APPENDICES I

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A. RANDSTAD PTO TICKETING & SUBSCRIPTIONS

A.1. RET

A.1.1. Subscriptions

The RET offers multiple types of subscriptions. Firstly there are the 20% and 40% discount subscriptions. The 20% discount is available for €6.70 per month, and is interesting for people that spend more than €33.50 per month on RET travels. The €40% costs €24.60 per month, and is beneficial when spending more than €61.50 per month on RET travels.

Secondly, there are the 'star subscriptions', which give the user free travelling in one or more zones, depending on the chosen subscription. This subscription includes services from RET, but also from Arriva, Connexxion, EBS, HTM, HTMBuzz and Qbuzz. The area coverage includes Rotterdam, Den Haag, Zoetermeer and Leiden. A '2 star subscription' gives the traveller free access to one chosen zone, and all the adjacent zones. These subscriptions vary from €52 per month or €520 per year for a 1 star subscription to €251 per month or €2510 per year for a 6 star subscription. Complete RET net coverage can be bought for €261 per month or €2969.50 per year. These subscriptions are also available for a reduced fare (under 11 or above 65 years old), which gives the user 34% off of the mentioned prices.

Lastly, there are the 'Always Reduction' subscriptions. These are not only valid for RET transport, but also for all other bus, tram and metro services in the Netherlands. The 20% reduction is €19 per month or €190 per year, and is suitable for people that travel for more than €95 per month or €950 per year. This subscription is interesting for people that have to be in various locations, thus a regional public transport subscription would not benefit them.

A.2. HTM

Travelling with the OV chip card costs €0.96 for the base fare and €0.166 per km. Reduced fares (children under 12, 65+) are €0.63 base fare and €0.109 per km.

HTM offers a 2-hour ticket for €4. A Day ticket is available for €7.10, and a 3-day ticket for €18. The tourist day ticket is available as well, offering public transport in Zuid Holland for €14.50. Night bus tickets are available for €5.

The star subscriptions are the same as the ones described in the RET chapter.

A.3. GVB

The regular pricing for OV chip card travels is €0.96 base tariff with €0.162 per km added. Reduced fares are €0.63 base tariff with €0.107 per km added (available for children up to 18 years, or people that are 65+).

1-hour tickets are available for €3.20, bus-tram-metro 1.5-hour tickets for €6.50 (which are also valid at Connexxion and EBS services). 24h are available for €8. GVB also offers 'multiple day tickets', which range from €13.50 for 48h to €36.50 for 168h (7 days). Night bus tickets are available for €4.50.

They offer the following subscriptions:

- GVB Zone (valid in one of Amsterdam's zones) for €49 per month or €490 per year
- GVB only for €97.50 per month or €975 per year
- Randstad Noord Zone (choose one centre zone, travel to adjacent zones based on the amount of stars, valid with GVB, Connexxion, EBS), price varies between €53.90 per month or €539 per year for a 1 star subscription to €250.20 per month or €2502 per year for a 6 star subscription
- Always Reduction: this is the same subscription as is described in the RET chapter
- Always free (full GVB coverage) for €296.95 per month or €2969.50 per year

A.4. NS

Travelling with NS trains can be done by using the OV chip card, by buying a ticket through the website or app, or at one of the ticket machines that are located on stations. A €1 premium is added to tickets bought at the station.

NS offers many types of subscriptions. The most recent addition to the range is the 'NS Flex' subscription: this gives the traveller the option to pay for all their travels at the end of the month. Other subscription types are:

- Off-peak 40% (40% reduction in off-peak hours and weekends) for €52 per year
- Always reduction (40% reduction in off-peak hours and weekends, 20% reduction in peak hours) for €28 per month or €276 per year
- Weekend free (free travelling in weekends, 40% reduction in off-peak hours) for €408 per year
- Off-peak free (free travelling in off-peak hours and weekends) for €1890 per year
- Always free (exactly what it sounds like) for €4152 per year
- Route free (unlimited travels on a specific route, off-peak hours 40% reduction), price depends on the route (Rotterdam Centraal to Den Haag Centraal free costs €165 per month)

B. GOVERNMENT MAAS PILOTS

The Dutch government is currently setting up seven regional MaaS pilots. For each of these projects, a MaaS provider can develop a solution, with the possibility of expanding the area in which they operate when the pilot proves to be successful.

B.1. Pilots

B.1.1. Rotterdam: accessibility of Rotterdam-The Hague airport

At this moment, the airport is only well accessible by car. International or national air travellers, airport employees and employees of companies that are situated close to the airport are in need of other transport options. If the pilot is successful, the MaaS solution can also be expanded towards the cities of Rotterdam and The Hague.

B.1.2. Amsterdam: providing alternatives for the (lease) car for the Zuidas

The Zuidas hosts many large, sometimes international companies. Employees of these companies tend to use the (lease) car to get to work and for business travel. It is expected that the current infrastructure cannot handle the demand, especially with large scale road improvement works that are planned for the coming years. MaaS could provide an answer, as long as it meets the requirements of improved sustainability, employee satisfaction, accessibility and flexibility.

B.1.3. Eindhoven: sustainability, smart mobility, co-mobility

This MaaS solution will focus on sustainable and CO2-neutral mobility. At first, the goal is to power all business related trips with sustainable energy, thus the MaaS platform will only show sustainable and CO2 emission free options. The service will be available for all inhabitants of the Eindhoven area.

B.1.4. Limburg: borderless mobility

The amount of car use is very high in Limburg, mainly because of the lack of options for border crossing mobility services. Providing this for inhabitants of Limburg, but also for German and Belgian visitors/commuters to the area is the goal of this MaaS solution.

B.1.5. Groningen-Drenthe: rural area accessibility

This area wishes to create a more integrated mobility system, in which private vehicle use is supplemented with a public transport and other mobility services, in order to keep the rural areas in these provinces accessible.

B.1.6. Twente: mobility for all

At this moment, the special care, educational, and daytime activity transport in Twente are organized by the ‘Reisbureau’, or travel agency. The type of transport is very much focused on specific target groups. The government body of the province wants to bring all these transport types together and add more mobility services to the total package. In time, the MaaS platform will be available for all inhabitants.

B.1.7. Utrecht-Leidsche Rijn: vinex-suburb accessibility

The Leidsche Rijn vinex-suburb has a spatial set up, many parking spaces and good infrastructure: the perfect recipe for a high private car usage. With the expected growth of this suburb, the mobility needs can only be assessed by increasing the share of public transport and bike in the modal split. The goal is to get people to use more active modes like biking and walking, and decrease peak hour travel through a discount. The service will be available for the whole city of Utrecht.

C. MINORITIES, LOW INCOME FAMILIES IN ROTTERDAM

Rotterdam is a very diverse city when looking at the population composition. Among the population there are many minority and lower income groups. These sometimes overlap, but not necessarily. In order to get insight in these groups, two interviews with experts are done. The first interview is with Cemile Sezer and Dinko Kajmovic of Sezer voor Diversiteit, an organisation that aims to connect and activate minority groups to help them participate in society in a better manner. The second interview was done with researchers at the Verkeersonderneming, a collaboration initiative between governmental organisations and large businesses in the Rotterdam area. They are currently running a large scale MaaS-pilot with a test group that represents the diverse population of Rotterdam.

C.1. Sezer voor Diversiteit

Within this group, there also is a big part that has a migration background. Rotterdam's population is very diverse, with 51% being people with a migration background. The largest ethnic groups are people from Suriname, Turkey, Morocco, the Antilles, Cape Verde, and people from other European countries.

For many people in this enormous group mobility is not a given. Sezer emphasizes the fact that mobility is necessary for everyone. Especially in the south of Rotterdam, many people are affected by the lack of mobility that is available to them. Mobility poverty has negative effects on the chances one can seize: jobs are out of reach, leisure options become limited, and many more negatives. There are not that many job opportunities in the south of the city, thus people that have a limited area they can reach by themselves are excluded from work more often.

Sometimes this is due to ignorance, other times a language barrier plays a role. Societal expectations and pressures from their minority group can also influence a disregard for certain options that are available to them. There is a high variety between different groups in what causes transport poverty, and how people look to solve this issue. How they experience mobility also depends on different factors: their values differ greatly per group.

In general, people from minority groups rely much less on the bike than people with a Dutch background. The car is popular, especially among older people and in the Moroccan and Turkish communities. Public transport is used often by younger people and the Surinam and Antillean communities.

C.1.1. Conclusion

One thing that should always be kept in mind about the poorer groups in Rotterdam: they are extremely diverse. Their backgrounds and cultural expectations, plus their persona living situation heavily influence how they move around.

C.2. Verkeersonderneming

In 2018 the Verkeersonderneming ('traffic company'), a collaboration between the Rotterdam municipality, the MRDH, the Ministry of Infrastructure and Watermanagement, Rijkswaterstaat, and the Port of Rotterdam started an experiment to monitor what a MaaS platform could mean for the people in Rotterdam.

One hundred inhabitants that reflected the population composition of the city well were each given a monthly mobility budget of €200,- for four months. What that mobility budget could be spent on changed each month: in the first month, participants could only travel with public transport, bus, tram, metro, the OV-fiets, a taxi service, and Greenwheels. In the month that followed, Gobike and Mobike are added to the mix, the third month Felyx and Uber are added, and in the last month car sharing becomes available. Each trip is tracked, hence the researchers could examine their travelling behaviour. The participants were asked to leave their private car as much as they could, but it would still be available to them.

The results are split up in five ethnic groups: no migration background, Moroccan, Surinam, Turkish, and other backgrounds. The results show that different population groups in the city behave very differently. The train was most popular with people without migration background or from other groups, while Turkish people were much less favouring this transport mode. They however were the highest using group when it came to trams. Metro usage was by far highest under Surinam and other groups. These differences could be due to group preferences and habits, yet spatial availability could also play a role. The insights from this research are a bit limited in the way that they only track what people did as far as paid mobility, as personal bike use is not included.

C.2.1. Conclusion

Like the experts at Sezer, the Verkeersonderneming researchers confirm the diversity that is present in Rotterdam's population. The data from this study gives some insight in what mobility solutions people use when they are provided with a budget that they can spend according to their own wishes. However, there is not much insight yet in how this would translate in a real-world situation where cost comes back into the choice making.

D. POTENTIAL MAAS USERS: A STUDY IN FINLAND

Sochor and Sarasini (2017) examined results of a national questionnaire (n = 1305) to explore the Finnish perspective on MaaS, which was done in 2014. 80% of the respondents lived in a suburban area or city center, and 66% used their car frequently. Their public transport connections were described as excellent or good in 53% of the cases, yet only 24% used it frequently. Half of the people had only used 1 or 2 transport modes in the last month.

The researchers asked them questions regarding their opinion on many components of MaaS, which could be scored from 1 (not at all attractive) to 5 (very attractive).

D.1. Results

Potential early adopters:
- Adults younger than 35
- People with high digital maturity
- Frequent public transport/combination of mode users
- Low income households

Potential laggards:
- Older adults
- People with low digital maturity
- Frequent car users

Furthermore, they found that a MaaS platform would be more attractive for leisure trips than for commutes. This could be due to the fact that leisure trips are less often based on a routine, as opposed to strong habits regarding commute journeys.

The following statements regarding MaaS were perceived to be very attractive or attractive by at least 50% of the respondents:
- Plan, book, pay, get tickets through one digital interface
- Help save money on transport
- Trying a new mobility service without needing a subscription
- Overview of transport costs
- Using your existing PT card to pay for other transport
- Better match mode choice to individual trips

E. INTERVIEW MARÍA ALONSO GONZALEZ

María Alonso Gonzalez is a PhD researcher in the Smart Public Transport Lab within TU Delft. Her PhD project involves the forecast and evaluation of new mobility services. In particular, she focuses on (sub)urban Demand Responsive Transport (DRT) (which includes both shared ride-hailing and microtransit). In her research, she takes the passenger perspective and analyses the usage of these services in relation to scheduled public transport, as well as the expected usage in an integrated network. Her research interests also include Mobility as a Service (MaaS), as full integration of the existing mobility services.

E.1.

E.1.1. What data was used for this research?

The data is from the Mobiliteitspanel Nederland, a panel that is organised by the Kennisinstituut voor Mobiliteit (KiM). Its data comes from of 2000 households that track all their movements during three days.

E.1.2. How were these groups identified?

The groups were defined using Latent Class Cluster Analysis. It is a clustering methodology. As input I had a series of attitudinal indicators that looked at different aspects of MaaS and UberExpress-like services.

E.1.3. What are the groups people are classified in?

See picture with the names I used in the clusters and the shares of each cluster. The first group, MaaS suited individuals, are people who love technology, and don't care about car ownership. The second group, Multimodal PT supporters, are people who love technology, and are frequent users of public transport. These two groups are the most 'MaaS-ready'. Almost half of the population belongs to one of these groups. The third group is not particularly into technology or multimodal transport. The fourth group is into technology, but also very much into their car. The fifth group is the least MaaS-ready, as it consists of individuals who are technophobic, and love their car.

E.1.4. What are characteristics of people that were MaaS-ready?

They tend to be young (esp 18-34 age group), highly educated and live in areas where the level of urbanity is the high.

E.1.5. What do you see to be main drivers and barriers for people to start to use a MaaS system?

Main barriers as explained in the workshop: technology adoption and ownership need. Especially mobile internet accessibility is crucial for a well-functioning MaaS system. Main drivers: availability of transport service options and easiness in use.

E.1.6. What's your personal opinion on MaaS? Do you think it is the future of transport?

MaaS is the integration of all mobility options. In that sense, I do think that MaaS is the future of transportation (at least in urban areas). But my personal opinion about MaaS and its future potential depends on how it is exactly defined (it is still quite differently defined by different

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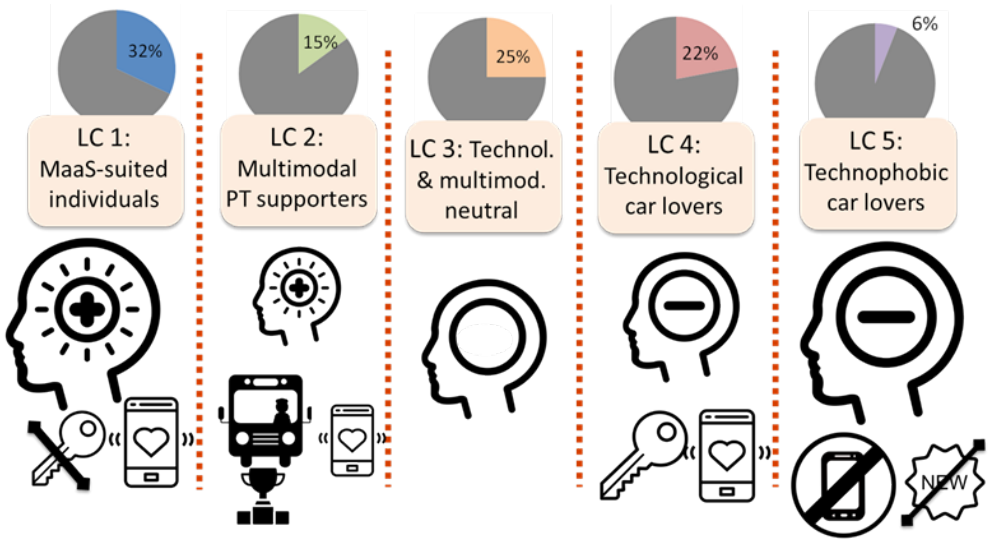

F. INTERVIEW ROTTERDAM TOURISM INFORMATION

To get information on tourism in Rotterdam, I interviewed Martin Perez, who works at Rotterdam Tourist Information.

F.2.1. Types of tourists?

There are multiple types of tourists visiting Rotterdam, they can be divided into three main groups. Firstly there are the people who visit the Netherlands for 5-10 days. They usually stay in Amsterdam for a few days, and then visit the bigger cities in the Randstad for each one day. They are usually advised to buy an anonymous OV chip card at their arrival, so they usually use public transport to get from point to point. They come in to Rotterdam by train or bus (from the ferry terminal from the UK), into Rotterdam Centraal. If they don't have an OV chip card, they mostly buy day tickets (€8) or 'Tourist Day Tickets'(€13,50), which give access to public transport in the Rotterdam/The Hague area. Sometimes they want the Hop-on Hop-off bus ticket, which is €17 per day.

Secondly there are business travellers. They often get into the city through Rotterdam The Hague Airport, and either get a taxi into the city, or use public transport. These people often stay for a very short time, usually two days at most. Their travels are generally paid for by the company, so the individual travellers are not too concerned with costs.

Thirdly, there are Dutch visitors who come to Rotterdam for a day, or a weekend. Often these people are a bit older, 50+, or families. Sometimes they come by train, but there also many people that come by car and park in the city centre. Some people park in P&Rs at the border of the city and travel further with public transport, when they have an OV chip card this is a feasible method, as P&Rs are often free or very cheap when the journey is continued with public transport (scan OV chip card when getting the exit parking ticket). However, when people don't have an OV chip card, they have to buy a public transport day ticket for €8. When travelling with multiple people, it is usually about the same price or even cheaper to just park in the city centre and walk between highlights than to use the P&R system.

F.2.2. Where do they go?

Inside the city: mainly Markthal, Euromast, Erasmusbrug, Rotterdam Centraal, museums like Kunsthal, Boijmans van Beuningen
Outside the city: Kinderdijk, Europoort/MaaSvlakte

F.2.3. When are they in town?

The peak season starts in the spring holiday May and continues all the way until the fall holidays in October. During the Christmas holidays another peak period is experienced. Outside these periods it is much less busy.

F.2.4. How do they plan travels?

When they come to the tourism office, they rarely know how to plan a trip. Sometimes they just want to know how to get somewhere and the personnel of the office helps them using 9292. In some instances the tourist has downloaded the 9292 app. More commonly they use the Google maps planning feature or just go to a public transport stop and try to figure it out from there, or use a physical map.

F.2.5. How do they pay for travels?

Dutch visitors mostly pay with debit cards. Foreign visitors pay with creditcard or cash (about a 50/50 split).

F.2.6. What is important to them when travelling?

The most important factor is hassle-free travel. They don't want to spend their holiday time working out how to get to the interesting places. Therefore they often just buy a day ticket or rent a bike for a day.

For non-business travellers cost is important. According to Martin people never complain about the €8 for a day, so this is a very reasonable fee for a full day of public transport travelling (bike rentals cost about €6,50 per day). However, the €4 for a 2 hour ticket is not perceived well, mostly because people rarely feel like they get their money's worth: they just use the ticket to travel for 15 minutes and use up the rest of the two hours outside public transport.

G. TRANSPORT MODE CHARACTERISTICS

G.1. Quantitative transport values

(?) = estimate

G.1.1. Cost

Investment costs

- Car: €30.566 (new, C-segment (Volkswagen Golf))4
- Electric car: €39.758 (new, C-segment (Volkswagen e-Golf))5
- Motorcycle: €10.000 (?)9
- Scooter: €2000 (?)9
- E-bike: €1800 (?)6
- Bicycle: €600 (?)6
- E-kick scooter €30017

Cost of use
Owned
The cost per 30 min is based on average distance per hour (see Speed) and variable cost km prices (fuel, repairs etc.)

- Car: €573 per month, €5,29 per 30 min8 (Volkswagen Golf)
- Electric car: €535 per month, €3,29 per 30 min8 (Volkswagen e-Golf)
- Motorcycle: €400 per month9
- Scooter: €100 per month, €1,87 per 30 min16
- E-bike: €15 per month (?), €0,06 per 30 min12
- Bicycle: €2 per month (?), free per 30 min

Non-owned

- E-kick scooter: €1 for unlocking, €0,15 per minute: €5,50 per 30 minutes (?)10
- E-scooter: €0,30 per minute, €9 per 30 minutes
- E-bike: €2 per hour, €15 per day11
- Bicycle: €1 per 30 minutes (Mobike), €3,85 per dag (OV-fiets)
- Walking: free!
- Train: €7,50 per 30 minutes (?), NS
- Lightrail: €4,50 per 30 minutes (?), RandstadRail
- Metro: €3 per 30 minutes (?), RET/GVB
- Tram: €2,20 per 30 minutes (?), RET/GVB/HTM
- Bus: €2,20 per 30 minutes (?), RET/GVB
- Taxi: €75 per 30 min (regular taxi) (?), €40 per 30 min (Uber) (?)
- Fast ferry: €4 per ticket, RET

G.1.2. Cost comparison of one hour car use vs. multimodal journey

costs of use car/30'	5,29
costs of use train 30'	7,5
costs of use metro 15'	1,5
costs of use scooter 15'	4,5
costs of use bike 15'	1
1h car	10,58
1h multimodal train, metro, scooter	13,5
1h multimodal train, metro, bike	10

G.1.3. Speed (max with current regulations, average (km/h));

- Car: 130, 451
- Electric car: 130, 451
- Motorcycle: 130, 50 (?)
- Scooter: 25-45, 211
- E-bike: 25, 17 (?)
- E-kick scooter: 25, 13 (?)
- Bicycle: 22 (?), 131
- Walking: 7, 51
- Train: 160/140 (HSL/regular), 441
- Lightrail: 802, 452
- Metro: 100, 25 (?)
- Tram: 603, 183 (?)
- Bus: 80/50 (within/outside city area), 18 (?)
- Taxi: 130, 451
- Fast ferry: 41, 1415

G.1.4. Environmental impact

Well-to-wheel kg CO2/km, with average amount of passengers

- Car: 0.22 (1,39 pax)13
- Electric car: 0.107 (1,39 pax) 13
- Motorcycle: 0.2614
- Scooter:0.2614
- E-bike: negligible
- E-kick scooter: negligible
- Bicycle: none
- Walking: none
- Train: 0.00613
- Lightrail: 0.02413
- Metro: 0.09513
- Tram: 0.08413
- Bus (non electric, urban): 0,14613
- Taxi: 0.22 (1,39 pax)13
- Fast ferry: ?

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H. CONTEXTMAPPING RESEARCH REPORT

H.1. Research goals

This explorative Contextmapping study is done to get a better understanding of travel habits of Millennial Urban Professionals (MUPs) in the Randstad area. There are several topics on which the study focuses:

- Travel modes: which do they use frequently, less frequently, never and why? Which combinations of travel modes are seen for multimodal journeys?
- Shared mobility: which shared mobility services have they used (or not)?
- Journey planning: how do people plan their journey, and what do they take into account when planning?
- Travelling on work vs. free days: what are the differences between routine and non-routine journeys?
- Exploring journey attributes: how do they experience the journey attributes mentioned in the Current mobility habits chapter when travelling?

H.2. Method

Contextmapping is a generative research method to let people construct their view of the context, by calling up their memories of the past and hereby eliciting their dreams of the future. Generative research methods help people express what they know, feel and dream, uncover tacit knowledge and latent needs (Visser, Stappers, Van der Lugt, & Sanders, 2005).

The setup of Contextmapping research is usually divided into three parts. Firstly there is the preparation part, in which the research goals and setup are established. The methods and techniques that will be used are decided upon. Finally, the study materials are prepared and participants gathered.

The second part of a Contextmapping study is gathering the information. In this case the information is based upon three main sources:

- Introductory interview: this interview had two main goals, getting to know the participant, and explaining the research setup and booklet to them. Each interview was done one-on-one and lasted for about 15 minutes.
- Sensitizing booklet: this booklet asked the participant to keep a travel diary for 5 days, including both work days and free days. This helps the participants keep track of their choices and how they experienced this.
- Group session: two two-hour sessions with 6 participants each were held. In this group session the booklets are discussed and two creative exercises are done to help the participants express their ideal journey.

The final part of the study is to analyse the gathered information. To get insights from this study, it is needed to transform the large amount of information gathered from the booklets, the group sessions and the creative assignments into quotes or evidence pieces. These can then be used to follow the analysis procedure are described by Visser et al. (2005), which is based on the Grounded Theory approach (Corbin & Strauss, 1990). The quotes and evidence pieces are put in clusters, which are named to describe the evidence in the cluster. These are then used to create patterns and an overall view.

H.3. Participants

The target group for this research were the Millennial Urban Professionals, or MUPs. To ensure that they were at least familiar with public transport and/or multimodal

travelling, the criterium of frequently using public transport was added. To gather the participants a research bureau was asked to select 14 participants based on the following criteria:

- Living in the urban area of Rotterdam (for accessibility reasons only Rotterdam area inhabitants are included)
- Between 25-37 years old
- Travel frequently with public transport
- Have a modal income or higher
- Work in an urban area
- Have a high education level

This resulted in a final group of 12 participants (of the 14 gathered participants, 1 did not meet the criteria, and 1 did not show up for the group session). There were 6 male and 6 female participants, ranging from 25 to 37 years old. They all lived in Rotterdam, except for one person who lived in Rijswijk. Four people lived by themselves, six people lived with a partner, and two lived with a friend. Five participants had one or more children. They worked in either Rotterdam or one of the other big cities in the Randstad. Two of the participants had an MBO education, nine HBO, and one WO.

H.4. Introduction interviews

H.4.1. Setup

The introduction interviews took place at a location of the participant's choice. With about half of the people this was their home, which gave a very interesting insight in wat type of person they were. Three people chose their work location to meet, and two people chose a location in public space.

The main goal of this introduction interview was to get baseline information on the participants regarding their mobility habits and explain the travel diary to them, so the results from the booklet are valuable.

H.4.2. Results

Several things surfaced immediately from the introduction interviews:

- MUPs do not have transport subscriptions, unless their employer gives them one
- No one used shared mobility services, with the exception of the OV-fiets, which was used by some people when visiting a place they did not visit frequently
- Routes to work are usually done out of routine, most people remember the schedule of public transport they use to get to their work. They do not look up schedules and travel options anymore, except for when they are already at their station or stop and the journey they usually take is not available anymore. Most people use 9292OV, some use specific apps for the transport provider they want to travel with (RET Realtime app, NS app)
- People that lived close to the city centre did not have a car anymore or are seriously considering selling theirs: they do not feel like owning a car is necessar with all the public transport options around them, and a lot of destinations in a bike-able range
- People that live in a less central area (Rotterdam Zuid/outside of the 'ring') often take the car to a P&R like Capelsebrug or Kralingse Zoom, and travel onward into the centre from there. Doing the whole journey by public transport is not favoured, because they either have to transfer a lot of times, or the journey would take a very long time

H.5. Sensitizing booklets

To sensitize the participants they kept a travel diary for five days. Sensitizing is a process where participants are triggered, encouraged and motivated to think, reflect, wonder and explore aspects of their personal context in their own time and environment (Visser et al., 2005).

The booklet started with several questions about the participant on the following topics: residential/work city, hobbies, living situation, owned transport modes, having an OV chip card/driving license, public transport subscriptions, frequently used public transport stops, and used planning apps.

The next pages of the travel diary consist of

several questions which the participant is asked to fill out each day:

- Today I'm… *working/free*
- Today I travelled with… *bike/e-bike/ car/electric car/train/metro/tram/ bus/walking/scooter/other*
- Today I'm travelling for…
- I had this stuff with me:
- I planned my journey with…
- I travelled together with…
- I travelled for … minutes in total
- This is what my travels looked like today (timeline to write each trip down
- This is how I experienced my travelling today (rating scale)
- This is what I liked/disliked about my travels today
- This played a role in my choices for travelling today:

At the end of the booklet the participant is asked to reflect on their travels by rating several their travels on multiple topics on a scale: bad/good, cheap/expensive, slow/fast, inflexible/flexible, unsafe/safe, inactive/active, uncomfortable/comfortable, complicated/ easy, bad/good for the environment, intensive/ relaxing. These questions were used to discuss their experiences in the group session.

H.6. Group sessions & creative assignments setup

In the group sessions the twelve participants were split over two two-hour sessions.
The sessions started with each participant discussing their booklet, showing what stood out to them, what they liked and what they did not like. The participants were encouraged to share experiences and use this time to start discussing with each other. This led to more insight in whether multiple people experienced the same situations, or if they experienced it in a completely different way.

After discussing the booklets two creative assignments were done. The first assignment asked the participants to create a collage about their favourite and least favourite transport mode. They were provided with multiple sheets with pictures and words, as well as writing and drawing materials. After 20 minutes of crafting they each explained the collage to the group in one minute. The second assignment asked them to create a collage about their ideal door-to-door journey. Again they were provided with pictures, words and drawing materials to express their ideal journey. At the end of the session, they each explained their last collage to the group.

Figure 33. Participants of one group session working on the creative assignment

H.7. Results

H.7.1. Participants: potential users?

Firstly, it seemed that only a few of the participants actually fall into the category of 'MUP' as described earlier. After getting to know them better during the interviews and the group sessions, only 6 of the participants suit the MUP profile. The other participants were not necessarily tech-savvy or interested in trying new experiences and products/services. One of the participants just finished studying, so the lack of income would also place them outside of the target group at this moment. However, he probably would fit into the target group when having a job.

Another criterium that needs to be added to the potential MaaS-user profile would be 'public transport-loving'. All the participants travelled with public transport frequently. Many of the participants did this because their employer paid for a public transport subscription. This heavily influenced their journey choices. However, there was a clear division within the participant group of people that liked travelling by public transport, and people that just did it because it was the obvious choice.

The public transport-loving participants explained they enjoyed travelling with public transport because they can spend their travel time on something else, like working, reading a book, listening to music, playing a game, using social media, just looking out of the window, eating, and catching up with friends.

The non-public transport-lovers said they would prefer taking the car, but circumstances prohibited this. Some did not have a driving license. In other cases the location that frequently had to go to was very hard to reach by car or parking was impractical.

H.7.2. Routine journeys

As expected, the participants made a clear division between their routine travels and irregular travels. Routine journeys are undertaken frequently, often multiple times per week. Irregular journeys are not undertaken on a regular basis. They have very different expectations and experiences with routine journeys and irregular journeys. This also leads to them finding different factors important during the trip.

Routine travels were mostly journeys between home and work locations. These were also the journeys they undertook most frequently. Because of this participants often memorised the schedule of their routes, including alternatives. It helped them to be more efficient with their travels.

However, this automation in the travelling process could lead to unawareness to changes. Many participants said they had missed the notifications of e.g. the holiday timetable, or a route not being available due to maintenance. Sometimes this happened because they had 'zoned out' during their journey, therefore not seeing the notification on in-vehicle screens or other announcements. This lead them to be surprised and annoyed when getting to the station at their regular time and finding out it did not run as expected. Sometimes they actually did pick up a notification on changes but still forgot about them as they followed their usual routine. In this case they did not mind. They just felt stupid, and thought it was their own fault. This example shows how strongly ingrained a travel routine can be.

Another important factor with routine journeys is that the participants become 'emotionally numb' towards their travels. Even though they knew it was an unpleasant journey, having to travel in peak hours, they did not experience the journey as negative: they knew they had to get through it anyway. As one participants said: "sometimes you just have to. I don't enjoy my trip being an hour, but I just need to get there'. Another participant explained she stopped thinking about the negatives of the journey in order get less irritated: she could not do anything about it, so she got herself to let go of any emotion regarding the journey.

None of the participants mentioned anything regarding this numbness for positive emotions. However, they also did not mention anything on positive experiences during routine journeys at all. They just mentioned that they liked nothing going wrong ("I didn't miss my connection, so that was nice"). Thus, there it is uncertain whether there also is a 'positive emotional numbness', or whether there were no positive experiences during the diary period.

H.7.3. Irregular journeys with a required time of arrival

On the other hand there are the irregular journeys. Participants described roughly two types of irregular journeys: those that require a specific time of arrival, and those that do not.

Journeys of the first category were in general events with a very specific start time like work meetings at a client, concerts or flights. In these instances, participants preferred not taking any risks and took a train earlier to create a bit more play room in case they missed a connection, or to have some more time to navigate in unknown areas.

H.7.4. Irregular journeys without a required time of arrival

The second category of journeys included journeys to casual family or friend visits, hobbies like going to the gym etc. These journeys are a sort of 'in between'-category of journeys, as people usually know the route or what line to take to these locations, yet they have little familiarity with schedules. At most they know if the line runs frequently or not. Having to take an infrequently running line lead to planning their journey; otherwise they would just go to the stop. These journeys look to be the least stressful.

Irregular journeys that are undertaken with public transport are planned with a planning app, usually 9292OV or the NS app. Journeys by bike, car or similar were planned using Google Maps when going to an unknown location. Little to no planning was involved in going to well-known locations. It is clear that irregular journeys require more planning than routine journeys.

Because of the lack of routine in these journeys, the participants did not seem to close themselves off of emotions during the journey. Journeys with a required time of arrival had more potential to be stressful, but this problem was tackled simply taking more time to complete the journey.

H.7.5. Who pays decides

Many of the participants were given a (part of a) public transport subscription by their employer. Many people that both worked and lived in the Rotterdam area were given an RET subscription, or they had to pay only a small part of the subscription themselves, being free to use it in their spare time as well. Some people received a 'traject vrij' subscription, letting them travel for free on a specific route. Others could just declare their travels costs after a certain period and get a refund that way. In any case the employer had a big influence on choices for routine journeys, and in some cases on other travel behaviour as well.

When participants had to pay for the travels themselves, they became more conscious about their travels and were more likely to look at multiple options.

H.7.6. Factors limiting travel choices

The participants mentioned two important factors that limited their transport mode options or heavily influenced them. The first one was not having a driving license (or having one, but not daring to drive). This obviously inhibited participants to travel by car themselves. They would often rely on their partner, family or friends to drive them. These people mentioned they would like to drive themselves, and said they would most likely use the car more often if they could. Public transport is the only way they can travel by themselves on journeys where they do not want to walk or bike.

The other important limiting factor was travelling with children. Almost all participants that had children travelled in a different way when travelling with their children than without. They would take the car or walk more often. If children were old enough, they would sometimes bike with them. Most of them did not take their children into public transport. The reasons for this remain guesswork. Many people were annoyed by children in public transport, so maybe they did not want to create these situations by bringing their own children.

A last factor that not always limited people's choices but did change the way they experienced the journey was having to transport large bags or other loads. Public transport, cycling and walking are not very suited to transport large (amounts of) bags. There often is no designated space. Sometimes there are baggage racks, but

they are often are placed overhead. This made it hard to get heavy bags into the racks. Non-closable bags are also not trusted to be transported in these racks, as people were afraid their goods would fall out of the bags.

H.7.7. Speed gap between public and private transport

A well known problem with public transport is that it sometimes is not as fast as private transport. Especially on longer journeys, the difference between the time it takes to complete a journey by car or by train can be big due to (badly connecting) transfers. This is a reason for more people to want to take the car for longer distances. This is mainly true for irregular journeys. On routine journeys, which are often commute trips, people did not mind as much because they could utilise the time on the train to work.

On journeys or trips within the city, people were annoyed with the detours that buses and trams often take. There were no mentions of this problem with metros. However, sometimes people still use BTM because the distance is too far to cover by bike, or because they just do not like to bike.

H.7.8. Dependence on OV chip card

In general, there were no mentions of the OV chip cards functioning. The only problem participants had with it was that they highly depended on it for public transport to be easily accessible and affordable. When they forgot the card, they suddenly realised how many barriers are taken away by it. One participant told the group about her recent experience of forgetting the card when having to travel with multiple transport providers: “you have to buy a temporary card, which is €3.50. But then I have to transfer to the bus and get another card, because it is another provider. That means I just payed €7 for the trip. I know it is my own fault that I forgot my OV chip card but having to pay €7 again for the return journey, you know…”. Other participants agreed with her wholeheartedly.

H.7.9. Transferring does not have to be bad

When transferring, there is a fine line between having to hurry, being perfectly on time and having to wait too long. When the connections are good, most people do not mind a transfer. However, there are many events that could transform a good into a bad connection.

The first and most obvious reason is having to wait for the next vehicle for too long. When it is cold and the stop does not provide shelter a long transfer is detrimental to a good travel experience. This mainly counts for routine journeys or irregular journeys with a required arrival time. A kiosk or other type of store makes a long transfer less undesirable.

Directly following having to wait for too long is having a very short time. Especially during peak hours, when the public transport system is at its busiest, this created stress for the participants. They described getting very annoyed with others being slow, especially at the OV gates. One of them would sit next to the doors in the train, because it was the only way for him to make the connection. He chose a more uncomfortable train trip over potentially missing his connection.

However, there is a brief moment in between having to hurry and having to wait, where the connection is experienced as good. One participant explained that due to a change in bus service in her work area the connection became just right, and that this was a very pleasant part of her journey. Other participants reacted to this with agreement.

Furthermore, the participants weighed several factors when deciding on a journey with transfers. Speed was of course on of the factors, but they sometimes preferred having a transfer less, even if that meant the journey took longer.

H.7.10. Travel information

In recent years the availability of on-the-go travel information has increased. Travellers appreciate this very much, but is very important for this information to be correct and reliable.

Some of the participants used the Realtime app RET offers to check at what time their vehicle would arrive. If it showed to be late, they left their location later and vice versa. Other participants in the group did not know this app existed but showed enthusiasm for this feature.

As discussed above, for routine journeys travellers often do not look for information

anymore. However, when their routine journey changes, they are not always aware. In the case of an unplanned change in schedule, people want to know what this means for the rest of their trip: how are they going to reach their destination? This lack of information provides opportunities for a new platform to be better at than current solutions.

Furthermore, many people mentioned struggling with route planning for public transport. This often started with the app they were using not displaying the correct stops, e.g. when searching for a certain stop, they would just get streets with that word in the name instead of the stop.

H.7.11. Comfort

What people expected for comfort levels depended on different factors. Firstly, it depended on whether or not they had to travel during peak hours. They recognised that it would be very difficult to maintain their expectations during peak hours, so they usually were OK with having lower service levels at these times. They did really not enjoy being crammed together, which happened mostly in the metro. Transferring at Beurs during peak hours was also a negative experience due to the large masses crowding the station.

Secondly it depends on whether they had a short or a long journey. As one person explained, she just had to travel three stops with the metro, so she did not mind not having a seat. However, having a seat feels like part of the basic comfort level that should be provided. As one participant said, 'I've paid for it, so I want a seat'.

Thirdly, temperature proved to be very important to the participants. They discussed the in-vehicle temperature, which was said to be way to high in the winter: everybody is dressed in warm clothes with thick coats, and the temperature in vehicles was not adjusted to this. Furthermore they were very negative about having to wait for a vehicle in the cold. Especially bus and tram stops provide very little shelter. A side note for these comments is that the diary and group sessions were done in a very cold period, so the items they mentioned here were maybe exaggerated.

Lastly many participants agreed to the bus and tram not being comfortable in general. This was mainly due to the vehicle shaking during the ride.

H.7.12. Activities during the journey

Many participants said they would use time on commute journeys to do some work. If travelling by train they used their laptop, while when travelling by BTM the phone was used more often. The train's interior is more suited to work with a laptop, while in BTM there is no tray table or space to put it. Reasons for working during the trip were mainly to reduce the work they had to do while in the office. Some participants mentioned they did not have strict work hours, so if they did some work while travelling, they could leave earlier.

To relax during the journey, most participants listened to music, read a book, used their smartphone for entertainment or just looked out of the window.

H.7.13. Privacy in private vehicles

One of the participants very much favoured the car over other transport modes. For him, this was also due to the privacy a car offers in comparison to e.g. public transport. He explained that he was very happy to take the car when going to a 'comic con' event, as he could wear his Batman outfit without feeling weird in a public space.

H.7.14. Awareness of travel factors

The only factor of the five asked factors at the end of the diary that all people had good awareness off was their total travel time. Most people confirmed their insight in total travel costs, but there were some people that expressed they had very little idea. However, many people were not aware of changes in their travels, like timetable changes. New transport services were also mostly unknown with these participants. This shows that there is still much to progress to book with information availability and clarity for travellers, in some cases when they are not looking for it themselves.

H.7.15. Descriptions of 'ideal door-to-door journeys'

One of the creative assignments asked the participants to create a collage for their ideal door-to-door journey. Some interesting suggestions are discussed here.

Firstly there was a participant that specifically asked for a multimodal planner. He said he would want to be able to travel with different travel modes depending on the time it takes, taking the car when it would be much faster (e.g. during peak hours), but having the option of taking public transport when it would suit the situation better.

Multiple participants wanted a multimodal planner that helped them decide. One participant had titled his assignment 'carefree travelling'. To him this involved giving an app his routine journey, and the app would help him decide what is best based on the weather and other circumstances. The app should let him know when he has to leave his location. The goal of this system was to arrive at your destination in a relaxed way, not having to stress about it. This vision was shared by more participants, expressing their wishes to actually enjoy their journey by relaxing or using the time to catch up with friends.

Another participant had a similar ideal journey, where the travel advice would be based on the distance. For short distances she preferred cycling, whereas for longer journeys she preferred taking the train.

Moreover, one participant had picked up on the high speed vacuum transport tubes that are in development at this moment, like the hyperloop. He said he would love to have his own personal connection to a hyperloop system, which enables him to travel anywhere he wants in a very short period of time, leaving him with more free time. This solved his struggles with having to adapt his travels to weather, and permitting him to bring on goods.

A last multimodal journey ideal was based more on new transport, but in a less futuristic way than the hyperloop idea. He would like to travel by electric step to a P&R, where he could just jump into a self-driving car he had booked in advance. This journey again showed that transferring does not have to be bad, as long as it does not take much time and there is a certainty of not missing the connection.

H.8. Conclusion

This explorative study has given much insight in travelling habits of urban inhabitants and their wishes. Even though not all the participants fit the 'MUP'-profile, all of them gave interesting insights in their travel behaviour.

One of the findings is that choices are very much constrained by employers. Often they provide for commuting transport, either by giving a public transport subscription or a lease car. As the commute travels were undertaken more frequently than irregular journeys, most of their journey choices were not based their own preferences, but from what their employer had provided them. Furthermore, they could often use these transport options in their own time as well, therefore influencing their irregular journeys as well. Thus, when developing a MaaS platform, it should be taken into account that travel choices are likely to depend on what employers offer.

There is a vast difference between how routine journeys and irregular journeys are experienced. Routine journeys are often done in an automated way: no travel information is searched for, as timetables are more or less memorised. This leads to travellers missing information on changes in their travels. The unawareness of changes in timetables was confirmed by the booklets. Furthermore, many of the participants had created a sort of emotional numbness regarding these journeys. They knew they had to get through it anyway, so they got themselves to stop feeling negative about unpleasant journeys. The strong routine most people had developed for their commute travels looks to be difficult to change, and might not be suited for a MaaS platform initially. However, providing information on changes in their routine journey would be very valuable.

Irregular journeys however are very different. This category can be split into two types of journeys, depending on whether a specific arrival time must be met or not. If this is the case, people were quite meticulous in their

planning, often taking extra time for the journey to ensure they had some play room in case anything did not go to plan. Without a required arrival time the participants were more loose in their approach, often not planning in advance, just leaving their location when it suited them. Irregular journeys look to be the most suitable to get people to start using a MaaS platform, as it includes more planning. Next to that there often is less awareness of the travel options in the destination area, making them more likely to try new mobility services.

A well-functioning Mobility as a Service-platform depends on travellers using different mobility types. Most participants however never used new mobility services. They often had experience with OV bikes before and really liked them, but no participant had used another service like Mobike, Felyx or car2go. This shows the need for actively getting travellers acquainted with new mobility services, as there is no certainty they will actually start using them once they are integrated in a MaaS platform.

Furthermore, connections are not necessarily seen as bad. When the transfer is just right in timing, people did not seem to mind. However, when provided with the choice to either have longer travel time but less transfers, or a shorter time with more transfers, the option of less transfers seemed to be favoured by several participants. There is no clear insight in what these choices depend on exactly, so more research is needed to know how to take this into account for an advanced journey planner.

Other insights were that even these frequent public transport users preferred the car sometimes. This was mainly due to the large speed gap in these journeys, or the destination being very hard to reach with public transport.

Lastly, the current dependence on the OV chip card was seen as very frustrating at times: when not having the chip card at hand, a well-functioning public transport system suddenly transforms into an expensive, unpleasantly complicated system.

I. ELECTRIC VEHICLES, AUTONOMOUS VEHICLES

H.9. Electric driving

Plug-in electric cars (PHEVs) and fully electric cars (FEVs) have become much more popular in recent years. At the beginning of 2014, there were around 5000 fully electric cars and 25.000 plug-in hybrid cars. At the start of 2018, there were almost 22.000 FEVs and 97.000 PHEVs: almost quadruple the amount of five years earlier (CBS, 2018). It is expected that in 2040, 55% of all new car sales and 33% of the global car fleet are electric (BloombergNEF, 2018).

H.9.1. Expected cost reduction

In November 2018, the Dutch government announced plans to heavily subsidize electric driving. When buying a new electric car, consumers get €6000 euro back in 2021. The refunded amount drops to €2200 in 2030. Furthermore, electric cars can be bought without bpm (purchasing tax) until 2025, and after 2025 consumer pay a €350 fee instead of a percentage. Driving tax (mrb) does not apply to electric driving until 2025, also for second hand electric cars. Furthermore, taxes on fossil car fuel are planned to increase with €0.01 per litre (NOS, 2018a).

Prices of electric vehicles are largely made up by the cost of the power train. As figure 34 shows, the extra cost that is paid for battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and hydrogen fuel cell electric vehicles (HFCEVs) in comparison to a mid-range (€21.000) internal combustion engine vehicle (ICEV) is expected to decrease significantly in the coming years. This is mainly due to price reduction in the power train, especially in the battery: 75% of power train costs are made up by the battery. (Wolfram & Lutsey, 2016)

H.9.2. Decreased environmental impact

Wolfram and Lutsey (2016) show the predictions for the decrease in CO2-equivalent greenhouse gas emissions (GHGE) compared to the well-to-wheel energy consumption (kWh) per 100 km, and the adjusted EU emissions standard in 2021. Well-to-wheel energy consumption captures all direct and indirect emissions of fuel and electricity production and vehicle operation. For all power trains, both WTW energy consumption per 100 km and GHGE decrease strongly. This trend is expected to continue until 2050, although how far GHGE can be reduced depends strongly on the efficiency and electric driving policies and standards that are set (Lutsey, 2015).

H.9.3. Consequences for driving

Not only the transport sector is affected by the mass shift to electric driving. Firstly, the electricity sector has to be able to supply enough energy to charge all EVs. Uncontrolled charging can significantly increase peak load of the electric grid. Smart/controlled charging can help decrease peak load and smooth the electricity demand curve. The total electricity demand is increasing, making electricity more expensive – regardless of whether you drive an electric vehicle or not. In return, electric vehicles could become part of the electric grid by charging when there is an excess of energy supply (sustainably sourced energy supplies are usually largest off peak times). When peak times arrive, the EVs could discharge to the system. (Wired, 2018b)

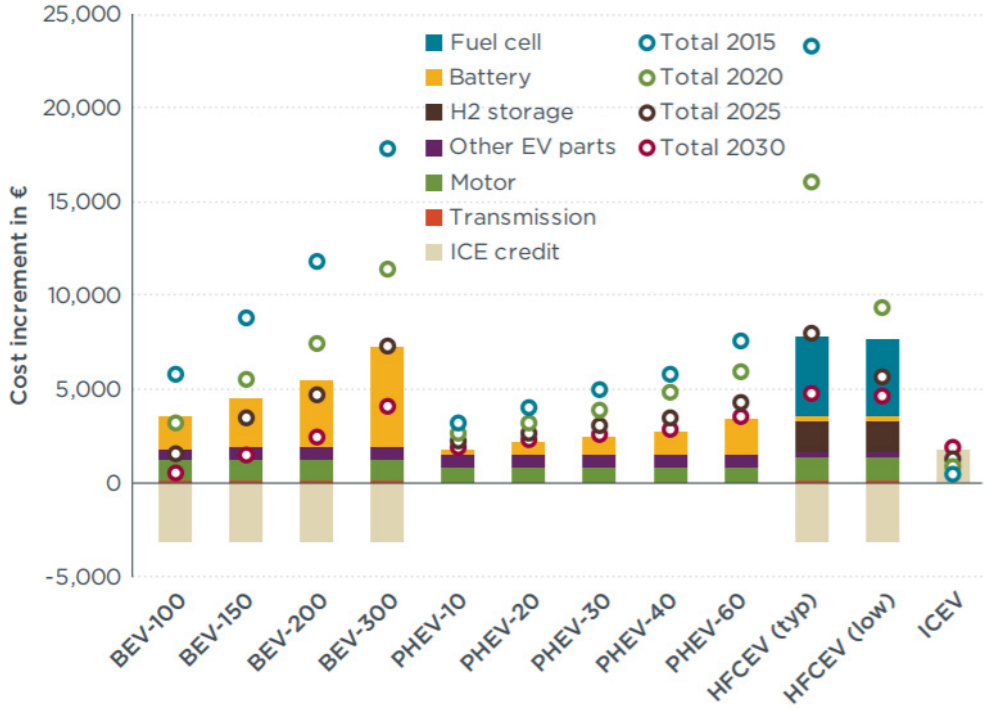

Figure 34. Cost breakdown of different power trains for a 2030 lower medium car. Circles show total incremental costs over a 2010 internal combustion engine vehicle (ICEV). The number (e.g. BEV-100) expresses the range in miles (Wolfram & Lutsey, 2016)

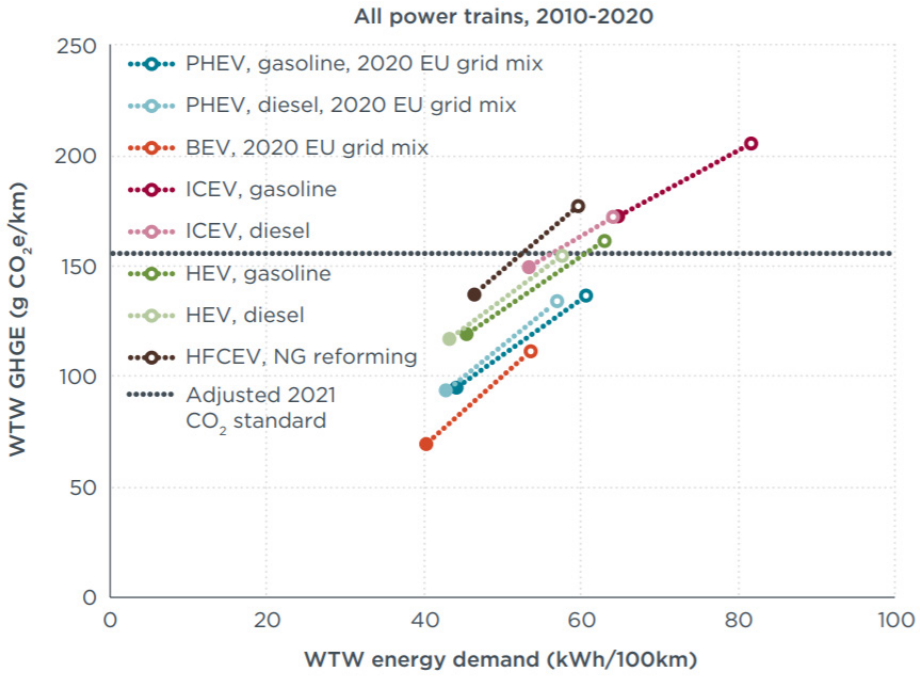

Figure 35. Well-to-wheel (WTW) greenhouse gas emission (GHGE) change from 2010 to 2020. Hollow dots represent 2010, filled dots represent 2020 (Wolfram & Lutsey, 2016)

H.10. Autonomous vehicles

In the 'self-driving car'-world, five levels of automation are identified, in ascending order of some small steering or acceleration tasks performed autonomously, to full automation in all conditions. There are many applications for each of the automation levels, but especially from level 4 (full automation in urban areas) on radical new opportunities can be identified. It's very likely the first autonomous vehicles will appear as taxis or ride-sharing vehicles, operating in limited conditions and areas, so operators have full control over all details. Autonomous vehicles are most likely electric vehicles. (TechEmergence, 2018; Wired, 2018a).

H.10.1. Development of AVs

Waymo (originally a Google division, now a separate company) is one of the frontrunners in the autonomous vehicle industry. Their cars have now driven more than 10 million miles on public roads. They are piloting with an autonomous vehicle fleet in Phoenix: people can actually use these autonomous vehicles to get around. (Waymo, 2018)

GM is currently developing an electric self-driving car specifically for ride-sharing, and is planning to introduce these vehicles in 2019, to create an integrated network of on-demand autonomous vehicles in the US. Renault plans to release a level 4 autonomous vehicle in 2020, Ford and BMW in 2021. Many others are in the pursuit to release an self-driving car on highway automation or urban automation level as soon as possible. (TechEmergence, 2018)

The autonomous driving technology is not only relevant for cars, but also for other vehicles that currently require a driver. Autonomy for metros, trains and trams is already implemented in cities like Copenhagen, Kobe, Potsdam, Paris, and many more. (Railway Technology, 2018)

H.10.2. Consequences of AV introduction

The impact of a transport system with autonomous vehicles instead of private car ownership are enormous. Below some of the expected effects are named, although there are many more expected (and unexpected) ones.

It's likely that AVs will operate in a "taxi" fleet: whenever you need to go somewhere, you just hail the AV, it brings you to your destination. The AV will then ride on to pick up the next traveller, or go to the storage area to charge or be maintained.

However, there are many other impacts of AV implementation that are less obvious. Present day cars are idle 96% of the time, while AVs could have a utilisation rate of 75%. As AVs do not need parking space in crowded areas, almost all parking lots in urban areas can be repurposed. Instead there will be many drop off points. (Duarte & Ratti, 2018)

Privacy is another controversial topic surrounding these vehicles. As there is no driver to keep watch, the vehicle itself will monitor the passengers, hereby knowing just about everything about them. If passengers are caught showing 'unwanted' behaviour, they can be denied access to AVs in the future. Next to keeping an eye on passengers, the vehicle can also monitor its surroundings. With large scale implementation of AVs, they are likely to become a surveillance system for street crime. Law enforcers can use data from vehicles to support decisions. (The Economist, 2018)

We will also be using our time on an autonomous vehicle completely differently from car time nowadays. Part of our rituals that surround transport can be shifted to in-vehicle time. Eating, working, having meetings, entertainment and many more things can be done while being transported. Personalised advertising during rides becomes commonplace, although it will be possible to buy ad-free rides at a higher price. (Medium, 2018)

J. THE FUTURE OF PUBLIC TRANSPORT IN ROTTERDAM

As described in the Challenge chapter, it is necessary to create a higher capacity transport network, yet keep the environmental and space impacts low. The most obvious solution for this problem is to increase the amount of travellers in public transport, while decreasing motorized individual transport. It however is the question if the current public transport network in Rotterdam can handle this increase in passengers. During peak hours some routes are already extremely busy.

J.1. National policies regarding Public Transport development

There are three pillars for the development of public transport towards 2040 (Ministry of Infrastructure and Water Management, 2019):
1. Focus on the power of PT
2. Door-to-door without barriers
3. Safe, sustainable and efficient

The first pillar emphasizes the focus on public transport between large cities in the Randstad and Zwolle, Arnhem-Nijmegen, Eindhoven and Breda. For Rotterdam's intracity mobility this document does not elaborate on specific directions, except for 'intensifying and improving the metro system'.

The second pillar is directed more towards MaaS solutions. The combination of (e-) bikes and public transport is said to be the optimal mobility solution in urban areas, as it is a relatively cheap, sustainable and healthy way of travelling. PT hubs are enhanced to create a better transfer environment and make multimodal journeys more attractive. Furthermore, transport providers are nudged to share data to make MaaS development easier.

The third pillar aims to make the whole PT sector emission free by 2030 by using green electricity and a circular approach in development and maintenance. Moreover the importance of liveability in cities is stressed, however there are no clear directions given for how policies on parking, the layout of public spaces and possible 'environmental zones' (milieuzones in Dutch).

How these goals are to be reached is still unclear. However, it is a good starting point and provides direction for all involved parties, including RET. Below the future of urban public transport in Rotterdam is discussed further.

J.2. Metro and lightrail connections

These high capacity modes are still very valuable for transporting many people in a very efficient manner. The per capita environmental impact of especially train services are very low. Therefore it is likely they still have a big role to play in the urban public transport of the future. However, adjustments need to be made to the system to facilitate the growth that is needed for a better urban environment.

Figure 7 shows RET's expectations for the used capacity of metros in 2025 and 2035 with a moderate growth rate of 3% per year. It is predicted that the system as it currently is will not suffice anymore somewhere between 2022 and 2029, with the peak hours being unbearably busy.

There are several options that are looked at to help alleviate the pressure on the system for the future. These plans are by no means final and sure to be executed, but must be looked at as a the company's hopes of creating a better public transport system in Rotterdam.

J.2.1. Automation of the current metro system

For the existing lines (A-E) automation of the network can help create much more capacity. Driverless systems allow for higher frequency, letting metros through up to every 90 seconds. In the current system metros ride about every 3 minutes on the busier routes during peak hours, so this could lead to a large improvement in capacity. The automation is hoped to be introduced in a phased way between 2025 and 2040.

J.2.2. Connection north & south with metro F

To create better connections between the north and south of the city, an extra metro line is added that runs between Rotterdam Centraal, Dijkzigt in the north, Zuidplein and Feyenoord in the south, and then to the Erasmus University in the north. With plans for a new 'Feyenoord City' a part of south-Rotterdam will be redeveloped, making the need for transport to and from this area even bigger.

J.2.3. Extra connections between Dordrecht and Den Haag (line G & H)

The current rail connections between Den Haag and Dordrecht are to be transformed into a double track connection in both directions, allowing for much higher frequency. One track can be used for faster trains with less stops, while the other can be used for a lightrail/ sprinter type connection that serves many stops within the area. This increases the total capacity of the train network a lot.

18.1 Future of motorized public transport

With electric buses, autonomous vehicles and Demand Responsive Transit becoming reality in the near future, the bus system is also up for a transformation. It is very unlikely that buses as we know them today will be present in the future public transport landscape, as newer options simply provide higher value for a lower impact.

Electric buses can provide a suitable alternative for conventional buses on high-demand routes, or on high-demand times. The environmental impact of electric vehicles depends highly on what type of electricity grid mix is used to power the buses. When using a green grid mix the impact can be as reduced by more than half when comparing to a diesel bus (Green Tech Media, 2018).

J.2.4. On demand transit

Low demand bus routes can be replaced by other services, like Demand Responsive Transit (DRT) services. There are three main constraints that need to be taken into account when looking at such a service: the amount of passengers per vehicle, the pick-up location of each passenger (stop-to-stop or door-to-door), and the specificity in pick-up time of each passenger (REF). These factors influence the travelling time and costs of the total journey. For passengers, the ideal scenario is to be picked up at exactly their location of choice, at exactly their chosen time, and take the shortest route to their destination. However, this is might not be optimal for the complete transport system. Therefore one of the main challenges in developing a Demand Responsive Transit (DRT) is to balance the passenger needs and the optimisation of the system for the transport provider.

The choices the transport provider makes regarding these two constraints also influence the type of service the DRT service becomes. Systems optimised to passenger needs are likely to be much more expensive yet provide a higher service quality. They have a higher resemblance to present-day taxis than bus services, and are therefore more attractive to travellers looking for a premium service.

RET has already made a first step in this direct with their STOPenGO pilot (see chapter 1). The STOPenGO buses start from a central departure location, and then travel the fastest route between the requested stops. These lines still follow a certain timetable (at least the departure time from the central location) and have fixed pick-up/drop-off locations. Therefore, it is only a semi-on demand bus service.

J.2.5. An example of DRT: online carpooling services

In the USA, ridesharing has really taken off. Companies like Uber and Lyft offer various services that balance the convenience for the rider and the price. The best-known variant is

the taxi service like UberX, where one person or group of up to four people are travelling in a traditional taxi way. They are picked up at their location and time of choice.

Next to UberX, there is UberPool. UberPool fares are much lower than for an UberX ride. With this service multiple people that are headed in the same general direction are transported with the same vehicle. Furthermore, passengers are asked to walk a short distance at both ends of the journey to a pick-up point or from a drop-off point. This helps to optimise routing and travelling time for the vehicle. Thus, this service has a much higher resemblance to a small bus service, except for the fact that the pick-up/drop-off locations and routes are customised for each trip.

An iteration on UberPool is UberExpress Pool. In this case, all passengers are asked to walk a short distance to the same pickup location, and are dropped off at the same spot. This is possible by taking a few minutes after the ride is requested to match several passengers based on their current location and destination. Fares for these rides are even lower than for UberPool.

Obviously profitability of a system like this depends highly on the amount of requested rides: if there are no requested similar rides, it is still as expensive as a private taxi ride. The choice can also be made to a have a minimum amount of riders for a trip to be executable with this service, yet this might lead to lower service levels for users when they are denied a trip. The lower cost benefit of a shared ride might then be outweighed by the inconvenience of the service. (The Verge, 2018)

J.2.6. DRT vehicle capacity

UberExpress Pool vehicles are optimally filled with three passengers (The Verge, 2018). The used vehicles are usually standard sized cars for 4-5 people, so three passengers plus one driver equate to a comfortable ride for all. The autonomous vehicles of WEpod can currently transport up to 6 passengers. It seems that a lower capacity is more suitable for DRT systems, yet more research needs to be done to find the optimal size in different conditions.

18.2 ADRT: a public or private responsibility?

If buses become smaller when adopting a DRT system, the line between taxi services, carpooling and buses becomes fine. This also raises the question which type of services are to be organised by private companies, and which should be facilitated by public transport. If the current situation is projected onto the future, at least taxi and probably carpooling services are provided by private companies. However, this becomes less clear when looking at DRT or even at Autonomous Demand Responsive Transit (ADRT). As much of the operational cost of a bus system (and especially when using smaller buses like in the STOPenGO service) comes from driver costs, in the long run ADRT is likely to be more cost-effective. The investments that are needed to adopt an ADRT bus system are possibly enormous, and it triggers the question whether it would be smarter to let private companies take care of it.

Which direction is taken highly depends on what policies are installed by the government, the MRDH and the municipality of Rotterdam. These parties ultimately have to finance any development of the public transport system, and have a big say in the way ADRT services are executed. Below two scenarios are outlined, which demonstrate the development of an ADRT system with or without government funding.

J.2.7. Scenario 1: ADRT is a public service

In this case, the ADRT service is likely to be an addition to the existing public transport network. This also means that the vehicles focus on areas that are underserved by existing public transport routes, especially in non-rail served areas. They can hereby replace present-day bus services in a more personalised and efficient way. When the destination lies outside the origin city or is on the other side of the origin city, the trips in AV buses should be part of a multimodal chain, where the main part of the journey is done by rail. This can be done by e.g. incentivising transferring to a rail service, or by constraining the area that can be covered in one ADRT trip.

As government bodies have a larger say in how this transport service is executed, it also

lends itself better for integration societal goals into the plans of the service. It provides large opportunities for keeping the busy areas in the city liveable. For example, time restrictions can be given to vehicles for staying within a certain area, or a higher fee is asked for trips into busy areas to discourage travellers.

Publicly organised ADRT is more likely to be a stop-to-stop service than a door-to-door service. A customised route is used to pick up or drop off the passengers at a few points that optimises the travel time. The vehicles used for a service like this are probably much smaller than conventional buses, but larger than a personal car. Services like this are more comparable to present-day bus services, and are therefore not experienced as premium services. The ride fare should reflect this as well.

The MRDH has expressed a big interest in developing autonomous public transport, and plans to invest in attracting pioneers in the AV market. This should help to make the region one of the first to pilot and adopt autonomous vehicles (OVpro, 2018). Several pilots throughout the region are probably realised before 2025.

Whether it is up to RET, another existing bus transport provider like Connexxion or EBS, or a whole new company is created to develop ADRT remains to be seen. The current contract for bus transport in Rotterdam is just renewed. With an end date in 2034 it can be expected that any major changes in the bus system are not done until this contract has ended.

J.2.8. Scenario 2: ADRT is organised by the private sector

When policy makers decide ADRT is not a public responsibility, there is space for private companies to provide for it. To gain traction for the service the high demand areas are served first. This can lead to even more imbalance in the amount of transport options in high demand versus low demand areas. Moreover, when many people choose to visit the busier areas in the city with an AV, these areas remain very crowded, which does not lead to improved liveability of the city. Therefore the municipality should decide whether or not busy areas are to become low vehicle zones or not. This includes the decision if vehicles have to use designated pick-up/drop-off points, or if they can use any legal spot for this.

In the case that the private sector develops ADRT, they are probably more of an evolvement of taxi services, rather than evolving from bus services. Therefore the vehicle sizes are probably smaller, resembling cars. As described in chapter 7.1, many car companies are experimenting with creating AV taxis, and Uber is already experimenting with carpooling services. Two categories of ADRT services are probably derived from the existing businesses: expensive private rides, and cheaper shared rides. Shared rides do not have to be the lesser version of private rides, as they provide other opportunities of spending time with known or unknown people. Algorithms can help link people that are likely to enjoy spending time together. Ridesharing is still a more efficient way of travelling for the complete system, as it requires less space and resources, thus it is worth it to design these systems in a way that people prefer sharing rides over private transport.

As said in chapter 7.1, the first level 4 AVs can be expected to be released in the next three years. Therefore it is highly likely that by 2025 several private providers of ADRT serve urban areas.

Figure 36. Plans for the development of the future metro network (RET)

Figure 37. Imaging of the HTM ADRT service