel van de

deur bereikbaar in het service gebied (geen overstap).	voertuigen als de stedelijke infrastructuur.
Routes en haltes zijn flexibel afhankelijk van de vraag en de verkeerssituatie.	Beschikbaarheid en aankomsttijd is onzekerder, want geen dienstregeling en afhankelijk van verkeersdrukte, waar OV vaak een vrije baan en prioriteit heeft.
Consument weet via profielen wie de chauffeur en mede reizigers zijn en kan direct feedback geven over de rit en bestuurder via de app.	
Reizigers hebben altijd een zitplaats	

Daarbij hebben vervoerders van vraaggestuurde diensten het voordeel dat ze via het digitale platform real time data kunnen verzamelen om het product continu te optimaliseren naar de vraag van de consument en de verkeerssituatie. Ook kunnen ze historische data van vraag gebruiken om toekomstige vraag te voorspellen en aanbod daarmee afstemmen. Daarbij worden ze niet beperkt om verbeteringen door te voeren, waar het traditioneel OV maar 1x per jaar zijn dienstregeling mag aanpassen van de vervoersautoriteit.

Uit het bovenstaande kan je afleiden en uit literatuur blijkt dat reizigers bij de keuze tussen traditioneel ov en vraaggestuurde ritdeeldiensten een trade-off maken tussen kosten (Figure 22), gemak, comfort, betrouwbaarheid en Reistijd (Table 20). Daarnaast spelen emotionele factoren een rol zoals gewoontegedrag en beeldvorming.

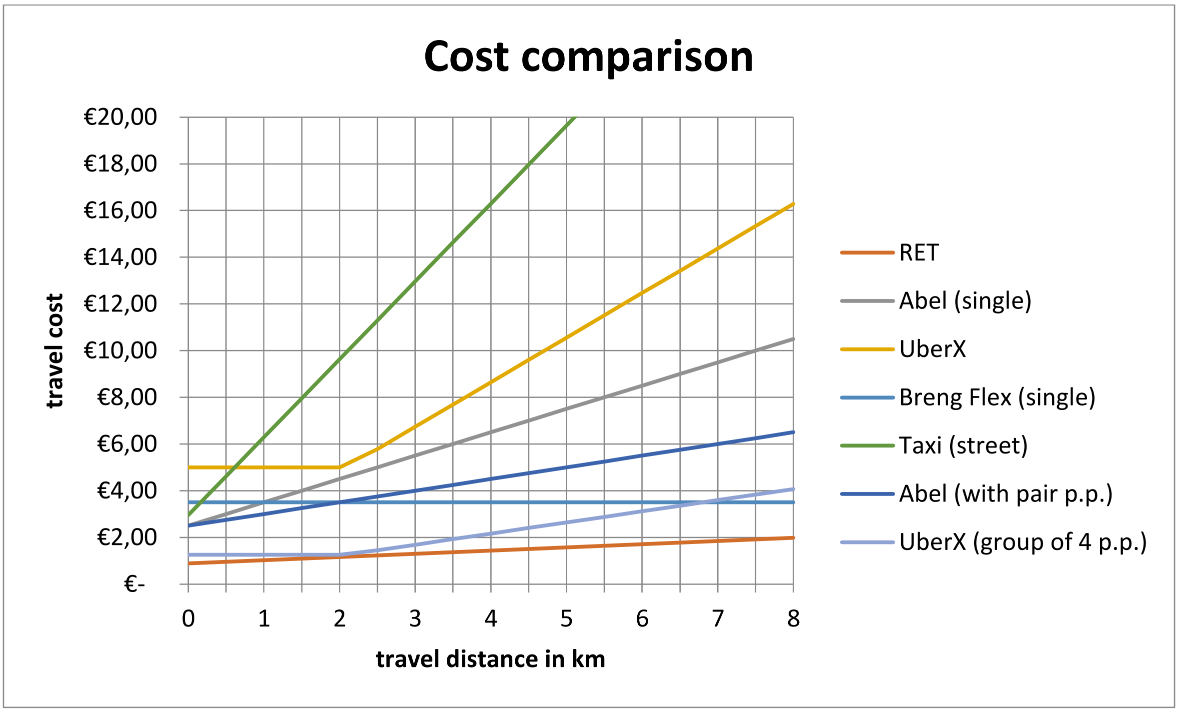


Figure 22: kosten schatting met een gemiddelde snelheid van 18,5 km/u.

BMT (direct)	BMT (indirect)	Microtransit	Ride-splitting	Ride-sourcing
Hidden wait time	Hidden wait time	Hidden wait time	Pick up time	Pick up time
Access time	Access time	Access time		
Waiting time transfer	Waiting time transfer	Waiting time transfer		
Vehicle ride time	Vehicle ride time	Vehicle ride time incl. detour	Vehicle ride time incl. detour	Vehicle ride time
Egress time	Line change time	Egress time		
	Waiting time transfer			
	Vehicle ride time			
	Egress time			

Table 20: reistijd differentiatie

Perceived travel time penalties

- Access and egress (2x)
- Waiting 3x (home is better than outside)
- Line change resistance
- Search resistance
- Experience main journey

Verder zijn er nog vele factoren uit de stedelijke omgeving die de aantrekkelijkheid van de systemen en daarmee de keuze van reiziger beinvloeden. Een greep hieruit zijn:

Congestie: gemiddeld is de reistijd over stedelijke wegen zo'n 30% hoger dan optimaal in de drie grote steden in Nederland. In de spits loopt dit op tot 60% volgens de Tom Tom index. OV kan vaak gebruikmaken van een vrije baan op de grote corridors, terwijl vraaggestuurde ritdeeldiensten momenteel volledig afhankelijk zijn van het verkeer.

Schaarste van ruimte: meerdere modaliteiten moeten gebruik maken van de schaarse ruimte in de stad, met name in de centra. De gemeente is bepalend in welke modaliteit prioriteit krijgt. Rail OV is het meest ruimte efficient in het vervoeren van grote groepen mensen over drukke corridors. Daarbij voeren Nederlandse gemeentes een beleid om auto's te weren uit stadcentra door ze er om heen te leiden.

Fietsgebruik: Nederlandse steden zijn compact en vlak en hebben daarmee een hoog fietsgebruik. Op de korte afstand is dit bij goed weer een zeer aantrekkelijk deur tot deur vervoersmiddel, mede omdat de voorzieningen voor fietsers van zeer hoog niveau zijn. Voor het zowel het OV als vraaggestuurde ritdeeldiensten is dit een grote concurrent.

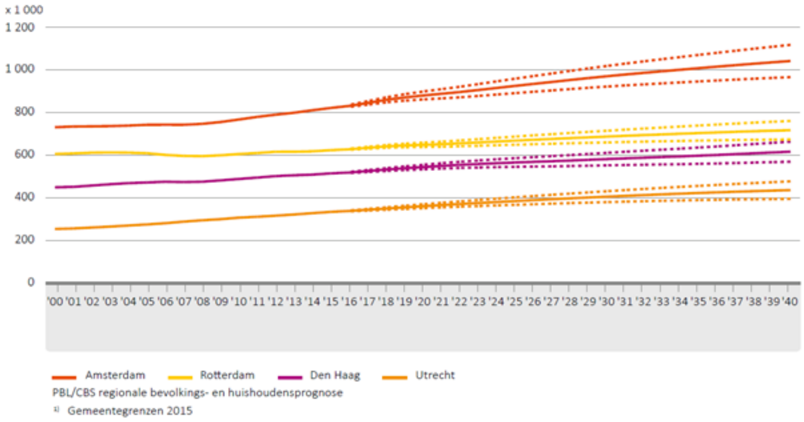
Regulering van taxi diensten: sinds 1 januari 2016 is de regulering van taxi diensten versoepeld. Er zijn geen beperkingen meer op aanbod, wat heeft geresulteerd in een explosieve groei van nieuwe chauffeurs in met name Amsterdam en in mindere mate Rotterdam. Ook mogen chauffeurs het nu als bijbaan doen. Als marktwerking zijn werk doet resulteert een groter aanbod in een lagere prijs en daarmee meer vraag. Tevens word de wachttijd korter.

Stedelijke dichtheid: OV is gebaat bij hoge dichtheden om voldoende vraag te genereren. Voor vraaggestuurde ritdeeldiensten is het voor het delen van ritten, zonder onwenselijk tijdsverlies ook makkelijker bij hoge dichtheden. Verder zijn ze gebaat bij grote steden, omdat de huidige niche doelgroep daar voornamelijk woont. Buiten de grote steden kan het ook, maar waarschijnlijk niet zonder subsidie.

Demografische gegevens grote steden:

Figure 23: Demographic characteristics major Dutch cities

8.1.2 Ontwikkeling van het inwonertal van de vier grote gemeenten[1] volgens de prognose en de 67%-prognose-intervallen



8.2.2 Ontwikkeling van het aantal huishoudens van de vier grote gemeenten[1] volgens de prognose en de 67%-prognose-intervallen

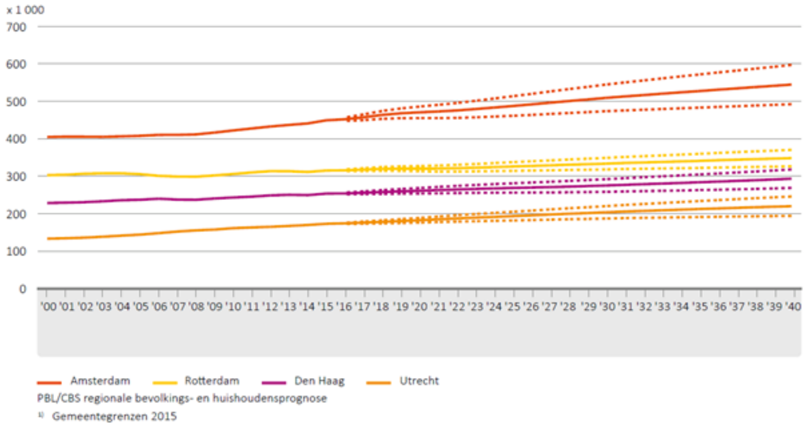
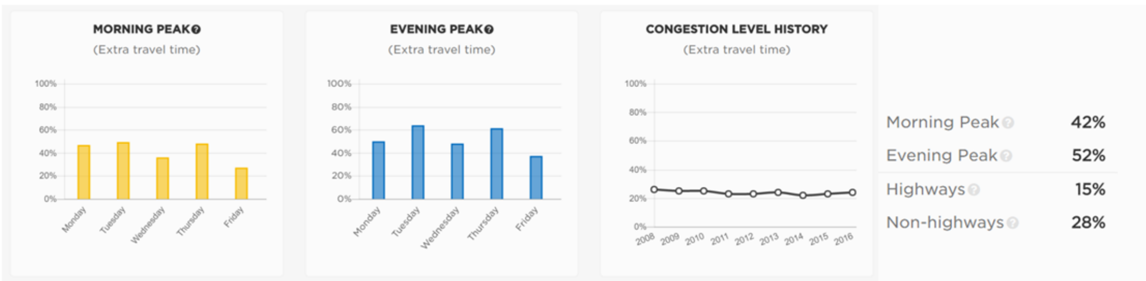
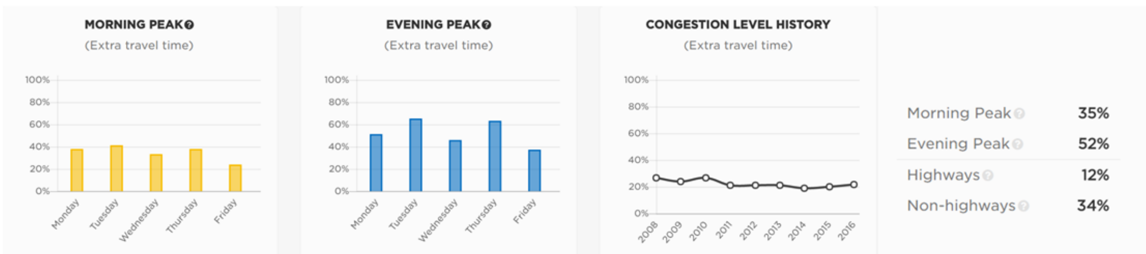


Figure 24: Urbanisation

Filedruk grote steden:

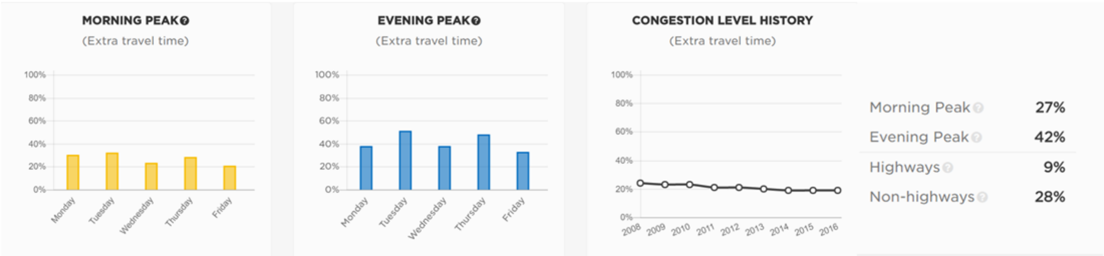


Tom Tom index 2016: Den Haag



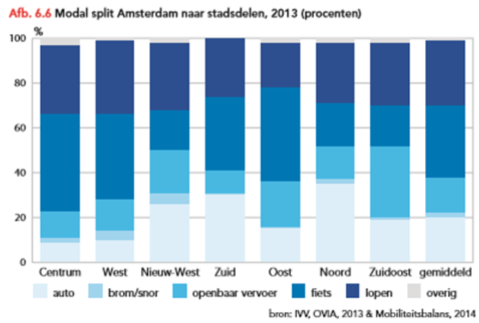
Tom Tom index 2016: Amsterdam

Figure 25: congestion in The Hague and Amsterdam



Tom Tom Index 2016: Rotterdam

Modal Split grote steden:



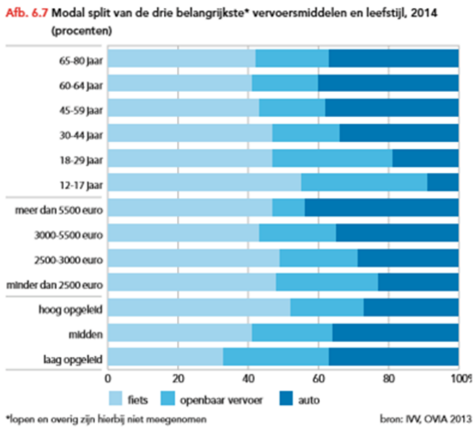
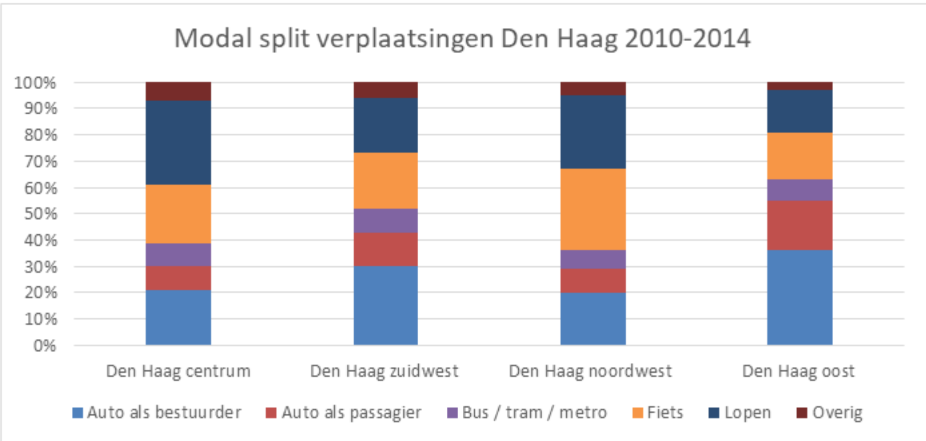


Figure 26: Congestion in Rotterdam (above) and modal split Amsterdam (below



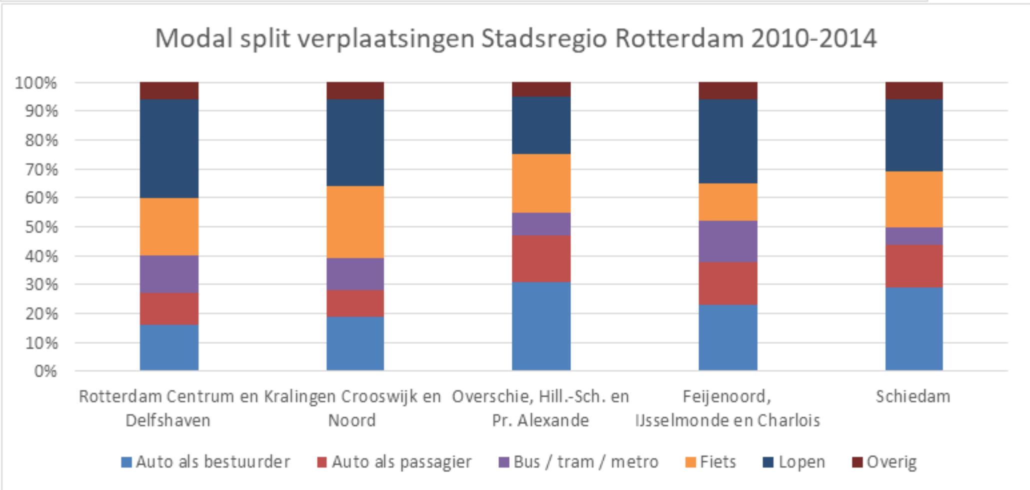


Figure 27: Modal split The Hague and Rotterdam