Owning or sharing, a private ride or a shared ride

A study into the future trend in adoption and usage of autonomous vehicles

Master Construction Management and Engineering
Eindhoven University of Technology

A.H.M. van Helvoirt – 0794459
08-01-2020

Graduation committee:

Prof.dr.ir. Bauke de Vries – Chairman – TU/e
Prof.dr.ir Soora Rasouli – First supervisor – TU/e
Dr. Dujuan Yang – Second supervisor – TU/e
Ir. Fieke Beemster – Company supervisor – TNO

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A.H.M. (Anouk) van Helvoirt
0794459

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Preface

This thesis is the final stage of my study at the Eindhoven University of Technology. At the start of my study my goal was to become an architect. However, during my time at the TU/e I developed more interest in the broader spectrum of the built environment. For this reason I started my masters in Construction Management and Engineering. During my masters my interest in mobility had grown. As a result, I chose the topic of my graduation project in this field. I am interested in human behavior as well. Therefore the topic of my gradation project fits with my interests. I hope this study can contribute in making predictions about future adoption and usage of AVs.

I would like to thank my supervisors from the TU/e, Soora Rasouli and Dujuan Yang, and my supervisors from TNO, Fieke Beemster and Eleni Charoniti. They spend a lot of time guiding me, providing critical feedback and helping me writing this thesis. I would like to thank Soora specifically for the regular and long meetings and the critical feedback during this project. Which helped improving this thesis a lot. Furthermore I want to thank TNO and the colleagues of the department of SUMS, for welcoming me and the opportunities I had in the department. I am also grateful that I was able to use a paid online panel with the help of TNO. Finally I would like to thank my family, friends and boyfriend for supporting and helping me during the past few months.

Furthermore, I am happy with my personal development while conducting my graduation project. I have learned about programming, choice modeling and many other subjects. I am delighted to finish my student career with this thesis and am ready for the next steps in my career.

Kind regards,

Anouk van Helvoirt
Eindhoven, January 2020

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Abstract

Developments of autonomous vehicles progress fast. Within a few decades people will be able to drive an autonomous vehicle (AV) (Litman, 2018). Apart from that, shared mobility is evolving and the population is interested to use shared mobility (Nazari, Noruzoliaee, & Mohammadian, 2018). These developments will not only change the travel behavior of individuals, but also the transportation sector as a whole (Harb et al., 2018). This research investigates people's willingness to adopt or use different kinds of autonomous vehicles. Mid-term and short-term decisions are investigated. A stated choice experiment (SCE) is used to research mid-term decisions. The experiment takes a look at people's willingness to adopt an owned AV or shared autonomous mobility. Short-term decisions are tested with a stated adaptation choice experiment (SACE). The choice experiment investigates people's interest to use different types of shared autonomous transportation modes. The following alternatives are investigated: single occupancy shared AV, multiple occupancy shared autonomous ride or autonomous public transportation. Before answering the choice tasks of the SACE, the respondents are asked to describe four reference trips. The reference trips are used to generate personalized choice tasks. Not only choice experiments are used in this research. The research also investigates attitudes, in order to research the influence of attitudes on people's decisions.

Both choice experiments and the attitudes are integrated in a questionnaire. The questionnaire is distributed via the online platform LimeSurvey. The answers of 902 respondents are analyzed with a hybrid choice model. The model simultaneously estimates the influence of the attitudes on the decisions. The results indicate that the respondents are almost equally interested in adoption of owned AVs as shared autonomous mobility. The attributes related to financial aspects and the attribute waiting time have a lot of influence on the decisions. The attitude towards sustainability positively influences the decision to adopt shared autonomous mobility. As for short-term usage of AVs, the respondents are most interested in usage of single occupancy shared AVs. The travel costs and the waiting time have a lot of influence on the decisions. The attitude towards sustainability positively influences the decision to use an AV shared with strangers and autonomous public transportation.

Keywords:
Autonomous vehicle
Shared mobility
Mid-term decisions
Short-term decisions
Hybrid choice model

Summary

The transportation sector is changing. Movements from one location to another will be different in the future, due to the development of autonomous vehicles and shared mobility services. Autonomous vehicles are vehicles that enable driving without human intervention. Autonomous vehicles have level five of automation. Furthermore shared economies are popular, and therefore the popularity of shared mobility is increasing. Both these developments lead to changes in the travel behavior of individuals. If an increasing number of people is interested in shared autonomous mobility, then car ownership will decrease. This will result in extra space in urban areas, because fewer parking places are needed. However, if many people use shared mobility, then it does not necessarily mean that the road capacity increases. Development of AVs increase the travel convenience, resulting in higher willingness to travel for a longer period of time. Only if people are willing to share rides with others, then road capacity can increase as well.

This research investigates people's willingness to adopt and use different kinds of autonomous vehicles, while focusing people's on mid-term and short-term decisions. The adoption of autonomous vehicles refers to mid-term decisions. Both the adoption of owned AVs and shared autonomous mobility are investigated. The analysis of short-term decisions only investigates shared autonomous transportation modes. Which are: a single occupancy ride, also shared autonomous vehicle (SAV), an autonomous ride shared with strangers, also shared autonomous ride (SAR), and autonomous public transportation (APT). Four research questions have been formulated:

- *What are driving factors in people's decisions toward adopting a privately owned autonomous vehicle versus adopting shared autonomous mobility?*
- *How do attitudes play a role in the choice to adopt a privately owned autonomous vehicle or shared autonomous mobility?*
- *If people are interested in shared mobility, then what are the driving factors (under which context) to choose between the usage of a shared autonomous vehicle, a shared autonomous ride or autonomous public transportation?*
- *How do attitudes influence the usage of either a shared autonomous ride, a shared autonomous vehicle or autonomous public transportation?*

The first two research questions refer to the mid-term decisions. The mid-term decisions are investigated with a stated choice experiment, including different attributes that belong to the alternatives. The attributes of the alternative AV ownership are: purchase price, depreciation costs and monthly costs. The value of the purchase price and depreciations costs depend on the respondents' answer. The attributes related to the adoption of shared autonomous mobility are: membership fee, price per kilometer, waiting time and reliability. The last two research questions refer to the short-term choices. The choices are investigated with a stated adaptation choice experiment. Before answering this choice experiment, the respondents indicate four reference trips taken 'last week or the week before'. These trips are used in the choice tasks. The respondent is asked how he/she would travel along the same ride, but then with one of the alternatives. Autonomous public transportation does not have any attributes and can only be chosen when the respondent uses public transportation during the reference trip. SAR and SAV have similar attributes: travel costs, waiting time, travel time and seating comfort. Shared autonomous ride has an extra attribute, describing with how many strangers the ride is shared. The travel costs and the travel time of the alternatives depend on the reference trips. These two choice experiments, together with statements investigating attitudes and questions about socio-demographics and travel characteristics are integrated in one questionnaire.

The questionnaire has a response rate of 902 respondents. Only the respondents that own a car or are willing to buy a car in the future filled in the SCE. The SCE has a sample size of 822 respondents. The respondents willing to use shared mobility answered the choice tasks of the SACE. In total, 765 respondents filled in the SACE. The results of both choice experiments are investigated with a hybrid choice model. The hybrid choice model is used to analyze the attitudes. The model enables simultaneous estimation of the parameters of the latent variables (attitudes).

A bit less than half of the respondents choose adoption of shared autonomous mobility. This is surprising, because not many respondents are current users of shared mobility. The financial attributes have most influence on the decisions made in the SCE. Increasing purchase prices and monthly costs discourage the respondents to adopt an owned AV. Likewise raising membership fees and prices per kilometer make the respondents less willing to choose the sharing option. Furthermore the respondents prefer short waiting times when considering adoption of shared autonomous mobility. The respondents that live in the city are most interested in adoption shared autonomous mobility. The respondents that often travel by car are most willing to purchase an AV. Furthermore retired respondents prefer adoption of shared autonomous mobility. Finally the respondents that have a positive attitude towards sustainability are most interested in adoption of shared autonomous mobility.

The results of the SACE show that most respondents prefer using single occupancy shared AVs. A ride shared with strangers is chosen one third of the time. Autonomous public transportation is the preferred alternative 10% of the time. APT was chosen almost half of the time, when the alternative was available in the choice tasks. The financial attribute has a big influence on the choices. Increasing travel costs make the respondent less willing to choose one of the alternatives. Furthermore, the respondents prefer short waiting times and low travel times. The respondents favor the business class as seating comfort level. Moreover the respondents prefer traveling with one stranger instead of multiple strangers. Furthermore, the respondents with a low level of education are most interested in usage of SAR and SAV. Respondents that live alone or with a partner are least interested in these alternatives. Finally, the respondents with a positive attitude towards sustainability are most willing to use a ride shared with strangers or autonomous public transportation.

Samenvatting

De mobiliteit sector is zich het laatste decennium flink aan het door ontwikkelen. Ontwikkelingen in autonome voertuigen en gedeeld vervoer veranderen verplaatsingen van de ene locatie naar een andere locatie. Autonome voertuigen zijn voertuigen die zonder menselijk ingrijpen kunnen rijden. Deze voertuigen beschikken daarmee over level vijf van autonomie. Verder neemt de populariteit van deel economieën en gedeeld vervoer toe. Beide ontwikkelingen zorgen voor veranderingen in reisgedrag van individuen. Autobezit zal afnemen wanneer steeds meer mensen geïnteresseerd zijn om gedeeld vervoer te gebruiken. Dit resulteert onder andere in extra ruimte in de stad, doordat er minder parkeerplaatsen nodig zijn. Wanneer een groot aantal mensen gedeeld vervoer gebruikt, betekent het niet direct dat de capaciteit van het wegennetwerk toeneemt. Autonome voertuigen zorgen voor efficiënt reizen, hierdoor zijn mensen bereid om langer en meer te reizen. Alleen als mensen bereid zijn om een rit te delen met anderen kan de capaciteit van het wegennetwerk toenemen.

Tijdens dit onderzoek is geanalyseerd of mensen verschillende soorten autonome voertuigen willen gebruiken. Hierbij ligt de focus op midden termijn en korte termijn beslissingen. Op midden termijn is onderzocht of mensen een autonome auto willen kopen of gebruik willen maken van gedeelde autonoom vervoer. De analyse van korte termijn beslissingen onderzoekt alleen gedeelde autonome voertuigen, deze bestaan uit: individuele gedeelde autonome rit, gedeelde autonome rit met onbekenden en autonoom openbaar vervoer. Vier onderzoeksvragen zijn hierbij geformuleerd:

- *Wat zijn de belangrijke factoren die de keuze beïnvloeden tussen het kopen van eigen autonome auto en gebruik maken van gedeeld autonoom vervoer?*
- *In welke mate spelen standpunten een rol bij de keuze tussen het kopen van een eigen autonome auto of het gebruik van gedeeld autonoom vervoer?*
- *Als mensen geïnteresseerd zijn in gedeeld vervoer, wat zijn dan de belangrijke factoren (in welke context) om te kiezen tussen gebruik van een gedeelde autonome auto, een gedeelde autonome rit en autonoom openbaar vervoer?*
- *In welke mate spelen standpunten een rol bij de keuze tussen gebruik van een gedeelde autonome auto, een gedeelde autonome rit en autonoom openbaar vervoer?*

De eerste twee onderzoeksvragen gaan over midden termijn keuzes. Deze keuzes zijn onderzocht met een Stated Choice experiment, inclusief verschillende attributen die bij de alternatieven horen. De volgende attributen horen bij eigendom van een autonome auto: aanschafkosten, afschrijvingskosten en maandelijkse kosten. De waardes van de aanschafsprijs en afschrijvingskosten zijn afhankelijk van een antwoord van de respondent. De attributen gerelateerd aan gebruik van gedeeld autonoom vervoer zijn: lidmaatschapskosten, prijs per kilometer, wachttijd en betrouwbaarheid. De laatste twee onderzoeksvragen zijn gerelateerd aan korte termijn keuzes. Deze keuzes worden onderzocht met een Stated Adaptation Choice experiment. Voordat het experiment wordt behandeld in de enquête, wordt aan de respondenten gevraagd vier ritten te beschrijven, deze zijn 'vorige week of de week daarvoor' ondernomen. De respondenten is gevraagd hoe

ze zouden reizen met een van de alternatieven, afhankelijk van de rit. Autonoom openbaar vervoer heeft geen attributen en kan alleen gekozen worden wanneer de respondent openbaar vervoer gebruikt tijdens de vooraf beschreven rit. De andere twee alternatieven hebben gemeenschappelijke attributen: reiskosten, reistijd, wachttijd en zitcomfort. De autonome rit gedeeld met onbekenden heeft een extra attribuut: aantal onbekenden. De reiskosten en reistijd zijn afhankelijk van de antwoorden over de rit. De twee experimenten, samen met statements gerelateerd aan standpunten en vragen over sociaal demografische factoren en reis gedrag, zijn samengevoegd in een enquête.

902 respondenten hebben gereageerd op de enquête. Alleen respondenten die een auto hebben of een auto willen kopen hebben het Stated Choice experiment ingevuld, met een totaal van 822 respondenten. De respondenten die gedeeld vervoer willen gebruiken hebben het Stated Adaptation Choice experiment ingevuld, met een totaal van 765 respondenten. De resultaten van beide experimenten zijn onderzocht met een Hybrid Choice model. Het model is gebruik om de standpunten te onderzoeken. Met het model is het mogelijk om de parameter van de standpunten simultaan te berekenen.

Iets minder dan het helft van de respondenten wil gedeeld autonoom vervoer gebruiken. Dit is verassend, want op dit moment gebruiken niet zo veel respondenten gedeeld vervoer. De financiële attributen hebben het meeste invloed op de beslissingen. Toenemende aanschaf en maandelijkse kosten ontmoedigen de respondenten om een autonome auto te kopen. Stijgende lidmaatschapskosten en de prijzen per kilometer maken de respondenten minder geïnteresseerd om gedeeld autonoom vervoer te kiezen. Verder prefereren respondenten korte wachttijden van het gedeelde voertuig. De respondenten die in de stad leven zijn het meest geïnteresseerd in gedeeld autonoom vervoer. De respondenten die vaak de auto gebruiken zijn het meest geïnteresseerd in de aanschaf van een autonome auto. Verder zijn gepensioneerde respondenten geïnteresseerd in gebruik van gedeeld autonoom vervoer. Tot slot zijn de respondenten met een positief standpunt naar duurzaamheid het meest bereid om gedeeld autonoom vervoer te gebruiken.

De resultaten van het Stated Adaptation Choice experiment laten zien dat de respondenten een individuele autonome rit prefereren. Een derde van de respondenten wil een rit gedeeld met anderen gebruiken en 10% van de respondenten kiest voor autonoom openbaar. Tevens is autonoom openbaar vervoer de helft van de tijd gekozen, wanneer deze optie beschikbaar was. De financiële attributen hebben veel invloed op de keuzes. Verder hebben de respondenten een voorkeur aan korte wachttijden, korte reistijden en de businessclass. De meeste mensen hebben de voorkeur om met één onbekende te reizen in plaats van meerdere onbekenden. De respondenten met een laag onderwijs niveau hebben de meeste interesse in een individuele rit of een rit gedeeld met onbekenden. De respondenten die alleen wonen of met een partner zijn het minst geïnteresseerd in deze alternatieven. Tot slot zijn de respondenten met een positief standpunt naar duurzaamheid het meest geïnteresseerd in een rit gedeeld met onbekenden of autonoom openbaar vervoer.

List of Abbreviations

AGFI	Adjusted goodness-of-fit statistic
AIC	Akaike Information Criterion
APT	Autonomous public transportation
AV	Autonomous vehicle
AVE	Average variance extracted
BIC	Bayesian information criterion
CFA	Confirmatory factor analysis
CFI	Comparative fit index
CR	Composite reliability
EFA	Exploratory factor analysis
GFI	Goodness-of-fit statistic
HCM	Hybrid choice model
Km	Kilometer
LT	Long-term
Min	Minutes
NFI	Normed-fit index
PT	Public transportation
RMSEA	Root mean square error of approximation
RT	Reference trip
SACE	Stated adaptation choice experiment
SAR	Shared autonomous ride
SAV	Shared autonomous vehicle
SC	Seating comfort
SCE	Stated choice experiment
SEAV	Electrical shared autonomous vehicle
ST	Short-term
TLI	Tucker-Lewis index
TT	Travel time
TU/e	Eindhoven University of Technology
VDT	Vehicle distance traveled

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1 .Introduction

The way people move from one location to another is changing, due to the emergence of ICT enabling shared mobility services. Moreover, prevalence of technologies such as autonomous vehicles (AVs) are on the horizon, accompanied by many behavioral changes (Litman, 2018). Autonomous vehicles enable driving without human interventions. These vehicles are robots with a high sensing level of their surroundings (Tettamanti, Varga, & Szalay, 2016). AVs have level five of automation, so the vehicles do not need a human driver (Kockelman et al., 2016). The development of AVs will most likely result in extreme changes in travel behavior. The elimination of human intervention in a vehicle will change the value of traveling time, since the user can conduct other activities during the ride. Travel distances will most likely increase, as well as the number of trips. On the long term, daily travel behavior triggers changes in work and home locations of individuals. Finally, AVs have impact on land-use development as a whole (Harb et al., 2018).

Automation in vehicles is not the only emerging technological development in the mobility sector. Increasing interest in sharing economies led to the emergence of shared mobility. The developments of car sharing, ride hailing and ride sharing services are an important milestone for mobility shifts. These technological developments reduce the need for a personally owned vehicle. A service including autonomous driving and shared mobility has the opportunity to make shared mobility services more reliable and flexible (Nazari, Noruzoliaee, & Mohammadian, 2018).

1.1 Research problem

The number of people and vehicles on the road network have impact on road congestion. Demand for mobility will probably increase, because it is easier to go to a destination with an autonomous vehicle. On the other hand, autonomous vehicles react on traffic and are able to connect with other (autonomous) vehicles and infrastructure. Therefore AVs will create extra capacity on the road network.

To that end, if the widespread adoption of autonomous vehicles is combined with increasing attractiveness of shared mobility, then the positive impact of autonomous vehicles will be elevated. Tendency to adopt shared AVs should be segregated from the willingness to adopt a privately owned AV. Adoption and usage of AVs involves two stages, mid-term decisions and short-term decisions. The mid-term decisions are decisions that influence travel behavior for a longer period of time. Mid-term choices refer to adoption of an owned AV or shared autonomous mobility. The short-term decisions are daily travel decisions. The decisions are related to usage of shared AVs. AV ownership may exacerbate the congestion and pollution or at least not significantly reduce it. Shared AVs have the opportunity to diminish the negative effects of mobility on congestion and pollution. Shared AVs decrease the number of vehicles being used. However, the service might still increase the total distance traveled, depending on the occupancy levels. If people are willing to share autonomous rides with others, then shared AVs can play a significant role in reducing congestion and pollution.

The development of autonomous vehicles influence modal shifts among people, which on their term highly influence the impact of AVs on the road network. For example, citizens that mainly use public transportation might adopt shared autonomous mobility, challenging the high expectations for a less congested future cities. However, those expectations will be firmly defendable, if this research shows that a great majority of the current car drivers are interested in shared autonomous vehicles as well.

While the above-mentioned criteria is worth to investigate. Understanding the influence of various characteristics of AVs on the decision making process is important as well. Furthermore there is heterogeneity among people's attraction to use a certain autonomous transportation mode. Not only social demographic and travel behavior differ per individual, but also attitudes explain inter-person differences. It is important to forecast market share for different kinds of AVs as realistic as possible, while taking such heterogeneities into account. The objective is to support city planners and authorities to draft the future city and infrastructure plan in line with the future mobility demand.

1.2 Research questions

The aim of this research is to predict adoption and usage of different types of autonomous vehicles, depending on mid-term and short-term decisions. The prediction is accompanied with getting knowledge of relevant attributes related to the alternatives. Both time frames will also be examined according to attitudes. The target group of this research are people that regularly travel by car or public transportation, since these existing transportation modes are easiest comparable to autonomous vehicles.

The mid-term investigation concerns the type of autonomous vehicle (owning or sharing) people are willing to adopt. The short-term research accounts for understanding of the usage of specific types of shared AVs: shared autonomous vehicles, shared autonomous rides and autonomous public transportation. The first alternative refers to single occupancy rides and the second alternative provides rides shared with strangers. The last alternative provides a ride with autonomous public transportation. To that end, the research questions are defined as following:

> *What are driving factors in people's decisions toward adopting a privately owned autonomous vehicle versus adopting shared autonomous mobility?*
>
> *How do attitudes play a role in the choice to adopt a privately owned autonomous vehicle or shared autonomous mobility?*

If people are interested in shared mobility, then what are the driving factors (under which context) to choose between the usage of a shared autonomous vehicle, a shared autonomous ride or autonomous public transportation?

How do attitudes influence the usage of either a shared autonomous ride, a shared autonomous vehicle or autonomous public transportation?

1.3 Research design

The research will be conducted with two choice experiment. The first experiment is a stated choice experiment (SCE). The experiment is used to investigate adoption of owned AVs and shared autonomous mobility. A stated adaptation choice experiment (SACE) is used to research people's short-term usage of shared autonomous transportation modes. The respondents indicate four reference trips per person. The answers on these trips are integrated in the choice tasks of the SACE. The attitudes will be tested with multiple statements related to these attitudes. The experiments and statements are integrated in a questionnaire, together with questions about socio-demographics and travel characteristics. After data collection, the choices and the attitudes are analyzed with a hybrid choice model (HCM). This model analyzes the choices of the experiments. The HCM also enables simultaneous estimation of the influence of the attitudes on the decisions.

The conceptual frameworks of both experiments are displayed in figure 1.1 and 1.2. Socio-demographics and travel characteristics influence the attitudes, as well as on the choices made in the experiments. Moreover, the attitudes and attributes influence the choices of both experiments. Both frameworks look similar. The difference between the models lies in the fact that the second choice experiment is designed and presented around the respondents' reference trips. Since the choices of the respondents in the SACE depend on the reference trips.

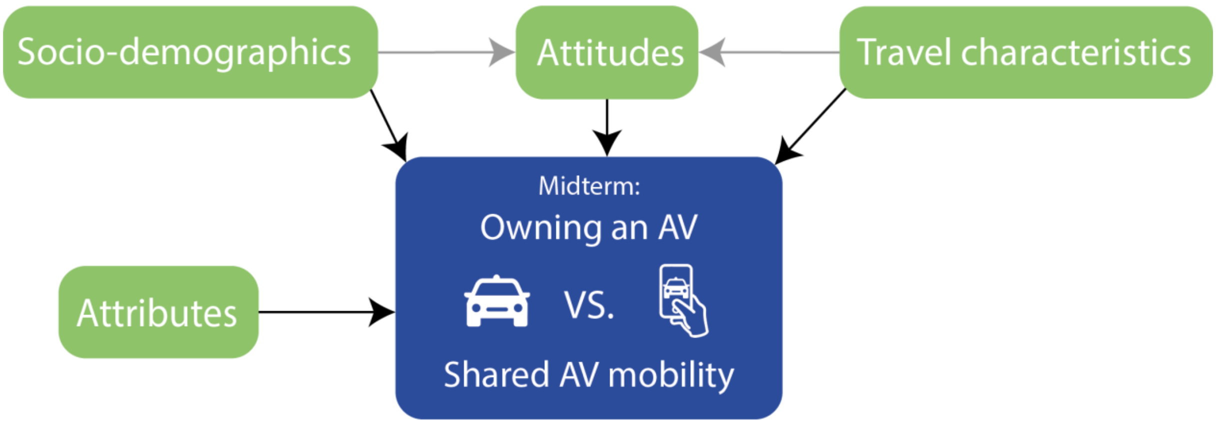


Figure 1.1: Conceptual model 1 - adopting an owned AV or a shared AV

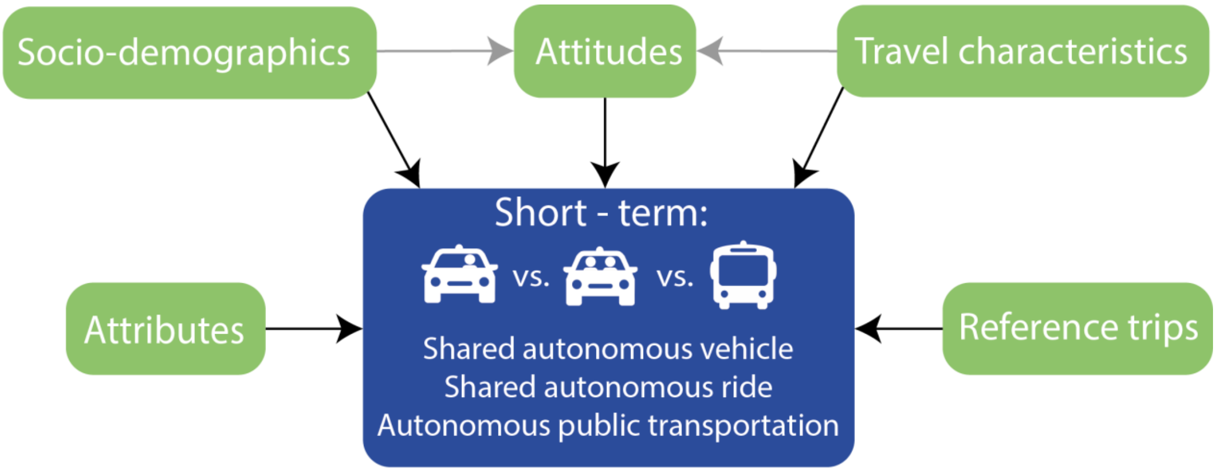


Figure 1.2: Conceptual model 2 - usage of a shared autonomous vehicle, shared autonomous ride or autonomous public transportation

1.4 Reading guide

The outline of the thesis is structured as follows. This chapter briefly explains the research, including the research problem, questions and design. The thesis continues with the literature review. Insights into the implementation and the potential of AVs are explained. Research similar to this research is described as well. The literature review ends with information about travel behavior. Chapter 3 explains the design of both choice experiments. The chapter also describes the questionnaire. Chapter 4 describes the pilot study, the data gathering process and the data cleaning process. The chapter ends with exploratory analysis of the socio-demographics, travel characteristics and reference trips. Chapter 5 describes the analysis of the attitudes, continues with background information of hybrid choice models and presents the final results of the hybrid choice models. The thesis ends with the conclusion of the research. The conclusion also consists of scientific and societal relevance, the limitations of this research and recommendations for future research.

2. Literature review

This literature review investigates future mobility usage, and potential adoption and usage of autonomous vehicles (AVs). Section 2.1 explains implementation of AVs. The potential of AVs and shared mobility is explained in section 2.2. Previous studies into adoption and usage of AVs are described in section 2.3. A summary of these studies is shown in appendix A. The chapter continues with a description of attitudes and personalities, which have influence on mobility behavior (section 2.4). The literature review ends with a conclusion.

2.1 Implementation of AVs

The role of future mobility on travel behavior is unknown. Uncertainties in future travel patterns, infrastructure planning, parking, and public transportation need to be unfold. (Litman, 2018). Car manufacturers, ride hailing companies, and technology companies are investing in automation of mobility. Developments in the technology of AVs are progressing quickly, because of competition between companies (Johnson & Walker, 2016). Many experts try to predict technology availability of AVs and adoption of AVs by potential users. Adoption of AVs in the global market is expected to happen between 2030 and 2040, even though the technology will be earlier available. High adoption levels of autonomous vehicles will change the transportation sector (Bernhart et al., 2014).

The implementation of autonomous vehicles is different than the implementation of other technologies. Implementation of AVs depends on two elements; technology and legislation. Legal and regulation issues are the main issues that prolong the implementation of AVs. If AV technology develops fast and national regulations approve AV implementation, then AVs will be implemented soon, with a potential market penetration rate of 10% in 2025 in the US market. If technology developments and regulation progress slowly, then it will take a while before AVs will be implemented (Johnson & Walker, 2016). The implementation process of AVs depends on government regulations, but also on financial help of governments. Help from the government leads to faster adoption of semi and fully autonomous vehicles (Viereckl et al., 2015).

AVs will be implemented between 2025 and 2045 in the Netherlands. The timing depends mostly on policies and technology. The execution of policies related to AVs and the development of AV technologies influence the transformation from manual driving to autonomous driving. However, a lot is uncertain about the developments of these aspects. A few years ago (2015), the Dutch government revealed having a positive attitude towards developments of autonomous vehicles. This attitude will boost the development of AVs in the Netherlands. Furthermore, the Netherlands has a dense and easily accessible highway network, which has both positive and negative effect on AV implementation. AVs will first be applied on the highway network. AVs can easily be implemented on the Dutch highway network, because the network is easily accessible. The negative side effect of the dense highway network is the complexity of the highway system. The network has many ramps and is a busy network (Milakis et al., 2017).

Even though the predictions are optimistic, reason exists to question the predictions. Implementation of new technologies is complex, and many obstacles and financial issues need to be taken into account. Many technical complications of AVs still need to be solved to implement AVs on the road network (Litman, 2018). It is fundamental to develop save and reliable AV technologies. AVs will not be operating until the vehicles are safe and reliable. Development of this technology is complex, certainly by taking the changing environment and weather complications into account (Anderson et al., 2016). Operation during heavy weather should be safe, however the current AV technologies do not have a solution for heavy weather situations (Litman, 2018).

2.2 The potential of AVs and shared mobility

2.2.1 Alternative transportation mode usage

AV ownership will be low at the start of the implementation stage of AVs, due to high purchasing costs of AVs. Therefore, AVs have the opportunity to become part of sharing services. Since future users are not able to afford an AV yet, but they will be able to adopt shared autonomous mobility (Bansal & Daziano, 2018).

AV development will probably influence modal shifts from public transportation to shared autonomous mobility (Levin & Boyles, 2015). Autonomous vehicles can be viewed as alternative for public transportation, and these transportation modes can become competitors. Shared AV services are safer, provide extra productivity and enable door to door services. Public transportation usage will decrease due to the advantages of shared autonomous mobility (Zmud, Sener, & Wagner, 2016). Initially usage of shared autonomous mobility will be expensive for public transportation users. The period between the initiation of AVs (with low numbers of users) and AVs becoming available for the general public is an important moment for transportation planners. Demand for public transportation will start slowly decreasing during this period (Levin & Boyles, 2015).

Demand for public transportation will decrease fast the moment AVs become affordable for the general public (Levin & Boyles, 2015). Shared autonomous mobility can either replenish or substitute public transportation, by respectably providing a first and last mile option or by providing a more efficient service. Shared AVs have the same benefits of a privately owned car, without the responsibilities related to car ownership (Krueger, Rashidi, & Rose, 2016). Cities with efficient public transportation, like bus rapid transit systems or sufficient metro systems, will encounters less modal shifts. These public transportation systems have potential to become faster than AVs, due to congestion on the road (Levin & Boyles, 2015).

Car ownership is decreasing. Car ownership has proven to encounter congestion, high costs and, inconvenience. Which results in reduced quality of life, when often using a manual car (Webb, Wilson, & Kularatne, 2019). Younger generations and millennials postpone getting a driving license. This trend ensures a shift from car ownership to car access, referring to ride hailing services and car sharing (Mounce & Nelson, 2019). Ride hailing services have already proven to decrease car ownership (Keeney T. , 2017). Automation in vehicles and developments in sharing services create efficient shared autonomous transportation services (Webb, Wilson, & Kularatne, 2019). High adoption of shared AV services lead to less vehicles being used at the same time. This cause will reduce congestion, because a car is only used 10% of the time nowadays (Spieser et al., 2014).

Shared autonomous mobility is convenient. The AV picks up an individual, drops the individual at the desired location, and drives to the next customer. No human intervention is needed for these services. Current taxi companies, ride sharing services and ride hailing companies are expected to change their business plans and are to invest in low cost mobility on demand services. Success of the sharing services would depend on the efficacy. A successful system triggers people to shift from car and public transportation usage to shared autonomous mobility. The fleet size of a sharing service together with the number of users affect the efficiency of the service. Many vehicles in the fleet and many users boost the efficiency of the sharing service. High efficiency will convince people to switch from their currently used transportation to a shared autonomous mobility. This development will change transportation in general and the automotive industry as a whole (Bernhart, 2014).

Furthermore, the development of ride hailing services have fast-forwarded developments in autonomous vehicles. Global urbanization of cities and the current most dominantly used transportation mode, the car, make ride hailing services successful. Car usage within the city leads to many problems, like parking scarcity and congestion. Which makes public transportation an interesting alternative in some cities (Chan, 2017). Such a city requires a reliable and accessible public transportation network. If the city does not have an efficient public transportation system, then car usage is dominant (Krueger, Rashidi, & Rose, 2016). On demand mobility provides personalized rides, so the services lies between car and public transportation usage. The service is more efficient than bad public transportation in some cities (Chan, 2017) and is a suitable alternative for car ownership (Haboucha, Ishaq, & Shiftan, 2017).

Shared vehicles can be used by one individual or peers at the same time. Ride hailing has the potential to transport multiple strangers with an origin and a destination in close proximity (Bansal & Daziano, 2018). Public agencies have tried to increase the popularity and usage of rides shared with others. High occupancy rates of cars reduce congestion and preserve fossil fuels. The convenience of ride sharing increases due to technology developments. These technology developments use real-time matching mechanisms of drivers and passengers, which increases occupancy rates (Lavieri & Bhat, 2019). UberPool is one of such ride sharing services, UberPool provides a car pool service. The service provides lower prices, albeit extra traveling time. UberPool is also an interesting alternative of public transportation. In general, usage of UberPool saves time and money, compared to public transportation usage (Schwieterman & Smith, 2018). Technologies enabling efficient use of pooled rides did not help to increase vehicle occupancy rates in the U.S. While multiple occupancy rides play a crucial role in decreasing congestion (Lavieri & Bhat, 2019).

Sharing a ride with strangers encounters some challengers, both for the driver and passengers. Concerns are related to privacy, trust and safety issues. Another threat for ride sharing is the extra time needed to pick up other passengers (Xia et al., 2019). The individuals willing to share a ride with others need to make a tradeoff between travel times, travel costs and the privacy of a ride. Time is the most important factor influencing usage of a ride shared with others. People do not like the waiting times involved with pooling. The user also cannot make last minute changes when sharing a ride with others. The current technologies can minimalize the time troubles of a ride shared with strangers, but still travel times can be an unreliable. There is another obstacle to share a ride with strangers, which is people's attitude towards ride sharing. Unknown co-travelers make people uncomfortable. People want personal space and do not want to have social contacts during the ride. Potential users might distrust the co-travelers or have other concerns related to privacy. Socio-demographics of the unknown co-travelers also make people hesitant to use shared rides, especially socio-demographics related to income, ethnicity and gender. Time and cost saving policies promote ride sharing, which positively influence people's willingness to share a ride with others. Automation in vehicles might make a ride shared with strangers more appealing, because costs of a ride can be mitigated (Lavieri & Bhat, 2019).

2.2.2 Value of travel time with AVs

The value of travel time is related to the costs of the time people spend in a vehicle. Thus if a person travels for a long period of time, then the person cannot use the time for another purpose, which costs money. Value of travel time is often used in choice models to compare travel costs and travel time (Athira et al., 2016). The driver needs to pay attention on the road during a manual ride. Usage autonomous vehicles changes the situation. The driver becomes the passenger and can conduct other activities during the ride. The value of travel time decreases (Cyganski, 2016), consequently the travel time, length of trips and the number of trips will increase (Heinrichs & Cyganski, 2015). The implementation of AVs changes the threshold of travel time. Future users are willing to travel for a longer period of time. The car might even become part of the living environment of the individual. Therefore, automation of vehicles highly influences the transformation of lifestyles (Begg, 2014).

The value of travel time of a passenger is currently 20% higher, than the value of travel time for the driver. The passenger does not need to pay attention on the road. The implementation of AVs make all drivers becoming passengers, so value of travel time decreases (CPB & PBL, 2015). The activities people typically do as passengers are talking, surfing Internet or watching out of the window. Only a small share of the activities is working (Bansal & Kockelman, 2015). Another study shows that only one third of its panel would do an activity during an autonomous ride. However, prediction of time usage during a ride with an AV is difficult, since AVs are not implemented yet (Cyganski, 2016).

The value of travel time does not only depend on the time and costs of a trip, but also on the level of comfort. The value of travel time changed when new technologies were introduced, like the smartphone and laptop. People are able to spend time more fruitful, due to these new technologies. As a conclusion, if the comfort level increases, then the value of travel time decreases (Kouwenhoven & de Jong, 2018).

2.2.3 Capacity

Demand for mobility depends on the road structure itself. If the road capacity increases, travel time and congestion decreases. Which leads to more demand for transportation. When the road network increases the vehicle distance traveled (VDT) raises as well. In general, when the road space increases by 1%, the VDT increases by 0.74%. Road capacity increases due to AVs, resulting in more demand for transportation (Fagnant & Kockelman, 2015).

AVs increase the efficiency of the transportation network, resulting in less congestion. An AV can communicate with other vehicles and the infrastructure systems itself. Therefore, distances between vehicles can be reduced and platoons can be formed, resulting in extra road capacity (Fagnant & Kockelman, 2015). Extra road capacity can only occur with high penetration rates of AVs or with cars having at least cooperative adaptive cruise control (Shladover, Su, & Lu, 2012). The benefits of AVs on road capacity differ per road network type. AVs are most efficient on highways, so AVs have most impace on road capacity of high ways. AVs have moderate influence on the capacity of urban environments (Milakis et al. 2017). The opportunity of AVs to platoon and drive smoothly (less accelerating and decelerating) leads to efficient fuel usage. On the other hand, more space on the road results in extra road users. Which increases fuel usage. Therefore the effect of AVs on the environment depends on demand for mobility (Wadud, MacKenzie, Leiby, 2016).

2.2.4 Activity travel pattern

Harb et al. (2018) conducted a research to test the transportation behavior of individuals and families. An 'autonomous vehicle' (car with chauffeur) was provided to the respondents for one week. This week is compared to the week before the AV was provided and the week afterwards. Millennials, families and retirees owning and using a car were asked to attend the experiment. The vehicle distance traveled (VDT) of the week with 'autonomous vehicle' increased by 83%, of which 21% were zero-occupancy kilometers. The respondents changed their behavior when the AV was available. They conducted longer and more trips. Mostly the retirees conducted more and longer trips. As conclusion, the annual distance traveled and travel behavior will transform due to autonomous vehicles (Harb et al., 2018).

Fagnant and Kockelman (2014) conducted a simulation to investigate the efficiency of shared autonomous vehicles in cities. If 3.5% of the vehicles is a shared AV, then the average waiting time is 20 seconds. In addition, 10 manual cars can be replaced by one shared AV. However, the transformation would lead to an increasing VDT. If users are located in close proximity and the penetration rate of shared AVs is high, then the VDT can be diminished (Fagnant & Kockelman, 2014). TIF (2014) did also a research to investigate the efficiency of shared AVs. The transportation network becomes more efficient when using shared AVs, especially when public transportation is sufficient. The number of owned cars can be diminished, while remaining the sufficient transportation network. However, the VDT will increase, because of repositioning of shared AVs (ITF, 2014). Spieser et al. (2014) researched the effect on the road network, by replacing all personally owned vehicles by shared AVs. The transportation demand can be met with one third of the currently used vehicles. However, decreasing number of vehicles does not provide a sustainable road structure, since all vehicles need to make zero-occupancy kilometers (Spieser et al., 2014). Dynamic ride sharing can be defined as a system arranging shared autonomous rides. The rides are arranged according to matching paths of individuals. Waiting times, traveling times, and costs can be optimized with this system. The service provides efficient rides. However, the VDT raises, due to zero-occupancy kilometers. The number of users of ride sharing services should increase, as well as flexibility of individuals, in order to reduce VDT (Fagnant & Kockelman, 2016). A Dutch simulation is conducted to investigate AV adoption in the Netherlands. If AVs become available, then usage of active transportation modes drops, car ownership declines, and usage of public transportation decreases. VDT and the hours spend in traffic will increase, due to shared AVs. Which results in increasing road pressure (Bergveld et al. 2018). Zero-occupancy rides will become normal in daily life after implementation of AVs. Zero-occupancy rides are made to search for a parking spot, run errands or pick up the next customer. Sometimes it might even be cheaper to let the car drive around, than parking the car at a parking spot. Which results in more congestion (Litman, 2018).

2.3 Adoption and usage of autonomous vehicles

2.3.1 General

The success of a technology depends on the market share. Rogers developed the technology adoption life cycle to explain adoption of new technologies. The bell-shaped curve is divided into 5 adoption categories, containing potential customers of an innovation. The model starts with a small percentage of innovators (2.5%). The innovators are the first customers. This group is enthusiastic about a technology and risks investing in a certain technology. Early adopters (13.5%) are the early adopters of a product, but are less willing to risk the failures of a technology. The early majority (34%) are still relatively early in the adoption process, but are more realistic towards innovations. This group first wants to observe the usefulness of the product. The late majority (34%) is pessimistic towards adopting a new technology. Finally, the laggards (16%) are not willing to adopt new technologies and are skeptical towards new technological products (Nijssen, 2014).

Adoption of a new technology depends on the technology itself and the personality of the adopters (Gkartzonikas & Gkritza, 2019). Adoption of an autonomous vehicle works different than adoption of, for example, a phone or camera. Due to the fact that adoption of AVs will change the travel behavior of individuals. In addition, purchasing an AV is a large acquisition. Therefore, penetration of AV in the mobility market will take more time than adoption of other technologies (Litman, 2018). However, nowadays customers rapidly adopt new technologies, compared to adoption of technologies a few decades ago. For example, 50% of the people adopted the telephone in a few decades, whereas 50% adoption of the mobile phone took only five years (McGrath, 2013).

Adoption and usage of AV depend on the acceptance of the potential users. Acceptance of AVs depends on the perception on the utility and usefulness of AVs. Furthermore, acceptance depends on satisfaction of AVs. AVs increase comfort of the individuals (Martens et al., 2011). Autonomous vehicles are still in the development stage, and civilians are still unaware of detailed functionalities of AVs. These uncertainties influence the prediction of acceptance of AVs (Cyganski, Fraedrich, Lenz, 2015). Acceptance of autonomous vehicles will influence the adoption of such vehicles. Increasing usage of AVs will lead to more autonomous vehicles on the road, allegedly safer roads and cleaner cities. Which on their turn can lead to even more demand for autonomous vehicles (Zmud, Sener, & Wagner, 2016).

Car manufactures claim that autonomous vehicles are a lot safer, since traffic accidents caused by human errors can be mitigated (Litman, 2018). 90% of all crashes are caused by human failure (Haboucha, Ishaq & Shiftan, 2017). Other advantages of AVs are: lower emissions and efficient fuel consumption (Gkartzonikas & Gkritza, 2019). Furthermore usefulness, comfort, safety and practicality are positive aspects of AVs according to potential users (Cyganski, Fraedrich, Lenz, 2015). While autonomous vehicles have many benefits, acceptance to use such vehicles is questionable, mainly due to concerns about: liability, hacking, misuse, safety, financial issues (Kyriakidis, Happee, & Winter, 2015), equipment failure (Bansal & Kockelman, 2015), ethical issues, privacy and technological dependency (Gkartzonikas & Gkritza, 2019).

2.3.2 Adoption of AVs

A lot of research is conducted to investigate and predict the adoption of new technologies, such as automation in vehicles, shared mobility and a combination of both. The results of these investigations predict the effect of AVs on the transportation network. This section describes different researches into adoption of AVs. More specifically most of these researches use choice experiments to investigate adoption of owned AVs, shared AVs or manual cars. Adoption of AVs refers to mid-term decisions, since people will use a certain mode for a longer period of time. A summary of the researches described in this section is shown in appendix A.

2.3.2.1 Costs of autonomous vehicles

Usage of a certain transportation mode highly depends on the transportation costs (Bösch et al., 2018). The costs of usage of an autonomous transportation mode heavily depends on the type of mode. The mode can be a privately owned AV or a shared mobility system. The ride can also be shared with others, which decreases the costs. The first generation purchased AVs will be used by the higher income classes. Ownership of an AV becomes affordable for the middle and lower classes after some decades. The exact prices of AV usage are uncertain (Litman, 2018). Autonomous taxi services will be a lot cheaper than manual taxi services, because the autonomous taxi does not need a human driver. Manual public transportation will become a competitor of the autonomous taxi, since manual public transportation is expected to be cheaper than autonomous taxis (Keeney, 2017).

Bösch et al. (2018) explored price differentiations between manual and level five autonomous vehicles with comprehensive bottom-up calculations. The costs to own a vehicle depends on fixed costs, like acquiring costs, and variable costs, like maintenance, insurance, cleaning, and fuel costs. Five transportation modes are investigated; rail transport, bus, individually used taxi, pooled taxi, and private car. The cheapest manual transportation modes are public transportation and the privately owned car. However, automation in vehicles twists these conclusions. Shared autonomous services do not need a driver. Which decreases the costs for shared services, especially when the ride is shared with strangers. Autonomous rides shared with others are potentially the biggest competitor with manual public transportation. Public transportation should become innovative and autonomous, to have a chance to compete with the shared AV services. Furthermore, AV ownership entails high acquiring costs than manual cars. However, autonomous vehicles drive more balanced, so the fuel cost will decrease by assumingly 10%. Accident rates will decrease, since AVs drive more safely. Therefore, insurance costs will decrease as well. However, the reaction of insurance business on the implementation of autonomous vehicles is uncertain. Which results in small cost differences between manual cars and AVs. Finally, the depreciation costs of AVs are expected to be 10% of the purchase price each year (Bösch et al., 2018).

Bansal and Kockelman (2015) carried out a survey to investigate people's opinions towards economic characteristics of automation in vehicles. The questionnaire was carried out in 2015 in Texas. The data was analyzed with an exploratory analysis. The willingness to pay (WTP) for automation was assessed. If the level of automation raises, then the accepted purchase price increases as well. The influence of costs on the adoption of shared autonomous mobility was assessed as well. Only small number of participants is willing to adopt shared autonomous mobility, if the price would be $1 per mile. Autonomous vehicles are not implemented yet, so possibly the above presented results will change rapidly during the implementation period of AVs (P. Bansal, K. Kockelman, 2015).

The dataset of the research of Bansal and Kockelman (2015) was combined with an US survey. The analysis used a multinomial logit model as methodology. The research investigates adoption rates and accepted purchase prices of AVs. More than half of the panel is not willing to pay for level 3 automation or higher. A Monte Carlo simulation was used to investigate adoption rates under different circumstances. Multiple purchase prices of level four autonomous vehicles were tested in the simulation. Multiple scenarios of people willingness to pay for automation were also added. Lower purchase prices, knowledge about AVs and adoption by acquaintances lead to higher adoption rates of AVs (Kockelman et al., 2016).

Costs of autonomous vehicles highly influence the decision to buy an AV. Daziano et al. (2017) researched what households want to pay for an AV. The research was conducted with a discrete choice model including 'quasi-customized' alternative attributes. The values of the attributes were estimated according to the income of the households. In order to calculate personalized price thresholds. This reasoning provides a legitimate price to the panel. Data analysis method was a conditional logit model. Most of the respondent are not willing to pay for automation. However, the decisions in the discrete choice model are theoretical, so real life decisions might differ (Daziano, Sarrias, & Leard, 2017).

2.3.2.2 AV ownership vs. manual vehicle adoption

Schoettle and Sivak (2015) carried out a research investigating user acceptance and adoption of AVs. The research uses a questionnaire, which is carried out in 2015. The data was reviewed with exploratory analysis. Only few respondents are interested in AV adoption. The majority of the panel prefers adoption of a manual vehicle or a semi-autonomous vehicle (Schoettle & Sivak, 2015). Another research by Schoettle and Sivak (2014) compares AV adoption in the U.S., U.K. and Australia with a questionnaire. Exploratory analysis is the methodology for the study. A bit more than half of the panel is interested in AV adoption. The respondents from the U.S. were more likely to have heard from AVs. The respondents for the U.S. are also more positive towards the technology in comparison to respondents from the U.K. and Australia (Schoettle & Sivak, 2014).

Kyriakidis et al (2015) researched future adoption of AVs with a questionnaire. The questionnaire had a response rate of 5000 respondents living in various countries. Descriptive statistics and spearman correlation coefficients were estimated to compare the socio-demographics and traveling characteristics of the individuals. Manual driving is still the preferred mode among the panel. Only a small share of the panel would enjoy driving with an AV. A small share of the panel is willing to pay more than $30.000 for full autonomous vehicles. In addition, a lot of respondents are against fully autonomous driving, and prefer semi-autonomous vehicles and manual vehicles. Respondents from developed countries are more concerned about data transmitting issues, than respondents from developing counties. These results do not guarantee actual travel behavior (Kyriakidis, Happee & de Winter, 2015).

Zmud et al. (2016) carried out a quantitative survey and qualitative interviews in Austin in 2015. The aim was prediction of adoption of autonomous vehicles. Exploratory analysis were applied to validate the results. Later the results were modeled with the CAMPO travel demand forecast model. The whole panel had a 'wait-and-see' attitude related to AV adoption. Half of the respondents was not likely to adopt AVs, and the other half was slightly interested in AV adoption. The attitude towards technology adoption and the attitude towards perception of privacy and safety are most influential. Austin is a car oriented city. Therefore only a fourth of the respondent was tempted to use shared autonomous mobility. The main limitation of this research is the sample size, which is quite small. In addition, future research should also investigate policy related questions in order to predict travel behavior (Zmud, Sener, & Wagner, 2016).

König and Neumayr (2017) examined the attitudes, advantages and barriers connected to adoption of AVs. The data was gathered with a questionnaire. Multiple statements were examined on a five and six point Likert scale. The data was analyzed with an exploratory analysis. Overall the respondents were positive towards AV adoption. Although the respondents would be comfortable if every AV has a feature, enabling the user to regain manual control over the car. A future viewpoint was formulated in the study, therefore the outcomes of the study could be biased (König & Neumayr, 2017).

Shabanpour et al. (2018) examined the influence of various attributes of AVs on people's willingness to adopt an AV. A decision model was used. The model was divided in two parts. First respondents were asked which attributes are most and least attractive. Later, the willingness to purchase an AV with corresponding attributes was tested. The first part is a best-worst choice experiment, which is analyzed with a multinomial logit model. The second part contains a binary choice model. The model is examined with a binary logit formulation. Data was gathered via an online platform in Chicago in 2016. The study found that the purchasing price and policy implications (liability for crashes and exclusive lane for AVs) are the most attractive attributes and have most influence on the decision to purchase an AV. Future research should include other attributes, like tax prices and congestion charges (Shabanpour et al., 2018).

2.3.2.3 AV ownership, shared AV adoption vs. manual vehicle adoption

Cyganski et al. (2014) compared the currently used transportation mode with fully autonomous vehicles and partial autonomous vehicles. A questionnaire was applied to gather data. Four alternatives were tested: the highway pilot feature, the valet parking feature, fully AVs and an on demand AV service. The data was scrutinized with exploratory qualitative and quantitative analyses (Cyganski, 2016). In general, the respondents are not enthusiastic about autonomous vehicles. Only half of the respondents would maybe consider replacing their current transportation mode by a fully or partial AV (Cyganski, Fraedrich, Lenz, 2015). Fully autonomous vehicles are the most attractive alternative. Shared AVs are the least popular alternative (Fraedrich & Lenz, 2016). The influential attitudes are: enjoyment of driving and people's imagination towards AV usage (Heinrichs & Cyganski, 2015). The research also concluded that usage of non-autonomous transportation modes would decrease when AVs are implemented. The research analyzes a future situation, but AVs are not yet reality. Opinions and attitudes might change once AVs are implemented (Cyganski, Fraedrich, Lenz, 2015).

Haboucha et al. (2017) compared user preferences for the manual car, a personally owned AVs and shared autonomous mobility. The preferences were analyzed with a stated preference experiment. This research uses the answers of the respondents to determine the values of the attributes. The respondents indicated the purchase price of their car, trip costs and parking costs. These answers are used to determine the values of the attributes. The answer of the respondents is multiplied by the percentage of the attribute level. In order to get the final value of the attributes. Random utility models were used to analyze the data. A nested structure was applied to analyze the latent variable. Later, a Logit Kernel model was used to test correlations. The panel is overall hesitant to use AVs. Usage of shared autonomous mobility is the least popular alternative, mostly among non-public transportation users. If shared autonomous mobility would be completely free, then only 75% of the panel would use a shared mode. The most influential attitudes are the attitude toward technology and enjoyment of driving. A new simplified technology is presented in the survey. A hypothetical situation is provided, which could bias the results (Haboucha, Ishaq, & Shiftan, 2017).

Lavieri et al. (2017) researched people's willingness to adopt AVs. Three alternatives are explored: non autonomous modes, AV ownership, shared autonomous mobility and a combination of AV ownership and usage of shared autonomous mobility. The choices were studied in connection with latent variables. The latent variables are the attitudes of the respondents. The attitudes are: safety concerns towards AVs, sustainably concerns, shared mobility affection and technology enthusiasm. A dataset from a travel survey gathered in Puget Sound region (state of Washington, U.S.) was used to perform the analysis. The choices are explored with a stated choice experiment. A generalized heterogeneous data model approach was used to analyze the data. Less than a third of the panel desires adoption of an AV. The participants with affection towards sustainability and technology are most interested in shared autonomous mobility adoption (Lavieri et al., 2017).

Kolarova et al. (2018) carried out a research estimating preferences for various transportation modes. The study investigates to what extend transportation behavior depends on the value of travel time. A questionnaire was distributed in Germany in 2017. The questionnaire contains a revealed and stated preference experiment. The revealed preferences experiment investigates the current mobility behavior, resulting in reference trips. The stated preference experiment is divided into two parts. The first part compares non-autonomous transportation modes: waking, cycling, car usage and public transportation usage. The second experiment explores AV preferences. Car usage was replaced by a privately owned AV and shared autonomous mobility in the second experiment. A Bayesian efficient design was created, strengthening the efficiency of both experiments. The data from the questionnaire was analyzed with a multinomial logistic regression model. Value of travel time becomes better when the AV is the transportation mode instead of the car. Furthermore, the respondents prefer an owned AV over shared autonomous mobility (Kolarova et al., 2018). Future research should analyze whether people are willing to share a ride with others (Steck et al., 2018).

The aim of the research of Pakusch et al. (2018) is investigation of preferences for manual and autonomous transportation modes. An online survey was distributed across Germany. A complete paired comparison was conducted. First manual modes were tested, which are: car ownership, car sharing and public transportation. Later, autonomous transportation modes were added to the experiment, which were: autonomous car and shared autonomous mobility. Two alternatives were displayed in each choice set. The respondent chooses the preferred option. The alternatives were ranked according to the choices of the respondents. A Bradley-Terry-Luce model was applied to scale the values of the ranks, so the results are utility scale values. The manual owned car is the preferred mode, followed by the autonomous car, then followed by public transportation, shared autonomous mobility and finally car sharing. Public transportation loses most users. The respondents want to use shared mobility instead. However, autonomous public transportation was not added in the study. This alternative could make a difference in the choices of the respondents and in the results (Pakusch et al., 2018).

The attitude influencing adoption of personal owned AVs and shared autonomous mobility was investigated by Pettigrew et al. (2019). In order to define segments of AV adoption, which represent the population. An online survey was spread among Australians, including socio-demographics, travel information and attitudes corresponding to AV adoption. A latent profile analysis used to divide the respondents among classes. Attitudes, intentions and AV knowledge are used to categorize the respondents. Seven different class solutions were analyzed according to the maximum likelihood estimator. The highest entropy was assigned to the best fitting model, which is a model with five classes. Later a one-way ANOVA test and a chi-square test was used to estimate the results. The classes vary from non AV adopters to early AV adopters. In general, the respondents have few knowledge about AVs and willingness to adopt AVs is moderate. Surprisingly the shared AV option is slightly more popular than AV ownership (Pettigrew, Dana, & Norman, 2019).

The trade-off between manual car and electrical shared AV (SEAV) was investigated by Webb et al. (2019). Two questionnaires were distributed among the same set respondents. In order to investigate changing opinions towards autonomous vehicles. The first survey contained general information about SEAVs. The second survey was the exactly the same, but contained extra information about SEAVs, including the benefits of SEAVs. People living within a 20 kilometer distance to Brisbane city center were target group. The researched alternatives are: 50% usage of a SEAV and 50% usage of a manual car, 80% usage of a SEAV and 20% by manual car, and the daily used transportation mode. The results were estimated by a multinomial logit model. The respondents are attached to their privately owned cars, but acknowledge the negative effects of car ownership. Half of the respondents is willing to adopt SEAV. Costs related to the alternatives have most influence on the decisions. The differences between the results of questionnaires is most significant among public transportation users. These users are more willing to use shared AVs after getting additional information in the second questionnaire. Future research should analyze age, gender and families with children in more detail (Webb, Wilson, Kularatne, 2019).

Stoiber et al. (2019) investigated people's willingness to use different kinds of AVs. Long- and short-term AV adoption is researched. Short-term decisions refer to daily choices between transportation modes. Long-term decisions are related the intention to purchase a vehicle or subscribe for either shared mobility or public transportation. Less car ownership and more shared mobility usage would be a preferred future scenario. The Swiss household energy demand survey contained a choice experiment, which tests AV preferences. Both short- and long-term decisions were tested. Manual vehicles were not included, since these vehicles are not viewed as vehicles that will be adopted in the future. Three alternatives are presented in each choice set in both time frames. The respondents indicate their preference on a five point Likert scale. One or two attributes are assigned to the alternatives, differing per choice set. The attribute levels were formulated in such way promoting shared autonomous mobility. The short-term choice experiment exists of a privately owned AV, an autonomous ride (the ride is a single occupancy ride in some choice sets), and autonomous shuttle/train. The alternatives of the long-term decisions are: owning an AV, membership for shared autonomous rides, and membership for autonomous public transportation. The survey also tested attitude related to autonomous traveling and attitude towards sharing a ride/vehicle. A generalized estimation equation ordinal logistic model was used to analyze the responses. The respondents graded the sharing option higher than AV ownership. Willingness to adopt shared autonomous mobility increases when the attributes related to sharing are attractive. The attributes of shared autonomous mobility are formulated quite positive, therefore actual behavior might differ (Stoiber et al., 2019). The research of Stoiber et al. (2019) is also related short-term usage of AVs, which is explained in section 2.3.3.

The world economic forum (2018) conducted a research to give background knowledge to policy makers for development of future mobility networks. Respondents from multiple cities around the world attended the questionnaire distributed in 2015. A bit more than half of the respondents are likely to adopt an AV, according to exploratory analysis. Although only 40% of the Dutch respondents are interested in AV adoption. Furthermore, a specific conjoint analysis about AV adoption was conducted among respondents from Boston. In order to investigate transportation mode usage during different circumstances. Multiple alternatives are investigated; public transportation, personal owned vehicles (manual and autonomous) and shared mobility (taxi/ride haling, SAV, SAR: either car or van). One third of the respondents from Boston are willing to use shared mobility. The majority is interested in shared autonomous mobility. Shared autonomous modes will recuse usage of public transportation and vehicle ownership (World Economic Forum, 2018). This research is also related to short-term usage of AVs, which is explained in section 2.3.3.

The same dataset was used by Nazari et al. (2018). The research investigates public interest in adoption of a personally owned AV or of shared autonomous mobility. The daily travel routines of the respondents are taken into account for this research. Five transportation modes were investigated: AV ownership, renting an AV, usage of a shared AV with driver, usage of a shared AV without driver and multimodal AV usage. Apart from that, two other alternatives are investigated in a separate experiment, specifically designed for commuters. The alternatives are: traveling alone with an AV and carpooling with an AV. The interest in these modes was tested on a 5 point scale. The analysis is divided in two modeling parts. First latent variables were evaluated with measurement and structural equations. Then the latent variables were modeled with multivariate and bivariate ordered probit models. The results show that half of the respondents do not want to adopt an AV. Only one third of the panel is interested in adoption of AVs. The respondents are almost equally interested in all five autonomous transportation modes, except form multimodal AV usage. Commuters are more interested in AV adoption. This group prefers the carpooling alternative. Moreover, the attitude towards safety is most influential and has negative influence on AV adoption. Both environmental concern and affection towards sharing have positive influence on AV adoption. One of the limitations in this study is that the costs of AV usage are not included (Nazari, Noruzoliaee, & Mohammadian, 2018). This research is also related to short-term usage of AVs, which is explained in section 2.3.3

Nair et al. (2018) used the same data as Nazari et al (2018) and Lavieri et al. (2017), but with different model settings. The data was transformed in rank ordered data, in order to apply the rank ordered probit model. The model estimated the utility per alternative. The following alternatives were taken into account: AV ownership, renting an AV, usage of a shared AV with driver and usage of a shared AV without driver (Nair et al., 2018). The result of the analysis is comparable to the validation of Nazari et al (2018). This research is also related to short-term usage of AVs, which is explained in section 2.3.3.

2.3.3 Usage of AVs

This section describes research into short-term usage of AVs, more specifically the researches investigate if people are willing to use AVs shared with others or prefer using a single occupancy shared ride. Other modes are also included in the researches. Four of the above described investigations are also related to this section, these are the investigations of Nazari et al (2018), Nair et al. (2018), Stoiber et al. (2019) and the world economic forum (2018).

Krueger et al. (2016) researched the preferences between usage of shared autonomous vehicles, shared autonomous rides and the currently used transportation mode. The first alternative provides a single occupancy shared autonomous ride and the second alternative provides autonomous rides shared with strangers. A stated choice experiment was used to investigate the preferences of the respondents. The attributes are: travel costs, waiting time and traveling time. Each respondent first entered information about their daily transportation routine, the information was used to formulate reference trips. The results were modeled with a mixed logit model. Overall the respondents prefer their current transportation mode. SAV is the more interesting among the respondents than SAR (Krueger, Rashidi, & Rose, 2016).

Bansal and Daziano (2018) carried out a research scrutinizing people's willingness to pay for automation and preferences for shared autonomous mobility. Citizens of New York City were approached to attend the stated choice experiment. The main experiment investigated adoption of: an Uber without ridesharing, an Uber with ride sharing or the daily used transportation mode. One of the attributes determined the level of automation of the alternatives. The values of the attributes were established according to the currently used transportation mode of the respondent. A pivot-efficient design was created as experimental design. A multinomial logit model was used to estimate the results. The respondents are willing to pay for low waiting/access times, in vehicle time and number of transfer stops. Furthermore, the respondents are not willing to pay a high price for automation, because the modes do not need a human driver. The main limitation of this study is the low number of respondents (Bansal & Daziano, 2018).

Lavieri & Bhat (2019) aimed to give new insight on people's willingness to travel with others or not. The study also investigates the effect on the value of travel time. The research is conducted by using a revealed and stated choice experiment. The sample consists of commuters from Dallas-Fort worth Metropolitan Area. Two alternatives are investigated: a private self-driving cab service and a shared self-driving cap service. The former provides a ride shared with others. The attributes and attitudes of the research are displayed in appendix A. The respondents is asked choose one of the alternatives, while the purpose (work or leisure activity) is indicated in each choice task. The data is analyzed with a Generalized Heterogeneous Data Model. The model enables simultaneous calculation of nominal and binary endogenous variables. The model uses a structural and measurement equation model. The respondents with privacy concerns are least willing to use a ride shared with others. The respondents that are time sensitive or have concerns towards privacy are less sensitive to better value of travel time. Finally, if privacy concerns can be solved, then autonomous pooled services have high market potential, especially for commute trips (Lavieri & Bhat, 2019).

2.4 Attitudes towards transportation modes and travel behavior

Motivations to buy and use a car depends on practical, symbolic and emotional factors. Practical factors refer to the ability to conduct activities during a ride, but also to the perceived flexibility, safety and convenience of a certain transportation mode. Symbolic aspects refer to the identity of a person and how the person wants to express himself/herself. Symbolic aspects are influenced by social networks. The emotional effects are non-instrumental needs, referring to desires and emotions connected to a transportation mode. Independence is, for example, an emotional effect. This desire influences usage of transportation mode. Practical factors are not the most important factor influencing car ownership. Symbolic and emotional aspects are underlying factors influencing car usage. Which make the car a popular transportation mode. Quality of life increases when the car is at disposal. Therefore the car ownership is preferred over public transportation usage. Policies and regulations are not always effective, because these only focus on the practical aspects of the car. Symbolic and emotional factors should be integrated in policies to apply successful policies (Steg, 2005).

Furthermore, two types of attitudes can be distinguished to explain travel behavior: specific and general attitudes. The general attitudes are exogenous and have low influence on travel behavior. Whereas specific attitudes are endogenous and have direct influence travel behavior. Travel behavior has influence on specific attitudes a well. Specific attitudes refer to the interest in and adoption of certain transportation mode. General attitudes refer, for example, to political attitudes and are not related to actual travel behavior (Kroesen & Caspar, 2018).

Anable (2005) attempted to segment the population according to their transportation behavior and attitudes. People's travel behavior should be analyzed in order to create policies promoting sustainable transportation and discouraging car usage. The fundamental factors influencing traveling behavior are practical, contextual, symbolic and emotional factors. The population can be divided into four car user segments and two non-car users segments. All these segments have unique characteristics and attitudes. The first segment contains malcontented motorists. These people are not willing to use public transportation or active modes, but are also not satisfied with car usage. The complacent car addicts mostly use the car and are not eager to use alternative transportation modes. Aspiring environmentalists decreased their car usage for sustainability reasons, but think they need a car. "Die hard" drivers are the most stubborn segment and are only willing to use the car. The car-less crusaders do not use the car and use alternative modes for environmental reasons. The reluctant riders cannot afford a car or are not able to drive. People from this segment mostly use public transportation. The segments show that people with different reasoning make the same transportation mode decisions. On the other hand, people with the same attitudes make different transportation mode decisions (Anable, 2005).

2.4.1 Short-term, mid-term and long-term mobility behavior

Decisions people make on a daily basis or for a longer period of time are part of the travel behavior of individuals. Short-term mobility decisions refer to daily mobility decisions. These mobility decisions are influenced by long-term and mid-term decisions. Mid-term and long-term mobility decisions are more complex and are related to each other. People's mid-term and long-term mobility involve their residential, educational and employment locations. The decsions also depend on changes of residentail, educational and employment locations. The possession of mobility tools are also part of mid-term and long-term mobility decisions. Car ownership and public transportation membership are examples of mobility tools. An adjustment in one of these aspects often results in changes of other areas as well. These adjustments can be seen within the life course of an individual. Residential, employment and education locations often change within five years. Whereas ownership of a type of mobility tools does not change often, especially car ownership. If people use one specific mobility tool for a long period of time, then the chance to use another mobility tool decreases. In conclusion the living environment is related to mobility tools and the other way around (Beige & Axhausen, 2008).

2.5 Conclusion

Two development will change the mobility sector. The developments are autonomous vehicles and shared mobility. Autonomous vehicles and shared mobility services provide new opportunities for citizens. First and last mile issues can be solved with both developments. Users can spend time in the vehicle more efficiently when using an AV, because the vehicles do not need a driver. The popularity of AVs leads to modals shifts. Car ownership will decrease, and public transportation will have a hard job competing with shared autonomous services. VDT will increase due to the development of AVs. In addition, demand for mobility will increase, together with the usage of shared AV services. Finally, the group of potential car users becomes bigger; Elderly, disabled people, and adolescents will be able to use a car.

AVs are beneficial on individual level. However, the effect of AVs on the road network is highly dependent on the future demand for AVs and usage of different kinds of AVs. Both owned and shared AVs increase the number of zero occupancy kilometers, because shared AVs need to reposition themselves. High penetration rates of shared vehicles and a high number of occupants in one single vehicle can help decreasing the VDT. As a conclusion, autonomous vehicles will change travel behavior of individuals and will transform the mobility network as a whole.

Adoption of AVs depends on the potential customers. Acceptance of AVs plays an important role in the adoption of AVs. Adoption of AVs starts with a small share and in time more people start using AVs. Different studies investigated acceptance, adoption and usage of AVs. If the study investigates the currently used transportation mode as alternative, then most people prefer using a manual transportation mode. The owned AV is preferred over adoption of shared AVs in the majority of the studies that investigate alternatives like, AV ownership and shared AVs. Only few studies compared single occupancy with multiple occupancy shared autonomous rides. Most respondent in these studies prefer the single occupancy shared autonomous rides.

Attitudes and personality are important factors determining adoption of a certain transportation mode. People’s long-term and mid-term decisions also influence daily mobility decisions.

3. Stated (adaptation) choice experiment designs

This chapter starts with an introduction about stated choice experiments (3.1). The chapter continues with the explanation the stated choice experiment (section 3.2), then the stated adaptation choice experiment (SACE) is explained in more detail (section 3.3). Later the experimental design is described (section 3.4). The questionnaire is presented in section 3.5. The chapter ends with a conclusion (section 3.6)

3.1 Introduction

Multiple methods are used to investigate people's preferences and choice behavior. Revealed preference or choice methods incorporates choice alternatives. The choice alternatives are real world examples. Hypothetical alternatives are investigated during stated modeling approaches, either with a stated preference or stated choice experiment. Stated preference experiments ask respondents to provide their preference for attributes or alternatives on a certain scale. The respondent chooses an alternative during a stated choice experiment. In such experiment, the respondent makes a tradeoff between the alternatives and chooses the most interesting alternative (Kemperman, 2000). Stated choice experiments are widely used approaches to present choice alternatives to a panel (Rose & Bliemer, 2004).

Two stated choice experiments are designed and used in this research. Fully autonomous vehicles (which are the focus of this study) are not yet available on the market. Consequently, the alternative are considered hypothetical, therefore the revealed preference/choice experiment would not fit. Stated preference experiments related to autonomous transportation modes are often used in previous research. Stated choice experiments are less often used. During a stated choice experiment people make an actual tradeoff, so the actual choices of the respondents are investigated. Which makes prediction of future behavior easier.

The respondents need to choose multiple times during a stated choice experiment. The respondents evaluate each alternative and corresponding attributes. Afterwards, the respondents choose the best alternative (Rose & Bliemer, 2004). Alternatives in a choice experiment can be labeled or unlabeled. Unlabeled alternatives by definition cannot be linked to any familiar alternative in the respondents' surroundings. Unlabeled alternatives ensure lower correlations among alternatives, due to the similarities of the alternatives from the perspective of respondents. However, labeled alternatives provide more context to the experiment and make the alternatives more realistic. The usage of labeled or unlabeled alternatives in a stated choice experiment depends on the research goal itself (Hensher et al., 2015).

Each alternative is represented by various attributes. The influence of each attribute on the alternatives is an important outcome of the stated choice experiment (Rose & Bliemer,

2009) Defining attributes and their levels is a complex task. Choosing the ranges of the attribute levels is complex, as too wide ranges would lead alternatives that are not really competitive. On the other hand, a narrow range would not only limit the evaluation of attributes importance, but also make alternatives similar. This effect makes the trade-off between alternatives hard. The attributes should also have realistic levels. The levels should not be too high or too low (Rose & Bliemer, 2009).

After determining alternatives, attributes and attribute levels, an experimental design should be generated. The experimental design is the distribution of the attribute levels among the choice sets. The used method plays a role in de independence of the assessment of each attribute and in the statistical accuracy. Various methods exists to achieve these goals. Each method has advantages and disadvantages. First, the full factorial design creates a design with all possible choice sets (Rose & Bliemer, 2009). A full factorial design is often too big to employ among reasonable number of respondents, given limited financial resource for data collection. A fractional factorial design uses only a fraction of all possible combinations. Before generating the fractional factorial design, the researcher should consider using blocking and adding interactions.

The main effect is the direct independent effect of attributes on the alternatives. The interaction effect is included, when reason exist to believe that certain combinations of attributes would significantly affect the attractiveness of alternatives. All interactions can be estimated independently with a full factorial design. Fractional factorial designs only allow modeling of a limited number of interactions or none at all. Another aspect worthwhile considering, while making an experiment design, is blocking. Blocking is added to decrease the number of choice tasks assigned to each respondent. During the development of the experimental design an extra (virtual) attribute is added to accommodate blocking. During the choice experiment the respondent only answers the choice tasks of one block (Hensher et al., 2015).

The two most often used methods to generate a fractional factorial design are orthogonal designs and efficient designs (Hensher et al., 2015). The orthogonal method is the traditional method to make experimental designs. The attributes are orthogonal, so the attributes are statistically independent. The method assures an independent estimation of the influence of each attribute on choices of alternatives (Rose & Bliemer, 2009). Efficient designs are suggested when the financial resources for data collection is limited, so significant parameter estimations cannot be realized given the sample size. Prior values of parameters are needed to generate efficient designs. An efficient design is typically recommended when previous research on the topic is available, because the prior value has effect on the final design. Furthermore the modeling method needs to be known a priori. Consequently, if the researcher wants to estimate various models (like multinomial logit model, mix logit model, regret model), than an efficient design cannot be used, since chosen model would affect the design. Efficient designs need smaller sample sizes and the standard error can be decreased, due to the requirements of efficient designs (Hensher et al., 2015).

3.2 Stated choice experiment – buying or sharing

A stated choice experiment is used to investigate people's midterm choices. The experiment investigates adoption of AV ownership versus adoption of shared autonomous mobility. Only fully autonomous transportation modes are considered as alternatives. These vehicles have level five of automation. AVs can drive by themselves and do not need a human driver. The detailed conceptual framework related to the SCE is displayed in figure 3.1. Socio-demographics, travel characteristics, attitudes and attributes influence the decisions made in the SCE. Before answering the choice tasks in the stated choice experiments, a short video is shown to the respondents. This video explains the concept of level five autonomous vehicles and gives more insight in the sharing concept.

The stated choice experiment takes a slightly different stand as opposed to many previous studies which aim to give insight in market share of autonomous vehicles. The experiment's focus will only be on autonomous transportation modes. Furthermore the alternative 'none' is not considered in the choice experiments. During the implementation face of AVs only a few people will adopt to AVs. Once AVs become more attractive, slightly more people start adopting AVs. Within years autonomous vehicles will gain high market share and AVs are adopted in greater number. Once this happens people need to choose between different autonomous transportation modes only.

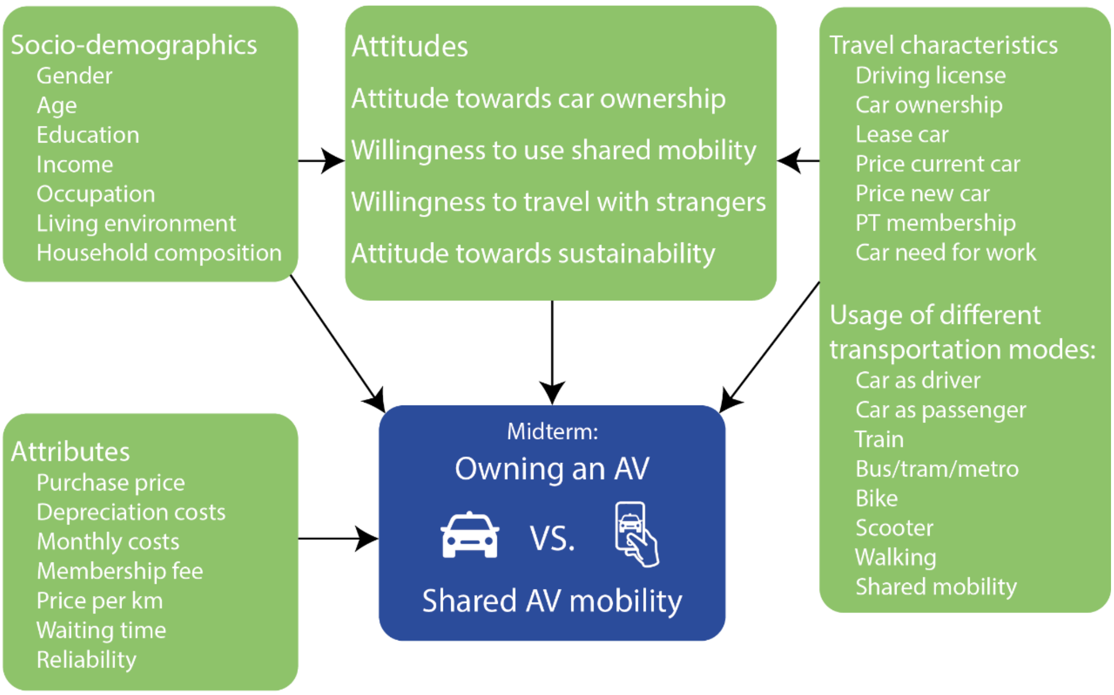


Figure 3.1: Sketch of framework for the experiment 1: adopting an owned or shared AV

3.2.1 Alternatives and attributes of the SCE

The alternatives of the SCE are purchasing an autonomous vehicle or adoption of shared autonomous mobility. Before introducing attributes and their levels, a short note regarding the definition of shared autonomous mobility would seems inevitable. A membership fee per month is envisaged, although with levels ranging from zero (no fee) to 60 euro. Moreover, car sharing services combined with autonomous technology makes the system also quite compatible with the conventional concept of ride hailing, as the car can provide door to door service after dropping of the passenger. The system of the vehicle knows the required time to be available again. The AV can either park and wait for the customer or provide services to other passengers. Consequently, the service could run similar to the conventional car sharing or ride hailing concept.

The attributes connected to AV ownership are: purchase price, depreciation and monthly costs. Membership fee, price per kilometer, waiting time and reliability are the attributes associated with shared autonomous mobility. The attributes and the attribute levels are displayed in table 3.1. The explanation of each attribute and the reasoning behind choosing the levels are described below. The number of attributes and attribute levels are important for the experimental design. Two and four attribute levels per attribute are used. This would lead to a smaller number of required profiles in the fractional factorial design, which is the adopted design method.

Table 3.1: Attributes and attribute levels the SCE

Attributes SCE	**Unit**	**Autonomous vehicle ownership**	**Shared autonomous mobility**
Purchase price (of current or future car)	€	90% / 100% / 110% / 120%	-
Depreciation costs (of the purchase price)	€/year	5% / 10%	-
Monthly costs (of the current car)	%	-35% / -20% / -5% / +10%	-
Membership fee	€/month	-	0 / 20 / 40 / 60
Price per kilometer	€/km	-	0,1 / 0,2 / 0,3 / 0,4
Waiting time	Minutes	-	1 / 4 / 7 / 10
Reliability 1		-	80% and 20% / 60% and 40%
Reliability 2		-	2 min too early and 2 min late / on time and 4 minutes too late

Purchase price:
The purchase price of AV is often used as attribute in literature, investigating what people are willing to pay for an AV. In this research, the purchase price of an AV is presented to the respondents with a personalized value. The presented purchase price depends on the answer of the respondent on a previously asked question:

- If the respondent owns a car, then the respondent is asked to indicate how much he/she is willing to pay for a (new) car, once the current car needs to be replaced.
- If the respondent does not own a car, then the respondent is asked to indicate for what price he/she would buy a (new) car, when a new car is needed in the upcoming five years.

If the respondent answers that he/she does not want to buy a car in the given situation, then the purchase price of the currently owned car is used to construct the attribute levels. The details of this question are further elaborated in section 3.5. The value of purchase price is constructed by multiplying the percentages (90%, 100%, 110% and 120%) by values reported by the respondents.

Depreciation costs:
The attribute depreciation costs of an AV is not a typically used attribute in previous studies. However, the attribute might have impact on the decision to buy an AV. Depreciation costs refers to the annual diminishing value of the AV. The attribute levels of depreciation costs have been set to 5% and 10% after consultation with relevant literature (chapter 2). 10% depreciation costs could resemble the depreciation costs of new AVs and 5% depreciation costs can resemble the deprecation costs of AVs that are a few years old. The depreciation costs are presented to the respondent as a value. The value of the attribute purchase price is multiplied by one of the attribute levels of depreciation costs (5% or 10%).

Monthly costs:
Monthly costs refer to expenses such as insurance, fuel, tax and maintenance. However, it is assumed that many people do not know what they exactly pay per month to sustain their cars. Gardner & Abraham (2007) confirm this assumption. Many of their respondents do not know or consider all costs involved with car ownership. Therefore a percentage is shown to the respondents. The percentage of monthly costs is compared to the monthly cost of manual car ownership. Operation costs, fuel costs and insurance costs of an AV are lower compared to ownership of a manual car, according to previous work. The maintenance costs will possibly remain the same (Bösch et al. (2018). For this reason, three attribute levels indicate lower monthly costs (-35%, -20% and -5%) and one attribute indicates higher monthly costs (+10%).

Membership fee:
The membership fee is the first attribute related to shared autonomous mobility. The fee is the price people need to pay to use shared AVs each month. The attribute levels of the membership fee have been configured to be 0, €20, €40 and €60 after screening relevant literature (chapter 2)

Price per kilometer:
Price per kilometer is the price people pay per kilometer when traveling with shared autonomous mobility. The attribute levels the attribute are determined according to the

attribute levels used in relevant literature. The attribute levels vary between €0.1 per kilometer and €0.4 per kilometer.

Average waiting time:
The attribute average waiting time is the average time the user needs to wait for the shared autonomous vehicle. Although one can argue that it is difficult to determine waiting time without having a specific trip and context. The counterargument would be that for a potential user of such service, it is important to have an idea of average waiting time before making any commitment by paying a membership fee. Four attribute levels are used: 1 minute, 4 minutes, 7 minutes and 10 minutes. This attribute also appears in the stated adaptation choice experiment.

Reliability:
Lastly, reliability is used differently than in previous research. The attribute reliability in this study refers to the reliability of the waiting time. The reliability refers to the chance the vehicle arrives on time or not. Reliability itself is made of a combination of two attributes: percentage and minutes. The percentage gives the probability that the vehicle will be too early, too late or on time. The minutes determine how many minutes the vehicle will be too early, too late or on time. The following combinations of reliability 1 and 2 are possible:

- 80% chance the vehicle arrives 2 minutes earlier, 20% chance the vehicle arrives 2 minutes later.
- 80% change the vehicle arrives on time, 20% change the vehicle arrives 4 minutes later.
- 60% chance the vehicle arrives 2 minutes earlier, 40% chance the vehicle arrives 2 minutes later.
- 60% change the vehicle arrives on time, 40% change the vehicle arrives 4 minutes later.

3.3 Stated adaptation choice experiment – SAV, SAR vs. APT

The main focus of the stated adaption experiment is to understand potential interest of usage of shared autonomous transportation modes. Respondents that are willing to use shared mobility will execute this second choice experiment. Before the SACE is tested, the respondents is asked whether they are current users of shared mobility or have any intention to use shared mobility in the future. In Addition, the system tracks their answers on the SCE, inspecting if the respondent chose at least once shared autonomous mobility. If one of these answers is positive, then the respondent proceeds with the SACE. Otherwise the respondent continuous with the statement questions.

The stated adaptation choice experiment investigates the short-term decisions of the respondents. These decisions are related to one single trip. The following alternatives are investigated: a ride shared with strangers, a single occupancy shared AV and autonomous public transportation. The detailed conceptual framework is shown in figure 3.2. Socio-demographics, travel characteristics, attitudes, attributes and reference trips impact the decisions made in the SACE. While the figure 3.2 seems to have overlap with figure 3.1, the core difference between the figures lies in the fact that the SACE is designed and presented to the respondents around their reference trips. The choices of the respondents depend on their reference trips. Furthermore some of the attribute levels will be pivoted for each respondent. While pivoting attributes is more complex in nature, it guarantees the realistic nature of the choice tasks.

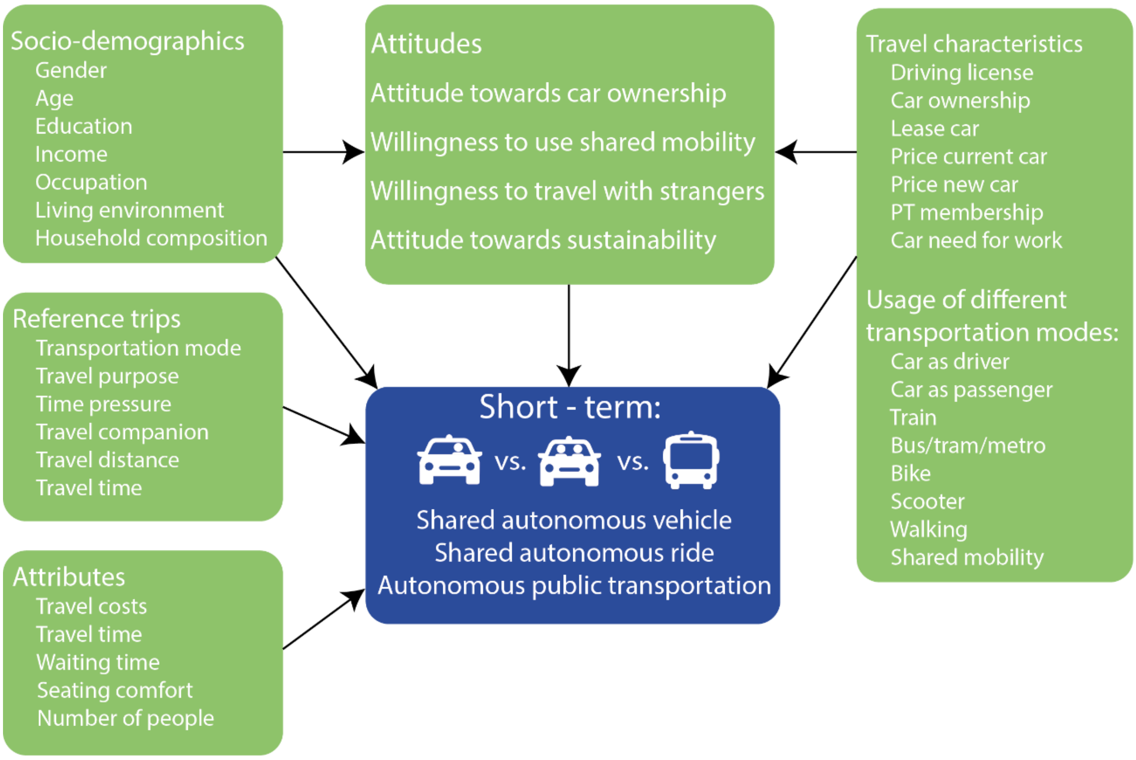


Figure 3.2: Sketch of framework for the experiment 2: usage of shared mobility, with or without strangers during the ride

The input of the SACE is determined according to the reference trips of the respondent. Each respondent answers questions about four trips he/she took by car or public transportation during 'this week or last week'. Details of each trip are asked in order to get a detailed overview of each reference trip. Section 3.5 provides an elaboration of the questions asked about the reference trips. The reason for targeting only trips conducted by car or public transportation is to guarantee that the distances traversed by the respondent make sense for using AVs. Each respondent fills in four choice tasks and each reference trip is connected to one choice task. The respondent is asked how he/she would travel along to the same route (reference trip), but then with one of the alternatives of the SACE.

3.3.1 Alternatives and attributes of the SACE

The choice tasks of the SACE either have two or three alternatives. The first alternative is a shared autonomous vehicle (SAV). This autonomous transportation mode provides shared individual rides. Only one user uses the shared AV at the same time. The shared autonomous vehicle gives the user much comfort and privacy, because the service provides single occupancy rides. The traveling costs are relatively high when using this transportation mode. The second alternative is a shared autonomous ride (SAR). This alternative provides autonomous rides shared with other passengers on board. These passengers are strangers. The service can provide cheaper rides than rides with SAV. However, the rides takes longer and the ride can be viewed as uncomfortable. The last alternative is autonomous public transportation (APT). This alternative is only presented in the choice task, when public transportation is the transportation mode of the reference trip. The alternative does not have attributes, because the main focus of this research remains autonomous vehicles. The respondents are told that APT has exactly the same characteristic as the mode they used during their reference trip, however the vehicle is autonomous. Examples of choice tasks excluding and including APT are shown in figure 3.7 and 3.8, respectively. All the alternatives have level five of automation, so the vehicles to not need a human driver. People, whose reference trips are conducted by car (so possibly car owners), are told to assume that their car is not available for this trip. In other words, the second survey has to be viewed as building up on the first choice experiment.

The attributes of the stated adaptation choice experiment are displayed in table 3.2. Travel costs, travel time, waiting time and seating comfort are associated with both SAV and SAR. Number of strangers is only relevant for SAR. The number of attributes and attribute levels have effect on the experimental design and number of blocks. Same as in the SCE, two and four attribute levels per attribute are used. This leads to a smaller number of required profiles as a consequence of fractional factorial design.

Table 3.2: Attributes and attribute levels the SACE

Attributes SACE	**Unit**	**SAV**	**SAR**
Trip cost	€/km	0.1 / 0.2 / 0.3 / 0.4	0.05 / 0.1 / 0.15 / 0.2
Waiting time	min	1 / 3 / 5 / 7	4 / 6 / 8 / 10
Travel time (% of travel time in the reference trip)		Low / High	Low / High
Car/train	%	80% / 100%	110% / 130%
Bus	%	60% / 80%	90% / 110%
Seating comfort		Economy / Business	Economy / Business
Number of strangers		-	1 / 2 / 3 / 4

Trip costs

Four levels are selected as the cost per kilometer. The total cost for each reference trip is shown to the respondents by multiplying the corresponding level to the distance travelled in the reference trip. The attribute travel cost is used in both alternatives, but with different attribute levels. Single occupancy autonomous rides are assumed to be more expensive than autonomous rides shared with strangers. The price per kilometer of the alternative SAV is the same as the price per kilometer used in the SCE. Literature is used to determine the attribute levels

Waiting time
The attribute levels for waiting times of SAV are considered smaller than those of SAR, because a SAV only needs to pick up one person and does not need to make detours. The attribute levels are shown in table 3.2. Literature was consulted to pick common sense attribute levels.

Travel time
The levels of the attribute travel time depend on the reported mode in the reference trip. In all cases, the travel time is a percentage multiplied to the reported travel time for the reference trip. The difference appears in the associated percentages. If the reference trip is made by car or train, then levels of SAV are 80% and 100%, while the levels of SAR would have 110% and 130% as values. If bus, tram or metro are used during the reference trip, then lower percentages are considered for SAV and SAR, due to all the stops during the ride with bus, tram or metro. When using the bus, tram or metro the percentages of SAV are 60% and 80%, and the percentages of SAR are 90% and 110%. More precisely, the percentages in table 3.2 are multiplied by the travel time of the reference trip. It goes without saying that the levels for SAV are lower than SAR, because a ride with SAR takes longer, due to the detours the transportation mode needs to make. Literature was consulted in making decision about attribute levels of travel time.

Number of strangers
This attribute is relevant for SAR and represents number of strangers sharing the same ride with the respondent. The attribute is added to analyze how sensitive people are to a crowded vehicle. The comfort level of a ride might decrease when more strangers travel in the vehicle. The number of people varies between one and four. Some previous research only used two attribute levels, informing the respondent whether the ride is shared with strangers or not.

Seating comfort
Lastly, the attribute seating comfort is added to the SACE. This attribute is not yet used in literature. Seating comfort is related to the personal space people have during a ride. The levels are tentatively labelled as *economy* and *business*. However, the attribute levels are presented with pictures, in order to communicate what type of seating environment the respondent can expect. Figure 3.3 shows the economy and business classes of both alternatives.

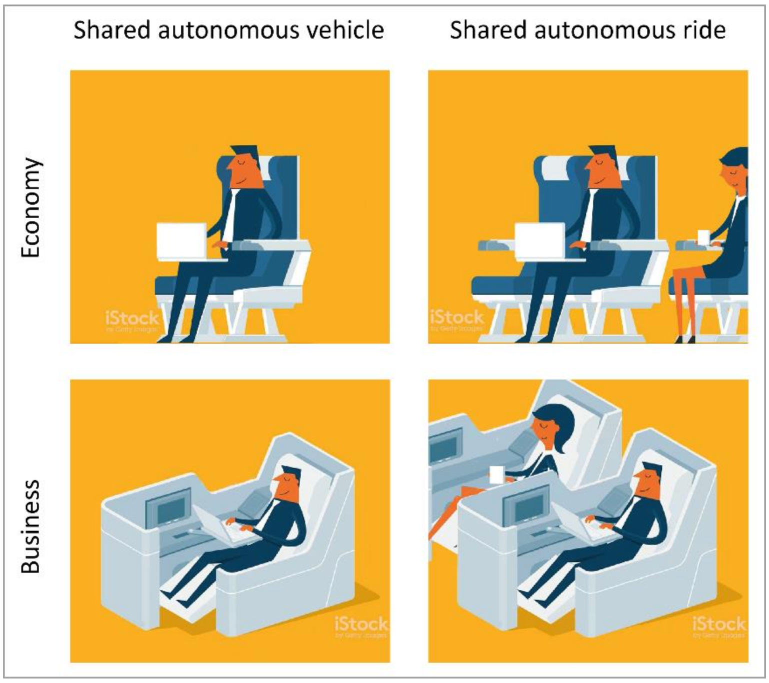


Figure 3.3: pictures of the attribute levels of seating comfort

3.4 Orthogonal fractional factorial design

Both stated choice experiments have similar designs. A full factorial design will give respectively $4^5 * 2^3$ and $4^5 * 2^4$ choice sets. Therefore a full factorial design would not be feasible for this research. A fractional factorial design is used, more specifically an orthogonal design. The design guarantees zero correlation among attributes. Adoption of an orthogonal fractional factorial design was chosen for various reasons. First of all, efficient designs require information or need expert knowledge (Hensher et al., 2015) of the value of parameters. However, level five autonomous vehicles are not implemented yet, so actual behavior of potential users is not yet tested. Consequently prior information is not available. Moreover, an efficient design is recommended when there is restriction on the sample size, due to the financial constraint. There was no financial restriction for this study, because there was access a paid panel.

The software SAS is used to create the experimental design. The input of the design of the SCE is shown in figure 3.4, and the input of the design of the SACE is shown in figure 3.5. After generating a design with SAS, the attribute levels are effect coded and the correlations of the attributes are checked, to guarantee the appropriateness of the designs. The experimental design of the SCE has 32 choice sets and four blocks. Each respondents reacts on eight choice tasks during the SCE. The SACE has 64 choice sets and 16 blocks. Four choice tasks will be answered by each respondent during the SACE. All attribute levels appear an equal number of times in the choice sets, so the attribute balance is guaranteed. The designs are shown in appendix B.

```
%mktruns(2**3 4**6)
%mktex(2**3 4**6, n=32)
proc print;
run;
```

Figure 3.4: Input in SAS for the experimental design of the SCE

```
%mktruns(2**4 4**5 16**1)
%mktex(2**4 4**5 16**1, n=64)
proc print;
run;
```

Figure 3.5: Input in SAS for the experimental design of the SACE

3.5 The questionnaire

Both choice experiments are integrated in one questionnaire. The questionnaire is made with LimeSurvey. This section explains the questionnaire and how the choice experiments are integrated in the questionnaire. The following order has been used in the questionnaire:

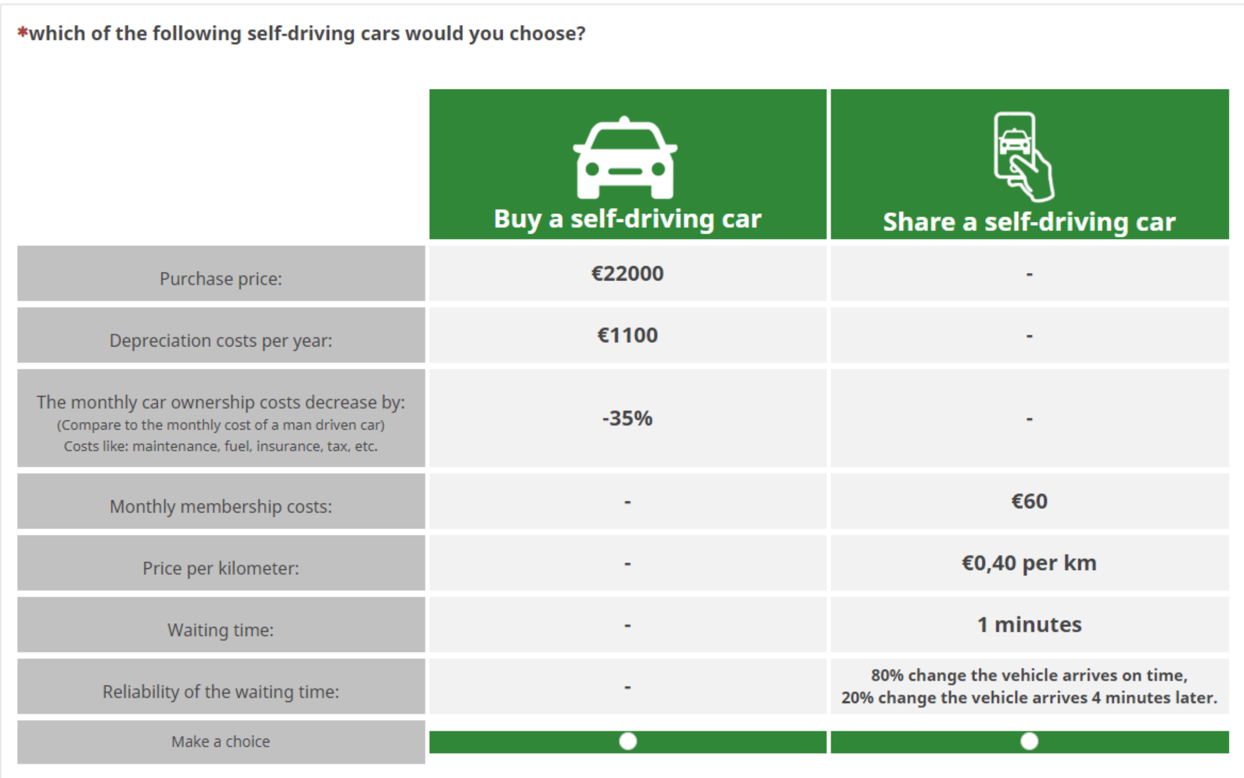
0. General information
1. Transportation modes
2. Car specific questions
3. Stated choice experiment
4. Reference trips
5. Stated adaptation choice experiment
6. Statements
7. Socio-demographics
8. Closing

The screenshots of the questionnaire are displayed in appendix C.

The questionnaire starts with providing general information about the research. In addition, the section explains that the questionnaire is anonymous, that the questionnaire takes 15 to 20 minutes and that the participation is voluntary. The questionnaire continuous with questions about typical use of different existing transportation modes. More precisely, the respondents are asked how often they use different transportation modes. Usage of the following transportation modes are investigated: car as driver, car as a passenger, train, bus/tram/metro, bike, walking, Scooter/motor/E-bike, shared mobility and another transportation mode. If the respondent uses another transportation mode, then respondent is asked to indicate which transportation mode he/she uses. Furthermore, the respondents are asked if ever used shared mobility. In case the answer is negative, then respondent is asked whether he/she would 'ever consider using shared mobility'. The answers on this question will be used as condition for the SACE.

Next, the respondents are asked about car usage, in order to get a perspective on the car usage of the respondent. The respondents are asked about: car ownership, driving license, usage of a lease car and the purchase price of their current car. The section ends with a question about what people would pay for a (new) car. The respondents that do not own a car are asked; if they would need to buy a car in the upcoming five years, then what would they pay for a (new) car. The respondents that own car are asked: once the current owned cars need to be replaced, what they would pay for (new) car. The question has a time frame of five years, in order to investigate mid-term preferences. The answer on this question will be used to construct the values of the purchase price of an AV in the SCE. The question is displayed as single choice option. An average of the answer is used to determine the value of the attribute purchase price. If the respondent answers that he/she does not want to buy a car in the explained situation and owns a car, then the purchase price of the currently owned car is used as the attribute level.

A video is shown to the respondent, before the SCE is started. The video explains autonomous vehicles in general and describes the alternatives. The explanation of shared AVs is detailed, because the concept is probably unknown to the respondents. Next, the choice sets are displayed to the respondents. An example is shown in figure 3.6. Only respondents that own a car or want to buy a car within the upcoming five years participate in the SCE. If the respondent does not have a car and does not want to buy a car, then the respondent is exempted from answering the SCE. The respondents that fill in the SCE get eight choice tasks, the choices tasks were randomized to prevent biases.


***which of the following self-driving cars would you choose?**

	Buy a self-driving car	Share a self-driving car
Purchase price:	€22000	-
Depreciation costs per year:	€1100	-
The monthly car ownership costs decrease by: (Compare to the monthly cost of a man driven car) Costs like: maintenance, fuel, insurance, tax, etc.	-35%	-
Monthly membership costs:	-	€60
Price per kilometer:	-	€0,40 per km
Waiting time:	-	1 minutes
Reliability of the waiting time:	-	80% change the vehicle arrives on time, 20% change the vehicle arrives 4 minutes later.
Make a choice	○	○

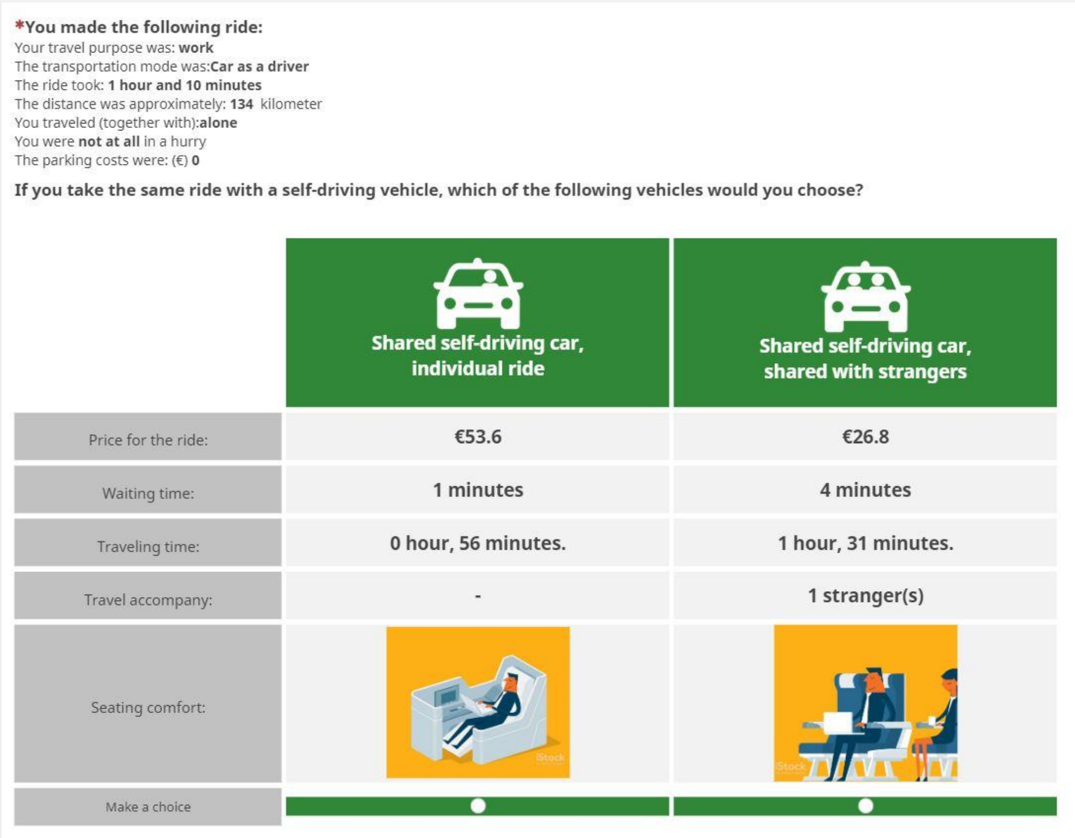
Figure 3.6: Example of a choice set of the SCE

The fourth section asks the respondents about their four reference trips. The input of this section is used in the stated adaptation choice experiment. The respondent is asked to think about four different rides he/she took by car or public transportation 'last week or the week before'. The respondent is asked to only describe trips taking less than four hours.

Furthermore the respondent should indicate different trips. Therefore the respondent is asked to describe rides to different locations and is asked to not indicate the return trip. The following aspects about the reference trips are asked:

- Transportation mode
- Travel purpose
- Travel time
- Travel distance
- If the transportation mode is public transportation:
    - Access and egress time
    - Waiting time
    - Travel costs
- If the transportation mode is car:
    - Parking costs
- Time pressure
- Travel accompany. If yes:
    - Who was the travel accompany?
    - Did the respondent travel with children? If yes:
        - The age of the children

After explaining the four reference trips, the respondents continue with a video. The video explains shared AVs in more detail. The video also demonstrates the possibility to use a ride shared with strangers or not. After the movie the respondents continue with the SACE. Figure 3.7 and 3.8 show examples of the choice sets. Each reference trip is combined with one choice task. The respondent answers four choice tasks in total. The order of the choice tasks is random to prevent biases.

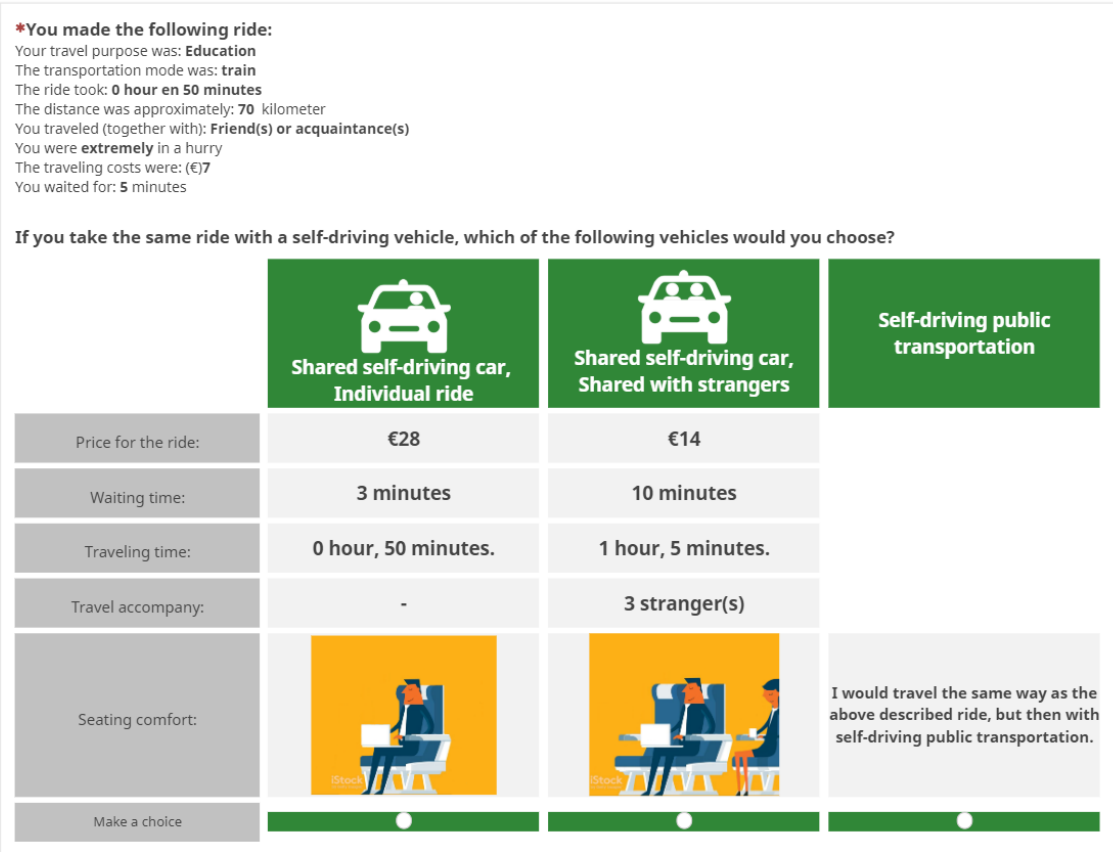


***You made the following ride:**
Your travel purpose was: **work**
The transportation mode was:**Car as a driver**
The ride took: **1 hour and 10 minutes**
The distance was approximately: **134** kilometer
You traveled (together with):**alone**
You were **not at all** in a hurry
The parking costs were: (€) **0**

If you take the same ride with a self-driving vehicle, which of the following vehicles would you choose?

	Shared self-driving car, individual ride	Shared self-driving car, shared with strangers
Price for the ride:	€53.6	€26.8
Waiting time:	1 minutes	4 minutes
Traveling time:	0 hour, 56 minutes.	1 hour, 31 minutes.
Travel accompany:	-	1 stranger(s)
Seating comfort:		
Make a choice		

Figure 3.7: Example of a choice set of SACE with two alternatives



***You made the following ride:**
Your travel purpose was: **Education**
The transportation mode was: **train**
The ride took: **0 hour en 50 minutes**
The distance was approximately: **70** kilometer
You traveled (together with): **Friend(s) or acquaintance(s)**
You were **extremely** in a hurry
The traveling costs were: (€)**7**
You waited for: **5** minutes

If you take the same ride with a self-driving vehicle, which of the following vehicles would you choose?

	Shared self-driving car, Individual ride	Shared self-driving car, Shared with strangers	Self-driving public transportation
Price for the ride:	€28	€14	
Waiting time:	3 minutes	10 minutes	
Traveling time:	0 hour, 50 minutes.	1 hour, 5 minutes.	
Travel accompany:	-	3 stranger(s)	
Seating comfort:			I would travel the same way as the above described ride, but then with self-driving public transportation.
Make a choice			

Figure 3.8: Example of a choice set of the SACE including self-driving public transportation

After the SACE, the attitudes are tested with statements. The following attitudes are tested: attitude towards car ownership, willingness to use shared mobility, attitude towards ride sharing and attitude towards sustainability. The attitudes are tested with multiple statements on a five point Likert scale. Some statements are from previous research and some are formulated exclusively for this research. Section 3.5.1 describes the attitudes in more detail. The final part of the questionnaire asks respondents to provide information about their socio-demographics. The flowing socio-demographics are asked: gender, age, level of education, income level, occupation, the need for a car for work, country of residents, postal code, perceived living environment, household composition, number of cars in the household, number of people that have a driving license in the household and public transportation membership.

3.5.1 Attitudes

The attitudes are the latent variables. The attitudes will be used in the hybrid choice model. The integration of attitudes in the hybrid choice model sheds light on research questions two and four:

> *How do attitudes towards sharing versus owning play a role in the choice to adopt shared autonomous vehicle mobility or a privately owned autonomous vehicle?*
>
> *How do attitudes influence the usage of either a shared autonomous ride, a shared autonomous vehicle or public autonomous transportation?*

Multiple statements are formulated In order to investigate the attitudes. The stamens are considered as indicators of the latent variables and help to measure the latent variables. The respondents are asked to indicate their level of agreement on the statements. The agreement is tested with a five point Likert scale: 1 is strongly disagree, 2 is disagree, 3 is neutral, 4 is agree and 5 is fully agree. The following statements are used:

Attitude towards car ownership:

1. I only have a car to drive from A to B (Steg, 2005).
2. If I find a transportation mode equal convenient as the car, I would not need a car (Steg, 2005).
3. A car gives me status and prestige (Steg, 2005).
4. I think the car has practical functions only (Steg, 2005).
5. I feel free and independent if I own a car (Steg, 2005).

Willingness to use shared mobility:

6. I think shared mobility will makes me more dependent.
7. I would use shared mobility if it doesn’t take more time (Amirkiaee & Evangelopoulos, 2018).
8. I would use shared mobility if it doesn’t cost me extra money (Amirkiaee & Evangelopoulos, 2018).

9. I would use shared mobility if it gives me the same comfort as owning a car.
10. I would use shared mobility if it is easy to order a ride or car.

Attitude towards ride sharing:

11. I think it is pleasant to meet new people (Amirkiaee & Evangelopoulos, 2018) in the train or bus.
12. I think it is uncomfortable when strangers are in close proximity of me in the train or bus.
13. I trust other travelers during a ride with public transportation (Amirkiaee & Evangelopoulos, 2018).
14. When I'm traveling with public transportation, I'm concerned that strangers will look at my smartphone or laptop.

Attitude towards sustainability:

15. For me it is important to use a sustainable transportation mode (Amirkiaee & Evangelopoulos, 2018).
16. I'm concerned about the negative environmental effects of car use (Anable, 2005).
17. Being environmentally responsible is an important part of who I am (Venhoeven et al., 2016).
18. My attitude towards sustainability influences my behavior.
19. It is important for me to make environmental friendly decisions (Amirkiaee & Evangelopoulos, 2018).

The attitude towards car ownership is directly related to the first choice experiment. The attitude explains whether people are attached to the car. According to Steg (2005), car ownership could be associated to symbolic and emotional aspects, rather than the practical functions of the car only. The statements are connected to all three aspects. The attitude towards car ownership probably influences the decision to purchase an AV or to adopt shared autonomous mobility.

The willingness to use shared mobility has an association with both choice experiments. The attitude represents people's interest to use shared mobility. The attitude towards car sharing is also investigated by Amirkiaee & Evangelopoulos (2018). Their statements investigate economic and time benefits of shared cars. Two of these statements are transformed and used in this research. The other three statements are formulated specifically for this research. If respondents are interested in shared mobility, then they might prefer adoption of shared autonomous mobility over AV ownership.

Attitude towards ride sharing is related to both choice experiments, but especially to the SACE. The attitude investigates people's trust in strangers and comfort when traveling with strangers. Two statements are copied from the research of Amirkiaee & Evangelopoulos (2018) and slightly transformed. The other two statements are formulated for this research.

The last attitudinal statements examines the attitude towards sustainability. It is assumed that shared mobility is more environmental friendly than car ownership, because less vehicles are needed. If the ride is shared with others, then less kilometers per vehicle are traveled, leading to less congestion. Four statements from different research are in this research. One statement is specifically formulated for this research.

3.6 Conclusion

This research uses two stated choice experiments. The experiments analyze the choices of the respondents regarding different autonomous transportation modes. The first choice experiment investigates people's decision towards adoption of either an owned AV or shared autonomous mobility. The attributes of AV ownership are: purchase price, depreciation and monthly costs. Membership fee, price per kilometer, waiting time and reliability are the attributes of shared autonomous mobility. The second experiment is a stated adaptation choice experiment. The respondents decide either using a shared autonomous vehicle, a shared autonomous ride or autonomous public transportation. The choices depend on the reference tips of the respondent. The attributes related to both SAV and SAR are: travel costs, travel time, waiting time and seating comfort. The number of strangers in the vehicle during a SAR is only related to SAR. Therefore this attribute is only added to the alternative SAR. Autonomous public transportation does not have any attributes.

An orthogonal fractional factorial design is created to develop the choice tasks. Blocking is used in both experiments, minimizing the number of choice tasks per respondents. The SCE has 32 choice tasks and uses four blocks. Each respondent fills in eight choice tasks during the SCE. The SACE has 64 choice tasks with 16 blocks. So each respondent reacts on four choice tasks during the SACE.

Both choice experiments are integrated in a questionnaire. The questionnaire starts with questions about people's travel behavior. The questionnaire continues with the stated choice experiments. The respondents is asked to describe four reference trips, after the SCE. The reference trips are used in the SACE that follows. After the SACE, the respondent answer statements related to the attitudes. The respondents answer 19 statements on a five point Likert scale. The statements are added to the questionnaire to investigate four attitudes. These four attitudes are: attitude towards car ownership, willingness to use shared mobility, attitude towards ride sharing and attitude towards sustainability. The questionnaire ends with questions about the socio-demographics of the respondent.

4. Data collection and exploration

Chapter four starts with a description of the pilot study (section 4.1). The chapter continues with the outcomes of the main study. Data gathering of the main study is explained in section 4.2. After data gathering, the data set is cleaned and prepared for analysis (section 4.3). Data analysis starts with exploratory analysis of the socio-demographics, travel characteristics and reference trips of the respondents (section 4.4).

4.1 Pilot study

Before explaining the pilot study, it is worth noting that the other sections and chapters of this report contain the information used in the main study. Only section 4.1 and appendix D provide details about the pilot study.

Before the full deployment of the main questionnaire, a pilot study was conducted. The lessons learned from the pilot study are used in the main study. The questionnaire of the pilot study was distributed on 25th of June 2019 via the online platform LimeSurvey. A paid panel is used to gather the responses of the pilot study. The respondents are asked to provide extra feedback at the end of the questionnaire. The feedback is used to improve the questionnaire of the main study.

The sample size of the pilot is 51 respondents. The sample has 53% male and 41% female respondents. 6% of the respondents did not indicate a gender. These respondents have unknown gender. Many respondents are quit old. For example, 37.3 % of the respondents is between 55 and 64 years old. Many of the respondents are retired (38%) or unemployed (14%). These respondents probably have a lot of time, so these respondents are more willing to be part of a paid online panel. Consequently the sample has a high number of older, retired and unemployed respondents. Most of the respondents are car owners (80.4%). The average purchase price of their cars is €19,000. The respondents are willing to pay €20,000 on average for a (new) car. Most of the reference trips are conducted by car (90%). Furthermore most respondents described trips to work, to social activities or to a store. The reference trips took on average 43 minutes and had an average distance of 42 kilometer. Most of the respondents were not in hurry. Moreover approximately half of the respondents traveled alone, and the other half traveled with someone else. The other results of the exploratory analysis of the pilot study are shown in appendix D.

Not all respondents match with the criteria set for the SCE and the SACE. 43 respondents met the requirements of the SCE and 36 respondents fit within the target group of the SACE. The SCE has 352 observations. AV ownership is chosen 55% of the time and shared autonomous mobility is chosen 45% of the time. The SCE has 144 observations, SAV is chosen for 71% of the time, SAR is chosen 22% of the time and autonomous public transportation is chosen 7% of the time.

Only few changes are made after the pilot study. The experimental design is modified to ensure sufficient analysis of the choices made during the experiments. Some of the respondent indicated high travel times and long travel distances of the reference trips. However travel times shorter than four hours are preferred. Otherwise the values of the attributes travel costs and travel time are not realistic. Therefore the respondents are asked to indicate trips taking less than 4 hours in the main study. Furthermore some attitude statements are adjusted and two attitude statements are added. As a result, the attitudes are covered by more statements in the main study, ensuring sufficient analysis of the attitudes. Moreover quotas are added to the main study. The quotas ensure sufficient average age of the sample in the main study. The quotas are explained in section 4.2. Finally the wording of some questions changed to make the questions more understandable.

4.2 Data gathering

This section continues with the data gathering of the main study. The questionnaire is developed in with LimeSurvey. LimeSurvey is also the online platform from where the questionnaire is distributed. The questionnaire is distributed with two manners, via a personal network and via a paid online panel. The questionnaire connected to the personal network is distributed via social media, mainly via WhatsApp and via email. The questionnaire of the personal network was available between the 1st till the 22nd of August 2019. The sample size of the questionnaire of the personal network is 259 respondents. 719 respondents reacted on the questionnaire of the paid online panel. The contact and services for this questionnaire are provided by Respondenten database.nl. Respondenten database.nl, on their term, used the services of Kantar to distribute the questionnaire. The respondents from the paid panel answered the questionnaire from the 16th till the 23rd of August 2019.

Both the questionnaire for the paid online panel and for the personal network have an English and a Dutch version. The questionnaire for the paid panel starts with two questions about gender and age. After these questions, quotas are used to calculate the number of respondents belonging to a certain age and gender group. A maximum number of respondents is allowed in these groups. Since the pilot study showed that the average age of the respondents is higher than the average age of the Netherlands. If quotas are not added to the main study, than the average age of the main study will probably be high.

Eight age groups and two gender groups are created, resulting in 16 groups. Eight groups represent the female respondents, and eight groups belong to the male respondents (table 4.1). A maximum number of respondents per group is determined according to the ages and gender of the population of the Netherlands in 2019 (CBS, 2018a). In order to get a representative sample for the Netherlands. If a maximum is reached, then the respondent belonging to a certain gender-age group is deleted from the survey. Table 4.1 shows the thresholds of the groups. In total 700 respondents are expected from the paid panel. However, the maximum number of respondents in the quota system is higher. Because the respondents starting, but not ending the survey, get a spot in these groups. The maximum number of females allowed in the groups is slightly higher, because 51% of the population of the Netherlands is female and 49% is male (CBS, 2018a). This resulted in a maximum of 413 females in the quotas and maximum of 399 males in the quotas.

Table 4.1: Distribution of age-gender groups in the quotas of LimeSurvey (CBS, 2018a)

	18-24	25-34	35-44	45-54	55-64	65-74	75+	Total
% of the Netherlands	10.8%	15.8%	14.8%	18.0%	16.7%	13.7%	10.1%	100%
Number of Females in group	45	65	61	75	69	57	42	413
Number of Males in group	43	63	59	72	67	55	40	399
Total	88	128	120	147	136	111	82	812

The questionnaire created for the personal network does not have any of the above described quotas. Questions about age and gender of the questionnaire for the personal network are asked at the end of the questionnaire. This is the original order, which is explained in section 3.5.

Both choice experiments have criteria. The respondents need to match with the criteria in order to fill in the choice experiments. The respondents owning a car or willing to buy a car in the future are the target group of the SCE. Since these respondents potentially need to tradeoff between AV ownership and shared autonomous mobility in the future. The respondents not willing to own a car do not need to make this tradeoff in the future. Respondents that own a car or want to buy a car within the upcoming five years participate in the SCE. If the respondent does not have a car and does not want to buy a car in the future, then the respondent does not fit the target group of the SCE and is excluded from the SCE.

The respondents that are willing to use shared mobility match the criteria of the SACE. These respondents probably need to tradeoff between different shared autonomous transportation nodes. The criteria are asked with multiple questions before participating in the SACE. A respondent participates in the SACE, if the respondent matches with one of the following requirements:

- The respondent is currently a user of shared mobility. The criteria is asked in the first question of appendix C1.
- The respondent would (maybe or certainly) consider using shared mobility. This criteria is asked in the third question of appendix C1.
- The respondent chooses shared autonomous mobility at least once during the SCE.

The respondents that are not willing to use shared mobility are excluded from the SACE.

4.3 Data cleaning

Some respondents answered some questions inaccurate. If the respondent answers too many questions inaccurate, then the respondent is deleted from the survey. The respondents are deleted according to: equal answers on the attitudinal questions, total time to complete the full questionnaire, indication of similar reference trips, indication of similar answers on the choice experiments, similar indication of usage of different transportation modes and gender. Appendix E1 shows which respondents are deleted and for which reason. First, the attitudes investigated in this research are essential in order to answer research questions two and four. 41 respondents filled in one answers in all 19 statements, so for example, a respondent only agreed on all statements. However, some statements refer to the negative side of an attitude and others refer to the positive side of an attitude. For example, statement 12 has a negative influence and statement 13 has a positive influence on the attitude towards ride sharing (section 3.5.1). Therefore, 41 respondents have been deleted from the sample. 20 of these 41 respondents were deleted for extra reasons, among which are: short answer times for the whole survey, four of the same reference trips, the same choices in the choice experiments or/and indicated usage of different transportation modes same amount of time. Furthermore, 35 respondents indicated an unknown gender due to an error in LimeSurvey. These respondents are deleted. Since having unknown genders in the final data set leads to unusual results and inaccurate conclusions. The final sample size is 902 respondents.

Table 4.2: The number of respondents used for analysis

	Total	Deleted	Used for analysis
Paid panel	719	41	678
Own network	259	35	224
Total	978	76	902

In addition, some reference trips connected to the SACE are also deleted. The reference trips are related to the choices made in the SACE. In particular the respondents are asked how they would travel along to the same route (reference trip), but then with one of the alternatives of the SACE. Furthermore the attributes levels of travel time and travel costs are depending on the reference trip. Therefore, the answers on the SACE are depending on the reference trips. If the respondent fills in imprecise answers, then the results of the choices in the SACE are unreliable. In total 146 reference trips are deleted. The reasons are shown in appendix E2. More than half of these rides (85 rides) are deleted due to indication of vacation trips as reference trips. The questionnaire is distributed during the holiday period, so indication of vacation trips were expected. Normally vacation trips take longer than regular rides to work or the supermarket. Many of these trips have long distances and travel times. The respondents were asked to indicate trips taking less than four hours, probably some respondents forgot this remark. Therefore, all reference trips taking longer than six hours are deleted.

Furthermore, 59 trips had a strange time and distance ratio. Either the respondent traveled only a few kilometers per hour for a quite long period of time, or the respondent had an impossibly high average speed. Trips with extreme low or high speeds are deleted. Finally, two of the respondents described inaccurate trips, one respondent had driving lessons during the trip and the other respondent described a ride with bicycle as transportation mode. In total 2946 reference trips are used for the analysis of the SACE, so the choice experiment has 2946 observations.

The questionnaire has some multiple choice questions with the possibility to indicate another answer, the option 'other'. The option 'other' is consulted when the respondent does not consider a fit within one of the provided answer categories. The respondent provides a personalized textual answer in a text frame in LimeSurvey. The category 'other' has only personalized answers. However, some of these answers do fit within the existing answer categories. The description below and appendix E3 explain the transformations performed on the dataset.

Socio-demographics:

- In the questionnaire there was the possibility to indicate another level of education. In case the respondents did not know in which category they would fit. All these answers are translated to existing levels of education; low, middle or high. The translations are similar to the categorization of the education levels used in OVIN.
- The option 'other' was available in the question about occupation. Some of the answers could be added to existing categories. Furthermore the variable occupation has seven categories, but it is more sufficient to use four or less categories for further analysis. Therefore occupation is transformed from seven categories to four categories. The following four categories belong to the new variable: student, working, unemployed and retired. The respondents in the 'other' category are: freelancers, retired respondents but doing some work, volunteers and housewives/housemen. The freelancers are added to the work category. The retired respondents doing a bit of work are added to the category retired. The housewives, housemen and volunteers are added in the category unemployed.
- The option 'other' exists in the in the question about country of residence. The respondents either indicate living in the Netherlands or in another country (option 'other'). One person answered four numbers. These numbers are interpreted as the postal code of the respondent. Since the question about postal code is asked after the question about country of residence.
- Some of the respondents indicated having 'other' household composition. 18 of these answers fit within one of the existing categories and are added to these categories.

Travel characteristics:

- The respondents could indicate whether they use another transportation mode in the question about usage of different transportation modes. Some respondent indicated that they use one of the existing options as ‘other’ transportation mode. These answers are added to the existing answer options. Some respondents also indicated using another transportation mode one to 10 times per year. These answers are very specific and are too detailed for further analysis. Since the respondent only uses this mode a few times per year. For example, some respondent indicated using the airplane one to 10 times per year as transportation mode. Usage of another transportation mode of these respondents is set to never. Five respondents indicated using a non-existing transportation mode (e.g. nvt). It is assumed that these respondents never use another transportation mode.

- The respondents indicated whether they have a lease car. In the question there was a possibility to indicate another way of using lease cars. Which means that the option ‘other’ was available. Six respondents indicated that they use lease cars in another way. These answers do not refer to lease cars, but for example to car sharing. The answers of these respondents are changed: these respondents do not have a lease car.
- The respondents could choose multiple options as public transportation memberships. Since it is possible to have more than one public transportation membership. For example, a respondent might have the NS off peak discount membership and the weekend free membership. However, this results in 13 variables. The respondent either has the specific public transportation membership or not. Therefore, the variable public transportation memberships is transformed to one variable. The respondents with multiple memberships fit within the category other.
- The category ‘other’ existed in the variable public transportation membership. 27 respondents indicated to have a NS card. People can put money on this card. However, having such card does not specifically mean that the person has a public transportation membership. Therefore, these respondents are added to the option: no membership. Two other respondent indicated a membership that fit within the existing categories.

Reference trips:

- The question about travel purpose has the answer category ‘other’. Some of the answers fit within this category, like going to the hospital or to the dentist. But 62 of the answers in the category ‘other’ could be added to existing categories. For example, museum visits or holiday related trips can be added to the category leisure.
- Travel company: the question about travel company is only available, when the person indicates traveling with others or indicates traveling with car as a passenger. However 8 respondents traveling with car as a passenger indicated that they traveled alone in the question about travel company. Assumingly, these respondents traveled by car as driver, but mistakenly choose car as a passenger (which is easy to be mistaken in LimeSurvey). Furthermore, 12 times respondents indicated an answer that can be added to the existing answer categories.

- The questionnaire is also answered by non-Dutch respondents. Some of these respondents use a point instead of comma as decimal mark. However, a comma is set as default decimal mark in LimeSurvey. Therefore some respondent indicated high values as parking costs or travel costs. For example, travel costs of €160 by bus are assumingly wrong. The person probably paid €1.60 for the ride. 11 of these values are changed.

4.4 Exploratory analysis

4.4.1 socio-demographics

After data preparation and data cleaning, the data analysis is initiated. The analysis starts with an exploratory analysis of the socio-demographic characteristics. Table 4.3 shows the distribution of the variables and the categories. Some variables are compared to the population of the Netherlands. The comparison is either described in the text or in table 4.3, depending on the availability of the information about the population of the Netherlands. Many the categories are merged to ensure a sufficient number of observations per category. Appendix F1 shows more details about the variables and the original categories of the variables.

Table 4.3: Socio-demographics of the respondents

Variable	Category	Frequency	%	% of NL
Gender	Female	470	52.1	50.8[1]
	Male	432	47.9	49.2[1]
Age	18-34 years old	239	26.5	26.6[1]
	35-54 years old	291	32.3	32.8[1]
	55-74 years old	323	35.8	30.5[1]
	75 years old or more	49	5.4	10.1[1]
Education	Low (Primary or middle school, or VMBO)	112	12.4	31.6[2]
	Middle (HAVO, VWO, MBO)	351	38.9	38.7[2]
	High (HBO, university)	439	48.7	29.7[2]
Income	€0-€20.000	201	22.3	
	€20.001-€40.000	316	35.0	
	€40.001 or more	263	29.2	
	"I prefer not to answer"	122	13.5	
Occupation	Student	90	10.0	
	Working	517	57.3	
	Unemployed, disability or other	127	14.1	
	Retired	168	18.6	

The need for a car to work	Yes	199	22.1	
	No	313	34.7	
	The respondent does not work	390	43.2	
Country of residence	Netherlands	886	98.2	
	Other	16	1.8	
Perceived living environment	Urban area	472	52.3	
	Slightly urban	110	12.2	
	Village	270	29.9	
	Rural	50	5.5	
Household composition	Single without child(ren)	252	27.9	
	Couple without child(ren)	344	38.1	
	Single/couple with child(ren)	234	25.9	
	Other	72	8.0	

1: (CBS, 2018a)
2: (CBS, 2019c)

First, gender is almost equal distributed. A bit more than half of the respondents is female. There are slightly more women than men in the Netherlands (CBS, 2018a). Therefore this variable represents the population in the Netherlands.

Initially the variable age has seven age groups. These groups are transformed in four age groups. The first three age groups have an approximately equal number of respondents. The age group with respondents older than 74 years is rather small. Since only few Dutch citizens are older than 74 years old (CBS, 2018a). One fourth of the sample is between 18-34 years old. One third of the respondents are between 35-54 years old. 35.8% of the sample is between 55 and 74 years old. Only 5.4% of the respondents is older than 74 years. The first two age groups are comparable to the population of the Netherlands. The age group of 55 to 74 years old is overrepresented compared to the population of the Netherlands. Finally, this sample underrepresents the people older than 74 years (CBS, 2018a).

Initially four educations levels existed. However, the category primary school and middle school has only 10 respondents. Respondents from this category are added to the category low level of education. Almost half of the respondents are highly educated. In the Netherlands only 30% of the population is highly educated. The percentage of respondents with a middle level of education is the same as the percentage of people with middle level of education in the Netherlands. The respondents with low level of education is small (12%) compared to the population of the Netherlands (32%) (CBS, 2019c).

The income levels are transformed from seven levels to four levels. 13.5% of the respondents is not willing to indicate what they earn. Therefore, only 780 respondents indicated their income. This group compared to the rest of the Netherlands. The income levels of this sample are not representative to the rest of the Netherlands (CBS, 2018c). One fourth of the respondents earns a low income. 40.5% of the respondents has an income between €20.001 and €40.000 per year. One third of the sample has a high income.

The variable occupation is transformed from seven categories to four categories. The categories student and retired remain the same. The three categories about work are merged into one category. The category 'other' and unemployed/disabled are merged. However, some respondents with 'other' occupation are added to the working or retired category, as explained in section 4.3. A bit more than half of the respondents works (57.3%). 10% of the respondents is a student. 14.1% of the respondents is unemployed, disabled or has another occupation. 18.6% of the respondents is retired. In the Netherlands 51% of the population works (CBS, 2018b), which is comparable to the results of this research. Moreover 7.2% of the population of the Netherlands are students (CBS, 2019a) (CBS, 2019b), so this research over represents the occupation student.

All the respondents that work answer an extra question. The question investigates the need to use a car for work to transport equipment or to go to an appointment which is badly accessible by public transportation or bike. Almost 60% of the working respondent does not need a car to do their job. The other respondents indicated needing a car for work. The frequencies of this variable do not match the frequencies of the variable occupation. During data preparation five respondents are added to the group with working respondents. These five respondents did not answer the question about the need for a car for work.

The majority of the respondents live in the Netherlands (98.2%). Only 16 respondents live in another country. The respondents indicate their perceived living environment in the question about the living environment. The variable had initially had five categories, which are transformed to four categories. The categories city center and urban (not in city center) are quite similar, so these categories might have been interpreted similarly by the respondents. Therefore these categories are merged. A bit more than half of the sample indicated living in an urban area. 12.2% of the sample lives in a slightly urban area. 29.9% of the respondent's lives in a village. Only 5.5% of the sample lives in a rural area.

The respondent could choose between six categories in the question about household composition. These categories are merged to four categories. The categories single and couple remain the same. The singles with children and couples with children are combined to one category. The categories 'other' and living with others are combined. In total 27.9% of the respondents lives alone. 38.1% of the sample lives with their partner. One fourth of the sample lives with their children. Finally 8% of the respondents has another household composition. In the Netherlands 38.3% of the people lives alone, so this research underrepresents the single households. 61.7% of the Dutch people lives with more than one person (CBS, 2019d). Consequently the outcomes of the variable household composition are not representative for the Netherlands.

The majority of the respondents is from the Netherlands. These respondents indicated their postal codes. The distribution of the respondents in the Netherlands are plotted in figure 4.1. The respondents are from all over the Netherlands. However, many respondents live in in the province of Noord-Brabant, because of the usage of the personal network to distribute the questionnaire. The distribution of the respondents in Noord-Brabant is shown in figure 4.2.

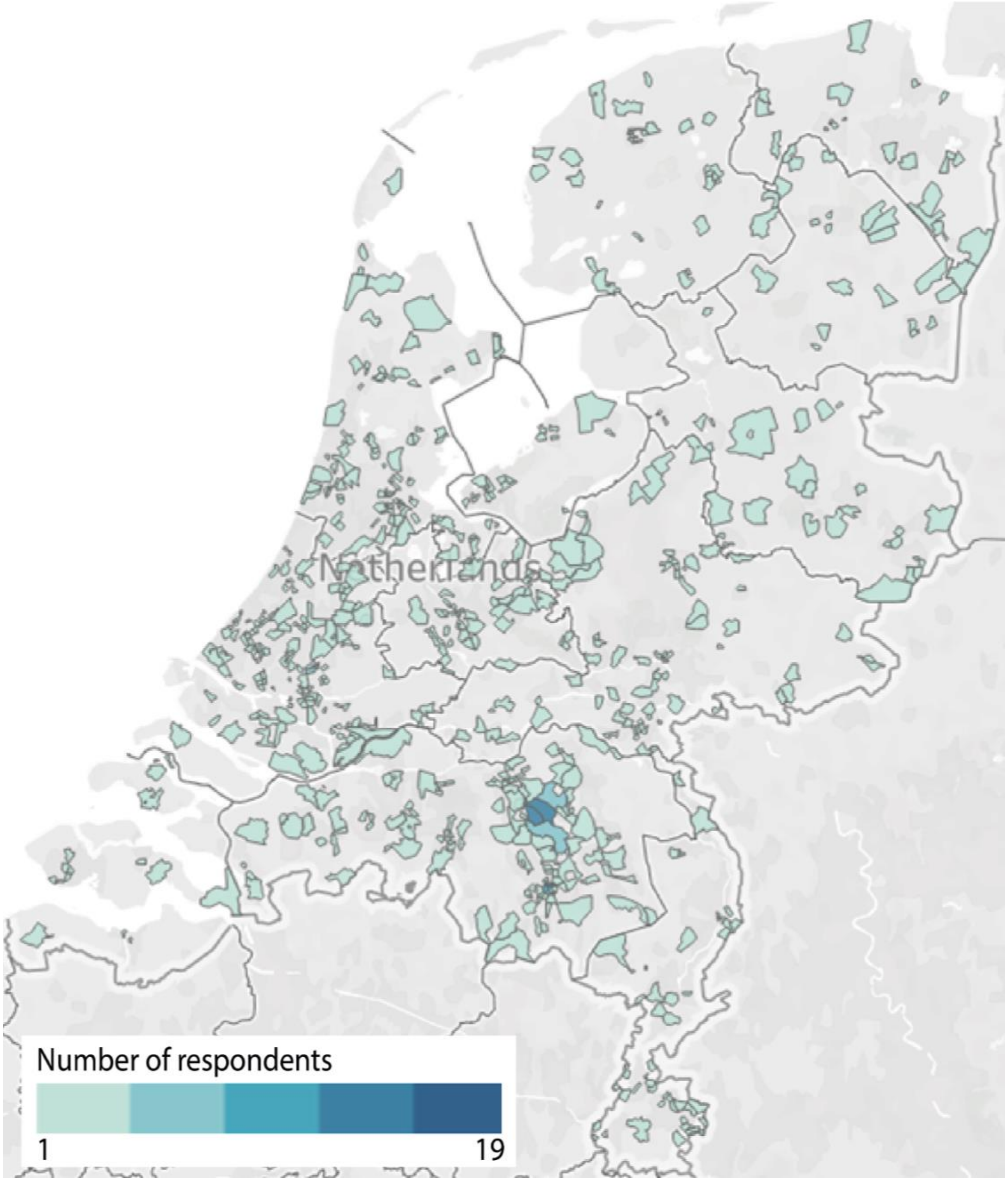


Figure 4.1: Distribution of the respondents in the Netherlands

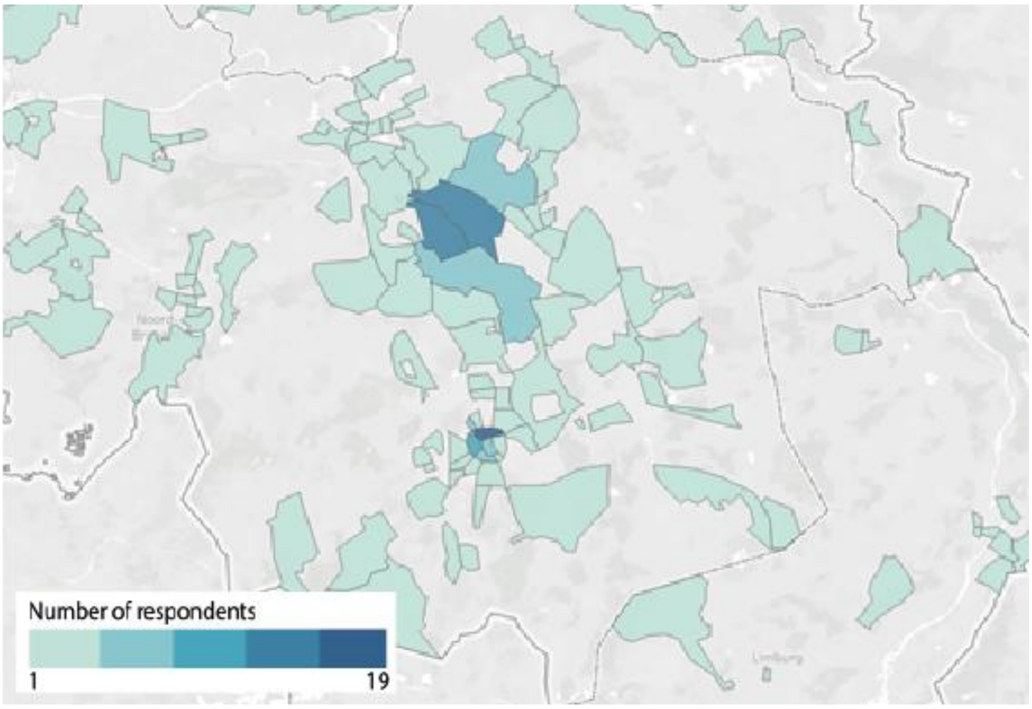


Figure 4.2: Distribution of the respondents in eastern Noord-Brabant

4.4.2 Travel characteristics

Not only questions about socio-demographics are asked, but also questions about travel characteristics. The results are shown in table 4.4 and 4.5. Some categories are minimized to ensure a sufficient number of observations per category. The original categories are shown in appendix F2.

Table 4.4: The travel characteristics of the respondents

Variable	Category	Frequency	%	% of NL
Driving license	No	83	9.2	20[1]
	Yes	819	90.8	80[1]
Car ownership	None	198	22.0	
	One car	611	67.7	
	Two or more cars	93	10.3	
Lease car	None	811	89.9	
	Lease car	91	10.1	
Household car ownership	None	73	8.1	
	One car	394	43.7	
	Two or more cars	188	20.8	
	Single household (these respondents did not answer this question)	247	27.4	

PT membership	None	556	61.6	
	PT Membership	346	38.4	
Willingness to use shared mobility	Already a user of shared mobility	127	14.1	
	Certainly	79	8.8	
	Maybe	428	47.5	
	Never	268	29.7	

1: (CBS, n.d.)

Table 4.5: The travel characteristics of the respondents

Variable		
Number of driving licenses in the household	Valid	655
	Missing	247
	Mean	2.2
	Median	2.0
	Std. Deviation	1.3
	Minimum	0
	Maximum	20
Price current car (€)	Valid	704
	Missing	198
	Mean	16760
	Median	12500
	Std. Deviation	13842
	Minimum	2750
	Maximum	80000
Price willing to pay for a new car (€)	Valid	822
	Missing	80
	Mean	15763
	Median	12500
	Std. Deviation	13092
	Minimum	2750
	Maximum	80000

First a question about driving license is asked. The majority of the respondents has a driving license. Only 9.2% of the sample does not have a driving license. In the Netherlands 80% of the inhabitants older than 17 years old has a driving license (CBS, n.d.). The variable is not representative for the Netherlands.

Car ownership is the second variable related travel characteristics. 22% of the respondents does not own a car. A majority of the respondents has one or more cars (78%). 67.7% of the respondents own one car. A small number of respondent (10.3%) owns two or more cars.

Only few respondents lease a car. 3.7% and 6.4% of the respondents lease respectively a company lease car and private lease car. These values are rather small, so the two categories are merged. The transformed variable consists of 10.1% car leasers and 89.9% of the sample does not lease a car.

The respondents are also asked to indicate how many cars are owned by the household members. This question is not asked to the respondents with a one person household (27.4%). These respondents indicated the number of cars they own in a previous question. The majority of the multiple person households owns one car or more cars (88.9%). Most of these household households own one car. 11.1% of the multiple person households does not own a car.

The respondents indicated the number of household members having a driving license. The single households are excluded from this question. The detailed results are shown in table 4.5. Most multiple person households have two household members with a driving license, because most household compositions are couples. On average, 2.2 persons have a driving license in a multiple person household. The maximum number of driving licenses is 20 licenses. This is probably a multiple person household, but not a family. Which is a category merged with 'other' household.

The section continues with the price the respondents paid for their car. The details of the variable are shown in table 4.5. On average the respondents paid €16,760 for their car. Half of the respondents paid less than €12,500 for their car. The purchase price of €20,000 is most popular. Furthermore, purchase prices below €20,000 have a high number of respondents. Only few respondents (14.5%) paid more than €20,000 for their current car.

Later a question asks the respondents what they are willing to pay for a future car. The answer is used to calculate the value for the purchase price of an AV. Purchase prices of €20,000 and €7,500 are most popular. The respondents not owning a car also indicated what they are willing to pay for a car, when they need a car. Which might explain the popularity of the purchase price €7,500. Since these respondents are probably not willing to pay a high purchase price for their future car. On average respondents are willing to pay €15,763 for their future car. This value is lower than the current purchase prices of the cars of the respondents. Some respondents indicated that they are not willing to purchase a car. If these respondents own a car, then the answer on the question about the purchase of the current car is used in this variable.

Only few categories of public transportation memberships sufficiently are represented. Therefore, all the public transportation memberships are merged into one category, PT (public transportation) membership. Many respondents do not have a public transportation membership and 38% of the respondents has a public transportation membership.

A question about willingness to use shared mobility is asked to define which respondents answers the choice tasks of the SACE. The respondents that already used shared mobility did not answer this question. 14.1% of the respondents already used shared mobility. Only 8.8% of the respondents is certainly willing to consider using shared mobility. Almost half of the sample would maybe consider using shared mobility. 29.7% of the respondents would never consider using shared mobility.

4.4.3 Usage of different of transportation modes

Table 4.6 shows how often the respondent use nine different kinds of transportation modes. The answers are related to the question displayed in appendix C1. Almost all the variables are transformed from five to four categories. The original frequencies for all five categories are shown in appendix F3.

Table 4.6: Usage of different transportation modes

Variable	Category	Frequency	%
Car as driver	4 or more days per week	366	40.6
	1 to 3 days per week	255	28.3
	1 to 4 days per month	102	11.3
	Never	179	19.8
Car as a passenger	1 or more times per week	296	32.8
	1 to 4 days per month	272	30.2
	1 to 10 days per year	228	25.3
	Never	106	11.8
Train	1 or more times per week	156	17.3
	1 to 4 days per month	125	13.9
	1 to 10 days per year	360	39.9
	Never	261	28.9
Bus/Metro/Tram	1 or more times per week	135	14.9
	1 to 4 days per month	154	17.1
	1 to 10 days per year	312	34.6
	Never	301	33.4
Bike	4 or more days per week	352	39.0
	1 to 3 days per week	187	20.7
	1 to 4 days per month	92	10.2
	Never	271	30.0
Scooter, motor or E-bike	4 or more days per week	92	10.2
	1 to 3 days per week	62	6.9
	1 to 4 days per month	58	6.4

	Never	690	76.5
Walking	4 or more days per week	405	44.9
	1 to 3 days per week	254	28.2
	1 to 4 days per month	122	13.5
	Never	121	13.4
Shared mobility	Using shared mobility	127	14.0
	Never	775	85.9
Other	4 or more days per week	4	0.4
	1 to 3 days per week	2	0.2
	1 to 4 days per month	2	0.2
	Never	894	99.1

Car as driver, bike usage and walking are the most often used transportation modes. Public transportation, scooter/motor/e-bike and shared mobility are not often used. Only 14% of the respondents uses shared mobility. Most of these respondents only uses shared mobility a few times per year. Shared mobility is the least often used transportation mode. The variable is transformed from five categories to two categories.

Walking is the most often used transportation mode. Almost half of the respondents indicated to walk one to four times per week. Only 13.4% of the respondent walks one to 10 times per year or never. The transportation mode walking is the third most often used transportation mode in the Netherlands (CBS, 2018d).

The second most often used transportation mode is car as driver. Car as driver is the most often used transportation mode used in Netherlands (CBS, 2018d). Two third of the respondents use car as driver one or more times per week. Few respondents use car as driver one to four times per month (11.3%). Only 19.8% of the sample uses car as driver one to ten times per year or never.

Car as a passenger is a less often used transportation mode. 32.8% of the respondent use car passenger one or more times per week. Approximately one third of the respondent uses car as driver a few times per month. 25.3% of the sample uses car as a passenger a few times per year. Only a few respondents (11.8%) never uses car as a passenger as transportation mode. In the Netherlands 14% of the trips are made as car passenger (CBS, 2018d).

Public transportation usage is not represented well. The categories four or more days per week and one to three times per week car are combined both for train and bus/metro/tram usage. Slightly more respondents use the train as transportation mode. Still approximately 16% of the respondents uses public transportation one or more times per week. A few respondents uses train and bus/tram/metro a few times per month (13.9% and 17.1%

respectively). Moreover, respectively 35% and 40% respondents use bus/train/metro and train occasionally. Roughly 30% of the respondent never uses public transportation. In the Netherlands 6% of the trips are made by train, bus, tram or metro (CBS, 2018d).

The bike is the third most often used transportation mode. In the Netherlands the bike is the second most often used transportation mode. 27% of the trips are taken by bike in the Netherlands (CBS, 2018d). In this sample, 39% of the respondents uses the bike four or more times per week. 20% of the respondents uses the bike one to three times per week. 30% of the sample uses the bike a few times per year or never.

Only few respondents use the scooter, motor or E-bike as transportation mode. 10% of the respondents uses one of the vehicles four or more times per week. The majority of the sample never uses these vehicles. The transportation modes are comparable to moped, which is used 1% of the trips in the Netherlands (CBS, 2018d).

Finally, the transportation mode 'other', most of the answers on this question are changed and are added to the existing transportation modes. Only eight persons use another transportation mode. These are the following transportation modes: Segway, electrical wheelchair and (local) taxi. The variable is not used for further analysis, since the response rate is low.

4.4.4 Reference trips

The reference trips give also valuable information for further analysis. In total 773 respondents filled in the SACE. Each of these respondents indicated four trips, resulting in 2946 reference trips (some reference trips are deleted, section 4.2). The information of the reference trips is shown in table 4.7 and 4.8. Low response rates of some categories are covered by adding them to other categories. The original categories are shown in appendix F4.

Table 4.7: Information about the reference trips

Variable	Category	Frequency	%
Transportation mode	Car	2265	76.9
	Train	377	12.8
	Bus	258	8.8
	Shared mobility	46	1.6
Travel purpose	Work	580	19.7
	Social/leisure	1297	44.0
	Groceries/shopping	636	21.6
	Other	433	14.7
Travel pressure	Not in a hurry	2287	77.6

	A bit in a hurry	470	16.0
	In a hurry	189	6.4
Travel companion 1	With others	1426	48.4
	Alone	1520	51.6
Travel companion 2	Nobody	1520	51.6
	Family	981	33.3
	Friends/acquaintances /colleagues	364	12.4
	Other	81	2.7
Travel with kids	No kids	2719	92.3
	With kids	227	7.7
Travel costs by PT	Transportation mode is not PT	2322	78.5
	Nothing	111	3.8
	Other, namely €…	391	13.2
	I don't know	133	4.5
Parking costs	Transportation mode is not car	635	21.5
	Nothing	2052	69.4
	Other, namely €…	182	6.2
	I don't know	88	3.0

Table 4.8: Information about the reference trips

Variable		
Travel distance (km)	Valid	2946
	Mean	42.049
	Median	20.000
	Std. Deviation	58.6076
	Minimum	.3
	Maximum	600.0
Travel time (minutes)	Valid	2946
	Mean	44.76
	Median	30.00
	Std. Deviation	44.360
	Minimum	1
	Maximum	360
Access time (minutes)	Valid	635
	Missing	2311
	Mean	7.77
	Median	5.00
	Std. Deviation	7.068

	Minimum	0.0
	Maximum	60.0
Egress time (minutes)	Valid	635
	Missing	2311
	Mean	7.23
	Median	5.00
	Std. Deviation	7.402
	Minimum	0
	Maximum	102
Waiting time (minutes)	Valid	635
	Missing	2311
	Mean	9.67
	Median	5.00
	Std. Deviation	9.893
	Minimum	0
	Maximum	100

First the indicated the transportation mode they used during the reference trip. The categories car as driver and car as a passenger are combined, because the transportation modes are similar; the new variable is car. The majority of the trips are taken by car (76.9%). Less trips are taken with public transportation (21.6%). 12.8% of the trips were taken by train and 8.8% of the trips are made with the bus, metro or tram. Only a few respondents travel with shared mobility (1.6%).

The second variable related to the reference trips is travel purpose. Seven categories are merged into four categories. The categories work and groceries/shopping remain the same. Social activities and leisure are merged to one category, because both purposes are similar. The category ‘other’ is a combination of the purposes education, dropping off/picking up and ‘other’. Only a few trips one of these purposes. Therefore the categories are merged. 14.7% of the trips are made for ‘other’ purpose. Most respondents indicated a social or leisure activity as purpose of the reference trip (44%). Doing groceries/shopping and going to work have approximately the same number of responses (respectively 21.6% and 19.7%). Surprisingly, the purpose work is not often chosen. However traveling to or from work is part of the daily travel pattern of many people. Nevertheless, the respondents are asked to indicate trips with different purposes. Therefore, most of the times work can only be indicated once. Which explains that only 19.7% of the trips have work as purpose.

The variable travel pressure had initially five categories. These categories are transformed into three categories. Not being in a hurry is similar to not at all being in a hurry. Therefore these categories are merged. Furthermore, only a few respondents indicated being in a big hurry. This category is merged with the category in a hurry. Most of the respondents

(77.6%) were not in a hurry during the reference trip. Few respondents were a bit in a hurry (16%). Only 6.4% of the respondents were in a hurry.

Two questions are asked about travel companion. First is asked if the respondent traveled alone or not. Afterwards is asked about the travel companion of the respondents, when traveling with others. A bit more than half (51.6%) of the respondents traveled alone. Most of the trips with travel compaction were taken with family (68.8%). Quite some trips are taken with friends, acquaintances or colleagues (25.5%). A few trips are made with 'other' companion. All the respondents having travel companion is asked whether they traveled with children or not. Only a few respondents travel with children (7.7%).

Furthermore, questions about the travel distance and travel times are asked. The average travel distance is 42 kilometers. However, half of the respondents traveled less than 20 kilometers during the reference trips. The minimum distance is 0.3 kilometers and the maximum distance is 600 kilometers. The average travel time is 44.8 minutes. The median travel time is 30 minutes, so half of the reference trips took less than 30 minutes. The minimum travel time was one minute and the maximum travel time was 360 minutes. A maximum travel time of six hours is used in order to remove the outliers for both variables. Figure 4.3 shows how the travel times and travel distances are distributed among the sample. Most respondents have relatively low travel times and low travel distances. The travel time and travel distance show almost a linear relationship.

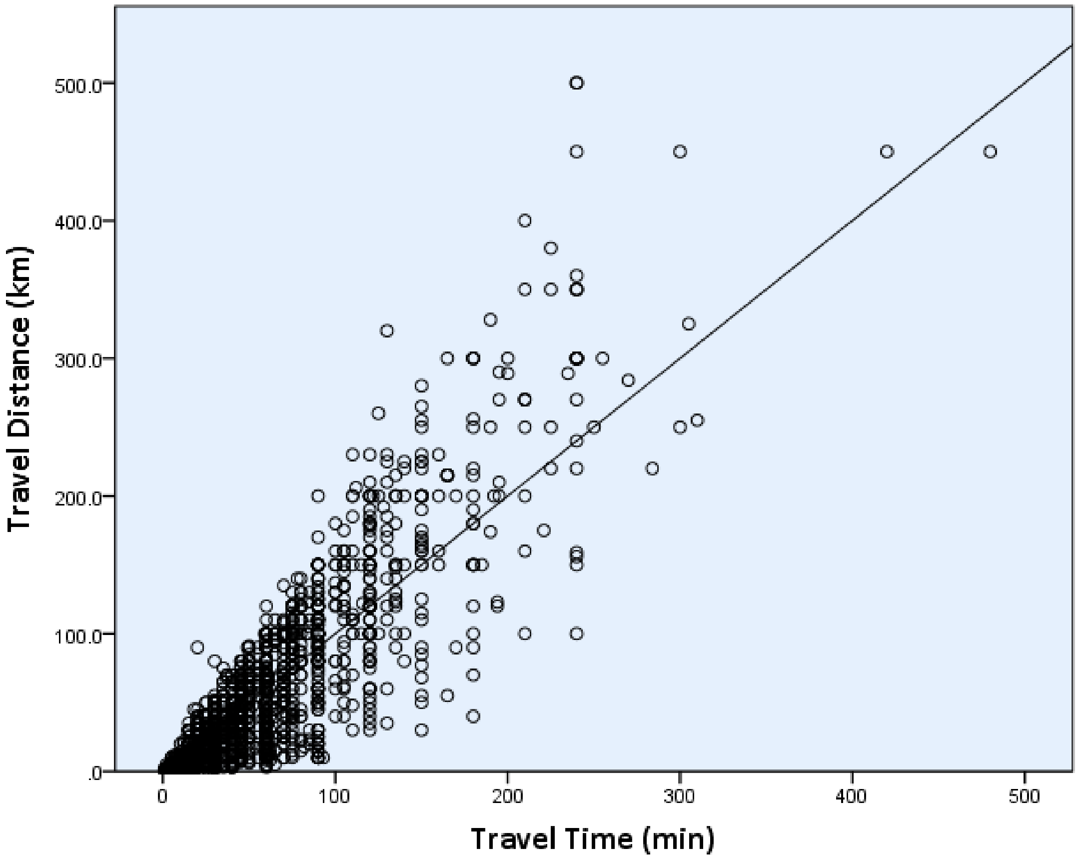


Figure 4.3: Distribution of travel time and travel distance

635 reference trips are taken by public transportation. The respondents indicated the access time, egress time and waiting time. The distributions of these times are shown in table 4.8 and figure 4.4. The average access time is 7.8 minutes and half of the respondents has an access time less than 5 minutes. The variable egress time has similar results as the access time, but has a higher maximum (102 minutes). The average egress time is 7.2 minutes and the median is also 5 minutes. Finally the waiting time, the average waiting time was 9.7 minutes. However, half of the respondents waited less than 5 minutes during their reference trips. The maximum waiting time is 100 minutes. The reference trips with an access, egress or waiting time longer than 110 minutes are deleted.

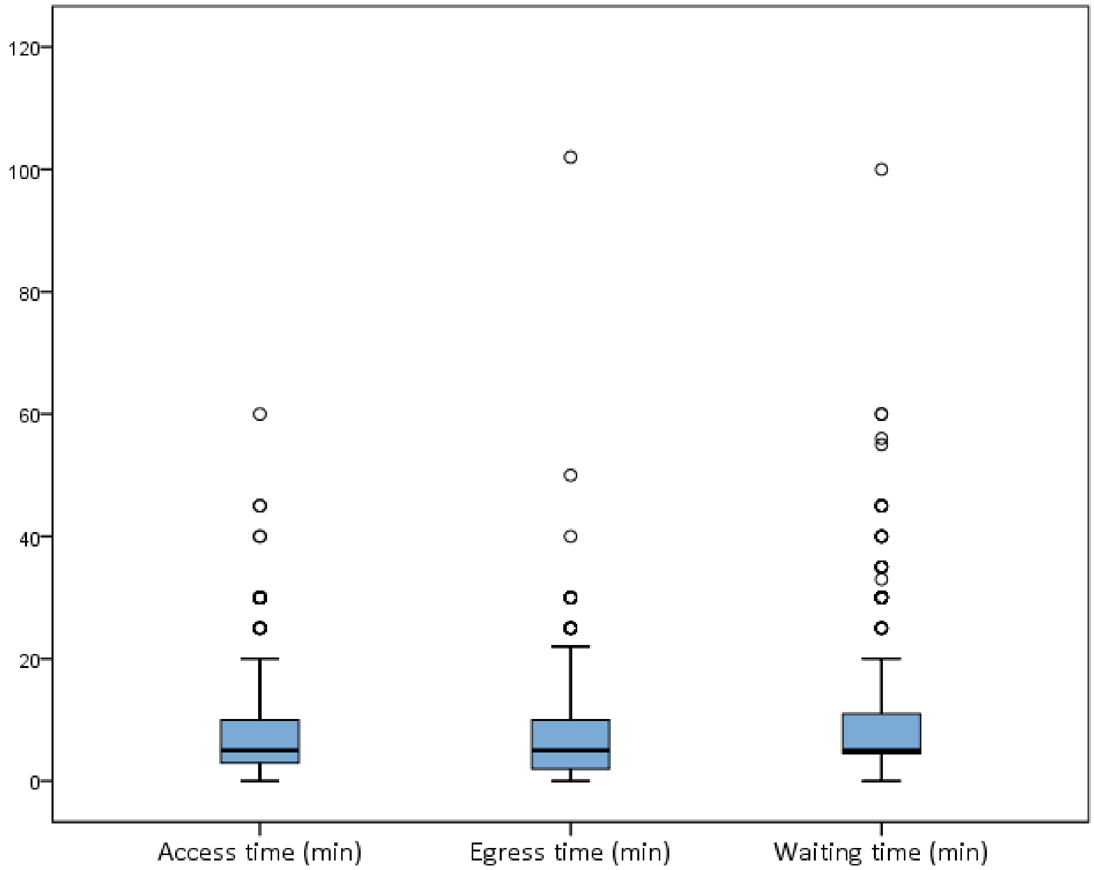


Figure 4.4: Distribution of access time, egress time and waiting time

4.5 conclusion

Before the main study is conducted a pilot study is conducted. The pilot study tests the sufficiency of the choice experiments and questionnaire. An online questionnaire is made with LimeSurvey. The questionnaire is distributes on the 25th of June 2019. 51 respondents reacted on the questionnaire of the pilot study. A bit more than half of the respondents is willing to adapt an owned AV. The results of the SACE show that 71% of the respondents wants to use SAV. The SAR is chosen 22% of the time. APT is chosen 7% of the time. The experimental design is changed after the pilot study. Some other small changes are also made to improve the questionnaire of the main study.

Data for the main study is collected via the online platform LimeSurvey. Data is collected between the 1^{st} till the 23^{nd} of August. Two ways are used to collect data: a paid online panel and a personal network. The main research has a sample size of 902 respondents. After data gathering the dataset is cleaned and prepared for further analysis. Exploratory analysis is conducted. The results of the following aspect are explored: socio-demographics, travel characteristics, the question about usage of different transportation modes and reference trips. Some of the results are representative for the population of the Netherlands. However, the representativeness of the Netherlands is only tested for a few variables, due to the availability of the data.

5. Analysis and results

5.1 Factor analysis of the attitudes

The attitudes in this research are the unobservable variables, also called latent variables. These variables cannot be directly measured. The statements included in this research are used to explain the attitudes. The statements are the observable variables, also called indicators. Factor analysis explores joint variations in response to latent variables (Schreiber et al., 2006). The technique is used to reach an understanding of the relations between the indicators, by estimating the number and nature of common factor (Hayton et al., 2004). The goal of factor analysis is to find the best model fit for the latent variables (Hooper et al., 2008).

19 statements are tested with a five point Likert scale. The statements investigate four attitudes: attitude towards car ownership, willingness to use car sharing, attitude towards ride sharing and attitude towards sustainability. The statements of the latent variables, including means and standard deviations, are shown in table 5.1. Factor analysis is used to examine the relations between the statements and attitudes. First explanatory factor analysis is executed (section 5.1.1), afterwards the results of the EFA are used to conduct confirmatory factor analysis (section 5.1.2).

Table 5.1: Results of the statements

	Attitude	**Statement**	**Mean**	**Std. Dev.**
1	Car ownership	I only have a car to drive from A to B	3.43	1.164
2	Car ownership	If I find a transportation mode equal convenient as the car, I would not need a car	3.44	1.079
3	Car ownership	A car gives me status and prestige	2.23	1.017
4	Car ownership	I think the car has practical functions only	3.58	1.005
5	Car ownership	I feel free and independent if I own a car	4.08	0.910
6	Car sharing	I think shared mobility will makes me more dependent	3.78	0.962
7	Car sharing	I would use shared mobility if it doesn't take more time	3.14	1.050
8	Car sharing	I would use shared mobility if it doesn't cost me extra money	3.33	1.098
9	Car sharing	I would use shared mobility if it gives me the same comfort as owning a car	3.33	1.054
10	Car sharing	I would use shared mobility if it is easy to order a ride or car	3.39	1.054
11	Ride sharing	I think it is pleasant to meet new people in the train or bus	2.76	0.999
12	Ride sharing	I think it is uncomfortable when strangers are in close proximity of me in the train or bus	3.32	1.054
13	Ride sharing	I trust other travelers during a ride with public transportation	3.23	0.850
14	Ride sharing	When I'm traveling with public transportation, I'm concerned that strangers will look at my smartphone or laptop	2.54	1.025
15	Sustainability	For me it is important to use a sustainable transportation mode	3.33	0.936

16	Sustainability	I'm concerned about the negative environmental effects of car use	3.28	1.013
17	Sustainability	Being environmentally responsible is an important part of who I am	3.30	0.923
18	Sustainability	My attitude towards sustainability influences my behavior.	3.22	0.942
19	Sustainability	It is important for me to make environmental friendly decisions	3.45	0.931

5.1.1 Exploratory factor analysis

Exploratory factor analysis (EFA) explores the influence of the indicators on the latent variables. The method investigates clusters of indicators, which have a high correlation with each other. EFA is also used to find the number of latent variables and indicators that are related to each other. Each indicator gets a factor loading. The factor loading is the Pearson correlation between the factor and the variable (Field, 2009). The factor loading is the level of association of the variable and the factor. The factor loading represents the variance defined by the variable of the factor. A minimum factor loading of 0.5 is often used during exploratory factor analysis. A factor loading of 0.5 or higher shows that the latent variable derives sufficient variance from the indicator (Rasouli & Kim, 2019). Factor analysis searches for common underlying relations, so common variance of the indicators has high influence on the results (Field, 2009). The eigenvalue explains the variance of the particular factor depending on the total variance. The eigenvalue is used to identify the number of factors. If the eigenvalue is higher than one, then the factor exists (Rasouli & Kim, 2019). The loading of the indicators on the latent variables can be calculated, after determining the number of latent variables. Most of the indicators have a high factor loading with the most relevant latent variable and low factor loadings with other latent variables. These results make the interpretation of the results difficult. Rotation is used to solve this problem. The technique discriminates between factors. Rotation ensures a maximal factor loading of the indicators on all latent variables (Field, 2009).

18 indicators are used in the exploratory factor analysis. Indicator two is not added in the final EFA, because the indicator was not significant. Varimax rotation is used to estimate the factor loadings. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy is 0.849, which is an excellent result for the EFA. The Bartlett's Test of Sphericity gives a significant result, because the chi-square is 7034.2 and the degrees of freedom are 153.

The final results of the EFA are shown in table 5.2. The indicators in the first column symbolize the statements in table 5.1. The output has five latent variables, but four latent variables are expected from the analysis. Statement five and six explain this results. Those statements are both related to the dependency on a transportation mode. Dependency becomes the fifth latent variable. The five latent variables explain 66.2% of the variance. The latent variable related to sustainability explains 21% of the variance, car sharing explains 17.6%, car ownership explains 9.6%, ride sharing explains 9.5% and dependency explains 8.4% of the variance. All communalities are higher than 0.4, this is a sufficient result.

Indicator 14 has a factor loading lower than 0.5. This indicator is related to attitude towards ride sharing. The indicator is added to the confirmatory factor analysis. In order to be able to investigate its influence on the latent variables.

Table 5.2: Results of exploratory factor analysis

	Sustainability	Car sharing	Car ownership	Ride sharing	Dependence	Communality	Eigenvalue	% of Variance
Indicator 17	.884	.050	.059	.093	-.015	0.796	3.786	21.032
Indicator 19	.879	.074	.013	.081	-.033	0.786		
Indicator 18	.853	.094	-.073	.075	-.072	0.754		
Indicator 16	.817	.166	.029	.047	-.144	0.719		
Indicator 15	.810	.181	.003	.080	-.124	0.711		
Indicator 8	.115	.880	.034	.096	-.123	0.814	3.170	17.611
Indicator 9	.075	.866	.066	.049	.052	0.765		
Indicator 10	.180	.865	.056	.131	-.084	0.808		
Indicator 7	.132	.844	-.040	.049	-.054	0.737		
Indicator 1	-.041	.086	.730	-.039	.143	0.564	1.727	9.596
Indicator 4	.062	.033	.716	.111	.247	0.591		
Indicator 3	-.043	.002	-.716	.027	.349	0.638		
Indicator 13	.151	.093	.048	.722	-.006	0.555	1.718	9.546
Indicator 12	-.022	-.043	-.027	-.689	.188	0.513		
Indicator 11	.163	.209	-.111	.650	.083	0.512		
Indicator 14	.093	.133	-.349	-.449	.269	0.422		
Indicator 5	-.112	-.021	.023	-.055	.800	0.656	1.509	8.385
Indicator 6	-.178	-.163	.103	-.138	.694	0.569		

5.1.2 Confirmatory factor analysis

Confirmatory factor analysis (CFA) is a theory driven technique, used to analyze the relationship between observed and unobserved variables (Schreiber et al., 2006). CFA analyzes the validity of the indicators. CFA is used to test multiple relations of indicators and latent variables. These relationships can be seen as hypotheses. The EFA of this research is the hypothesis for the CFA. Multiple aspects are analyzed during the CFA. First the factor loadings of the indicators are determined. The construct validity is also examined, specifically the convergent and discriminant validity are used to assess the results of the CFA. The convergent validity analyzes to what extend the indicators are correlated with the latent variable. Two measures are used: the composite reliability (CR) and the average variance extracted (AVE) (Rasouli & Kim, 2019). The CR should be higher than 0.6 and the AVE should be greater than 0.5 (Ahmad et al., 2016). The discriminant validity should show that the latent variables are not related to each other. A model has a poor discriminant validly, when the correlation between two latent variables is higher than the square root of one of the AVEs (Rasouli & Kim, 2019). Finally the goodness of fit of the model is tested during the CFA. Multiple fit indices are used to determine the model fit. The recommended thresholds for the fit indices are: chi square / degrees of freedom < 3.0, RMSEA < 0.07, GFI > 0.95, AGFI > 0.95, CFI > 0.95, TLI > 0.95 and NFI > 0.95 (Hooper et al., 2008).

Amos is used to conduct the CFA. Multiple combinations of the latent variables and the indicators are tested during the analysis. The willingness to use car sharing is removed from the analysis, because the attitude is strongly related to the choices and considerations of the respondents during the choice experiments. Consequently, four latent variables and 14 indicators are analyzed. The following attitudes are added to the CFA: attitude towards sustainability (1), attitude towards car ownership (2), attitude towards sharing a ride (3) and dependency (4). The results of the CFA with four latent variables and all 14 indicators are shown in figure 5.1, table 5.3, table 5.4 and appendix G1. The results of this CFA are not yet sufficient.

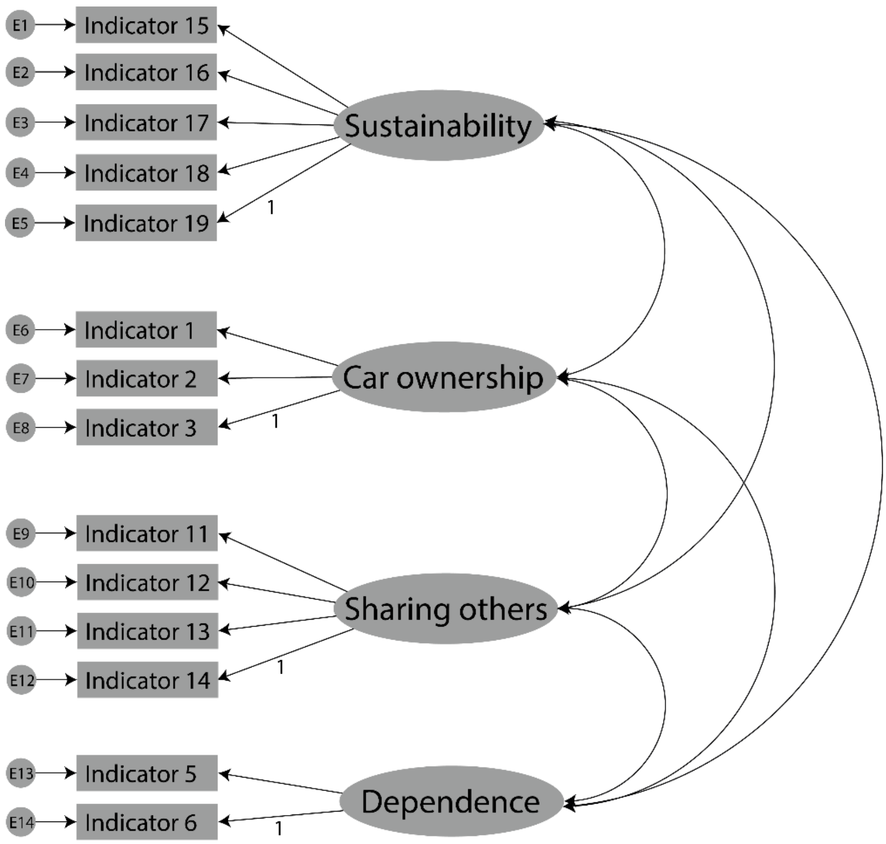


Figure 5.1: Structure of CFE of the starting model

Table 5.3: CFA results of the starting model

		Estimate	CR	AVE
Indicator 19	Sustainability	0.862	0.916	0.687
Indicator 18	Sustainability	0.836		
Indicator 17	Sustainability	0.86		
Indicator 16	Sustainability	0.795		
Indicator 15	Sustainability	0.788		
Indicator 4	Car Ownership	0.715	0.293	0.337
Indicator 3	Car Ownership	-0.395		

Indicator 1	Car Ownership	0.587		
Indicator 6	Dependence	0.761	0.587	0.424
Indicator 5	Dependence	0.518		
Indicator 14	Share with others	0.301	0.029	0.243
Indicator 13	Share with others	-0.606		
Indicator 12	Share with others	0.511		
Indicator 11	Share with others	-0.504		

Model fit: chi square / degrees of freedom = 4,723, RMSEA = 0.064, GFI = 0.949, AGFI = 0.925, CFI = 0.936, TLI = 0.936, NFI = 0.920

Table 5.4: Correlation and discriminant validity of the starting model

	Sustainability	**Car Ownership**	**Dependence**	**Share with others**
Sustainability	**0.829**			
Car Ownership	0.033	**0.581**		
Dependence	-0.341	0.142	**0.651**	
Share with others	-0.321	-0.131	0.385	**0.493**

The process for finding the best model is shown in appendix G2. Eight models are analyzed in total. The attitude towards car ownership has an insignificant indicator in model three, so the attitude is removed from the CFA. Attitude towards ride sharing and dependency did not reach sufficient CR and AVE. Therefore these two latent variables are deleted from the CFA. Only attitude towards sustainability remains in the final model. The final model of the CFA is displayed in figure 5.2 and table 5.5. The unstandardized output, including standard error and significance, is displayed in appendix G3. The model consists of five indicators and one latent variable. The CR and AVE are higher than the on beforehand set criteria of 0.6 and 0.5, respectively. The goodness of fit indices indicate a sufficient model. The model has high factor loadings, the standardized factor loadings are between 0.760 and 0.869.

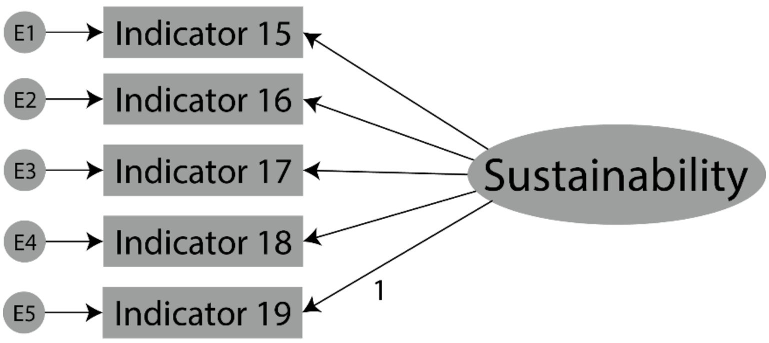


Figure 5.2: Structure of final model of the CFE

Table 5.5: Results of final model of the CFA

		Estimate	CR	AVE
Indicator 19	Sustainability	0.869	0.91286	0.67766
Indicator 18	Sustainability	0.845		
Indicator 17	Sustainability	0.867		
Indicator 16	Sustainability	0.768		
Indicator 15	Sustainability	0.760		

Model fit: chi square / degrees of freedom = 1.520, RMSEA = 0.024, GFI = 0.997, AGFI = 0.990, CFI = 0.999, TLI = 0.998, NFI = 0.998

5.2 Hybrid choice model

5.2.1 Background

Research has tried to improve the discrete choice models. The improvement should ensure a more representative prediction of choices and better understanding of choice behavior of individuals (Walker & Ben-Akiva, 2002). In order to do so, 'soft' variables, like attitudes and opinions, are added to these models. The 'soft' variables are latent variables. Latent variables cannot directly be measured. A choice model with latent variables is a hybrid choice model. The hybrid choice model is an extended discrete choice model. Discrete choice models analyze individual choices among a sample and investigate people's utility towards certain alternatives (Hensher et al., 2015).

The standard random utility model assumes that individuals derive utility from the chosen alternative. The explanatory variable (X) and choice (Y) are the observed variables, the utility (U) is an unobserved variable. The choice of the individual is depending on the utility the individual derives from the alternative. The utility can be determined according to the following formula (Walker & Ben-Akiva, 2002):

$$U_{in} = X_n * \beta_x + \varepsilon_n \quad (5.1)$$

U_n is the utility of respondent n. X_n represents the explanatory variables, which are the observed exogenous variables. β is the vector of the unknown parameters and ε_n is the random disturbance for alternative and the respondent. Random utility modeling is based on maximization of the utility. If the individual chooses alternative i instead of alternative j, then the following formula is applicable (Walker & Ben-Akiva, 2002):

$$U_{in} \geq U_{jn} \quad (5.2)$$

The structure of the hybrid choice model of this research is presented in figure 5.3. The observable variables of the model are the explanatory variables, the attributes of the alternatives, the indicators and the choices. The unobservable variables are the latent variables, disturbances and utilities. The model provides exhaustive flexibility, makes it possible to combine models and is computationally feasible (Walker & Ben-Akiva, 2002).

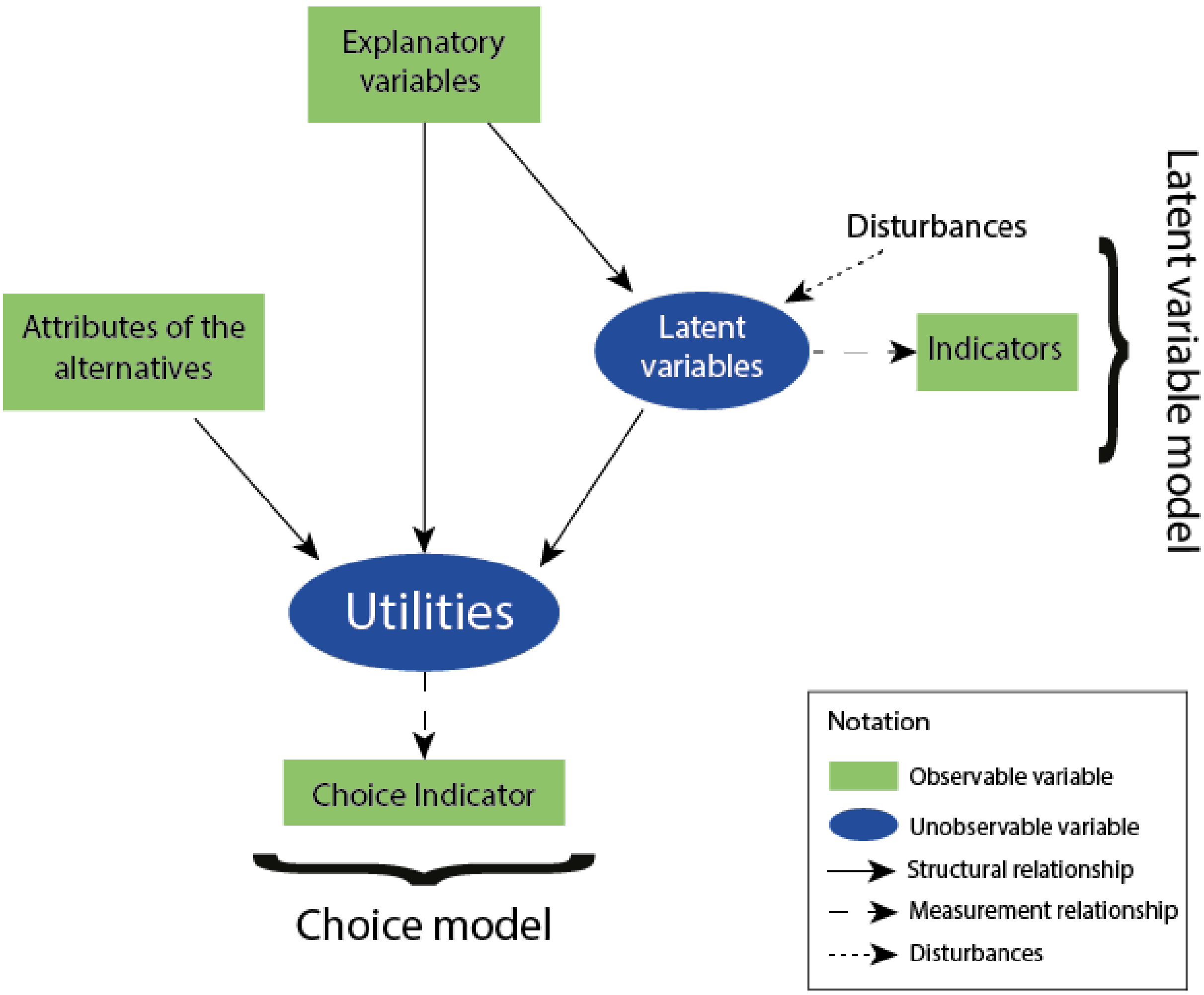


Figure 5.3: Structure of hybrid choice model

Attitudes, personality and opinions are often used in behavioral science to analyze psychological factors. However, these latent variables cannot be directly measured. Latent variables are unobservable variables and have no direct measurement technique. Latent variable modeling techniques are used to get the information form the latent variables. Indicators are used to describe latent variables. Indicators are attitudinal or personality statements used to investigate the latent variable. The indicators are used to determine the relationship of the indicators on the latent variable. The latent variable model is presented in the right part of figure 5.3. The model consists of latent variables, indicators and disturbances. These elements represent the latent variable model. The utility is calculated according to the following choice model (Walker & Ben-Akiva, 2002):

$$U_n = X_n * \beta_x + L_n * \beta_L + M_{nq} * \beta_M + \varepsilon_n \quad (5.3)$$

L_n is the latent variable of respondent n, M_{nq} represent the attributes of the alternatives. The latent variable is calculated according to a structural equation (Kim, Rasouli, & Timmermans, 2014):

$$L_n = \Gamma^L X_n + \omega_n \quad (5.4)$$

The latent variable (L_n) is depending on: the explanatory variables (X_n), the parameter (Γ^L) and the disturbance is $\omega_n \sim D(\theta_\omega)$. The model cannot be estimated without observable variables describing the latent variables. The indicators are the observable variables. The indicators are investigated with the measurement equation (Walker & Ben-Akiva, 2002):

$$I_n = \Lambda^I L_n + \nu_n \quad (5.5)$$

The equation describes the indicators of respondent n (I_n). The indicators are depending on the latent variables (L_n), a set of parameters (Λ^I) and the disturbance $\nu_n \sim D(\theta_\nu)$ (Walker & Ben-Akiva, 2002).

5.2.2 Modeling software

The hybrid choice models of this research are calculated with Apollo. Apollo is a free software package, which is implemented by using the programming language R. Apollo is an easy to use tool and the system is transparent and accessible. The users can decide by themselves to view as much or as little detail of the underlying system. Apollo enables generation of simple models, but the user can extent a model and make it as complex as preferred. Apollo is a flexible, customizable and easy to use software package (Hess & Palma, 2019).

The codes generating the results of the hybrid choice models are shown in appendix H. Code 1 is used to generate the results of the SCE. Code 2 does this task for the results of the SACE. Both codes are similar to each other. Quite often a hashtag appears in the code, meaning that Apollo will not use the input written after the hashtag. Which makes it easy to include or exclude certain variables. Furthermore all function names related to Apollo start with 'Apollo_'.

All the estimated variables are effect coded, except from a few variables having ratio measurement levels. The effect coded variables have 'the number of levels minus one' columns in the program. Which means that one level has no designated column. This is the base level, the base level is coded with -1. The value of the base level is manually calculated, according to the outcomes of the other levels. For example, the variable age, age has four categories. The category 75 or older is the base level. Table 5.6 shows how the variable age looks like in the data set.

Table 5.6: Example of effect coded variables

Age of respondent:	Age 18-34	Age 35-54	Age 55-74
18-34 years old	1	0	0
35-54 years old	0	1	0
55-74 years old	0	0	1
75 years old or more	-1	-1	-1

Only the attitude sustainability is used in the hybrid choice model. The reason is explained in section 5.1. The five statements are tested with a five point Likert scale. The values are transformed. The new value is: the old value minus the mean of the indicator. The new values are centered in proximity to zero. The respondents with neutral attitudes have values around zero. The value of a statement is negative when a respondent disagrees, and the value is positive when the respondent agrees with a statement. The values can be normally distributed by centering the values to zero. Which makes further research less complicated.

The structural equation of the latent variables is added as continuous random coefficient in Apollo. Inter individual mixing is applied for the random coefficient, so the latent variable is analyzed per respondent. The random coefficients are further explained below. The following structural equation is used in the model:

$$Randcoeff[Sus] = mu_{sus} + sig_{sus} * \eta_{sus} \quad (5.9)$$

The formula calculates the random coefficient of sustainability (sus) for each respondent. The constant (mu_{sus}) is assumed to be low, because the values are standardized around zero. Sig_{sus} is the standard deviation. The measurement equation is integrated in a normal probability density function in Apollo. The function used a normal distribution to estimate the results of the indicators. The mean is set to zero, which further explains the reason to normalize the values of the indicators to zero. The Lambda of the measurement equation is also calculated. Lambda represents the factor loading of the indicator. Lambda is dependent on the structural equation of the model. Furthermore the log likelihoods of all indicators are calculated as part of the normal probability density function.

The alternative specific constants and the standard deviation of the random panel effect are also calculated within a continuous random coefficient. The following formula is used:

$$Randcoeff[Alt_x] = mu_x + sig_x * \xi_x \quad (5.10)$$

The formula calculates the random coefficient of alternative x, the alternative specific constant (mu_x) and the standard deviation of the random panel effect (sig_x). All the random coefficients are calculated with 500 Halton draws. Inter individual draws are used, which means that the random coefficient is calculated per individual. Furthermore, the random coefficients are normally distributed.

All the utility functions have the results of the alternative specific random coefficients, as well as the random coefficients of the latent variables. Furthermore the alternative specific attributes, socio-demographics, travel characteristics (and variables related to the reference trips) are added to the utility functions. The socio-demographics and travel characteristics related to shared AV adoption (SCE) and APT (SACE) have a value of zero. Which means that these variables are the base variable. Base variables are used for identification purposes. Finally, the panel effect is taken into account when estimating the model.

5.3 Results of the stated choice experiment

A hybrid choice model is used to analyze the results of the SCE. Not all respondents match with the criteria of the SCE. Respondents that do not own a car or do not want to buy a car in the future are deleted from the SCE. 822 respondents fulfill the criteria of the SCE and answered the choice tasks. An equal distribution of the blocks is favorable for the analysis of the SCE. Table 5.7 shows the distribution of the blocks. Every block has almost an equal amount of responses, which is beneficial for further analysis. A total of 6576 observations are investigated. AV ownership is chosen 54.7% of the choice tasks and shared autonomous mobility is chosen 45.3% of the choice tasks.

Table 5.7: Distribution of the blocks of the SCE

Block	frequency	%
1	212	25.8%
2	205	24.9%
3	195	23.7%
4	210	25.5%
Total	822	

The code described in section 5.2.2 is used to generate the results of the hybrid choice model. Model generation starts with a model including almost all variables. The results of this starting model is shown in appendix I1. The starting model has a sufficient Rho^2 and Rho^2 adjusted. Many variables related to the latent variable and many attributes are significant. However, a lot of the socio-demographics and travel characteristics are insignificant. Multiple other models are generated to find more satisfying results. Appendix I2 shows the process used to find the best model. The table shows which variables are integrated in the different models. 15 models are generated in total. The 15th model is the final model. The two attributes related to reliability are transformed into one variable with four levels, since these two attribute are combined in the choice tasks (section 3.2).

The results of the final model of the SCE are shown in table 5.8, 5.9, 5.10 and 5.11. The bold text of the estimates in the tables represent significant variables. A detailed model summary is shown in appendix I3. The log likelihood is -10141.48 at the beginning of the estimation. The final log likelihood is -7208.43. The model has a Rho^2 of 0.289 and a Rho^2 adjusted of 0.284. Both have acceptable values, implying that the model explains the data fairly well. The Akaike Information Criterion (AIC) and Bayesian information criterion (BIC) of the final model are lower than the AIC and BIC of the starting model. Thus the final model has a better fit starting model. The alternative specific constant related to AV ownership has a positive value and is significant. The alternative specific constant of adoption of shared autonomous mobility is zero. Thus AV ownership is preferred over shared autonomous mobility, when not considering any other effect. The standard deviation of the random panel effect of both alternatives is significant. Which means that cross sectional heterogeneity exists among the respondents matching the criteria of the SCE.

Table 5.8: Model summary of the SCE

Model summary of the SCE

LL start	-10141.48
LL whole model	-7208.432
AIC	14512.86
BIC	14838.84
ρ^2	0.289
ρ^2 adjusted	0.284

The t-ratio is used to determine the significance of the variables in the hybrid choice model. If a variable has a t-ratio is between -1.96 and 1.96, then the variable is insignificant. Each attribute and socio-demographic variable has a base level. The base level equals -1, based on effect coding. The value of the base level is calculated according to the values of the other levels, which is the sum of the other levels multiplied by -1.

Attitude towards sustainability has significant and positive influence on the decision to adopt shared autonomous mobility. The parameter has a value of 0.7861. Thus respondents with a positive attitude towards sustainability seem more willing to adopt shared autonomous mobility. The other results related to the latent variable are shown in table 5.11. The parameter of the latent variable is simultaneously calculated. The CFA concluded that only attitude towards sustainability is sufficient for further analysis. Therefore only attitude towards sustainability is added in the hybrid choice model. The lambdas and standard deviations of the indicators are significant, which implies that the CFA is sufficiently executed. The constant of the latent variable is 0.0046, which is a small value. The standard deviation is 0.6722 and significant.

Table 5.9: Results related to the first alternative: AV ownership

Alternative 1: owned AV

			Estimate	Std.err.	t-ratio(0)
Alternative-specific constant			**2.3037**	0.7338	3.1394
Standard deviation of the random panel effect parameter			**1.5336**	0.3537	4.3354
Socio-demographic variables	Gender	Male	0.2026	0.1557	1.3013
		Female	-0.2026		
	Age	18-34 year	0.3021	0.3501	0.8628
		35-54 year	**-0.8607**	0.3204	-2.6860
		55-74 year	0.1552	0.2645	0.5868
		>75 year	0.4034		
	Occupation	Student	1.1134	0.7230	1.5400
		Work	**-2.7538**	1.1355	-2.4252
		Unemployed	**1.5073**	0.5293	2.8474

		Retired	0.1331		
	Need a car for work	Yes	**1.4452**	0.5597	2.5819
		No	**1.1809**	0.5290	2.2324
		Non-working respondent	-2.6261		
	Living environment	Urban	**-0.8678**	0.2930	-2.9615
		Slightly urban	**-0.8812**	0.3851	-2.2885
		Village	0.1179	0.3224	0.3656
		Rural	1.6311		
	Usage of car as driver	4 or more days per week	**1.0641**	0.2411	4.4126
		1-3 days per week	**0.5738**	0.2619	2.1907
		1-4 days per month	**-0.8946**	0.3437	-2.6025
		10 times per year - never	-0.7433		
Alternative-attribute variables	Purchase price	90%	**0.4868**	0.0718	6.7774
		100%	**0.2867**	0.0703	4.0780
		110%	**-0.2031**	0.0696	-2.9197
		120%	-0.5703		
	Depreciation	5%	0.0073	0.0421	0.1746
		10%	-0.0073		
	Monthly costs	decrease by 35%	**0.2099**	0.0726	2.8902
		decrease by 20%	**0.1566**	0.0707	2.2129
		decrease by 5%	**-0.1599**	0.0717	-2.2282
		increase by 10%	-0.2066		
Latent-attitude variables	N/A				

Table 5.10: Results related to the second alternative: adoption of shared AVs

Alternative 2: shared autonomous vehicle

			Estimate	Std.err.	t-ratio(0)
Alternative-specific constant	N/A				
Standard deviation of the random panel effect parameter			**-3.4391**	0.2315	-14.8587
Socio-demographic variables	N/A				
Alternative-attribute variables	Monthly membership fee	€ 0	**0.9329**	0.0735	12.6988
		€ 20	**0.4453**	0.0707	6.3023
		€ 40	**-0.4146**	0.0713	-5.8148
		€ 60	-0.9636		
	Price per km	€ 0.10	**0.5753**	0.0715	8.0477
		€ 0.20	**0.1754**	0.0706	2.4835
		€ 0.30	**-0.2299**	0.0705	-3.2598
		€ 0.40	-0.5209		
	Waiting time	1 minute	**0.4059**	0.0714	5.6859
		4 minutes	-0.0087	0.0701	-0.1237
		7 minutes	**-0.2018**	0.0713	-2.8295
		10 minutes	-0.1955		
	Reliability	80% - 20% & 2 min too early - 2 min late	-0.0576	0.0712	-0.8084
		80% - 20% & on time - 4 min late	0.0081	0.0707	0.1140
		60% - 40% & 2 min too early - 2 min late	-0.0410	0.0702	-0.5840
		60% - 40% & on time - 4 min late	0.0905		
Latent-attitude variables	Sustainability		**0.7861**	0.2004	3.9226

Table 5.11: Results of the latent variable

Latent-attitude results

			Estimate	Std.err.	t-ratio(0)
Sustainability	Constant		-0.0046	0.0235	-0.1954
	Standard deviation		**0.6722**	0.0386	17.3952
	Lambda	Indicator 1	1		
		Indicator 2	**1.1530**	0.0708	16.2779
		Indicator 3	**1.1888**	0.0694	17.1252
		Indicator 4	**1.1749**	0.0699	16.8178
		Indicator 5	**1.1953**	0.0697	17.1488
	Standard deviation	Indicator 1	1		
		Indicator 2	**0.6352**	0.0186	34.2040
		Indicator 3	**0.4682**	0.0167	28.0692
		Indicator 4	**0.5238**	0.0169	31.0490
		Indicator 5	**0.4721**	0.0167	28.2063

This section continues with a description of the attributes related to the alternatives. As well as the relevant socio-demographics having (significant) influence on the decisions made during the SCE. Figure 5.4 and table 5.9 show the statistics and the marginal utility of the attributes related to AV ownership. The attribute purchase price has significant influence on the decision to buy an AV. If the purchase price becomes higher, then respondents are less eager to buy an AV. The purchase price is the most influential attribute related to the first alternative. The attribute depreciation cost has almost no influence on the decision to purchase an AV. The attribute is also insignificant. However, respondents are slightly more willing to buy an AV, when the deprecation costs are 5%. The monthly costs have significant influence on the decision to purchase an AV. The respondents have higher marginal utility, when the monthly costs are minimal.

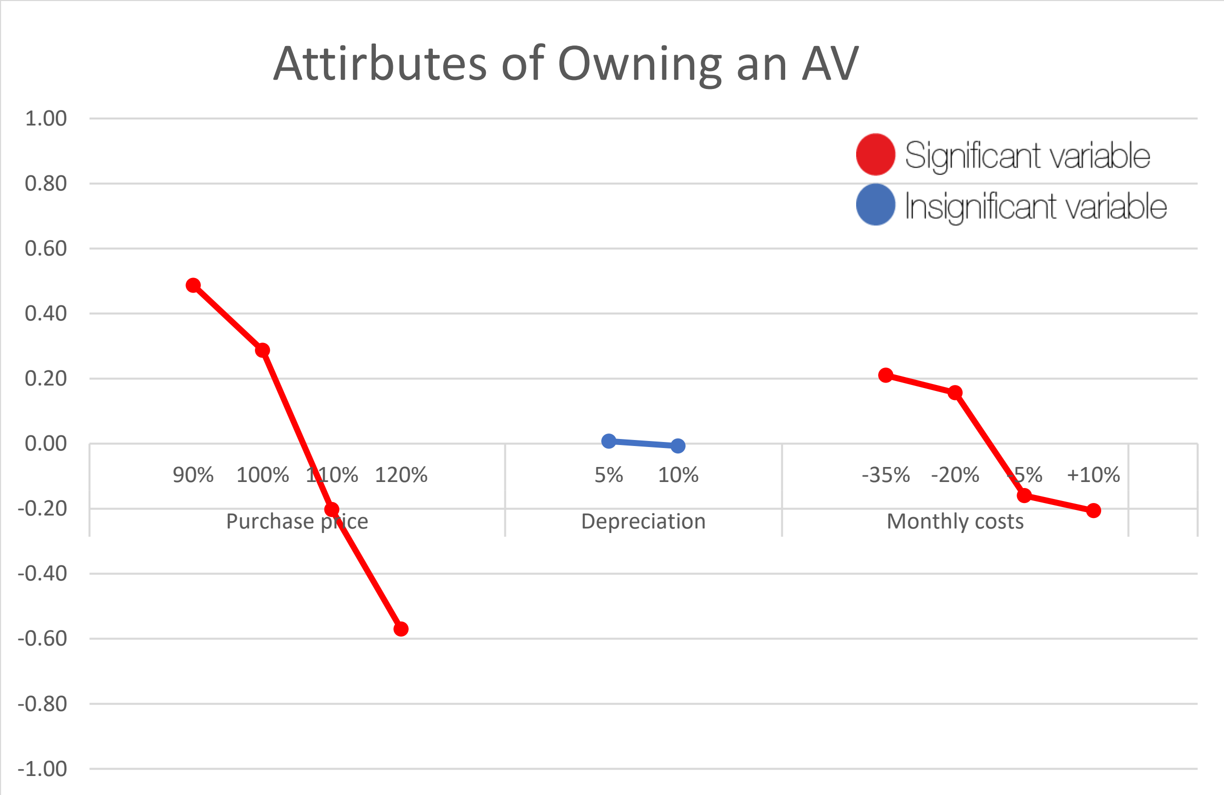


Figure 5.4: Results of the marginal utility of the attributes related to AV ownership

The marginal utility and statistics of the attributes related to adoption of shared autonomous mobility are displayed in figure 5.5 and table 5.10. The green line in figure 5.5 shows that one variable is almost significant, which means than only one of the categories is insignificant. Membership fee has much influence on the decision to adopt shared autonomous mobility. A membership fee of €0 is the preferred and a fee of €60 is least preferred. The attribute price per kilometer has also big influence on the decision to adopt shared autonomous mobility. This attribute has a negative influence on the decisions. If the price per kilometer increases, then the willingness to adopt shared autonomous mobility decreases. Both membership fee and price per kilometer have a significant influence on the decision to adopt shared autonomous mobility. The attribute waiting time is significant, apart from a waiting time of four minutes. The attribute shows that short waiting times are preferred. Waiting times seven and ten minutes have a similar influence on the decisions. The latter is even slightly preferred over a waiting time of seven minutes. A three minutes' difference between long waiting times is only small, which explains the similarities of seven and ten minutes waiting times. The last attribute is reliability. For ease of interpretation, the attributes related to reliability are merged to one attribute. The respondents prefer a vehicle that arrives 60% of the times on time and 40% of the times 4 minutes late. The least preferred attribute level is a vehicle arriving 80% of the times two minutes too early and 20% of the times two minutes late. The respondents are less interested in shared autonomous mobility, when the vehicle might be too early. The respondents might need time to prepare, like packing a bag, before the vehicle arrives. However, this attribute is insignificant.

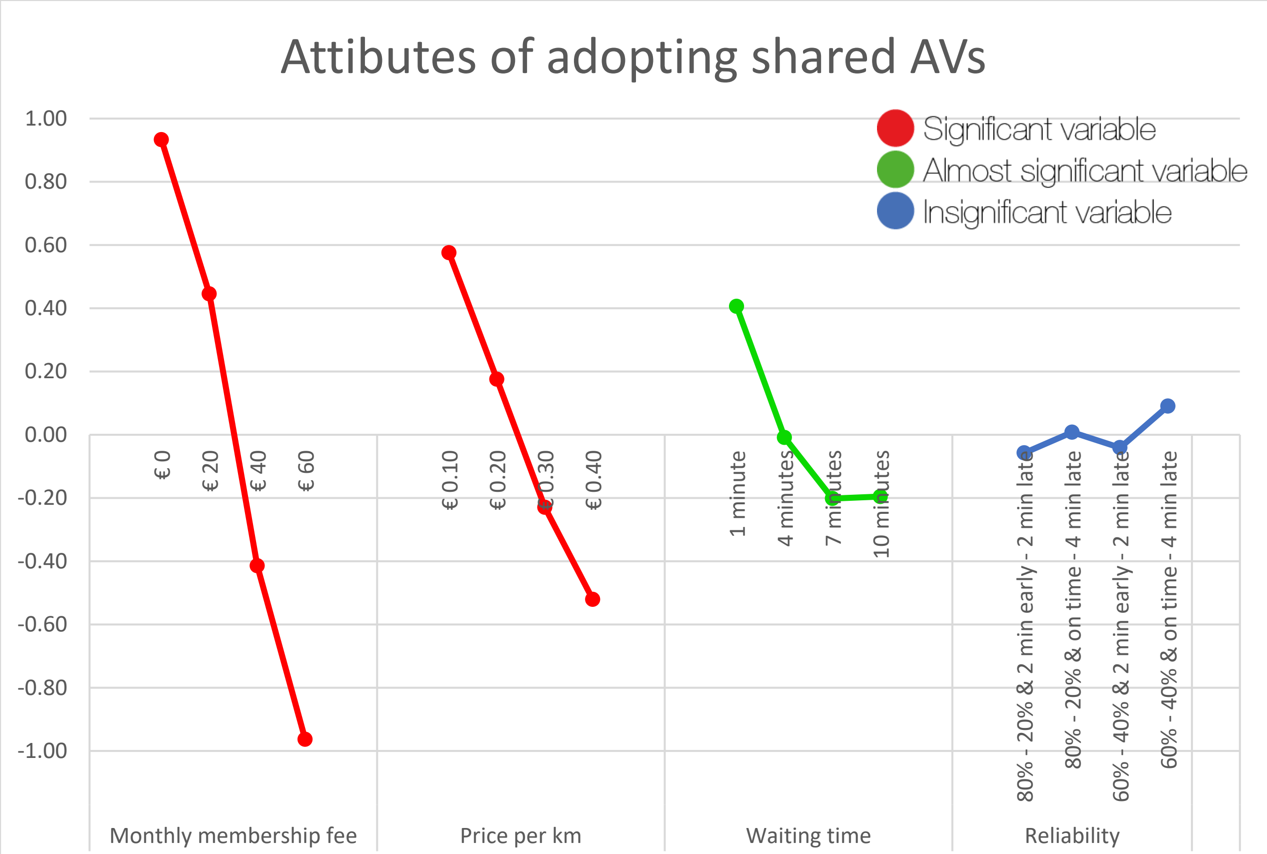


Figure 5.5: Results of the marginal utility of the attributes related to adoption of shared AVs

The socio-demographics: gender, age, occupation, the need for a car for work, living environment and usage of car as driver, influence the choices of the respondents. The influence of the socio-demographics on the decision to purchase an AV or not is shown in table 5.9 and figure 5.6. The red bars in figure 5.6 show the fully significant variables. The green bars in figure 5.6 show the almost significant variables, which means than only one of the categories of a variable is insignificant

Both gender and age are not fully significant, but are relevant to include in the final model. These variables are important factors describing the respondents. Male respondents are slightly more willing to purchase an AV than the female respondents. Respondents over 74 years old are most willing to own AV. Respondents between 35 and 54 years old prefer adoption shared autonomous mobility. The willingness of the younger generations to adopt shared autonomous mobility is expected, because younger generations postpone getting a driving license and use car access instead of car ownership (Mounce & Nelson, 2019). However, respondents between 18 and 34 years old are more willing to purchase an AV.

Occupation and the need for a car for work are related to each other. Only the employed respondents answered a question about the need for a car to perform their work. The employed respondents are least willing to adopt an owned AV, according to the variable occupation. However, form the variable the need for a car for work can be concluded that, working respondents are willing to adopt an owned AV. The respondents needing a car for work are slightly more willing to adopt an owned AV than the respondents that do not need a car for work. Respondents not having work as occupation are not willing to adopt an owned AV, according to the variable the need for a car for work. Form the variable occupation can be concluded that the students and unemployed respondents are most willing to own an AV. Retired respondents are slightly willing to adopt an owned AV.

Living environment is also a significant socio-demographic of the model. Respondents living in the city are most willing to adopt shared autonomous mobility, while respondents living in villages are willing to buy an AV and respondents living in rural areas are most willing to purchase an AV. Villages and rural areas are less accessible by public transportation and shared mobility than cities. The respondents living in villages and rural areas might be more attached to their owned cars. Consequently, the respondents might think that shared mobility is less convenient in villages and rural areas. Therefore these respondents are more willing to adopt an owned AV. The difference between urban areas and slightly urban areas is small, because these living environments do not differ a lot. Usage of the car as driver has a significant influence on the decisions. If respondent uses car as driver more often, then the respondent is more interested in AV ownership. Respondents using car as driver more than four days per week are most interested in AV ownership. Respondents using car as driver one to three days per week are a bit less interested in adoption of an owned AV. The group using car as driver a few times per month and the respondents that never or barely use car as driver are most willing to adopt shared autonomous mobility.

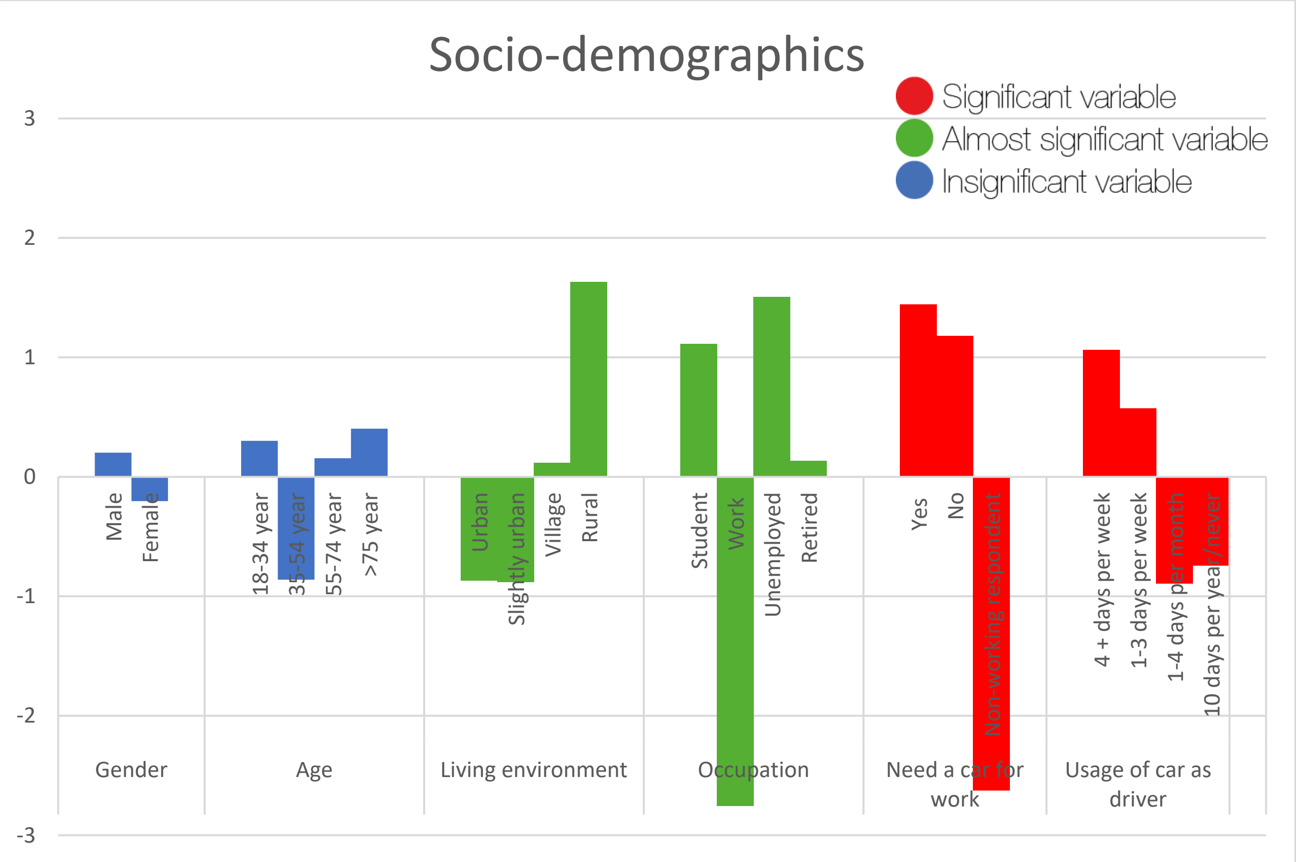


Figure 5.6: Results of the marginal utility of the socio-demographics related to adoption owned AVs

5.4 Results of the stated adaptation choice experiment

Section 5.4 describes the results of the SACE. Not all respondents match the criteria of the SACE. Only respondents that are willing to use shared mobility are included in the SACE. 765 respondents were asked to indicate their reference trip and fill in the SACE. The data sets has 2846 reference trips, which is also the number of observations of SACE. An equal distribution of the blocks is preferred for further analysis, table 5.12 shows the distribution of the blocks according to the reference trips. 16 blocks are integrated in the experiment. The blocks are used between 5.3% and 7.2% of the times. The choices of the SACE are more complex than the choices of the SCE. The alternative autonomous public transportation (APT) is only available, when public transportation was the transportation mode of the reference trip. APT was available during 21.6% of the observations. APT is chosen 9.8% of the choice tasks. If the APT was available, then the respondents choose APT 45.4% of the choice tasks. Usage of shared autonomous vehicles is the most popular alternative, which is chosen 59.1% of the choice tasks. Shared autonomous rides are chosen in 31.1% of the observations. A summary of the choices is shown in table 5.13.

Table 5.12: Distribution of the blocks

Block	Frequency	%
1	200	6.8
2	181	6.1
3	196	6.7
4	167	5.7
5	190	6.4
6	173	5.9
7	179	6.1
8	207	7.0
9	170	5.8
10	205	7.0
11	167	5.7
12	171	5.8
13	186	6.3
14	212	7.2
15	185	6.3
16	157	5.3
Total	2946	100.0

Table 5.13: Decisions of the respondents in the SACE

	SAV	SAR	APT
Times available	2946	2946	635
% times available	100.0	100.0	21.6
Times chosen	1741	917	288
% chosen overall	59.1	31.1	9.8
% chosen when available	59.1	31.1	45.4

The code used to generate the hybrid choice model of the SACE is similar to the code of the SCE. The code explained in section 5.2.2 is used to obtain results. First a HCM with almost all variables is generated. The results are shown in appendix J1. The Rho^2 and Rho^2 adjusted of the model are acceptable. Most of the variables related to the latent variable and attributes are significant. Only a few of the socio-demographics and travel characteristics are significant. After the staring model, some of the insignificant variables are deleted to get a better model. This process continues till the remaining socio-demographics and travel characteristics are significant. The process is shown in appendix J2. Some interactions are integrated in the model during the search for the best model.

Model 12 has most of the significant variables of all models. The model is displayed in appendix K. The model contains the variable travel time of the reference trip. This variable is complicated, because the travel time of the reference trip is used to calculate the value of the attribute travel time. Instead an interaction related to the travel time of the reference trip is added. The travel time of the reference trip is transformed into a variable with two categories: travel times less than 30 minutes and longer than 30 minutes. 30 minutes traveling time is used as threshold, because 30 minutes travel time is the median of the variable. The variable is multiplied by the attribute seating comfort. Which is motivated by the assumption that respondents might prefer a luxurious alternative when traveling for a longer period of time. 16 models are generated in total, appendix J2 shows the process of getting the best model. Model 16 has the best fit, the results are shown in table 5.14, 5.15, 5.16, 5.17 and 5.18. The extensive model summary is shown in appendix J3.

The log likelihood of the final model is -7250.924 at the start. The log likelihood of the whole model is -5618.593. The Rho^2 of the model is 0.225 and the Rho^2 adjusted is 0.217. These values are acceptable and explain the data fairly. The BIC and AIC of the final model are lower than the BIC and AIC of the starting model and model 12. Which means that the final model has the best fit. The alternative specific constant related to SAV is 0.4230, the alternative specific constant of SAR is -0.1168 and the alternative specific constant of APT is zero. Which means that SAV is the preferred alternative and SAR is the least preferred alternative. However, the alternative specific constants are not significant. The standard deviations of the panel effect of SAV and APT are significant, which means that the random panel effect exists for SAV and APT.

Table 5.14: Model summary of the SACE

Model summary of the SACE	
LL start	-7250.924
LL whole model	-5618.593
AIC	11355.19
BIC	11708.49
ρ^2	0.225
ρ2 adjusted	0.217

The socio-demographics gender, age, education and household composition remain in the final model. Also the transportation mode of the reference trip has a place in the final model. The t-ratio determines the significance of the variables in the hybrid choice model. A variable is not significant if the t-ratio is between -1.96 and 1.96. Furthermore the variables of the HCM are effect coded.

The results related to the latent variable of the SACE are displayed in table 5.18. The calculation of this latent variable is identical to the calculation of the latent variable of the HCM related to the SCE. The parameter for attitude towards sustainably is simultaneously calculated. Furthermore the conclusions of the EFA and CFA are used to do the calculation. The lambda and standard deviation of the indicators are significant, implicating a sufficient execution of the factor analysis. The constant is quite small and insignificant, because the values of the indicators are normalized to zero. The standard deviation is 0.6426 and is significant. The attitude towards sustainability has almost a significant influence on usage of shared autonomous rides. The parameter has a value of 0.2835. Attitude towards sustainability has larger impact usage of APT, albeit the impact is insignificant. The parameter has a value of 0.4311. Both values are positive, because assumingly respondents with a positive attitude towards sustainability are more willing to adopt a sustainable transportation mode.

Table 5.15: Results of the first alternative: usage of shared autonomous vehicles

Alternative 1: Shared autonomous vehicle

			Estimate	Std.err.	t-ratio(0)
Alternative-specific constant			0.4230	0.4919	0.8600
Standard deviation of the random panel effect parameter			**1.6949**	0.2534	6.6894
Socio-demographic variables	Gender	Male	**0.9143**	0.4540	2.0138
		Female	-0.9143		
	Age	18-34 year	0.1719	0.4817	0.3569
		35-54 year	0.2221	0.4674	0.4751
		55-74 year	-0.5280	0.4784	-1.1036
		>75 year	0.1341		
	Education	Low	**1.6379**	0.6469	2.5319

		Middle	-0.7208	0.4182	-1.7235
		High	-0.9171		
	Household composition	Single	**-0.7735**	0.3522	-2.1965
		Couple	**-0.9024**	0.3896	-2.3160
		Family (with children)	0.7919	0.4885	1.6210
		Other	0.8840		
Reference trips variables	Transportation mode	Car	**0.7360**	0.1701	4.3273
		Train	**-0.7159**	0.2124	-3.3708
		Bus	-0.0117	0.2181	-0.0534
		Shared mobility	-0.0084		
Alternative-attribute variables	Price per km	€ 0.10	**1.4589**	0.1157	12.6117
		€ 0.20	**0.3320**	0.0962	3.4514
		€ 0.30	**-0.7855**	0.0959	-8.1866
		€ 0.40	-1.0054		
	Waiting time	1	**0.2191**	0.0980	2.2357
		3	**0.2618**	0.0972	2.6919
		5	-0.0700	0.0948	-0.7383
		7	-0.4108		
	Travel time*	Low	0.0917	0.0548	1.6727
		High	-0.0917		
	Seating comfort	Economy	-0.0563	0.0575	-0.9791
		Business	0.0563		
Interactions	TT of reference trip * SC	<30 min *economy / 30> min *business	**0.1395**	0.0606	2.3028
		<30 min *business / 30> min *economy	-0.1395		
Latent-attitude variables	N/A				

*If the respondent travels by car or train, then the travel time of the reference trip is multiplied by 80% (low) or 100% (high). If the respondent travels by bus/tram/metro, then the travel time of the reference trip is multiplied by 60% (low) or 80% (high).

Table 5.16: Results of the second alternative: usage of shared autonomous rides

Alternative 2: Shared autonomous ride

			Estimate	Std.err.	t-ratio(0)
Alternative-specific constant			-0.1168	0.4728	-0.2470
Standard deviation of the random panel effect parameter			0.8409	0.4950	1.6989
Socio-demographic variables	Gender	Male	0.7237	0.4386	1.6500
		Female	-0.7237		
	Age	18-34 year	0.5642	0.4677	1.2063
		35-54 year	0.3169	0.4563	0.6946
		55-74 year	-0.6302	0.4685	-1.3450
		>75 year	-0.2509		
	Education	Low	**1.7558**	0.6322	2.7772
		Middle	-0.7188	0.4081	-1.7615
		High	-1.0370		
	Household composition	Single	-0.4046	0.3389	-1.1939

		Couple	**-0.8817**	0.3792	-2.3253
		Family (with children)	0.6102	0.4754	1.2834
		Other	0.6762		
Alternative-attribute variables	Price per km	€ 0.05	**0.8917**	0.0952	9.3623
		€ 0.10	**0.2145**	0.0930	2.3061
		€ 0.15	**-0.3128**	0.0978	-3.1992
		€ 0.20	-0.7934		
	Waiting time	4	**0.2524**	0.0939	2.6891
		6	0.1521	0.0941	1.6164
		8	-0.1241	0.0968	-1.2816
		10	-0.2804		
	Travel time*	Low	**0.1365**	0.0548	2.4919
		High	-0.1365		
	Number of strangers	1	**0.3380**	0.0936	3.6102
		2	-0.1205	0.0969	-1.2438
		3	-0.0049	0.0945	-0.0515
		4	-0.2126		
	Seating comfort	Economy	-0.0961	0.0554	-1.7333
		Business	0.0961		
Interactions	TT of reference trip * SC	<30 min *economy / 30> min *business	0.0327	0.0590	0.5545
		<30 min *business / 30> min *economy	-0.0327		
Latent-attitude variables	Sustainability		0.2835	0.1504	1.8850

*If the respondent travels by car or train, then the travel time of the reference trip is multiplied by 110% (low) or 130% (high). If the respondent travels by bus/tram/metro, then the travel time of the reference trip is multiplied by 90% (low) or 110% (high).

Table 5.17: Results of the third alternative: usage of autonomous public transportation

Alternative 3: Autonomous public transportation

			Estimate	Std.err.	t-ratio(0)
Alternative-specific constant	N/A				
Standard deviation of the random panel effect parameter			**-2.6603**	0.4143	-6.4211
Socio-demographic variables	N/A				
Alternative-attribute variables	N/A				
Latent-attitude variables	Sustainability		0.4311	0.3303	1.3053

Table 5.18: Results of the latent variable

Latent-attitude results

			Estimate	Std.err.	t-ratio(0)
Sustainability	Constant		-0.0034	0.0244	-0.1389
	Standard deviation		**0.6426**	0.0398	16.1580
	Lambda	Statement 1	1	NA	NA
		Statement 2	**1.1547**	0.0765	15.0858

		Statement 3	**1.1954**	0.0744	16.0635
		Statement 4	**1.2020**	0.0754	15.9514
		Statement 5	**1.1705**	0.0732	15.9872
	Standard deviation	Statement 1	1	NA	NA
		Statement 2	**0.6477**	0.0195	33.1317
		Statement 3	**0.4473**	0.0169	26.4529
		Statement 4	**0.4764**	0.0170	27.9536
		Statement 5	**0.4618**	0.0168	27.5546

The influence of all four attributes on the decision to use a SAV is shown in table 5.15 and figure 5.7. The red lines in figure 5.7 show the significant variables. The green line in figure 5.7 shows that the waiting time is almost significant, which means than only one of the categories of a variable is insignificant. It is worth noting that the values of travel costs and travel time depend on the attribute level, but also on the answer of the respondent on the reference trips.

The line of the travel costs is steep, indicating a big influence of the travel costs on the decision to use a SAV. If the travel costs become higher, then the willingness to use SAV decreases. The attribute travel costs is significant. The attribute waiting time is almost significant. Surprisingly, a waiting time of three minutes is preferred over a waiting time of one minute. The reason might be that respondents need some time to prepare before the vehicle arrives, like packing a bag. Consequently a waiting time of one minute is too short. The difference between the marginal utility of one minute and three minutes waiting time is small. Maybe the respondents do not mind waiting an extra two minutes. In general short waiting times are preferred over longer waiting times. Furthermore, low travel times have more marginal utility than high travel times. The travel time does not have a lot of influence on the choice to use SAV. A reason might be the small differences between the attribute levels. The last attribute related to the alternative SAV is seating comfort. The attribute has only small influence on the choice to use SAV. Business seats are preferred over economy seats, because business seats are more luxurious and comfortable. The attribute is insignificant.

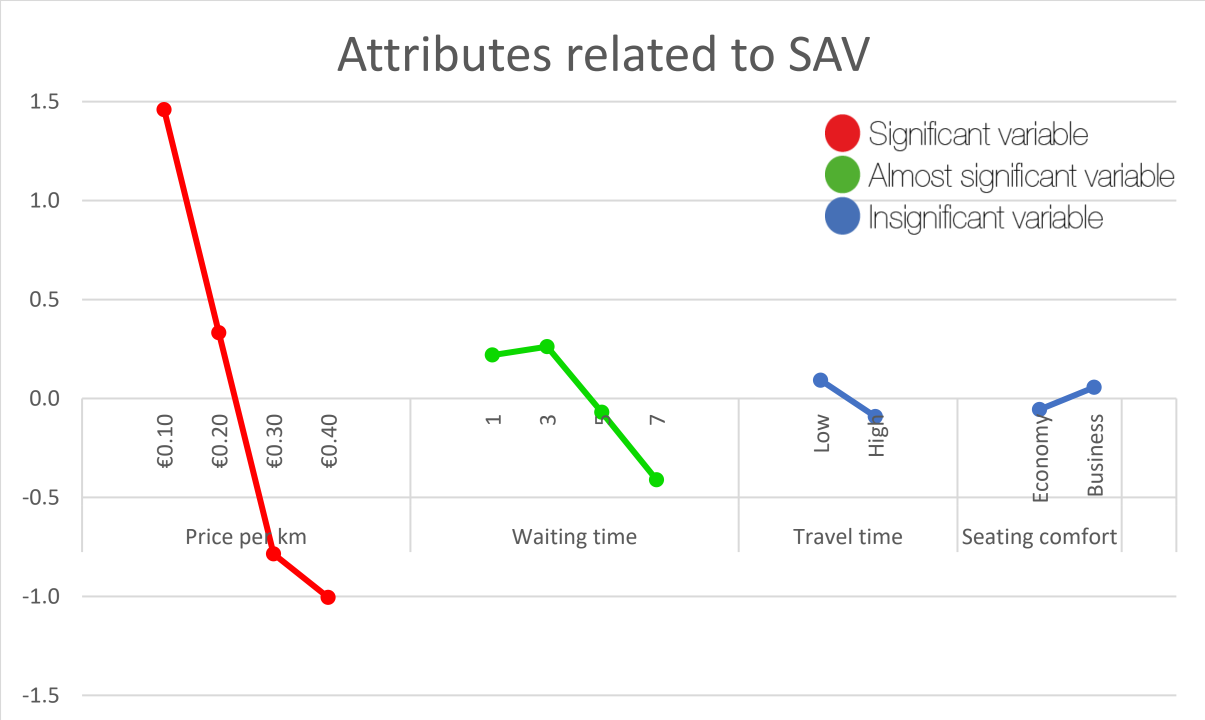


Figure 5.7: Results of the marginal utility of the attributes related to usage of shared autonomous vehicles

The results of the attributes related to SAR are displayed in table 5.16 and figure 5.8. The red lines in figure 5.8 show the fully significant attributes. The value of the attribute travel costs and travel time depend on the input of the respondents of their reference trip.

The travel costs have the biggest influence on the choices. As expected, the respondents prefer the lowest price per kilometer. An increasing price per kilometer has negative effect on the decision to use SAR. The attribute has significant influence on the decisions. Furthermore the respondents prefer low waiting times. This attribute has moderate effect on the decision to use SAR. Only the waiting time of four minutes is significant. As expected the respondents prefer lower travel times over longer travel times. This attribute has significant effect on respondents' decision. As for the marginal utility associated with the number of strangers in the car, respondents would prefer having only one stranger on board. An autonomous ride shared with four strangers is the least preferred attribute level. The attribute level one stranger is significant. The business seats are preferred over the economy seats, because the business seats offer more luxury. The attribute has slightly higher influence on the decision to use SAR than the choice to use SAV, but the attribute is not significant.

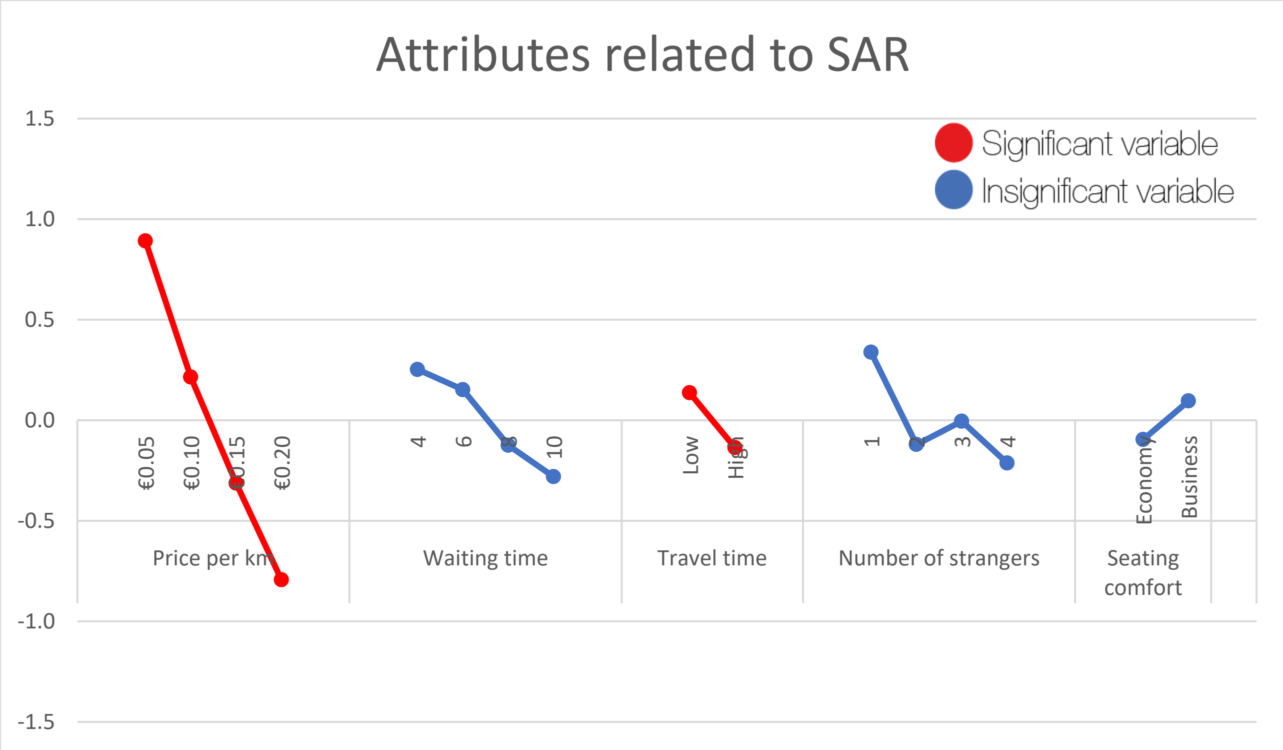


Figure 5.8: Results of the marginal utility of the attributes related to usage of shared autonomous rides

The interaction between travel time of the reference trip (RT) and seating comfort is investigated. The variable travel time of the reference trip is transformed into two categories: a travel time less than 30 minutes and a travel time more than 30 minutes. The categories are effect coded. The first category has a value of 1 and the second category has a value of -1. The attribute seating comfort is also effect coded. The attribute level economy has a value of one and business has a value of -1. The travel time of the reference trip is multiplied by the attribute seating comfort to calculate the interaction. The multiplication has two outcomes; either one or -1. One stands for either a travel time less than 30 minutes with an economy seat or a travel time longer than 30 minutes with a business seat. The base level (-1) stands for either a travel time less than 30 minutes with a business seat or a travel time longer than 30 minutes with an economy seat. The categories in summary:

1: Travel time <30 min and economy / Travel time > 30 min and business

-1: Travel time <30 min and business / Travel time > 30 min and economy

The interaction is related to both alternatives, figure 5.9 and 5.10 show the results of the interactions. The red line in figure 5.9 shows the significance of the interaction related to SAV. The outcome related to category one is positive and the outcome related to category -1 is negative. Either if the travel time is short (less than 30 minutes) with an economy seat or if the travel time is long with a business seat, then the respondent is more likely to choose a SAV or SAR. The economy seat might be preferred when traveling for a short period of time. Simply because paying for business class for a short trip might not seem a reasonable choice according the respondents. The business seat, on the other hand, might be more comfortable when traveling for a longer period of time.

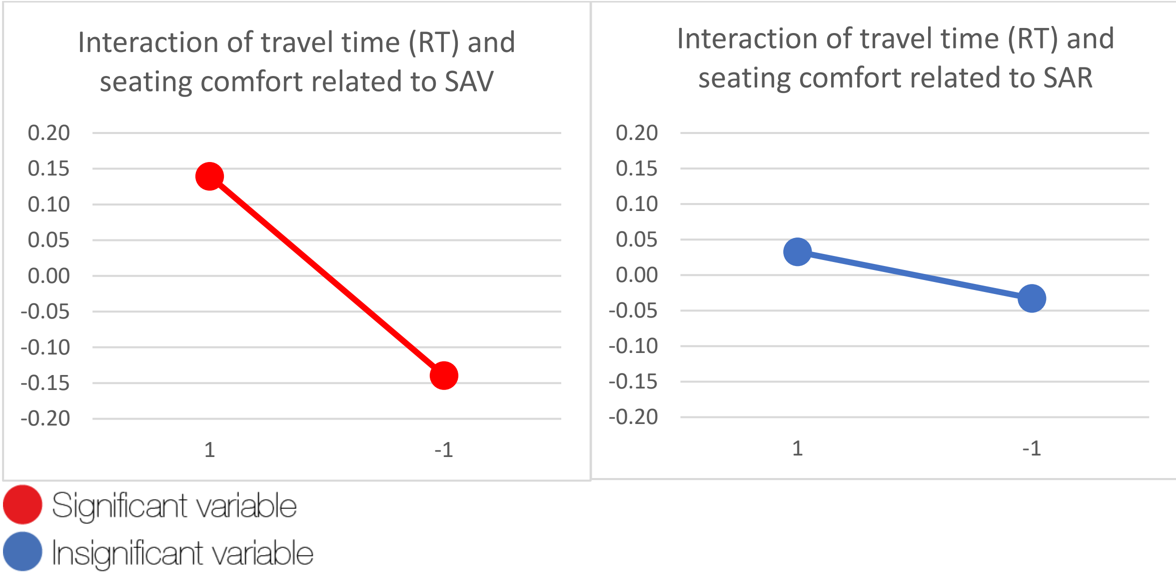


Figure 5.9: Interaction of travel time (RT) and seating comfort related to SAV
Figure 5.10: Interaction of travel time (RT) and seating comfort related to SAR

The impact of the socio-demographics on the decision to use SAV and SAR are shown in figures 5.11 and 5.12. The red lines in the figures show the fully significant variables. The green bars show the almost significant variables, which means that one of the categories of the variable is insignificant.

Male respondents are most willing to use a SAV and SAR. The difference between male and female respondents is biggest when choosing a SAV. Gender has significant effect on usage of SAV, while its role to use SAR is insignificant. The variable age has slightly different yet understandable effect on SAV and SAR. The highest interest in SAV is among the age category of 35-54, while the youngest age group 18-34 is highly interested in SAR. Although the effect of age is not significant. Moreover, respondents with low level of education are most willing to use SAV and SAR. Highly educated respondents are least willing to use either SAV or SAR. The category low level of education has a positive influence and a significant effect on both alternatives. The other education levels are insignificant. The outcomes related to education have no clear reasoning. Families with children and other household compositions are most willing to use the SAV and SAR. Respondents living with a partner show lowest interest in usage of both mobility options, followed by the respondents living alone. Only the household composition couple has significant influence on both alternatives. The household composition single has significant influence on the decision to use SAV.

The influence of the transportation mode of the reference trip on SAV usage is calculated. The influence of the variable on APT cannot be calculated, because only the respondents traveling with public transportation during the reference trip can choose this alternative. So SAR is the base level of the transportation mode of the reference trip. The transportation modes car and train have significant influence on the decisions of the respondents. These modes have the strongest influence on the decision to use SAV or not. Car users are most willing to use SAV. Probably, because the trip was initially made with a car and SAV is most similar to the car. Train as transportation mode of the reference trip has negative influence on the choice to use SAV, because the other modes are more similar to train usage.

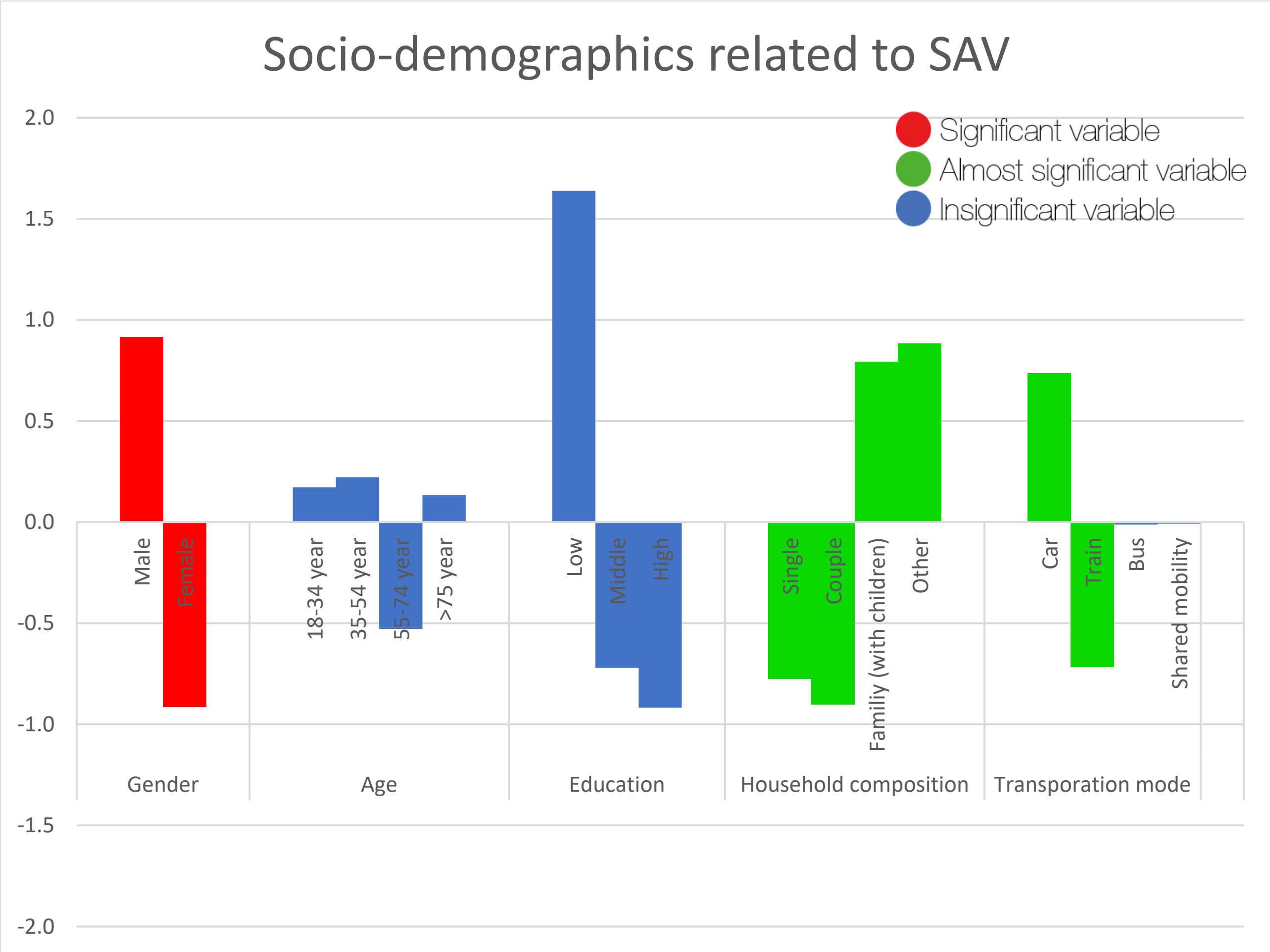


Figure 5.11: Results of the marginal utility of the socio-demographics related to usage of shared autonomous vehicles

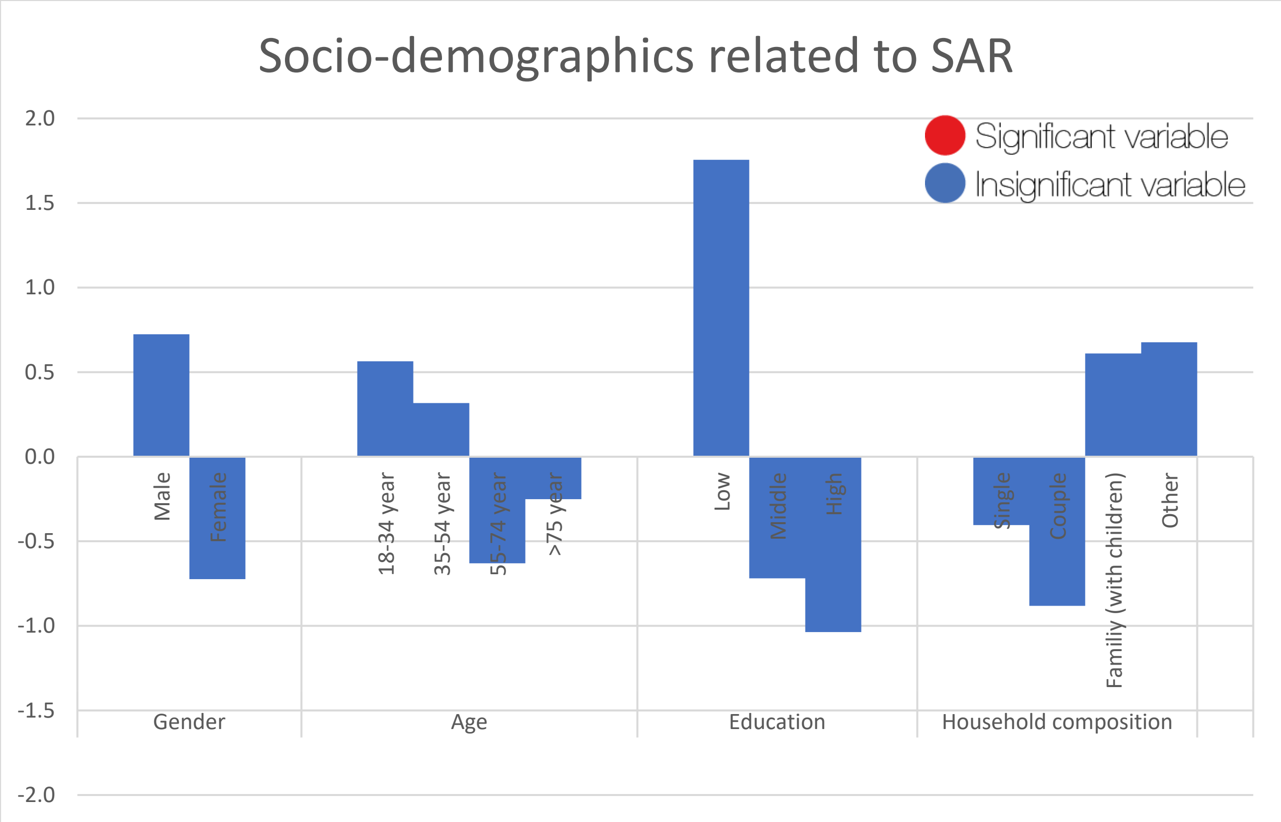


Figure 5.12: Results of the marginal utility of the socio-demographics related to usage of shared autonomous rides

5.5 conclusion

Before the analysis of the choices, factor analysis is used to analyze the statements and attitudes. First exploratory factor analysis is conducted, afterwards confirmatory factor analysis is performed. Only the attitude towards sustainability is suitable for further analysis. The choices of the respondents are analyzed with hybrid choice models. The models enable simultaneous estimation of the latent variable, which is the attitude towards sustainability. Apollo is used to generate the results of the hybrid choice models.

The SCE has a response rate of 822 respondents. The respondents that own a car or are willing to buy a car in the future filled in the stated choice experiment. A bit less than half of the respondents is willing to adopt shared autonomous mobility. Slightly more than half of the respondents wants to adopt an owned AV. The purchase price, monthly costs, membership fee and price per kilometer have the most and significant influence on the decisions made in the SCE. Socio-demographics also influence the decisions. Living environment, occupation, the need for a car for work and usage of car as driver have a significant influence on the mid-term decisions. Finally, the respondents with a positive attitude towards sustainability are most willing to adopt shared autonomous mobility.

A total of 765 respondents reacted on the SACE. The respondents that are willing to use shared mobility answered the choice tasks of the SACE. Almost 60% of the respondents prefers using a SAV. One third of the respondents want to use SARs. 10% of the respondents choose usage of autonomous public transportation. When APT was available in the choice tasks, the alternative was chosen almost 50% of the times. The attribute price per kilometer has most influence on the decisions, but also the waiting time has moderate influence. Education, household composition and the transportation mode of the reference trips are the socio-demographics influencing the decisions made in the SACE. The respondents with a positive attitude towards sustainability are most willing to use SAR or APT.

6. Conclusion

Technology developments in autonomous vehicles proceed quickly. Furthermore shared mobility services are improving and getting more popularity by the population. Both developments change travel behavior and the transportation sector. The main goal of this research is to investigate which type of autonomous transportation mode people are willing to adopt and use in the future. The choices depend on midterm and short-term decisions. In addition, investigation of the influence of relevant attributes on the willingness to use or adopt autonomous transportation modes is part of the aim of this study. Attitudes that influence people's decisions are researched as well. The research is divided into two timeframes; mid-term adoption of AVs and short-term usage of AVs. These timeframes have been investigated using two choice experiments. This research has four research questions. Two research questions investigate mid-term AV adoption and two research questions investigate short-term AV usage. The following research questions concern mid-term AV adoption:

> *What are driving factors in people's decisions toward adopting a privately owned autonomous vehicle versus adopting shared autonomous mobility?*
>
> *How do attitudes play a role in the choice to adopt a privately owned autonomous vehicle or shared autonomous mobility?*

Two autonomous transportation modes are investigated to test midterm decisions. The respondents could choose adoption of AV ownership or adoption of shared autonomous mobility. The choices were investigated with a stated choice experiment. The respondents decided in multiple choice tasks to adopt one of the alternatives. Respondents that own a car or are willing to purchase a car within the upcoming five years answered the choice tasks of the SCE. These people potentially need to tradeoff between AV ownership and shared autonomous mobility in the future. The total sample size is 902 respondents, of whom 822 answered the choice tasks belonging to the SCE. The decisions of these respondents are analyzed with a hybrid choice model. The model is able to calculate the influence of attitudes simultaneous. The results of the model show that the respondents are almost equally interested in AV ownership as in shared autonomous mobility. However, slightly more respondents are willing to purchase an AV.

The purchase price and monthly costs are the attributes with most influence on the decision to own an AV. An increasing purchase price negatively influences the decision to buy an AV. This result was also identified in previous research; respondents prefer lower purchase prices of AVs (Haboucha et al., 2017; Daziano et al., 2017). Furthermore, in this research, the respondents prefer decreasing monthly costs. Adoption of shared autonomous mobility is strongly influenced by financial attributes. The respondents prefer low membership fees and low prices per kilometer. The membership fee has slightly more influence on the choices made in the SCE. The waiting times of shared autonomous mobility also affects the decisions. Short waiting times are preferred over long waiting times. Furthermore, the respondents favor a vehicle that arrives a few minutes late over a vehicle that arrives too early. To conclude, the financial attributes have most influence on the choices of the respondents. The attribute waiting time has also mayor influence on respondents' decisions to either adopt an owned AV or shared autonomous mobility. These conclusions are part of the answer on the first research question.

The first research question is also answered by the influence of the socio-demographics on the decisions made in the SCE. Respondents living in rural areas are most willing to purchase an AV. Respondents living in villages are moderately interested in AV ownership. Respondents living in the city have negative marginal utility towards adoption of an owned AV. Furthermore, occupation has a significant influence on the decision to own an AV. Students, unemployed respondents and retired respondents are interested in AV ownership. Working respondents are not interested to purchase an AV. However, only the working respondents answered a question about the need for a car for work. Both respondents that need and do not need a car for work are interested in AV ownership. The respondents that need a car for work are slightly more willing to purchase an AV. The respondents that did not fill in the question about the need for a car for work are non-working respondent. The non-working respondents have negative marginal utility towards AV ownership. Furthermore the respondents often using a car are most interested in AV ownership. Respondents that only drive a car a few days per month or less are less willing to adopt an owned AV.

The second research question is answered by the results of the attitudes. Only the attitude towards sustainably has been found sufficient to use in the hybrid choice model. In general, the respondents have a neutral or positive attitude towards sustainability. Respondents with a positive attitude towards sustainability are more willing to adopt shared autonomous mobility. Respondents with negative attitude towards sustainability are more likely to purchase an AV. The results are as expected, because shared vehicles are assumed to be more sustainable than car ownership. Which is consistent with literature.

Short-term autonomous vehicle usage is investigated using the other two research questions:

> *If people are interested in shared mobility, then what are the driving factors (under which context) to choose between the usage of a shared autonomous vehicle, a shared autonomous ride or autonomous public transportation?*
>
> *How do attitudes influence the usage of either a shared autonomous ride, a shared autonomous vehicle or autonomous public transportation?*

A stated adaptation choice experiment is used to investigate people's short-term choices. Before answering the choice tasks, the respondents were asked to describe four reference trips. These trips are trips taken ‘last week or the week before’. The respondents made their decisions in the SACE according to their reference trips. The respondents were asked how they would travel along the same trip, but then with one of the alternatives of the SACE. Furthermore the values of the attributes travel time and travel costs depended on the reference trips. Three hypothetical transportation modes are used in the SACE to investigate the future usage of shared autonomous vehicles. The first alternative is the shared autonomous vehicle, the service provides single occupancy rides. The second alternative is shared autonomous ride, the autonomous ride is shared with strangers. The last alternative is autonomous public transportation. Only respondents using public transportation during their reference trip have the opportunity to choose APT. Current users of shared mobility or respondents willing to use shared mobility in the future fit within the target group of the SACE. The choices of 765 respondents were used for the analysis. Most respondents prefer using single occupancy shared autonomous vehicles. SAR is chosen in one third of the observations. Almost half of the respondents is willing to use autonomous public transportation (APT) when the alternative is available, which is 21.6% of the observations. However, APT is only chosen 10% of the time in total.

The choices to use a SAV or a SAR are negatively influenced by the price per kilometer. Higher travel costs make the respondents less willing to use a SAV or a SAR. Haboucha et al. (2017) also concluded that low trip costs are preferred among their panel. Moreover short waiting times are preferred over long waiting times. However, when using a SAV, then the waiting time of three minute is slightly preferred over a waiting time of one minute. Likewise, the respondents favor a vehicle arriving a few minutes late over a vehicle that arrives too early, according to the results of the SCE. Probably people need a few minutes to prepare before the vehicle arrives. Long waiting times make the respondents less interested in usage of a SAV or SAR. Furthermore, the respondents prefer business seats over the economy seats, especially when the ride is shared with others. The attribute number of strangers is only related to SAR. The respondents prefer traveling with one stranger over multiple strangers. The alternative APT does not have any attributes, because the alternative is compared to the mode used during the reference trip. The similarities of APT to the currently used transportation mode might make the respondents more eager to choose APT. Which explains the popularity of the alternative.

The choices made during the SACE are also influenced by some socio-demographics. Respondents with a lower level of education are most interested in usage of SAV and SAR. There is not a clear explanation for this result. The respondents living alone or with a partner are not as much interested in usage of SAV and SAR as families with children and other household compositions. Furthermore, if the car is used as transportation mode during the reference trip, then the respondent is most interested to use SAV. Since usage of a SAV is most similar to car usage. The respondents using the train during the reference trip are less interested in SAV usage, probably because the other alternatives are more similar to train usage.

The influence of the attitude towards sustainability is also investigated by using the hybrid choice model. The results answer the last research question. The attitude towards sustainability has the most and positive influence on the decision to use autonomous public transportation. The attitude towards sustainability also positively influences the decision to use shared autonomous rides. To conclude, the respondents with a positive attitude towards sustainability are most willing to use APT or SAR. Nazari et al. (2018) had a similar conclusion: the respondents with a green travel pattern are more willing to share a ride with others. From the results of both experiments can be concluded that the respondents with a positive attitude towards sustainability are most interested in adoption and usage of shared autonomous transportation modes.

6.1 Scientific relevance

This research contributes by providing knowledge about mid-term adoption of an owned AV or shared autonomous mobility. Furthermore the research gives information about short term usage of different shared autonomous transportation modes. Two choice experiments are used to investigate the decisions. The decisions of 902 respondents are investigated with a hybrid choice model, in order to simultaneously calculate the influence of attitudes. Pivoted attributes are used to personalize the choice tasks. Furthermore reference trips are used to investigate people's short-term choices.

Mid-term and short-term choices are investigated. Only one other study uses time frames to investigate usage of AVs, which is the study of Stoiber et al (2019). The research of Stoiber et al. (2019) uses a stated preference experiment and investigates the influence of different instruments instead of attributes. Furthermore, only Stoiber et al. (2019) investigates the alternative autonomous public transportation. To the best of the author's knowledge, no other investigation uses autonomous public transportation as an alternative.

The current situation of the respondents is used to determine the levels of the attributes. Which provides the respondents with realistic alternatives. The answers respondents gave are integrated in the following attributes: purchase price (SCE), deprecation costs (SCE), travel time (SACE) and travel costs (SACE). Only few other research used pivoted attributes. Furthermore, the choices made in the SACE depend on the reference trip indicated by the respondents. Which is not often seen in similar research. Moreover, this research investigated attributes related to travel convenience and travel comfort, where other studies mostly focused on financial attributes. The attributes: monthly costs, reliability of the waiting time, seating comfort and number of strangers, are not used (to the best of the author's knowledge) in previous research in a similar context to this research.

Finally, this research and previous research into AV adoption and usage have been adding attitudes to the choice models. However, only this research uses hybrid choice models to analyze the results. In this research, the method has proven being suitable to analyze the outcomes of the choice experiments and the influence of attitudes on the choices.

6.2 Societal relevance

Modal shifts from manual transportation modes to autonomous transportation modes influences the transportation sector and urban areas. This research showed that almost half of the respondents are willing to adopt shared autonomous mobility instead of a personally owned AV, when both options become autonomous. Therefore, car ownership will decrease and more people will be adopting shared autonomous mobility. If car ownership decreases, then fewer parking places are necessary for AVs. This will lead to more public space in cities, but also to more free space in other areas. These areas can be used for other purposes, like housing, offices, recreational facilities or green spaces. These results are related to mid-term decisions.

The short-term decisions have implications for the capacity on the road network. The penetration rate of users of shared autonomous modes has no direct effect on the road capacity. Since shared vehicles need to reposition themselves to pick up the next customer(s), resulting in zero-occupancy kilometers. However, if people start sharing a ride with others, then fewer vehicles are necessary to meet travel demand. One-third of the time respondents are willing to share a ride with others, which will decrease the vehicle distance traveled. Since less rides are necessary to bring people to their destination. However, if shared autonomous modes are more popular than public transportation, then the VDT increases, leading to more AVs on the road.

6.3 Limitations and recommendations

This research asks the respondents to choose between different autonomous transportation modes during choice experiments. The decisions of the respondents are hypothetical. Actual behavior might differ from the decisions made in the choice experiments. Other circumstances play a role when making the actual decision. Even though this research tried to make the choices as realistic as possible.

Many respondents are deleted from the sample for multiple reasons. Trial and error could be used to test if all these respondents really needed to be deleted. But due to timing reasons different sample sizes have not been tested in the different hybrid choice models.

Furthermore every hybrid choice model consists of all attributes, the attitude towards sustainably and some socio-demographics and travel chrematistics. Many combinations of different socio-demographics and travel characteristics are tested. However, generation of one single hybrid choice model takes much time. Therefore limited combinations of different socio-demographics and travel characteristics could be tested.

The alternative APT could be investigated in more detail. First of all, future research could put more consideration into the role of APT. Attributes can be added to this alternative, to investigate how the attributes influence the decisions to use autonomous public transportation. Future research could also make the alternative APT available when the car is the transportation mode of the reference trip. The results could provide information about the willingness of car users to use APT. To conclude the role of public transportation could be investigated in more detail in future research.

Only the attitude towards sustainably is added to the hybrid choice model, even though five latent variables have been investigated. Future research could investigate the attitude towards car ownership, the attitude towards ride sharing and dependency in more detail. The attitude towards car sharing is not used in the hybrid choice models, because the attitude is too much related to the choices made in the choice experiments. Therefore, the attitude does not need to be added in future research. Finally, personality traits in relation to the adoption and usage of AVs should be investigated in future research. Personality traits provide information about the individual. The traits might also influence the decision making process of individuals. Personality traits like risk taking, being adventurous and having privacy concerns can be investigated in future research.

Finally hybrid choice models are used to analyze the outcomes of the choice experiments. Indicators are needed to analyze attitudes, because attitudes cannot be directly measured. The hybrid choice model uses the indicators to simultaneously estimate the influence of attitudes on the choices. A hybrid choice model is recommended to use in future research that uses a stated choice experiment and attitudes.

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Appendix

Appendix A – Summary of studies similar to this study

Authors	Alternatives	Attributes	Attitudes	methodology
Bansal and Daziano (2018)	Uber without ride sharing	Walking/access time		Logit-Mixed Logit Model
	Uber with ride sharing	Actual traveling time		
	Daily used transportation mode	Trip costs		
		Parking costs		
		CO2 emission		
		Level of automation		
Bansal and Kockelman (2015)	Manual transportation mode	Price	Attitude towards new technologies.	Exploratory analysis
	Owning an AV	Levels of automation	Attitude towards safety-regulation strategies	
	Shared AV system			
	Shared autonomous ride			
Bösch et al. (2018)	(autonomous) rail transport	Fixed costs		comprehensive bottom-up calculations
	(autonomous) bus	Variable costs		
	(autonomous) individually used taxi			
	(autonomous) pooled taxi			
	(autonomous) private car			
Cyganski et al. (2014)	Highway pilot	Purpose of AV trip	Visualize using AV	Exploratory qualitative analysis and exploratory quantitative analysis
	Valet parking		Pleasure of driving	
	Fully automated vehicle			
	Vehicle on demand service			
Daziano et al. (2017)	Hybrid Vehicle	Purchase Price	Attitude toward automated cars	Discrete choice model

	Plug-in hybrid electric vehicle	Costs to drive 100 miles		
	Electric vehicle	Electric driving range		
	Gasoline vehicle	Recharging time		
		Autopilot package		
Haboucha et al. (2017)	Manual car	Capital costs	Technology interest	Random utility models
	Owning an AV	Trip costs	Concern of the environment	
	Shared AV system	Parking costs	Enjoyment of driving	
			Public transportation usage	
			Supporting AV technology	
Kockelman et al. (2016)	Manual transportation mode	Price	Attitude towards econometric models	Multinomial logit model
	Owning an AV	Level of automation	Driving behavior	
	Sharing AV system		Attitude towards new technologies	
	Shared autonomous ride			
Kolarova et al. (2018)	Daily used transportation mode	Traveling time	Value of traveling time	Multinomial logistic regression model
	Shared AV system	Access time		
	Owning an AV	Waiting time		
		Ride sharing		
		Costs per km		
König and Neumayr (2017)	Manual transportation mode		Willingness to ride	Exploratory analysis
	Autonomous vehicle		Willingness to buy	
			Adoption of AV	
			Perception of benefits	
			Perception of concerns	
Krueger, Rashidi and Rose (2016)	Transportation mode of reference trip	Price	Value of traveling time	Mixed logit model
	Shared autonomous vehicle	Waiting time		
	Shared autonomous ride	Traveling time		

Kyriakidis et al (2015)	Owning a manual car	Price	Enjoyment of driving	Correlational analyses
	Owning an car with semi automation	Level of automation		
	Owning an fully autonomous car		Concerns towards AV	
			Willingness to pay for automation	
Lavieri & Bhat (2019)	private self-driving cab service	Travel time	privacy sensitivity	
	shared self-driving cap service	Travel costs	time-sensitivity	
		Additional passengers	interest in productive use of travel time	
Lavieri et al. (2017)	Not interested in AV		Affection with sustainability	Multimodal probit kernel model
	Owning an AV		Enthusiast about technology	
	Shared AV system			
	Both owning or sharing an AV			
Nazari et al. (2018)	Owning an AV		Safety concerns	Multivariate and bivariate ordered probit model
	Rented AV		Environmental concern	
	Shared AV with driver		Affection towards sharing	
	Shared AV without driver			
	Multimodal AV usage			
	AV alone			
	AV carpool			
Nair et al. (2018)	Owning an AV		Safety concerns	Rank ordered probit model
	Rented AV		Environmental concern	
	Shared AV with driver		Affection towards sharing	
	Shared AV without driver			
Pettigrew et al. (2019)	Manual transportation mode		Purchase intention of AVs	Latent profile analysis
	Owning an AV		Perceived benefits of AVs	
	shared AV system		Concerns of AVs	

Pakusch (2018)	Manual car ownership			Bradley-Terry-Luce model
	Manual car sharing			
	Public transportation			
	Owning an AV			
	Shared AV system			
Shabanpour et al. (2018)	Owning an AV	Purchase price	Perception of benefits	Multinomial logit model
	Not purchase an AV	Fuel costs	Perception of concerns	
		Driving range		
		Safety		
		Emission rate		
		Driver liability for crashes		
		Exclusive lane for AVs		
Schoettle and Sivak (2015)	Manual driving			Exploratory analysis
	Semi automation			
	Full automation			
Schoettle and Sivak (2014)	Manual driving			Exploratory analysis
	Full automation			
Stoiber et al. (2019)	Privately owned AV (ST*)	Price per km	Attitude to autonomous traveling	Generalized estimation equation ordinal logistic model
	Shared autonomous ride (ST*)	Walking distance	Attitude toward sharing a ride/vehicle	
	Autonomous shuttle/train (ST*)	Shared with others		
	Purchase an AV (LT*)	Number of persons		
	Membership of shared autonomous taxis (LT*)	Reliability		
	Public transportation pass (LT*)	Waiting time		
		Traveling time		
		Investment		
The world economic forum (2018)	Public transportation	Purpose		Exploratory analysis
	Personal vehicle (manual and autonomous)	Traveling group		
	On demand services (taxi/ride haling, SAV, SAR car, SAR van)	Weather		

		Time of day		
		Duration		
Webb et al. (2019)	50% ESAV, 50% manual	Costs per km	Enjoyment of driving	Multinomial logit model
	80% ESAV, 20% manual	Number of serious accidents	Concern of emissions	
	Daily used transportation mode	Increase in urban space	Preference to share	
		Extra in vehicle time	Affection with public transportation	
Zmud, Sener & Wagner (2016)	Manual transportation mode		'Wait-and-see' attitude	Exploratory analysis
	AV adoption in general		Technology adoption	
	Owning an AV		Perception of privacy	
	Shared AV system		Safety concerns	
			Trust in technology	

*ST is the abbreviation of short-term, LT is the abbreviation of long term.

Appendix B – Experimental design

B1: Experimental design of the SCE

The attributes in blue letters belong to the first alternative, the letters in red are the attributes related to the second alternative.

Choice task	Purchase price	Depreciation costs	Monthly costs	Membership fee	Price per km	Waiting time	Reliability 1	Reliability 2	Block
1	1	2	3	2	1	1	2	2	2
2	1	2	2	4	2	2	1	1	4
3	4	2	4	3	2	2	2	2	3
4	1	2	4	4	4	1	1	2	3
5	3	1	2	4	3	1	1	1	2
6	2	1	2	3	1	2	2	1	2
7	3	2	2	1	4	4	2	2	1
8	4	1	2	2	3	4	1	2	3
9	4	2	2	3	4	1	2	1	4
10	2	1	3	1	2	1	1	2	4
11	2	2	2	2	2	3	1	2	1
12	3	2	1	3	1	4	1	2	4
13	3	2	4	1	2	3	2	1	2
14	2	1	4	3	3	1	2	2	1
15	2	1	1	1	4	2	1	1	3
16	1	1	4	1	3	4	2	1	4
17	1	1	1	3	4	3	1	2	2
18	4	1	1	4	2	4	2	2	2
19	4	1	4	2	1	3	1	1	4
20	2	2	4	2	4	4	1	1	2
21	2	2	1	4	3	3	2	2	4
22	2	2	3	4	1	4	2	1	3
23	1	1	3	3	2	4	1	1	1
24	3	1	4	4	1	2	1	2	1
25	3	2	3	3	3	3	1	1	3
26	3	1	3	2	4	2	2	2	4
27	3	1	1	2	2	1	2	1	3
28	4	1	3	4	4	3	2	1	1
29	4	2	1	1	1	1	1	1	1
30	4	2	3	1	3	2	1	2	2
31	1	2	1	2	3	2	2	1	1
32	1	1	2	1	1	3	2	2	3

B2: Experimental design of the SACE

The attributes in blue letters belong to the first alternative, the letters in red are the attributes related to the second alternative.

Choice task	Price per km	Waiting time	Travel time	Seating comfort	Price per km	Waiting time	Travel time	Number of people	Seating comfort	Block
1	1	2	2	2	4	1	1	1	1	5
2	1	3	1	1	2	3	1	1	2	15
3	1	4	1	2	3	2	2	1	1	8
4	3	2	2	1	2	1	2	4	2	12
5	3	4	1	1	2	4	1	3	2	5
6	1	2	2	2	3	3	1	2	1	3
7	2	4	2	1	3	4	2	4	1	16
8	1	3	1	1	4	2	1	3	2	16
9	4	1	1	1	1	3	1	3	1	12
10	1	2	2	2	1	2	1	4	1	7
11	3	2	2	1	3	2	2	1	2	11
12	3	1	2	2	3	4	1	4	1	9
13	2	4	2	1	4	2	2	3	1	2
14	2	1	1	2	4	1	2	1	2	3
15	1	1	2	1	2	2	2	2	2	1
16	4	3	2	1	4	1	2	1	1	7
17	2	3	2	2	2	1	1	4	2	11
18	1	3	1	1	1	1	1	2	2	9
19	3	1	2	2	2	3	1	1	1	16
20	1	1	2	1	3	1	2	3	2	10
21	2	1	1	2	1	2	2	4	2	13
22	4	1	1	1	3	2	1	1	1	6
23	3	3	1	2	2	2	2	2	1	14
24	2	1	1	2	3	3	2	2	2	5
25	3	3	1	2	1	4	2	1	1	10
26	2	3	2	2	3	2	1	1	2	12
27	4	2	1	2	2	3	2	1	2	2
28	4	2	1	2	4	2	2	3	2	9
29	3	2	2	1	4	4	2	2	2	6
30	3	2	2	1	1	3	2	3	2	8
31	4	3	2	1	3	3	2	2	1	13
32	2	3	2	2	1	3	1	3	2	6
33	2	2	1	1	4	3	1	4	1	10
34	2	4	2	1	1	1	2	2	1	15
35	4	4	2	2	1	4	1	1	2	14
36	2	1	1	2	2	4	2	3	2	7

37	4	4	2	2	3	1	1	3	2	1
38	4	3	2	1	1	2	2	4	1	5
39	3	1	2	2	1	1	1	2	1	2
40	2	2	1	1	2	2	1	2	1	4
41	1	4	1	2	4	4	2	2	1	12
42	1	1	2	1	4	3	2	4	2	14
43	2	3	2	2	4	4	1	2	2	8
44	4	2	1	2	1	1	2	2	2	16
45	2	2	1	1	1	4	1	1	1	1
46	4	2	1	2	3	4	2	4	2	15
47	2	4	2	1	2	3	2	1	1	9
48	1	3	1	1	3	4	1	4	2	2
49	3	1	2	2	4	2	1	3	1	15
50	4	3	2	1	2	4	2	3	1	3
51	1	2	2	2	2	4	1	3	1	13
52	2	2	1	1	3	1	1	3	1	14
53	4	1	1	1	2	1	1	4	1	8
54	1	1	2	1	1	4	2	1	2	4
55	1	4	1	2	1	3	2	3	1	11
56	1	4	1	2	2	1	2	4	1	6
57	3	4	1	1	4	1	1	1	2	13
58	4	1	1	1	4	4	1	2	1	11
59	3	4	1	1	1	2	1	4	2	3
60	4	4	2	2	4	3	1	4	2	4
61	3	3	1	2	4	3	2	4	1	1
62	4	4	2	2	2	2	1	2	2	10
63	3	4	1	1	3	3	1	2	2	7
64	3	3	1	2	3	1	2	3	1	4

Appendix C – Screenshots of the questionaire

C0: General information

LimeSurvey

Load unfinished survey

Language: English Change the language

Adoption and usage of self-driving vehicles

Sharing or buying

Dear Sir/Madam,

The following questionnaire is part of a graduation project at the Technical University of Eindhoven in cooperation with TNO. The goal of this research is to predict which type of self-driving vehicle people would prefer using in the future.

If you travel regularly by car or public transportation, we are interested in your travel behavior and your future mobility decisions. Your participation in this research is important to predict future adoption and usage of various services provided by self-driving vehicles. Please note that the level of automation in this questionnaire refers to level 5. Level 5 automation means that the vehicle can drive safely by itself and does not need a human driver. This survey also investigates shared mobility. Nowadays people increasingly use shared mobility. For example consider Uber, which is an online platform which provides taxi rides with personally owned cars. It is also getting easier and more comfortable to use shared cars.

Filling in the questionnaire takes between 15 to 20 minutes. Participation is voluntary and you can pause or stop the questionnaire at any moment. In order to pause the questionnaire, you can click on 'resume later' in the right upper corner during the completion of the questionnaire. The gathered data will be handled carefully to protect your privacy. The data will be processed with protected software. Furthermore, the collected data will be anonymized and used for statistical purposes only. After completion, the data will be saved in a safe environment and will be stored a few years after completion of this research.

Thank you in advance for your participation.

Next

C1: Transporation mode

The second question only appears if the respondent uses another transportation mode; either 4 or more days per week, 1 to 3 days per week, 1 to 4 days per month or 1 to 10 days per year. The Third question appears if the respondent never uses shared mobility.

LimeSurvey

Resume later   Exit and clear survey

1. Transportation modes

The following questions are about your current travel behavior.

*How often do you use the following transportation modes to reach a certain destination?

	4 or more days per week	1 to 3 days per week	1 to 4 days per month	1 to 10 days per year	Never
Car as driver	○	○	○	○	○
Car as passenger	○	○	○	○	○
Train	○	○	○	○	○
Bus/metro/tram	○	○	○	○	○
Bike	○	○	○	○	○
Scooter/motor/E-bike	○	○	○	○	○
Walking	○	○	○	○	○
Shared ride: car sharing or ride hailing (e.g. Greenwheels or Uber)	○	○	○	○	●
Another transportation mode	●	○	○	○	○

*Which other transportation mode do you use 4 or more days per week

*Shared mobility is a way of transportation, where the car is shared with other people. A new and user-friendly taxi service is available, called Uber, with Uber you can order a ride via an app and you will be picked up and dropped off at your desired location. Also it is becoming easier to use shared cars (or rent cars). When you use a shared car and you arrive on your final destination, the car becomes available for the next person.

Would you ever consider using shared mobility in the future?

○ Never

○ Maybe

○ Certainly

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C2: Car specific questions

The question about the purchase price of the current car and the question about engine type only appears if the respondent owns one or more cars.

LimeSurvey

Resume later Exit and clear survey

2. Car specific questions

*Do you have a driving license?

Yes No

*Do you own a car?

- Yes, one car
- Yes, two cars or more
- No

*Do you have a lease car?

- Yes, a private lease car
- Yes, a company lease car
- No
- Other:

*What is the purchase price of your car?

- €500-€5000
- €5000-€10.000
- €10.000-€15.000
- €15.000-€25.000
- €25.000-€35.000
- €35.000-€50.000
- €50.000 or more

If you have two or more cars, indicate the purchase price of the car you use most often.

*What is the engine type of your car(s)?

- [ ] LPG
- [ ] Gasoline
- [ ] Diesel
- [ ] Hybrid
- [ ] Electrical
- [ ] Other: ____

*
- If you need to buy a (new) car in the upcoming 5 years
- Or if your car needs to be replaced in the upcoming 5 years

What would you pay to buy this (new) car?
(if you only have a lease car, what would be the value of your new (or other) lease car?)

- ○ €1000-€5000
- ○ €5000-€10.000
- ○ €10.000-€15.000
- ○ €15.000-€25.000
- ○ €25.000-€35.000
- ○ €35.000-€50.000
- ○ €50.000 or more
- ○ I do not plan to buy a (new) car in this situation.

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C3: Stated choice experiment

First a movie is shown to the respondents (separate document: appendix C3.1), then the choice tasks are anwered. Only two choice tasks are shown, the respondent fills in eight choice tasks.

LimeSurvey

Resume later Exit and clear survey

3. Adoption of the self-driving car

The upcoming sections are about self-driving cars, which do not need a human driver. These cars will possibly drive on the roads in the future. In the following questions we will present 8 different situations in which you can choose between a self-driving car which you can buy or a subscription for shared self-driving cars. The shared self-driving car provides you a **door to door ride.** It is also possible to transport groceries, a wheelchair or a stroller with this car.

Watch the video for more explanation.

Put the sound on.

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LimeSurvey

Resume later   Exit and clear survey

*Which of the following self-driving cars would you choose?

	Buy a self-driving car	Share a self-driving car
Purchase price:	€20000	-
Depreciation costs per year:	€2000	-
The monthly car ownership costs decrease by: (Compare to the monthly cost of a man driven car) Costs like: maintenance, fuel, insurance, tax, etc.	-20%	-
Monthly membership costs:	-	€20
Price per kilometer:	-	€0,20 per km
Average waiting time:	-	7 minutes
Reliability of the waiting time:	-	80% change the vehicle arrives on time, 20% change the vehicle arrives 4 minutes later.
Make a choice	○	○

*Which of the following self-driving cars would you choose?

	Buy a self-driving car	Share a self-driving car
Purchase price:	€20000	-
Depreciation costs per year:	€1000	-
The monthly car ownership costs increase by: (Compare to the monthly cost of a man driven car) Costs like: maintenance, fuel, insurance, tax, etc.	+10%	-
Monthly membership costs:	-	€40
Price per kilometer:	-	€0,30 per km
Average waiting time:	-	1 minutes
Reliability of the waiting time:	-	60% change the vehicle arrives on time, 40% change the vehicle arrives 4 minutes later.
Make a choice	○	○

C4: Referenced trips

Only two refernce trips are displayed, because the quesitons of all four trips are similar. However the respondetns using car as driver, car as a passenger and shared mobilty get a quesition about parking costs. Respondents traveling by train or bus/tram/metro get questions about access time, egress time, waiting time and travel costs.
If the respondetns travels alone no aditional quesiotna are asked. When the respondent travels with others, aditonal questions are asked: travel company, if the respondent traveld with children, if so the respondent is asked about the age of the children.

LimeSurvey

Resume later Exit and clear survey

4. Rides

In the following section we will ask you questions about 4 different rides you took. Please think about 4 different rides you took last week (or the week before) by **car or public transportation**. Describe rides taking less than 4 hours. We would like you to describe rides to various locations. For example: work, the supermarket, family visits, etc. Please describe only outbound rides.
If you are not able to think of 4 different rides, describe the outbound and inbound ride.

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LimeSurvey

Resume later   Exit and clear survey

Ride 1

The following questions are about the first ride.

*What was the main transportation mode of this ride?

Car as driver

If your ride consisted of multiple transportation modes, please indicate the transportation mode you used for the longest period of time. For example, if you took the train, but you walked to the train station first, the transportation mode you should indicate is the train.

*what was the purpose of this ride? To:

Please choose...

*How long did the total trip take?

Hour: 0

Minutes:

If you do not know the exact traveling time, please provide an approximation of the traveling time.

*What was the distance of this trip in kilometers? If you do not know the exact distance, please provide an approximation of the distance.

kilometer

*How much did you pay to park the car?

Nothing

I don't know

€

*Were you in a hurry during this ride?

	1	2	3	4	5	
Not at all	○	○	○	○	○	A lot

*Did you travel alone?

Yes | No

*Who was your traveling companion?

- Family member(s)
- Friend(s) or acquaintance(s)
- Colleague(s)
- Other:

*Did you travel with kids?

Yes | No

*What was the age of the youngest child during the ride?

Please choose...

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LimeSurvey

Resume later   Exit and clear survey   Lar

Ride 2

The following questions are about the second ride.

*What was the main transportation mode of this ride?

Train

If your ride consisted of multiple transportation modes, please indicate the transportation mode you used for the longest period of time. For example, if you took the train, but you walked to the train station first, the transportation mode you should indicate is the train.

*what was the purpose of this ride? To:

Please choose...

*How long did the total trip take?

Hour: 0

Minutes:

If you do not know the exact traveling time, please provide an approximation of the traveling time.

*What was the distance of this trip in kilometers? If you do not know the exact distance, please provide an approximation of the distance.

kilometer

*The following questions are about your traveling time:

how long did you cycle or walk to the departure point of public transportation? minutes

how long did you cycle or walk from the endpoint of public transportation to your final destination? minutes

What was your total waiting time of your trip with public transportation? minutes

*How much did you approximately pay for your trip with public transportation?

- Nothing
- I don't know
- €

*Were you in a hurry during this ride?

	1	2	3	4	5	
Not at all	○	○	○	○	○	A lot

*Did you travel alone?

Yes No

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C5: Stated adaptation choice experiment

First a movie is shown to the respondents (separate document: appendix C5.1), then the choice tasks are anwered. Only two choice tasks are shown, the respondent fills in four choice tasks.

LimeSurvey

Resume later Exit and clear survey

5. Usage of shared self-driving cars

In this section we ask you again, to make choices, this time between shared self-driving cars. The first shared self-driving car provides you a private ride. The second provides you a ride that is shared with strangers during the ride. Both services provide you a door to door service. It is also possible to transport groceries, a wheelchair or a stroller with this car. Furthermore the service works the same as the service shown in the movie.

Watch the video for more explanation.

Put the sound on.

Previous

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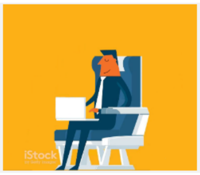
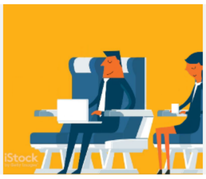
LimeSurvey

Resume later Exit and clear survey

***You made the following ride:**

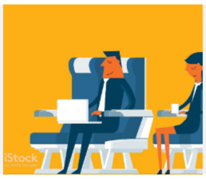
Your travel purpose was: **Social activity (meeting friends or family members)**
The transportation mode was: **Car as passenger**
The ride took: **1 hour and 40 minutes**
The distance was approximately: **100** kilometer
You traveled (together with): **Colleague(s)**
You were **extremely** in a hurry
The parking costs were: (€) **0**

If you take the same ride with a self-driving vehicle, which of the following vehicles would you choose?

	Shared self-driving car, individual ride	Shared self-driving car, shared with strangers
Price for the ride:	€20	€5
Waiting time:	3 minutes	10 minutes
Traveling time:	1 hour, 20 minutes.	1 hour, 50 minutes.
Travel accompany:	-	1 stranger(s)
Seating comfort:		
Make a choice	○	○

***You made the following ride:**
Your travel purpose was: **Leisure (sports, hobby, etc.)**
The transportation mode was: **bus/metro/tram**
The ride took: **0 hour en 10 minutes**
The distance was approximately: **10** kilometer
You traveled (together with): **Family member(s) with children of 4 years old or less**
You were in a hurry
The traveling costs were: (€)**10**
You waited for: **5** minutes

If you take the same ride with a self-driving vehicle, which of the following vehicles would you choose?

	Shared self-driving car, Individual ride	Shared self-driving car, Shared with strangers	Self-driving public transportation
Price for the ride:	€3	€2	
Waiting time:	5 minutes	8 minutes	
Traveling time:	0 hour, 6 minutes.	0 hour, 11 minutes.	
Travel accompany:	-	4 stranger(s)	
Seating comfort:			I would travel the same way as the above described ride, but then with self-driving public transportation.
Make a choice	○	○	○

C6: Attitudes

LimeSurvey

Resume later   Exit and clear survey

6. Statements

*do you agree with the following statements?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I only have a car to drive from A to B.	○	○	○	○	○
If I find a transportation mode equal convenient as the car, I would not need a car.	○	○	○	○	○
A car gives me status and prestige.	○	○	○	○	○
I think the car has practical functions only.	○	○	○	○	○
I feel free and independent if I own a car .	○	○	○	○	○
I think shared mobility will makes me more dependent.	○	○	○	○	○
I would use shared mobility if it doesn't take more time.	○	○	○	○	○
I would use shared mobility if it doesn't cost me extra money.	○	○	○	○	○
I would use shared mobility if it gives me the same comfort as owning a car.	○	○	○	○	○
I would use shared mobility if it is easy to order a ride or car.	○	○	○	○	○

*do you agree with the following statements?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I think it is pleasant to meet new people in the train or bus.	○	○	○	○	○
I think it is uncomfortable when strangers are in close proximity of me in the train or bus.	○	○	○	○	○
I trust other travelers during a ride with public transportation.	○	○	○	○	○
When I'm traveling with public transportation, I'm concerned that strangers will look at my smartphone or laptop.	○	○	○	○	○
For me it is important to use a sustainable transportation mode.	○	○	○	○	○
I'm concerned about the negative environmental effects of car use.	○	○	○	○	○
Being environmentally responsible is an important part of who I am.	○	○	○	○	○
My attitude towards sustainability influences my behavior.	○	○	○	○	○
It is important for me to make environmental friendly decisions.	○	○	○	○	○

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C7: Socio-demograpics

The question about the need to use a car for work only appears if the respondent work. Furthermore the question about the postal code of the respondetn only appeas if the respondent lives in the Netherlands. The question about the number of driving lisences and cars in the household only appears if the respondent does not have a single household.

LimeSurvey

Resume later Exit and clear survey

7. General questions

*Please indicate your gender?

Female | Male

*What is your age?

- 17 years or younger
- 18-24 years
- 25-34 years
- 35-44 years
- 45-54 years
- 55-64 years
- 65-74 years
- 75 years or older

*What is your highest level of education?

- Primary school or middle school
- Low level of education (VMBO)
- Middle level of education (HAVO, VWO, MBO)
- High level of education (HBO, university)
- Other:

If you are still a student you can indicate your current level of education.

*what is your yearly gross income?

- €0-€10.000
- €10.001-€20.000
- €20.001-€30.000
- €30.001-€40.000
- €40.001-€50.000
- €50.001 or more
- I prefer not to answer.

*What is your occupation?

- Scholar or student
- Employed (paid), more than 30 hours per week
- Employed (paid), between 12 and 30 hours per week
- Employed (paid), less than 12 hours per week.
- Unemployed or disability
- Retired
- Other:

*Do you need a car during your work to do your job?
For example, to transport equipment or to go to an appointment which is badly accessible by public transportation or bike.

Yes | No

*In which country do you currently live?

- The Netherlands
- Other:

*What is your four digit postal code of your residential place?

*How would you describe your living environment?

- City center
- Urban, not in city center
- Slightly urban
- Village
- Rural

*What is your household composition?

- ○ Single without children
- ● Couple without children
- ○ Couple with child(ren)
- ○ Single with child(ren)
- ○ Living with others (no family)
- ○ Other: ____

*How many people in your household have a driving license?

____

*How many cars are in use within your household?

- ○ none
- ○ 1 car
- ○ 2 or more cars

*What kind of public transportation membership do you have?

- ☐ Student
- ☐ NS businesscard
- ☐ NS weekend discount (40% discount in weekends)
- ☐ NS off peak discount (40% discount in weekends and off peak hours)
- ☐ NS all-time discount (40% discount in weekends and outside peak hours, 20% discount in peak hours)
- ☐ NS weekend free (unlimited traveling during weekends)
- ☐ NS peak free (unlimited traveling during weekends and off peak hours)
- ☐ NS always free (unlimited traveling)
- ☐ OV discount (20% discount on bus, tram and metro)
- ☐ OV free (unlimited traveling with bus, tram, metro and train)
- ☐ Border membership (unlimited travel along a select route form the border)
- ☐ Route free (unlimited travel along a select route)
- ☐ None
- ☐ Other: ____

Previous Next

C8: Closing

LimeSurvey

Resume later   Exit and clear survey

8. Thank you

Thank you for filling in the questionnaire, do you have any remarks or questions?

If you have specific questions, feedback or remarks you can send an email to A.h.m.v.helvoirt@student.tue.nl.

Previous

Submit

Appendix D – Exploratory analysis of the pilot study

D1: Socio-demographics

Variable	Category	Frequency	%
Gender	Female	21	41.2
	Male	27	52.9
	Unknown	3	5.9
Age	18-24 years old	0	0.0
	25-34 years old	2	3.9
	35-44 years old	4	7.8
	45-54 years old	9	17.6
	55-64 years old	19	37.3
	65-74 years old	13	25.5
	75 years old or more	4	7.8
Education	Primary school and middle school		
	Low (VMBO)	6	11.8
	Middle (HAVO, VWO, MBO)	24	47.1
	High (HBO, university)	21	41.2
Income	€0-€10.000	1	2.0
	€10.001-€20.000	8	15.7
	€20.001-€30.000	9	17.6
	€30.001-€40.000	12	23.5
	€40.001-€50.000	9	17.6
	€50.001 or more	6	11.8
	"I prefer not to answer"	6	11.8
Occupation	Student	0	0.0
	Working (30 or more hours per week)	13	25.5
	Working (12-30 hours per week)	9	17.6
	Working (12 or less hours per week)	0	0.0
	Unemployed or disability	7	13.7
	Retired	20	39.2
	Other	2	3.9
The need for a car to work	Yes	10	19.6
	No	12	23.5
	The respondent doesn't work	29	56.9

Living environment	City center	4	7.8
	Urban, not in city center	26	51.0
	Slightly urban	5	9.8
	Village	13	25.5
	Rural	3	5.9
Household composition	Single without child(ren)	18	35.3
	Couple without child(ren)	22	43.1
	Single with child(ren)	1	2.0
	Couple with child(ren)	10	19.6
	Living with others (no family)		
	Other		

D2: Travel characteristics

Variable	Category	Frequency	%
Driving license	No	3	5.9
	Yes	48	94.1
Car ownership	None	10	19.6
	One car	36	70.6
	Two or more cars	5	9.8
Price current car	People not owning a car	10	19.6
	€500-€5000	3	5.9
	€5000-€10.000	8	15.7
	€10.000-€15.000	7	13.7
	€15.000-€25.000	14	27.5
	€25.000-€35.000	2	3.9
	€35.000-€50.000	6	11.8
	€50.000 or more	1	2.0
Price new car	€1000-€5000	4	7.8
	€5000-€10.000	7	13.7
	€10.000-€15.000	4	7.8
	€15.000-€25.000	10	19.6
	€25.000-€35.000	5	9.8
	€35.000-€50.000	4	7.8
	€50.000 or more	1	2.0
	I do not plan to buy a (new) car in this situation	16	31.4
PT membership	Yes	48	94.1
	No	3	5.9

Willingness to use shared mobility	Already a user of shared mobility	2	3.9
	Certainly		
	Maybe	25	49.0
	Never	24	47.1

D3: Usage of different kinds of transportation modes

Variable	Category	Frequency	%
Car as driver	4 or more days per week	24	47.1
	1 to 3 days per week	9	17.6
	1 to 4 days per month	5	9.8
	1 to 10 days per year	4	7.8
	Never	9	17.6
Car as a passenger	4 or more days per week	4	7.8
	1 to 3 days per week	11	21.6
	1 to 4 days per month	6	11.8
	1 to 10 days per year	16	31.4
	Never	14	27.5
Train	4 or more days per week	6	11.8
	1 to 3 days per week	2	3.9
	1 to 4 days per month	6	11.8
	1 to 10 days per year	21	41.2
	Never	22	43.1
Bus/Metro/Tram	4 or more days per week		
	1 to 3 days per week	3	5.9
	1 to 4 days per month	7	13.7
	1 to 10 days per year	15	29.4
	Never	26	51.0
Bike	4 or more days per week	16	31.4
	1 to 3 days per week	11	21.6
	1 to 4 days per month	6	11.8
	1 to 10 days per year	5	9.8
	Never	13	25.5
Scooter, motor or E-bike	4 or more days per week	7	13.7
	1 to 3 days per week	5	9.8
	1 to 4 days per month	1	2.0
	1 to 10 days per year	0	0.0
	Never	38	74.5

Walking	4 or more days per week	19	37.3
	1 to 3 days per week	19	37.3
	1 to 4 days per month	3	5.9
	1 to 10 days per year	2	3.9
	Never	8	15.7
Shared mobility	4 or more days per week	1	2
	1 to 3 days per week	1	2
	1 to 4 days per month	0	0.0
	1 to 10 days per year	0	0.0
	Never	49	96.1

D4: Reference trips

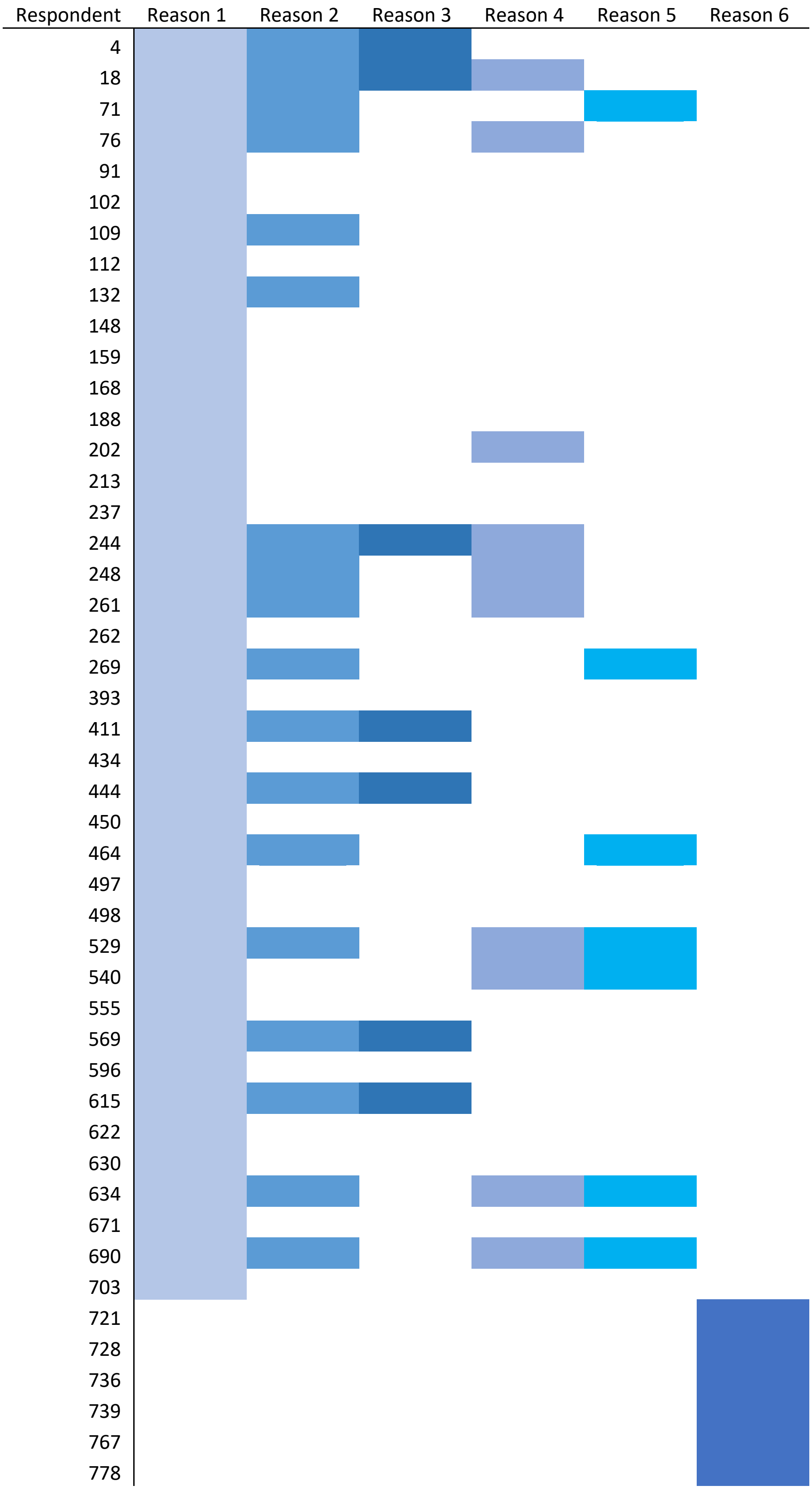
Variable	Category	Frequency	%
Transportation mode	Car as driver	96	68.6
	Car as a passenger	28	20.0
	Train	9	6.4
	Bus/tram/metro	6	4.3
	Sharing	1	.7
Travel purpose	Work	29	20.7
	Education		
	Social	37	26.4
	Groceries/shopping	33	23.6
	Leisure	16	11.4
	Dropping off	17	12.1
	Other	8	5.7
Travel pressure	Not at al	90	64.3
	Not	25	17.9
	Bit	20	14.3
	Hurry	3	2.1
	Big hurry	2	1.4
Travel companion	With others	68	48.6
	Alone	72	51.4

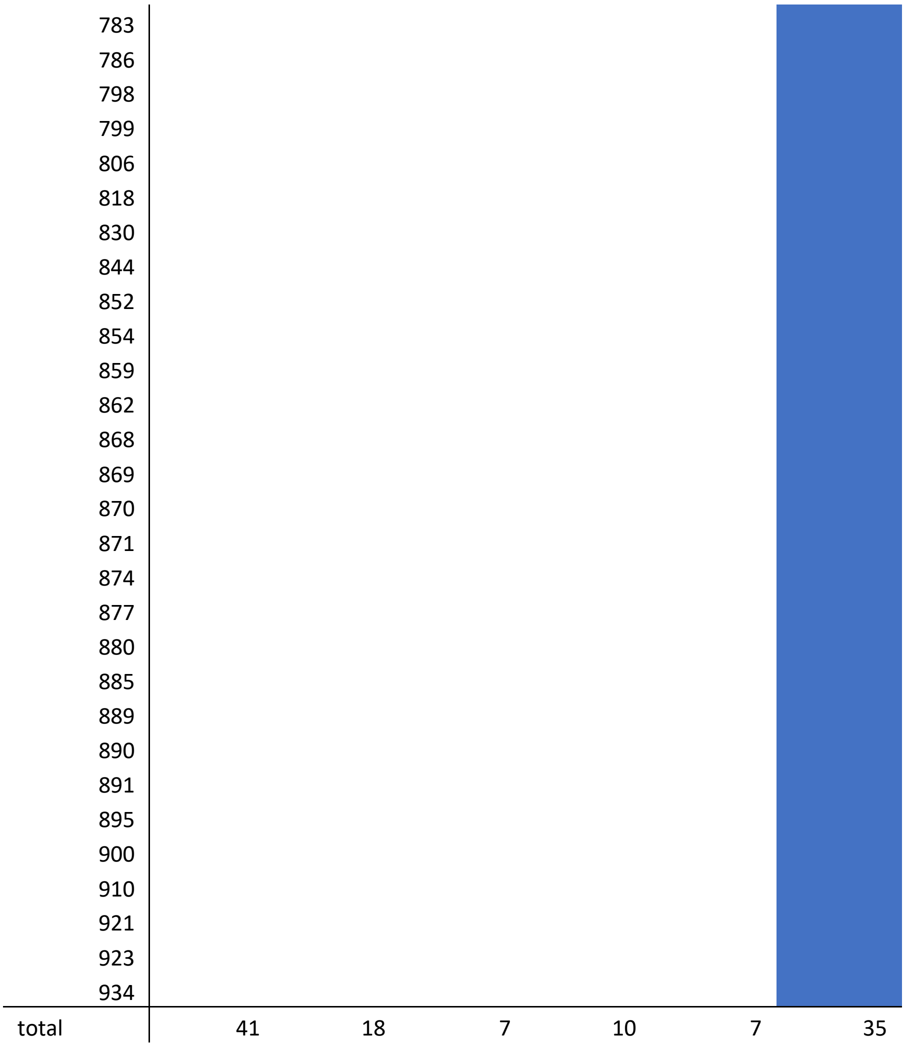
Variable		
Travel distance (km)	Valid	140
	Mean	41.9
	Median	16.5
	Std. Deviation	56.763
	Minimum	1
	Maximum	260

Travel time (minutes)	Valid	140
	Mean	43.44
	Median	30.00
	Std. Deviation	38.128
	Minimum	3
	Maximum	185

Appendix E – Data cleaning

E1: Deleted respondents

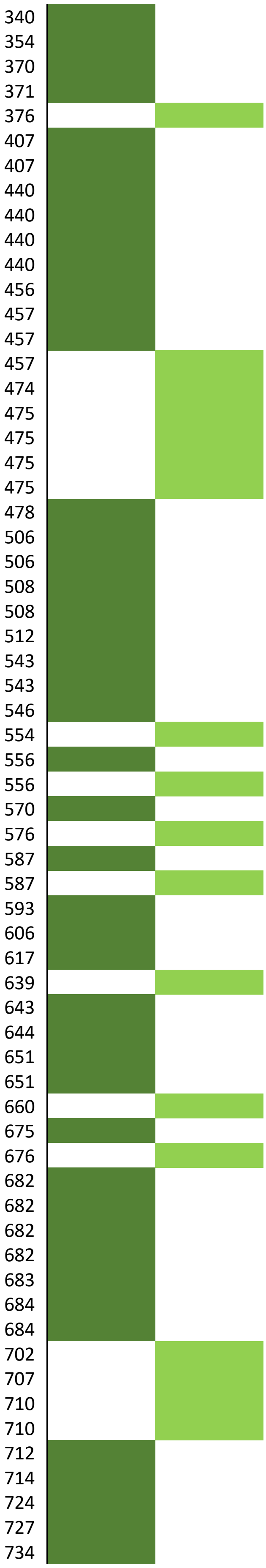




Reason 1	Equal answers on the statements
Reason 2	Total time to complete the full questionnaire is short
Reason 3	Indicated equal usage of different transportation modes
Reason 4	The reference trips are the same
Reason 5	Equal answers on the choice experiments
Reason 6	Gender is 'no answer'

E2: Deleted reference trips

Respondent	Reason 1	Reason 2	Reason 3
5	■		
12		■	
12		■	
12		■	
12		■	
22	■		
22	■		
22	■		
51			■
58	■		
58	■		
58	■		
58	■		
77	■		
77	■		
77	■		
77	■		
88	■		
88	■		
96	■		
96	■		
96		■	
98	■		
104	■		
104	■		
128	■		
129		■	
149	■		
155		■	
155		■	
155		■	
155		■	
163		■	
165		■	
168		■	
210	■		
210	■		
220	■		
230		■	
249		■	
251	■		
256		■	
256		■	
271		■	
271		■	
287	■		
287		■	
287		■	
290		■	
292		■	
309	■		
311		■	
311		■	
311		■	
316	■		
328	■		
338		■	
340	■		
340	■		


340
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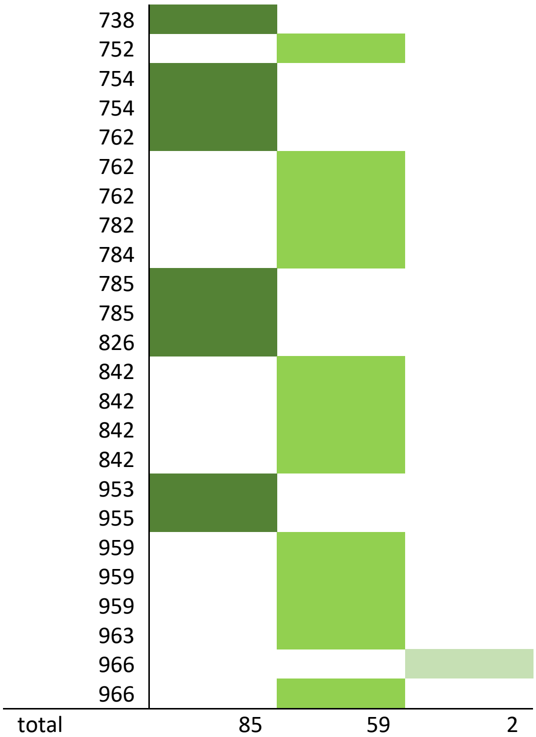
714
724
727
734



Reason 1	The travel time is longer than six hours
Reason 2	The speed (km/hour) is unreliable
Reason 3	De mode or purpose is not representative

E2: Changed answers

The option 'other' is consulted when the respondent does not consider a fit within one of the provided answer categories. The respondent provides a personalized textual answer in a text frame. Some of these answers do fit within the existing answer categories. The transformations on the answers in the category 'other' are shown in appendix E2.

Variable	Category	Answer	Number of respondents	New category
Socio-demographics				
Education level	Other	Mulo	1	Lower education
		Certificates HBO	1	higher education
		MAVO	3	lower education
		VWO	1	middle education
		University	3	higher education
Occupation (7 categories)	Other	Retired	2	Retired
Occupation (4 categories)	Other	Freelancer	5	Working
		Retired, bit working	2	Retired
		Housewife/houseman	23	Unemployed
		Volunteer	4	Unemployed
Nationality		1071 (assumingly postal code)	1	Netherlands
household composition	Other	Couple/single, having kids who not living with their parents anymore	10	Couple No Children
		Couple no children/with partner	3	Couple No Children
		Relationship, not living together	3	Single
		Married with children	1	Couple with children
		Single	1	Single
		Widow	1	Single
Travel characteristics				
Usage of different transportation modes	Other	Car	2	Car as driver
		Bike	2	Bike
		Bus/tram/metro	4	Bus/Tram/Metro
		Scooter/motor	2	Scooter, Motor and E-bike
		Step	1	N/A
		Boat	2	N/A
		Airplane	8	N/A
		Taxi	4	N/A
		E-step	2	N/A
		Rollerblades	1	N/A

		Answer is not a transportation mode	5	N/A
Lease car	Other	Owned car	2	No lease car
		Sharing membership	2	No lease car
		Rented car	1	No lease car
		Car of parents	1	No lease car
NS membership	Other	PT card (to put money on)	27	No membership
		Off peak discount	2	Off peak discount
Reference trip				
Ride purpose	Other	Vacation related (incl. weekend trips)	29	Leisure
		Family/friends visit	7	Social activity
		Day trip (incl. museum/concert)	15	Leisure
		Sport	1	Leisure
		dropping someone off	1	dropping someone off or picking someone up
		Related to groceries/shopping	3	Doing groceries or shopping
		Work related trips	2	Work
		Restaurant	4	Social activity
Travel company	Other	Nobody	8	N/A
		Dogs	3	N/A
		Family members	3	Family member(s)
		Neighbor / roommate	2	Friend(s) or acquaintance(s)
		Sport team / drama club	2	Friend(s) or acquaintance(s)
		"buddy"	2	Friend(s) or acquaintance(s)

Appendix F – Exploratory analysis

F1: Socio-demographics

Variable	Old categories	Frequency	%	New categories	Frequency	%
Age	18-24 years old	93	10.3	18-34 years old	239	26.5
	25-34 years old	146	16.2	35-54 years old	291	32.3
	35-44 years old	115	12.7	55-74 years old	323	35.8
	45-54 years old	176	19.5	75 years old or more	49	5.4
	55-64 years old	194	21.5			
	65-74 years old	129	14.3			
	75 years old or more	49	5.4			
Education	Primary school and middle school	10	1.1	Low (Primary or middle school, or VMBO)	112	12.4
	Low (VMBO)	102	11.3	Middle (HAVO, VWO, MBO)	351	38.9
	Middle (HAVO, VWO, MBO)	351	38.9	High (HBO, university)	439	48.7
	High (HBO, university)	439	48.7			
Income	€0-€10.000	97	10.8	€0-€20.000	201	22.3
	€10.001-€20.000	104	11.5	€20.001-€40.000	316	35.0
	€20.001-€30.000	149	16.5	€40.001 or more	263	29.2
	€30.001-€40.000	167	18.5	"I prefer not to answer"	122	13.5
	€40.001-€50.000	107	11.9			
	€50.001 or more	156	17.3			
	"I prefer not to answer"	122	13.5			
occupation	Student	90	10.0	Student	90	10.0
	Working (30 or more hours per week)	349	39.2	Working	517	57.3
	Working (12-30 hours per week)	141	15.6	Unemployed, disability or other	127	14.1
	Working (12 or less hours per week)	22	2.4	Retired	168	18.6
	Unemployed or disability	100	11.1			
	Retired	166	18.6			
	Other	34	3.0			
The need for a car to work	Yes	199	22.1			
	No	313	34.7			
	The respondent doesn't work	390	43.2			
Living environment	City center	134	14.9	Urban area	472	52.3

	Urban, not in city center	338	37.5	Slightly urban	110	12.2
	Slightly urban	110	12.2	Village	270	29.9
	Village	270	29.9	Rural	50	5.5
	Rural	50	5.5			
Household composition	Single without child(ren)	252	27.9	Single without child(ren)	252	27.9
	Couple without child(ren)	344	38.1	Couple without child(ren)	344	38.1
	Single with child(ren)	28	3.1	Single/couple with child(ren)	234	25.9
	Couple with child(ren)	206	22.8	Other	72	8.0
	Living with others (no family)	53	5.9			
	Other	19	2.1			

F2: Travel characteristics

Variable	Old categories	Frequency	%	New categories	Frequency	%
Lease car	None	811	89.9	None	811	89.9
	company lease car	33	3.7	lease car	91	10.1
	Private lease car	58	6.4			
Household car ownership	None	73	8.1			
	One car	394	43.7			
	Two or more cars	188	20.8			
	one person household	247	27.4			
Number of driving licenses in the household	0	11	1.2			
	1	105	11.6			
	2	399	44.2			
	3	70	7.8			
	4	40	4.4			
	5	13	1.4			
	6	5	.6			
	7	9	1.0			
	8	2	.2			
	20	1	.1			
	Household composition is single	247	27.4			
Price current car	People not owning a car	198	22.0			
	€ 2,750	117	13.0			
	€ 7,500	144	16.0			
	€ 12,500	133	14.7			
	€ 20,000	179	19.8			

	€ 30,000	72	8.0			
	€ 42,500	46	5.1			
	€ 80,000	13	1.4			
Price new car	€ 2,750	10	1.1			
	€ 3,000	129	14.3			
	€ 7,500	199	22.1			
	€ 12,500	158	17.5			
	€ 20,000	183	20.3			
	€ 30,000	92	10.2			
	€ 42,500	38	4.2			
	€ 80,000	13	1.4			
	"I do not plan to buy a (new) car in this situation"	80	8.9			
PT membership	Student	59	6.5	None	556	61.6
	NS business card	34	3.8	PT Membership	346	38.4
	NS Weekend discount	13	1.4			
	NS Off peak discount	117	13.0			
	NS All-time discount	14	1.6			
	NS weekend free	9	1.0			
	NS off peak free	7	.8			
	NS Always free	5	.6			
	OV discount	13	1.4			
	OV free	28	3.1			
	Route free	11	1.2			
	None	556	61.6			
	Other	36	4.0			

F3: Usage of different transportation modes

Variable	Old categories	Frequency	%	New categories	Frequency	%
Car as driver	4 or more days per week	366	40.6	4 or more days per week	366	40.6
	1 to 3 days per week	255	28.3	1 to 3 days per week	255	28.3
	1 to 4 days per month	102	11.3	1 to 4 days per month	102	11.3
	1 to 10 days per year	61	6.8	Never	179	19.8
	Never	118	13.1			
Car as a passenger	4 or more days per week	43	4.8	1 or more times per week	296	32.8
	1 to 3 days per week	253	28.0	1 to 4 days per month	272	30.2
	1 to 4 days per month	272	30.2	1 to 10 days per year	228	25.3
	1 to 10 days per year	228	25.3	Never	106	11.8
	Never	106	11.8			
Train	4 or more days per week	63	7.0	1 or more times per week	156	17.3

	1 to 3 days per week	93	10.3	1 to 4 days per month	125	13.9
	1 to 4 days per month	125	13.9	1 to 10 days per year	360	39.9
	1 to 10 days per year	360	39.9	Never	261	28.9
	Never	261	28.9			
Bus/Metro/Tram	4 or more days per week	49	5.4	1 or more times per week	135	14.9
	1 to 3 days per week	86	9.5	1 to 4 days per month	154	17.1
	1 to 4 days per month	154	17.1	1 to 10 days per year	312	34.6
	1 to 10 days per year	312	34.6	Never	301	33.4
	Never	301	33.4			
Bike	4 or more days per week	352	39.0	4 or more days per week	352	39.0
	1 to 3 days per week	187	20.7	1 to 3 days per week	187	20.7
	1 to 4 days per month	92	10.2	1 to 4 days per month	92	10.2
	1 to 10 days per year	78	8.6	Never	271	30.0
	Never	193	21.4			
Scooter, motor or E-bike	4 or more days per week	92	10.2	4 or more days per week	92	10.2
	1 to 3 days per week	62	6.9	1 to 3 days per week	62	6.9
	1 to 4 days per month	58	6.4	1 to 4 days per month	58	6.4
	1 to 10 days per year	32	3.5	Never	690	76.5
	Never	658	72.9			
Walking	4 or more days per week	405	44.9	4 or more days per week	405	44.9
	1 to 3 days per week	254	28.2	1 to 3 days per week	254	28.2
	1 to 4 days per month	122	13.5	1 to 4 days per month	122	13.5
	1 to 10 days per year	51	5.7	Never	121	13.4
	Never	70	7.8			
Shared mobility	4 or more days per week	3	0.3	Using shared mobility	127	14.0
	1 to 3 days per week	8	0.9	Never	775	85.9
	1 to 4 days per month	30	3.3			
	1 to 10 days per year	86	9.5			
	Never	775	85.9			

F4: Reference trips

Variable	Old categories	Frequency	%	New categories	Frequency	%
Transportation mode	Car as driver	1611	54.7	Car	2265	76.9
	Car as a passenger	654	22.2	Train	377	12.8
	Train	377	12.8	Bus	258	8.8
	Bus	258	8.8	Shared mobility	46	1.6
	Shared mobility	46	1.6			

Travel purpose	Work	580	19.7	Work	580	19.7
	Education	79	2.7	Social/leisure	1297	44.0
	Social activity	832	28.2	Groceries/shopping	636	21.6
	Groceries/shopping	636	21.6	Other	433	14.7
	Leisure	465	15.8			
	Dropping off	203	6.9			
	Other	151	5.1			
Travel pressure	Not at all in a hurry	1773	60.2	Not in a hurry	2287	77.6
	Not in a hurry	514	17.4	A bit in a hurry	470	16.0
	A bit in a hurry	470	16.0	In a hurry	189	6.4
	In a hurry	156	5.3			
	In a big hurry	33	1.1			
Travel companion 2	Nobody	1520	51.6	Nobody	1520	51.6
	Family	981	33.3	Family	981	33.3
	Friends/ acquaintances	311	10.6	Friends/ acquaintances/ colleague	364	12.4
	Colleague	53	1.8	Other	81	2.7
	Other	81	2.7			
Travel with kids	No kids	2719	92.3	No kids	2719	92.3
	4 years or younger	87	3.0	With kids	227	7.7
	Between 5 and 8 years old	35	1.2			
	Older than 8 years old	105	3.6			

Appendix G – Confirmatory factor analysis

G1: The unstandardized output, standard errors and significance of the indicators of the starting model

		Estimate	S.E.	C.R.	P
Indicator 19	Sustainability	1			
Indicator 18	Sustainability	0.982	0.031	31.677	***
Indicator 17	Sustainability	0.989	0.030	33.156	***
Indicator 16	Sustainability	1.004	0.034	29.152	***
Indicator 15	Sustainability	0.918	0.032	28.743	***
Indicator 14	Share with others	1			
Indicator 13	Share with others	-1.667	0.263	-6.345	***
Indicator 12	Share with others	1.745	0.281	6.212	***
Indicator 11	Share with others	-1.628	0.263	-6.192	***
Indicator 4	Car Ownership	1			
Indicator 3	Car Ownership	-0.559	0.077	-7.254	***
Indicator 1	Car Ownership	0.951	0.126	7.519	***
Indicator 6	Dependence	1			
Indicator 5	Dependence	0.644	0.095	6.763	***

G2: Process of getting the best model

Model	Conditions	factors and indicators	Remark	Changes
Model 1	Model fit		not sufficient	
	CR and AVE	Sustainability	Sufficient	
		Car Ownership	Too low	
		Share with others	Too low	
		Dependence	Too low	
	Factor loadings	Indicator 3 (2)	Below 0.4	
		Indicator 14 (3)	Below 0.4	Indicator 14 is deleted in next model
Model 2	Model fit		not sufficient	
	CR and AVE	Sustainability	Sufficient	
		Car Ownership	Too low	
		Share with others	Too low	
		Dependence	Too low	
	Factor loadings	Indicator 3 (2)	Below 0.4	Indicator 3 is deleted in next model
Model 3	Model fit		Sufficient	
	CR and AVE	Sustainability	Sufficient	
		Car Ownership	Sufficient	
		Dependence	Too low	
		Share with others	Too low	

	Factor loadings	Indicator 1 (2)	Below 0.4	
		Indicator 4 (2)	Higher than 1 and not significant	
	Other			Car ownership is deleted in next model
Model 4	Model fit		Sufficient	
	CR and AVE	Sustainability	Sufficient	
		Share with others	Too low	
		Dependence	Too low	
	Factor loadings	Indicator 12 (3)	Below 0.5	Indicator 12 is deleted in next model
Model 5	Model fit		Sufficient	
	CR and AVE	Sustainability	Sufficient	
		Share with others	Too low	
		Dependence	Too low	
	Other			Model 5.1: sustainability and share with others Model 5.2: sustainability and dependence
Model 5.1	Model fit		Sufficient	
	CR and AVE	Sustainability	Sufficient	
		Dependence	Too low	
	Other			Dependence is deleted in next model
Model 5.2	Model fit		Sufficient	
	CR and AVE	Sustainability	Sufficient	
		Share with others	Too low	
	Other			Share with others is deleted in next model
Model 6	Model fit		Sufficient	
	CR and AVE	Sustainability	Sufficient	
1= sustainability, 2= car ownership, 3= share with others, 4 = dependence				

G3: The unstandardized output, standard errors and significance of the indicators of the final model

		Estimate	S.E.	C.R.	P
Indicator 19	Sustainability	1			
Indicator 18	Sustainability	0.984	0.030	32.306	***
Indicator 17	Sustainability	0.989	0.029	33.702	***
Indicator 16	Sustainability	0.961	0.035	27.541	***
Indicator 15	Sustainability	0.879	0.032	27.103	***

Appendix H – Code of the hybrid choice models

H1: Code related to the results of the SCE

```
### Clear memory
rm(list = ls())

### Load Apollo library
library(apollo)

### Initialise code
apollo_initialise()

### Set core controls
apollo_control = list(
  modelName  = "SCE1_output",
  modelDescr = "SCE1 buy or share",
  indivID    ="ID",
  mixing     = TRUE,
  nCores     = 4
)

# ################################################################# #
#### LOAD DATA AND APPLY ANY TRANSFORMATIONS                     ####
# ################################################################# #

### Import database
setwd(" location of database on computer ")
database = read.table("SCE1.csv", header=TRUE, sep=",")

### Changes in database
database$attitudeST15=database$attitude15-mean(database$attitude15)
database$attitudeST16=database$attitude16-mean(database$attitude16)
database$attitudeST17=database$attitude17-mean(database$attitude17)
database$attitudeST18=database$attitude18-mean(database$attitude18)
database$attitudeST19=database$attitude19-mean(database$attitude19)

# ################################################################# #
#### DEFINE MODEL PARAMETERS                                      ####
# ################################################################# #

### Starting values of parameters
apollo_beta = c(

  #Alternative 1: buying an AV
  mu_buy = 0,
  sig_buy = 0,
  beta_alt1xPP1= 0,
  beta_alt1xPP2= 0,
  beta_alt1xPP3= 0,
  beta_alt1xDC=0,
  beta_alt1xMC1=0,
  beta_alt1xMC2=0,
  beta_alt1xMC3=0,

  #Alternative 2: sharing an AV
```

```
 mu_share = 0,
 sig_share = 0,
 beta_alt2xMF1= 0,
 beta_alt2xMF2= 0,
 beta_alt2xMF3= 0,
 beta_alt2xPK1=0,
 beta_alt2xPK2=0,
 beta_alt2xPK3=0,
 beta_alt2xWT1=0,
 beta_alt2xWT2=0,
 beta_alt2xWT3=0,
beta_alt2xrel1=0,
beta_alt2xrel2=0,
beta_alt2xrel3=0,

 #socio-demograpics; alt 1

# beta_buy_drivelisence= 0,
  beta_buy_CarDr4moredw=0,
  beta_buy_CarDr1_3dw=0,
  beta_buy_CarDr1_4dm=0,
# beta_buy_CarPas1moredw=0,
# beta_buy_CarPas1_4dm=0,
# beta_buy_CarPas1_10dy=0,
# beta_buy_Train1moredw=0,
# beta_buy_Train1_4dm=0,
# beta_buy_Train1_10dy=0,
# beta_buy_Bus1moredw=0,
# beta_buy_Bus1_4dm=0,
# beta_buy_Bus1_10dy=0,
# beta_buy_Bike4moredw=0,
# beta_buy_Bike1_3dw=0,
# beta_buy_Bike1_4dm=0,
# beta_buy_Scooter4moredw=0,
# beta_buy_Scooter1_3dw=0,
# beta_buy_Scooter1_4dm=0,
# beta_buy_Walk4moredw=0,
# beta_buy_Walk1_3dw=0,
# beta_buy_Walk1_4dm=0,
# beta_buy_Sharing_yes=0,
# beta_buy_CarOwn1=0,
# beta_buy_CarOwn2More=0,
# beta_buy_CarLease=0,

 beta_buy_GenderMale=0,
 beta_buy_Age18_34=0,
 beta_buy_Age35_54=0,
 beta_buy_Age55_74=0,
# beta_buy_EducationLow=0,
# beta_buy_EducationMiddle=0,
# beta_buy_Income0_20=0,
# beta_buy_Income20_40=0,
# beta_buy_Income40more=0,
 beta_buy_OccuStudent=0,
 beta_buy_OccuWork=0,
 beta_buy_Occu_ohter_unempl=0,
```

```
 beta_buy_Envi_urban=0,
 beta_buy_Envi_slightUrban=0,
 beta_buy_Envi_village=0,
# beta_buy_HH_Single=0,
# beta_buy_HH_Couple=0,
# beta_buy_HH_Kids_singlecouple=0,
# beta_buy_NS_Membership=0,

 beta_buy_CarWork_yes=0,
 beta_buy_CarWork_no=0,
# beta_buy_Household_lisence=0,
# beta_buy_HH_car_none=0,
# beta_buy_HH_car_1=0,
# beta_buy_HH_car_2more=0,

# socio-demograpics; alt 2

# beta_share_drivelisence= 0,
 beta_share_CarDr4moredw=0,
 beta_share_CarDr1_3dw=0,
 beta_share_CarDr1_4dm=0,
# beta_share_CarPas1moredw=0,
# beta_share_CarPas1_4dm=0,
# beta_share_CarPas1_10dy=0,
# beta_share_Train1moredw=0,
# beta_share_Train1_4dm=0,
# beta_share_Train1_10dy=0,
# beta_share_Bus1moredw=0,
# beta_share_Bus1_4dm=0,
# beta_share_Bus1_10dy=0,
# beta_share_Bike4moredw=0,
# beta_share_Bike1_3dw=0,
# beta_share_Bike1_4dm=0,
# beta_share_Scooter4moredw=0,
# beta_share_Scooter1_3dw=0,
# beta_share_Scooter1_4dm=0,
# beta_share_Walk4moredw=0,
# beta_share_Walk1_3dw=0,
# beta_share_Walk1_4dm=0,
# beta_share_Sharing_yes=0,
# beta_share_CarOwn1=0,
# beta_share_CarOwn2More=0,
# beta_share_CarLease=0,

 beta_share_GenderMale=0,
 beta_share_Age18_34=0,
 beta_share_Age35_54=0,
 beta_share_Age55_74=0,
# beta_share_EducationLow=0,
# beta_share_EducationMiddle=0,
# beta_share_Income0_20=0,
# beta_share_Income20_40=0,
# beta_share_Income40more=0,
 beta_share_OccuStudent=0,
 beta_share_OccuWork=0,
 beta_share_Occu_ohter_unempl=0,
```

```
 beta_share_Envi_urban=0,
 beta_share_Envi_slightUrban=0,
 beta_share_Envi_village=0,
# beta_share_HH_Single=0,
# beta_share_HH_Couple=0,
# beta_share_HH_Kids_singlecouple=0,
# beta_share_NS_Membership=0,

 beta_share_CarWork_yes=0,
 beta_share_CarWork_no=0,
# beta_share_Household_lisence=0,
# beta_share_HH_car_none=0,
# beta_share_HH_car_1=0,
# beta_share_HH_car_2more=0,

 #Latent-attitude variables

 Beta_sus=0,
 constant_sus=0,

 lambda_sus_buy=0,
 lambda_sus_share=0,
 zeta_sus15 = 1,
 zeta_sus16 = 1,
 zeta_sus17 = 1,
 zeta_sus18 = 1,
 zeta_sus19 = 1,
 sigma_sus15 = 1,
 sigma_sus16 = 1,
 sigma_sus17 = 1,
 sigma_sus18 = 1,
 sigma_sus19 = 1
 )

### Parameters to be kept fixed at their starting value
apollo_fixed = c(

 #Alternative 2: sharing an AV
 "mu_share",

# "beta_share_drivelisence",
 "beta_share_CarDr4moredw",
 "beta_share_CarDr1_3dw",
 "beta_share_CarDr1_4dm",
# "beta_share_CarPas1moredw",
# "beta_share_CarPas1_4dm",
# "beta_share_CarPas1_10dy",
# "beta_share_Train1moredw",
# "beta_share_Train1_4dm",
# "beta_share_Train1_10dy",
# "beta_share_Bus1moredw",
# "beta_share_Bus1_4dm",
# "beta_share_Bus1_10dy",
# "beta_share_Bike4moredw",
# "beta_share_Bike1_3dw",
# "beta_share_Bike1_4dm",
```

```
 # "beta_share_Scooter4moredw",
 # "beta_share_Scooter1_3dw",
 # "beta_share_Scooter1_4dm",
 # "beta_share_Walk4moredw",
 # "beta_share_Walk1_3dw",
 # "beta_share_Walk1_4dm",
 # "beta_share_Sharing_yes",
 # "beta_share_CarOwn1",
 # "beta_share_CarOwn2More",
 # "beta_share_CarLease",

  "beta_share_GenderMale",
  "beta_share_Age18_34",
  "beta_share_Age35_54",
  "beta_share_Age55_74",
 # "beta_share_EducationLow",
 # "beta_share_EducationMiddle",
 # "beta_share_Income0_20",
 # "beta_share_Income20_40",
 # "beta_share_Income40more",
  "beta_share_OccuStudent",
  "beta_share_OccuWork",
  "beta_share_Occu_ohter_unempl",
  "beta_share_Envi_urban",
  "beta_share_Envi_slightUrban",
  "beta_share_Envi_village",
 # "beta_share_HH_Single",
 # "beta_share_HH_Couple",
 # "beta_share_HH_Kids_singlecouple",
 # "beta_share_NS_Membership",

  "beta_share_CarWork_yes",
  "beta_share_CarWork_no",
 # "beta_share_Household_lisence",
 # "beta_share_HH_car_none",
 # "beta_share_HH_car_1",
 # "beta_share_HH_car_2more",

  #Latent-attitude variables

 lambda_sus_buy,
  "zeta_sus15",
  "sigma_sus15"
)

# ################################################################# #
#### DEFINE RANDOM COEFFICIENTS                                 ####
# ################################################################# #

### Set parameters for generating draws
apollo_draws = list(
  interDrawsType = "halton",
  interNDraws    = 500,
  interUnifDraws = c(),
  interNormDraws = c("eta_sus", "xi_buy", "xi_share"),

```

```
  intraDrawsType = '',
  intraNDraws    = 0,
  intraUnifDraws = c(),
  intraNormDraws = c()
)

### Create random parameters
apollo_randCoeff = function(apollo_beta, apollo_inputs){
  randcoeff = list()

  randcoeff[["SUSTAINABILITY"]] = constant_sus + Beta_sus*eta_sus

  randcoeff[["beta_buy"]] =  mu_buy +  sig_buy *  xi_buy

  randcoeff[["beta_share"]] =  mu_share +  sig_share * xi_share

   return(randcoeff)
}
# ################################################################# #
#### GROUP AND VALIDATE INPUTS                               ####
# ################################################################# #

apollo_inputs = apollo_validateInputs()

# ################################################################# #
#### DEFINE MODEL AND LIKELIHOOD FUNCTION                    ####
# ################################################################# #

apollo_probabilities=function(apollo_beta, apollo_inputs, functionality="estimate"){

  ### Attach inputs and detach after function exit
  apollo_attach(apollo_beta, apollo_inputs)
  on.exit(apollo_detach(apollo_beta, apollo_inputs))

  ### Create list of probabilities P
  P = list()

  #attitude sustainability
  sustainability1 = list(outcomeNormal=attitude15,
                   xNormal=zeta_sus15*SUSTAINABILITY,
                   mu=0,
                   sigma=sigma_sus15,
                   rows=(option==1))

  sustainability2 = list(outcomeNormal=attitude16,
                   xNormal=zeta_sus16*SUSTAINABILITY,
                   mu=0,
                   sigma=sigma_sus16,
                   rows=(option==1))

  sustainability3 = list(outcomeNormal=attitude17,
                   xNormal=zeta_sus17*SUSTAINABILITY,
                   mu=0,
                   sigma=sigma_sus17,
                   rows=(option==1))

```

```
sustainability4 = list(outcomeNormal=attitude18,
                       xNormal=zeta_sus18*SUSTAINABILITY,
                       mu=0,
                       sigma=sigma_sus18,
                       rows=(option==1))

sustainability5 = list(outcomeNormal=attitude19,
                       xNormal=zeta_sus19*SUSTAINABILITY,
                       mu=0,
                       sigma=sigma_sus19,
                       rows=(option==1))

P[["indic_sus15"]] = apollo_normalDensity(sustainability1, functionality)
P[["indic_sus16"]] = apollo_normalDensity(sustainability2, functionality)
P[["indic_sus17"]] = apollo_normalDensity(sustainability3, functionality)
P[["indic_sus18"]] = apollo_normalDensity(sustainability4, functionality)
P[["indic_sus19"]] = apollo_normalDensity(sustainability5, functionality)

### List of utilities: these must use the same names as in mnl_settings
V = list()

V[['buy']]  = (
beta_buy+
lambda_sus_buy*SUSTAINABILITY+

beta_alt1xPP1*alt1xPP1+
beta_alt1xPP2*alt1xPP2+
beta_alt1xPP3*alt1xPP3+
beta_alt1xDC*alt1xDC+
beta_alt1xMC1*alt1xMC1+
beta_alt1xMC2*alt1xMC2+
beta_alt1xMC3*alt1xMC3+

# beta_buy_drivelisence*drivingLisence+
beta_buy_CarDr4moredw*CarDr4moredw+
beta_buy_CarDr1_3dw*CarDr1_3dw+
beta_buy_CarDr1_4dm*CarDr1_4dm+
# beta_buy_CarPas1moredw*CarPas1moredw+
# beta_buy_CarPas1_4dm*CarPas1_4dm+
# beta_buy_CarPas1_10dy*CarPas1_10dy+
# beta_buy_Train1moredw*Train1moredw+
# beta_buy_Train1_4dm*Train1_4dm+
# beta_buy_Train1_10dy*Train1_10dy+
# beta_buy_Bus1moredw*Bus1moredw+
# beta_buy_Bus1_4dm*Bus1_4dm+
# beta_buy_Bus1_10dy*Bus1_10dy+
# beta_buy_Bike4moredw*Bike4moredw+
# beta_buy_Bike1_3dw*Bike1_3dw+
# beta_buy_Bike1_4dm*Bike1_4dm+
# beta_buy_Scooter4moredw*Scooter4moredw+
# beta_buy_Scooter1_3dw*Scooter1_3dw+
# beta_buy_Scooter1_4dm*Scooter1_4dm+
# beta_buy_Walk4moredw*Walk4moredw+
# beta_buy_Walk1_3dw*Walk1_3dw+
# beta_buy_Walk1_4dm*Walk1_4dm+
# beta_buy_Sharing_yes*Sharing_yes+
```

```
# beta_buy_CarOwn1*CarOwn1+
# beta_buy_CarOwn2More*CarOwn2More+
# beta_buy_CarLease*CarLease+

 beta_buy_GenderMale*GenderMale+
 beta_buy_Age18_34*Age18_34+
 beta_buy_Age35_54*Age35_54+
 beta_buy_Age55_74*Age55_74+
# beta_buy_EducationLow*EducationLow+
# beta_buy_EducationMiddle*EducationMiddle+
# beta_buy_Income0_20*Income0_20+
# beta_buy_Income20_40*Income20_40+
# beta_buy_Income40more*Income40ormore+
 beta_buy_OccuStudent*Occu_sudent+
 beta_buy_OccuWork*Occu_work+
 beta_buy_Occu_ohter_unempl*Occu_ohter_unempl+
 beta_buy_Envi_urban*Envi_urban+
 beta_buy_Envi_slightUrban*Envi_slightUrban+
 beta_buy_Envi_village*Envi_village+
# beta_buy_HH_Single*HH_Single+
# beta_buy_HH_Couple*HH_Couple+
# beta_buy_HH_Kids_singlecouple*HH_Kids_singlecouple+
# beta_buy_NS_Membership*NS_Membership+

 beta_buy_CarWork_yes*CarWork_yes+
 beta_buy_CarWork_no*CarWork_no
# beta_buy_Household_lisence*Household_lisence+
# beta_buy_HH_car_none*HH_car_none+
# beta_buy_HH_car_1*HH_car_1+
# beta_buy_HH_car_2more*HH_car_2more
 )

 V[['share']]  =(
 beta_share+
 lambda_sus_share*SUSTAINABILITY+

 beta_alt2xMF1*alt2xMF1+
 beta_alt2xMF2*alt2xMF2+
 beta_alt2xMF3*alt2xMF3+
 beta_alt2xPK1*alt2xPK1+
 beta_alt2xPK2*alt2xPK2+
 beta_alt2xPK3*alt2xPK3+
 beta_alt2xWT1*alt2xWT1+
 beta_alt2xWT2*alt2xWT2+
 beta_alt2xWT3*alt2xWT3+
 beta_alt2xrel1*alt2xrel1+
 beta_alt2xrel2*alt2xrel2+
 beta_alt2xrel3*alt2xrel3+

# beta_share_drivelisence*drivingLisence+
 beta_share_CarDr4moredw*AutoBes4moredw+
 beta_share_CarDr1_3dw*AutoBes1_3dw+
 beta_share_CarDr1_4dm*AutoBes1_4dm+
# beta_share_CarPas1moredw*AutoPas1moredw+
# beta_share_CarPas1_4dm*AutoPas1_4dm+
# beta_share_CarPas1_10dy*AutoPas1_10dy+
```

```
# beta_share_Train1moredw*Train1moredw+
# beta_share_Train1_4dm*Train1_4dm+
# beta_share_Train1_10dy*Train1_10dy+
# beta_share_Bus1moredw*Bus1moredw+
# beta_share_Bus1_4dm*Bus1_4dm+
# beta_share_Bus1_10dy*Bus1_10dy+
# beta_share_Bike4moredw*Bike4moredw+
# beta_share_Bike1_3dw*Bike1_3dw+
# beta_share_Bike1_4dm*Bike1_4dm+
# beta_share_Scooter4moredw*Scooter4moredw+
# beta_share_Scooter1_3dw*Scooter1_3dw+
# beta_share_Scooter1_4dm*Scooter1_4dm+
# beta_share_Walk4moredw*Walk4moredw+
# beta_share_Walk1_3dw*Walk1_3dw+
# beta_share_Walk1_4dm*Walk1_4dm+
# beta_share_Sharing_yes*Sharing_yes+
# beta_share_CarOwn1*CarOwn1+
# beta_share_CarOwn2More*CarOwn2More+
# beta_share_CarLease*CarLease+

 beta_share_GenderMale*GenderMale+
 beta_share_Age18_34*Age18_34+
 beta_share_Age35_54*Age35_54+
 beta_share_Age55_74*Age55_74+
# beta_share_EducationLow*EducationLow+
# beta_share_EducationMiddle*EducationMiddle+
# beta_share_Income0_20*Income0_20+
# beta_share_Income20_40*Income20_40+
# beta_share_Income40more*Income40ormore+
 beta_share_OccuStudent*Occu_sudent+
 beta_share_OccuWork*Occu_work+
 beta_share_Occu_ohter_unempl*Occu_ohter_unempl+
 beta_share_Envi_urban*Envi_urban+
 beta_share_Envi_slightUrban*Envi_slightUrban+
 beta_share_Envi_village*Envi_village+
# beta_share_HH_Single*HH_Single+
# beta_share_HH_Couple*HH_Couple+
# beta_share_HH_Kids_singlecouple*HH_Kids_singlecouple+
# beta_share_NS_Membership*NS_Membership+

 beta_share_CarWork_yes*CarWork_yes+
 beta_share_CarWork_no*CarWork_no
# beta_share_Household_lisence*Household_lisence+
# beta_share_HH_car_none*HH_car_none+
# beta_share_HH_car_1*HH_car_1+
# beta_share_HH_car_2more*HH_car_2more
 )

  ### Define settings for MNL model component
 mnl_settings = list(
  alternatives = c(buy=1, share=2),
  avail        = list(buy=1, share=1),
  choiceVar    = choicex,
  V = V
 )

```

```
  ### Compute probabilities using MNL model
  P[["choice"]] = apollo_mnl(mnl_settings, functionality)

  ### Likelihood of the whole model
  P = apollo_combineModels(P, apollo_inputs, functionality)

  ### Take product across observation for same individual
  P = apollo_panelProd(P, apollo_inputs, functionality)

  ### Average across inter-individual draws
  P = apollo_avgInterDraws(P, apollo_inputs, functionality)

  ### Prepare and return outputs of function
  P = apollo_prepareProb(P, apollo_inputs, functionality)
  return(P)
}

# ################################################################# #
#### MODEL ESTIMATION                                            ####
# ################################################################# #

model = apollo_estimate(apollo_beta, apollo_fixed,
                        apollo_probabilities,
                        apollo_inputs)

# ################################################################# #
#### MODEL OUTPUTS                                               ####
# ################################################################# #

### Show output in screen
apollo_modelOutput(model)

### Save output to file(s)
apollo_saveOutput(model)
```

H2: Code related to the results of the SACE

```
### Clear memory
rm(list = ls())

### Load Apollo library
library(apollo)

### Initialise code
apollo_initialise()

### Set core controls
apollo_control = list(
  modelName  = "SCE2_output",
  modelDescr = "SCE2 buy or share",
  indivID    ="ID",
    mixing     = TRUE,
   nCores     = 4
)

```

```
# ################################################################# #
#### LOAD DATA AND APPLY ANY TRANSFORMATIONS                    ####
# ################################################################# #

### Import database
setwd(" location of database on computer ")
database = read.table("SCE2.csv", header=TRUE, sep=",")

### Changes in database
database$attitudeST15=database$attitude15-mean(database$attitude15)
database$attitudeST16=database$attitude16-mean(database$attitude16)
database$attitudeST17=database$attitude17-mean(database$attitude17)
database$attitudeST18=database$attitude18-mean(database$attitude18)
database$attitudeST19=database$attitude19-mean(database$attitude19)

# ################################################################# #
#### DEFINE MODEL PARAMETERS                                    ####
# ################################################################# #

### Starting values of parameters
apollo_beta = c(

  #Alternative 1: SAV
  mu_SAV = 0,
  sig_SAV = 0,
  beta_alt1xPK1= 0,
  beta_alt1xPK2= 0,
  beta_alt1xPK3= 0,
  beta_alt2xWT1= 0,
  beta_alt2xWT2= 0,
  beta_alt2xWT3= 0,
  beta_alt1xTT=0,
  beta_alt2xSC=0,
 #beta_TT_30_SC_SAV=0,
 #beta_TT_30_60_SC_SAV=0,
  beta_TTxSC_SAV=0,

  #Alternative 2: SAR
  mu_SAR = 0,
  sig_SAR = 0,
  beta_alt2xPK1=0,
  beta_alt2xPK2=0,
  beta_alt2xPK3=0,
  beta_alt2xWT1=0,
  beta_alt2xWT2=0,
  beta_alt2xWT3=0,
  beta_alt2xTT=0,
  beta_alt2xNP1=0,
  beta_alt2xNP2=0,
  beta_alt2xNP3=0,
  beta_alt2xSC=0,
 # beta_TT_30_SC_SAR=0,
 #beta_TT_30_60_SC_SAR=0,
  beta_TTAxSC_SAR=0,
 # beta_SAR_SCxNP1=0,
 # beta_SAR_SCxNP2=0,
```

```
# beta_SAR_SCxNP3=0

 #Alternative 3: APT
 mu_APT = 0,
 sig_APT = 0,

 #socio-demograpics; SAV

# beta_SAV_drivelisence= 0,
# beta_SAV_AutoBes4moredw=0,
# beta_SAV_AutoBes1_3dw=0,
# beta_SAV_AutoBes1_4dm=0,
# beta_SAV_AutoPas1moredw=0,
# beta_SAV_AutoPas1_4dm=0,
# beta_SAV_AutoPas1_10dy=0,
# beta_SAV_Train1moredw=0,
# beta_SAV_Train1_4dm=0,
# beta_SAV_Train1_10dy=0,
# beta_SAV_Bus1moredw=0,
# beta_SAV_Bus1_4dm=0,
# beta_SAV_Bus1_10dy=0,
# beta_SAV_Bike4moredw=0,
# beta_SAV_Bike1_3dw=0,
# beta_SAV_Bike1_4dm=0,
# beta_SAV_Walk4moredw=0,
# beta_SAV_Walk1_3dw=0,
# beta_SAV_Walk1_4dm=0,
# beta_SAV_Sharing_yes=0,
# beta_SAV_CarOwn1=0,
# beta_SAV_CarOwn2More=0,
# beta_SAV_CarLease=0,

 beta_SAV_GenderMale=0,
 beta_SAV_Age18_34=0,
 beta_SAV_Age35_54=0,
 beta_SAV_Age55_74=0,
 beta_SAV_EducationLow=0,
 beta_SAV_EducationMiddle=0,
# beta_SAV_Income0_20=0,
# beta_SAV_Income20_40=0,
# beta_SAV_Income40more=0,
# beta_SAV_OccuStudent=0,
# beta_SAV_OccuWork=0,
# beta_SAV_Occu_ohter_unempl=0,
# beta_SAV_Envi_urban=0,
# beta_SAV_Envi_slightUrban=0,
# beta_SAV_Envi_village=0,
 beta_SAV_HH_Single=0,
 beta_SAV_HH_Couple=0,
 beta_SAV_HH_Kids_singlecouple=0,
# beta_SAV_NS_Membership=0,

# beta_SAV_Household_lisence=0,
# beta_SAV_HH_car_none=0,
# beta_SAV_HH_car_1
# beta_SAV_HH_car_2more=0,
```

```
 #socio-demograpics; SAR

# beta_SAR_drivelisence= 0,
# beta_SAR_AutoBes4moredw=0,
#  beta_SAR_AutoBes1_3dw=0,
# beta_SAR_AutoBes1_4dm=0,
# beta_SAR_AutoPas1moredw=0,
# beta_SAR_AutoPas1_4dm=0,
# beta_SAR_AutoPas1_10dy=0,
# beta_SAR_Train1moredw=0,
# beta_SAR_Train1_4dm=0,
# beta_SAR_Train1_10dy=0,
# beta_SAR_Bus1moredw=0,
# beta_SAR_Bus1_4dm=0,
# beta_SAR_Bus1_10dy=0,
# beta_SAR_Bike4moredw=0,
# beta_SAR_Bike1_3dw=0,
# beta_SAR_Bike1_4dm=0,
# beta_SAR_Walk4moredw=0,
# beta_SAR_Walk1_3dw=0,
# beta_SAR_Walk1_4dm=0,
# beta_SAR_Sharing_yes=0,
# beta_SAR_CarOwn1=0,
# beta_SAR_CarOwn2More=0,
# beta_SAR_CarLease=0,

 beta_SAR_GenderMale=0,
 beta_SAR_Age18_34=0,
 beta_SAR_Age35_54=0,
 beta_SAR_Age55_74=0,
 beta_SAR_EducationLow=0,
 beta_SAR_EducationMiddle=0,
# beta_SAR_Income0_20=0,
# beta_SAR_Income20_40=0,
# beta_SAR_Income40more=0,
# beta_SAR_OccuStudent=0,
# beta_SAR_OccuWork=0,
# beta_SAR_Occu_ohter_unempl=0,
# beta_SAR_Envi_urban=0,
# beta_SAR_Envi_slightUrban=0,
# beta_SAR_Envi_village=0,
 beta_SAR_HH_Single=0,
 beta_SAR_HH_Couple=0,
 beta_SAR_HH_Kids_singlecouple=0,
# beta_SAR_NS_Membership=0,

# beta_SAR_Household_lisence=0,
# beta_SAR_HH_car_none=0,
# beta_SAR_HH_car_1=0,
# beta_SAR_HH_car_2more=0,

 #socio-demograpics; APT

# beta_APT_drivelisence= 0,
# beta_APT_AutoBes4moredw=0,
```

```
 # beta_APT_AutoBes1_3dw=0,
 # beta_APT_AutoBes1_4dm=0,
 # beta_APT_AutoPas1moredw=0,
 # beta_APT_AutoPas1_4dm=0,
 # beta_APT_AutoPas1_10dy=0,
 # beta_APT_Train1moredw=0,
 # beta_APT_Train1_4dm=0,
 # beta_APT_Train1_10dy=0,
 # beta_APT_Bus1moredw=0,
 # beta_APT_Bus1_4dm=0,
 # beta_APT_Bus1_10dy=0,
 # beta_APT_Bike4moredw=0,
 # beta_APT_Bike1_3dw=0,
 # beta_APT_Bike1_4dm=0,
 # beta_APT_Walk4moredw=0,
 # beta_APT_Walk1_3dw=0,
 # beta_APT_Walk1_4dm=0,
 # beta_APT_Sharing_yes=0,
 # beta_APT_CarOwn1=0,
 # beta_APT_CarOwn2More=0,
 # beta_APT_CarLease=0,

   beta_APT_GenderMale=0,
   beta_APT_Age18_34=0,
   beta_APT_Age35_54=0,
   beta_APT_Age55_74=0,
   beta_APT_EducationLow=0,
   beta_APT_EducationMiddle=0,
 # beta_APT_Income0_20=0,
 # beta_APT_Income20_40=0,
 # beta_APT_Income40more=0,
 # beta_APT_OccuStudent=0,
 # beta_APT_OccuWork=0,
 # beta_APT_Occu_ohter_unempl=0,
 # beta_APT_Envi_urban=0,
 # beta_APT_Envi_slightUrban=0,
 # beta_APT_Envi_village=0,
   beta_APT_HH_Single=0,
   beta_APT_HH_Couple=0,
   beta_APT_HH_Kids_singlecouple=0,
 # beta_APT_NS_Membership=0,

 # beta_APT_Household_lisence=0,
 # beta_APT_HH_car_none=0,
 # beta_APT_HH_car_1=0,
 # beta_APT_HH_car_2more=0,

#Reference trips

   beta_SAV_RitMode_Car=0,
   beta_SAV_RitMode_Train=0,
   beta_SAV_RitMode_Bus=0,
 # beta_SAV_RitPurpose_Work=0,
 # beta_SAV_RitPurpose_social_leisure=0,
 # beta_SAV_RitPurpose_shop=0,
 # beta_SAV_RitDistance=0,
```

```
 beta_SAV_RitTravelTime=0,
# beta_SAV_Pressure_not=0,
# beta_SAV_Pressure_bit=0,
# beta_SAV_RitAlone=0,
#  beta_SAV_Kids=0,

 beta_SAR_RitMode_Car=0,
 beta_SAR_RitMode_Train=0,
 beta_SAR_RitMode_Bus=0,
# beta_SAR_RitPurpose_Work=0,
# beta_SAR_RitPurpose_social_leisure=0,
# beta_SAR_RitPurpose_shop=0,
# beta_SAR_RitDistance=0,
 beta_SAR_RitTravelTime=0,
# beta_SAR_Pressure_not=0,
# beta_SAR_Pressure_bit=0,
# beta_SAR_RitAlone=0,
# beta_SAR_Kids=0,

# beta_APT_RitPurpose_Work=0,
# beta_APT_RitPurpose_social_leisure=0,
# beta_APT_RitPurpose_shop=0,
# beta_APT_RitDistance=0,
 beta_APT_RitTravelTime=0,
# beta_APT_Pressure_not=0,
# beta_APT_Pressure_bit=0,
# beta_APT_RitAlone=0,
# beta_APT_Kids=0,

 #Latent-attitude variables

 Beta_sus=0,
 constant_sus=0,

 lambda_sus_SAV=0,
 lambda_sus_SAR=0,
 lambda_sus_APT=0,
 zeta_sus15 = 1,
 zeta_sus16 = 1,
 zeta_sus17 = 1,
 zeta_sus18 = 1,
 zeta_sus19 = 1,
 sigma_sus15 = 1,
 sigma_sus16 = 1,
 sigma_sus17 = 1,
 sigma_sus18 = 1,
 sigma_sus19 = 1
 )

### Vector with names (in quotes) of parameters to be kept fixed at their starting value in apollo_beta, use
apollo_gamma_fixed = c() if none
apollo_fixed = c(

 #Alternative 3: APT
 "mu_APT",

```

```
# "beta_APT_AutoPas1_4dm",
# "beta_APT_AutoPas1_10dy",
# "beta_APT_Train1moredw",
# "beta_APT_Train1_4dm",
# "beta_APT_Train1_10dy",
# "beta_APT_Bus1moredw",
# "beta_APT_Bus1_4dm",
# "beta_APT_Bus1_10dy",
# "beta_APT_Bike4moredw",
# "beta_APT_Bike1_3dw",
# "beta_APT_Bike1_4dm",
# "beta_APT_Walk4moredw",
# "beta_APT_Walk1_3dw",
# "beta_APT_Walk1_4dm",
# "beta_APT_Sharing_yes",
# "beta_APT_CarOwn1",
# "beta_APT_CarOwn2More",
# "beta_APT_CarLease",

 "beta_APT_GenderMale",
 "beta_APT_Age18_34",
 "beta_APT_Age35_54",
 "beta_APT_Age55_74",
 "beta_APT_EducationLow",
 "beta_APT_EducationMiddle",
# "beta_APT_Income0_20",
# "beta_APT_Income20_40",
# "beta_APT_Income40more",
# "beta_APT_OccuStudent",
# "beta_APT_OccuWork",
# "beta_APT_Occu_ohter_unempl",
# "beta_APT_Envi_urban",
# "beta_APT_Envi_slightUrban",
# "beta_APT_Envi_village",
 "beta_APT_HH_Single",
 "beta_APT_HH_Couple",
 "beta_APT_HH_Kids_singlecouple",
# "beta_APT_NS_Membership",

# "beta_APT_Household_lisence",
# "beta_APT_HH_car_none",
# "beta_APT_HH_car_1",
# "beta_APT_HH_car_2more",

# The alternative SAR is used to fix the transporation mode
 "beta_SAR_RitMode_Car",
 "beta_SAR_RitMode_Train",
 "beta_SAR_RitMode_Bus",
# The alternative SAR is used to fix the transporation mode

# "beta_APT_RitPurpose_Work",
# "beta_APT_RitPurpose_social_leisure",
# "beta_APT_RitPurpose_shop",
# "beta_APT_RitDistance",
 "beta_APT_RitTravelTime"
# "beta_APT_Pressure_not",
```

```
 # "beta_APT_Pressure_bit"
 # "beta_APT_RitAlone",
 # "beta_APT_Kids"

  #Latent-attitude variables

   "lambda_sus_SAV",
   "zeta_sus15",
   "sigma_sus15",
  )

# ################################################################# #
#### DEFINE RANDOM COEFFICIENTS                              ####
# ################################################################# #

### Set parameters for generating draws
apollo_draws = list(
  interDrawsType = "halton",
  interNDraws    = 500,
  interUnifDraws = c(),
  interNormDraws = c("eta_sus", "xi_SAV", "xi_SAR", "xi_APT"),

  intraDrawsType = '',
  intraNDraws    = 0,
  intraUnifDraws = c(),
  intraNormDraws = c()
)

  ### Create random parameters
  apollo_randCoeff = function(apollo_beta, apollo_inputs){
  randcoeff = list()

  randcoeff[["SUSTAINABILITY"]] = constant_sus + Beta_sus*  eta_sus

  randcoeff[["beta_SAV"]] =  mu_SAV +  sig_SAV * xi_SAV

  randcoeff[["beta_SAR"]] =  mu_SAR +  sig_SAR * xi_SAR

  randcoeff[["beta_APT"]] =  mu_APT +  sig_APT * xi_APT

  return(randcoeff)
}
# ################################################################# #
#### GROUP AND VALIDATE INPUTS                               ####
# ################################################################# #

apollo_inputs = apollo_validateInputs()

# ################################################################# #
#### DEFINE MODEL AND LIKELIHOOD FUNCTION                    ####
# ################################################################# #

apollo_probabilities=function(apollo_beta, apollo_inputs, functionality="estimate"){

  ### Attach inputs and detach after function exit
  apollo_attach(apollo_beta, apollo_inputs)
```

```
on.exit(apollo_detach(apollo_beta, apollo_inputs))

### Create list of probabilities P
P = list()

#attitude sustainability
 sustainability1 = list(outcomeNormal=attitude15,
                    xNormal=zeta_sus15*SUSTAINABILITY,
                     mu=0,
                     sigma=sigma_sus15,
                     rows=(ritnr==1))

 sustainability2 = list(outcomeNormal=attitude16,
                     xNormal=zeta_sus16*SUSTAINABILITY,
                     mu=0,
                     sigma=sigma_sus16,
                     rows=(ritnr==1))

sustainability3 = list(outcomeNormal=attitude17,
                    xNormal=zeta_sus17*SUSTAINABILITY,
                    mu=0,
                    sigma=sigma_sus17,
                    rows=(ritnr==1))

 sustainability4 = list(outcomeNormal=attitude18,
                    xNormal=zeta_sus18*SUSTAINABILITY,
                    mu=0,
                    sigma=sigma_sus18,
                    rows=(ritnr==1))

sustainability5 = list(outcomeNormal=attitude19,
                    xNormal=zeta_sus19*SUSTAINABILITY,
                    mu=0,
                    sigma=sigma_sus19,
                    rows=(ritnr==1))

P[["indic_sus15"]] = apollo_normalDensity(sustainability1, functionality)
P[["indic_sus16"]] = apollo_normalDensity(sustainability2, functionality)
P[["indic_sus17"]] = apollo_normalDensity(sustainability3, functionality)
P[["indic_sus18"]] = apollo_normalDensity(sustainability4, functionality)
P[["indic_sus19"]] = apollo_normalDensity(sustainability5, functionality)


### List of utilities: these must use the same names as in mnl_settings, order is irrelevant
V = list()

V[['SAV']]  = (
beta_SAV+
lambda_sus_SAV*SUSTAINABILITY+

beta_alt1xPK1*alt1xPK1+
beta_alt1xPK2*alt1xPK2+
beta_alt1xPK3*alt1xPK3+
beta_alt2xWT1*alt1xWT1+
beta_alt2xWT2*alt1xWT2+
beta_alt2xWT3*alt1xWT3+
```

```
 beta_alt1x1*alt1xTT+
 beta_alt2x2*alt1xSC+
# beta_TT_30_SC_SAV*TT_30_SC
# beta_TT_30_60_SC_SAV*TT_30_60_SC
 beta_TTxSC_SAV*TTxSC

# beta_SAV_drivelisence*drivingLisence+
# beta_SAV_AutoBes4moredw*AutoBes4moredw+
# beta_SAV_AutoBes1_3dw*AutoBes1_3dw+
# beta_SAV_AutoBes1_4dm*AutoBes1_4dm+
# beta_SAV_AutoPas1moredw*AutoPas1moredw+
# beta_SAV_AutoPas1_4dm*AutoPas1_4dm+
# beta_SAV_AutoPas1_10dy*AutoPas1_10dy+
# beta_SAV_Train1moredw*Train1moredw+
# beta_SAV_Train1_4dm*Train1_4dm+
# beta_SAV_Train1_10dy*Train1_10dy+
# beta_SAV_Bus1moredw*Bus1moredw+
# beta_SAV_Bus1_4dm*Bus1_4dm+
# beta_SAV_Bus1_10dy*Bus1_10dy+
# beta_SAV_Bike4moredw*Bike4moredw+
# beta_SAV_Bike1_3dw*Bike1_3dw+
# beta_SAV_Bike1_4dm*Bike1_4dm+
# beta_SAV_Walk4moredw*Walk4moredw+
# beta_SAV_Walk1_3dw*Walk1_3dw+
# beta_SAV_Walk1_4dm*Walk1_4dm+
# beta_SAV_Sharing_yes*Sharing_yes+
# beta_SAV_CarOwn1*CarOwn1+
# beta_SAV_CarOwn2More*CarOwn2More+
# beta_SAV_CarLease*CarLease+

 beta_SAV_GenderMale*GenderMale+
 beta_SAV_Age18_34*Age18_34+
 beta_SAV_Age35_54*Age35_54+
 beta_SAV_Age55_74*Age55_74+
 beta_SAV_EducationLow*EducationLow+
 beta_SAV_EducationMiddle*EducationMiddle+
# beta_SAV_Income0_20*Income0_20+
# beta_SAV_Income20_40*Income20_40+
# beta_SAV_Income40more*Income40ormore+
# beta_SAV_OccuStudent*Occu_sudent+
# beta_SAV_OccuWork*Occu_work+
# beta_SAV_Occu_ohter_unempl*Occu_ohter_unempl+
# beta_SAV_Envi_urban*Envi_urban+
# beta_SAV_Envi_slightUrban*Envi_slightUrban+
# beta_SAV_Envi_village*Envi_village+
 beta_SAV_HH_Single*HH_Single+
 beta_SAV_HH_Couple*HH_Couple+
 beta_SAV_HH_Kids_singlecouple*HH_Kids_singlecouple+
# beta_SAV_NS_Membership*NS_Membership+

# beta_SAV_Household_lisence*Household_lisence+
# beta_SAV_HH_car_none*HH_car_none+
# beta_SAV_HH_car_1*HH_car_1+
# beta_SAV_HH_car_2more*HH_car_2more+

 beta_SAV_RitMode_Car*RitMode_Car+
```

```
 beta_SAV_RitMode_Train*RitMode_Train+
 beta_SAV_RitMode_Bus*RitMode_Bus+
# beta_SAV_RitPurpose_Work*RitPurpose_Work+
# beta_SAV_RitPurpose_social_leisure*RitPurpose_social_leisure+
# beta_SAV_RitPurpose_shop*RitPurpose_Shop+
# beta_SAV_RitDistance*RitDistance+
 beta_SAV_RitTravelTime*RitTravelTime
# beta_SAV_Pressure_not*Pressure_not+
# beta_SAV_Pressure_bit*Pressure_bit
# beta_SAV_RitAlone*RitAlone+
# beta_SAV_Kids*Kids_yes
   )


 V[['SAR']]  =(
 beta_SAR+
 lambda_sus_SAR*SUSTAINABILITY+

 beta_alt2xPK1*alt2xPK1+
 beta_alt2xPK2*alt2xPK2+
 beta_alt2xPK3*alt2xPK3+
 beta_alt2xWT1*alt2xWT1+
 beta_alt2xWT2*alt2xWT2+
 beta_alt2xWT3*alt2xWT3+
 beta_alt2xTT*alt2xTT+
 beta_alt2xNP1*alt2xNP1+
 beta_alt2xNP2*alt2xNP2+
 beta_alt2xNP3*alt2xNP3+
 beta_alt2xSC*alt2xSC+
# beta_TT_30_SC_SAR*TT_30_SC_SAR
# beta_TT_30_60_SC_SAR*TT_30_60_SC_SAR
 beta_TTAxSC_SAR*TTAxSC_SAR
# beta_SAR_SCxNP1*SCxNP1
# beta_SAR_SCxNP2*SCxNP2
# beta_SAR_SCxNP3*SCxNP3

# beta_SAR_drivelisence*drivingLisence+
# beta_SAR_AutoBes4moredw*AutoBes4moredw+
# beta_SAR_AutoBes1_3dw*AutoBes1_3dw+
# beta_SAR_AutoBes1_4dm*AutoBes1_4dm+
# beta_SAR_AutoPas1moredw*AutoPas1moredw+
# beta_SAR_AutoPas1_4dm*AutoPas1_4dm+
# beta_SAR_AutoPas1_10dy*AutoPas1_10dy+
# beta_SAR_Train1moredw*Train1moredw+
# beta_SAR_Train1_4dm*Train1_4dm+
# beta_SAR_Train1_10dy*Train1_10dy+
# beta_SAR_Bus1moredw*Bus1moredw+
# beta_SAR_Bus1_4dm*Bus1_4dm+
# beta_SAR_Bus1_10dy*Bus1_10dy+
# beta_SAR_Bike4moredw*Bike4moredw+
# beta_SAR_Bike1_3dw*Bike1_3dw+
# beta_SAR_Bike1_4dm*Bike1_4dm+
# beta_SAR_Walk4moredw*Walk4moredw+
# beta_SAR_Walk1_3dw*Walk1_3dw+
# beta_SAR_Walk1_4dm*Walk1_4dm+
# beta_SAR_Sharing_yes*Sharing_yes+
```

```
# beta_SAR_CarOwn1*CarOwn1+
# beta_SAR_CarOwn2More*CarOwn2More+
# beta_SAR_CarLease*CarLease+
 beta_SAR_GenderMale*GenderMale+
 beta_SAR_Age18_34*Age18_34+
 beta_SAR_Age35_54*Age35_54+
 beta_SAR_Age55_74*Age55_74+
 beta_SAR_EducationLow*EducationLow+
 beta_SAR_EducationMiddle*EducationMiddle+
# beta_SAR_Income0_20*Income0_20+
# beta_SAR_Income20_40*Income20_40+
# beta_SAR_Income40more*Income40ormore+
# beta_SAR_OccuStudent*Occu_sudent+
# beta_SAR_OccuWork*Occu_work+
# beta_SAR_Occu_ohter_unempl*Occu_ohter_unempl+
# beta_SAR_Envi_urban*Envi_urban+
# beta_SAR_Envi_slightUrban*Envi_slightUrban+
# beta_SAR_Envi_village*Envi_village+
 beta_SAR_HH_Single*HH_Single+
 beta_SAR_HH_Couple*HH_Couple+
 beta_SAR_HH_Kids_singlecouple*HH_Kids_singlecouple+
# beta_SAR_NS_Membership*NS_Membership+
# beta_SAR_Household_lisence*Household_lisence+
# beta_SAR_HH_car_none*HH_car_none+
# beta_SAR_HH_car_1*HH_car_1+
# beta_SAR_HH_car_2more*HH_car_2more+
 beta_SAR_RitMode_Car*RitMode_Car+
 beta_SAR_RitMode_Train*RitMode_Train+
 beta_SAR_RitMode_Bus*RitMode_Bus+
# beta_SAR_RitPurpose_Work*RitPurpose_Work+
# beta_SAR_RitPurpose_social_leisure*RitPurpose_social_leisure+
# beta_SAR_RitPurpose_shop*RitPurpose_Shop+
# beta_SAR_RitDistance*RitDistance+
 beta_SAR_RitTravelTime*RitTravelTime
# beta_SAR_Pressure_not*Pressure_not+
# beta_SAR_Pressure_bit*Pressure_bit
# beta_SAR_RitAlone*RitAlone+
# beta_SAR_Kids*Kids_yes
   )
 V[['APT']]  = (
 beta_APT +
 lambda_sus_APT*SUSTAINABILITY+
# beta_APT_drivelisence*drivingLisence+
# beta_APT_AutoBes4moredw*AutoBes4moredw+
# beta_APT_AutoBes1_3dw*AutoBes1_3dw+
# beta_APT_AutoBes1_4dm*AutoBes1_4dm+
# beta_APT_AutoPas1moredw*AutoPas1moredw+
# beta_APT_AutoPas1_4dm*AutoPas1_4dm+
# beta_APT_AutoPas1_10dy*AutoPas1_10dy+
# beta_APT_Train1moredw*Train1moredw+
# beta_APT_Train1_4dm*Train1_4dm+
```

```
# beta_APT_Train1_10dy*Train1_10dy+
# beta_APT_Bus1moredw*Bus1moredw+
# beta_APT_Bus1_4dm*Bus1_4dm+
# beta_APT_Bus1_10dy*Bus1_10dy+
# beta_APT_Bike4moredw*Bike4moredw+
# beta_APT_Bike1_3dw*Bike1_3dw+
# beta_APT_Bike1_4dm*Bike1_4dm+
# beta_APT_Walk4moredw*Walk4moredw+
# beta_APT_Walk1_3dw*Walk1_3dw+
# beta_APT_Walk1_4dm*Walk1_4dm+
# beta_APT_Sharing_yes*Sharing_yes+
# beta_APT_CarOwn1*CarOwn1+
# beta_APT_CarOwn2More*CarOwn2More+
# beta_APT_CarLease*CarLease+

 beta_APT_GenderMale*GenderMale+
 beta_APT_Age18_34*Age18_34+
 beta_APT_Age35_54*Age35_54+
 beta_APT_Age55_74*Age55_74+
 beta_APT_EducationLow*EducationLow+
 beta_APT_EducationMiddle*EducationMiddle+
# beta_APT_Income0_20*Income0_20+
# beta_APT_Income20_40*Income20_40+
# beta_APT_Income40more*Income40ormore+
# beta_APT_OccuStudent*Occu_sudent+
# beta_APT_OccuWork*Occu_work+
# beta_APT_Occu_ohter_unempl*Occu_ohter_unempl+
# beta_APT_Envi_urban*Envi_urban+
# beta_APT_Envi_slightUrban*Envi_slightUrban+
# beta_APT_Envi_village*Envi_village+
 beta_APT_HH_Single*HH_Single+
 beta_APT_HH_Couple*HH_Couple+
 beta_APT_HH_Kids_singlecouple*HH_Kids_singlecouple+
# beta_APT_NS_Membership*NS_Membership+

# beta_APT_Household_lisence*Household_lisence+
# beta_APT_HH_car_none*HH_car_none+
# beta_APT_HH_car_1*HH_car_1+
# beta_APT_HH_car_2more*HH_car_2more+

# beta_APT_RitPurpose_Work*RitPurpose_Work+
# beta_APT_RitPurpose_social_leisure*RitPurpose_social_leisure+
# beta_APT_RitPurpose_shop*RitPurpose_Shop+
# beta_APT_RitDistance*RitDistance+
 beta_APT_RitTravelTime*RitTravelTime
# beta_APT_Pressure_not*Pressure_not+
# beta_APT_Pressure_bit*Pressure_bit
# beta_APT_RitAlone*RitAlone+
# beta_APT_Kids*Kids_yes
 )

  ### Define settings for MNL model component
   mnl_settings = list(
   alternatives = c(SAV=1, SAR=2, APT=3),
   avail        = list(SAV=alt1av, SAR=alt2av, APT=alt3av),
   choiceVar    = choicex,
```

```
    V = V
  )

  ### Compute probabilities using MNL model
  P[["choice"]] = apollo_mnl(mnl_settings, functionality)

  ### Likelihood of the whole model
  P = apollo_combineModels(P, apollo_inputs, functionality)

  ### Take product across observation for same individual
  P = apollo_panelProd(P, apollo_inputs, functionality)

  ### Average across inter-individual draws
   P = apollo_avgInterDraws(P, apollo_inputs, functionality)

  ### Prepare and return outputs of function
  P = apollo_prepareProb(P, apollo_inputs, functionality)
  return(P)
}

# ################################################################# #
#### MODEL ESTIMATION                                            ####
# ################################################################# #

model = apollo_estimate(apollo_beta, apollo_fixed,
                        apollo_probabilities,
                        apollo_inputs)


# ################################################################# #
#### MODEL OUTPUTS                                               ####
# ################################################################# #

### Show output in screen
apollo_modelOutput(model)

### Save output to file(s)
apollo_saveOutput(model)
```

Appendix I – Results of the SCE

I1: Results starting model

I1.1: Model summary

Results of the SCE

Number of individuals	822	
Number of observations	6576	
Number of draws	500	
LL start	-10141.48	
LL whole model	-7180.825	
LL indicator 1	-1146.943	
LL indicator 2	-1160.744	
LL indicator 3	-1094.445	
LL indicator 4	-1113.859	
LL indicator 5	-1099.448	
LL choice	-2771.588	
AIC	14527.65	
BIC	15091.32	
Estimated parameters	83	
Iterations	136	
ρ^2	0.292	
ρ^2 adjusted	0.284	
	Alt 1: buy AV	Alt 2: share AV
Times available	6576	6576
Times chosen	3599	2977
Percentage chosen overall	54.7%	45.3%
Percentage chosen when available	54.7%	45.3%

I1.2: Results of the first alternative

Alternative 1: AV ownership

			Estimate	Std.err.	t-ratio(0)
Alternative-specific constant			**2.8380**	1.0201	2.7821
Standard deviation of the random panel effect parameter			**-3.3874**	0.2179	-15.5482
Socio-demographic variables	Gender	Male	0.1842	0.1513	1.2178
		Female	-0.1842		

	Age	18-34 year	0.2728	0.3665	0.7444
		35-54 year	-0.4588	0.3271	-1.4025
		55-74 year	-0.1422	0.2759	-0.5152
		>75 year	0.3281		
	Education	Low	-0.5512	0.3305	-1.6675
		Middle	0.1571	0.2165	0.7256
		High	0.3941		
	Income	€0-€20.000	-0.3460	0.3365	-1.0283
		€20.001-€40.000	-0.0899	0.2361	-0.3810
		€40.001 or more	0.1380	0.2690	0.5129
		"I prefer not to answer"	0.2980		
	Occupation	Student	**2.0081**	0.7331	2.7393
		Work	**-3.0139**	1.3048	-2.3099
		Unemployed, disability or other	**1.0945**	0.5580	1.9614
		Retired	-0.0886		
	Need a car for work	Yes	**1.3927**	0.6288	2.2147
		No	**1.2074**	0.5878	2.0540
		The respondent doesn't work	-2.6001		
	Living environment	Urban	**-0.8466**	0.2716	-3.1168
		Slightly urban	-0.5217	0.3557	-1.4667
		Village	0.3049	0.2698	1.1301
		Rural	1.0634		
	Household composition	Single without child(ren)	-0.1611	1.6796	-0.0959
		Couple without child(ren)	-0.0403	0.6083	-0.0663
		Single/couple with child(ren)	0.2577	0.6229	0.4138
		Other	-0.0563		
	Nr. driving licenses in the household		0.0472	0.1813	0.2603
	Household car ownership	None	-1.4444	0.7865	-1.8365
		One car	0.6671	0.6000	1.1119
		Two or more cars	0.1483	0.7066	0.2099
		One person household	0.6290		
Travel characteristics	Driving license	Yes	-0.7176	0.3812	-1.8827
		No	0.7176		
	PT membership	PT Membership	**-0.4437**	0.1833	-2.4204
		None	0.4437		
	Car ownership	One car	-0.0935	0.2993	-0.3125
		Two or more cars	-0.1302	0.4007	-0.3250
		None	0.1302		
	Car lease	Lease car	0.2895	0.2338	1.2381
		None	-0.2895		
	Usage of car as driver	4 or more days per week	0.5456	0.2983	1.8290
		1-3 days per week	**0.6812**	0.3117	2.1851
		1-4 days per month	-0.3535	0.3725	-0.9491

		10 times per year - never	-0.8732		
	Usage of car as a passenger	1 or more times per week	-0.1465	0.2505	-0.5849
		1 to 4 days per month	0.1491	0.2298	0.6491
		1 to 10 days per year	0.2351	0.2581	0.9107
		Never	-0.2377		
	Usage of train	1 or more times per week	-0.2317	0.3379	-0.6856
		1 to 4 days per month	0.4368	0.3582	1.2192
		1 to 10 days per year	**-0.8886**	0.2460	-3.6118
		Never	0.6835		
	Usage of bus/tram/metro	1 or more times per week	0.0582	0.3295	0.1766
		1 to 4 days per month	-0.1744	0.3304	-0.5279
		1 to 10 days per year	**0.5449**	0.2541	2.1440
		Never	-0.4286		
	Usage of bike	4 or more days per week	**-0.6133**	0.2475	-2.4776
		1 to 3 days per week	0.4924	0.2583	1.9062
		1 to 4 days per month	0.0455	0.3721	0.1224
		Never	0.0753		
	Usage of scooter	4 or more days per week	**-0.9196**	0.4408	-2.0862
		1 to 3 days per week	**0.8363**	0.4109	2.0351
		1 to 4 days per month	0.1973	0.4985	0.3958
		Never	-0.1140		
	Usage of walking	4 or more days per week	-0.2527	0.2266	-1.1154
		1 to 3 days per week	0.0353	0.2543	0.1389
		1 to 4 days per month	-0.2002	0.3158	-0.6338
		Never	0.4176		
	Usage of shared mobility	Using shared mobility	-0.1382	0.2213	-0.6246
		Never	0.1382		
Alternative-attribute variables	Purchase price	90%	**0.4874**	0.0719	6.7831
		100%	**0.2865**	0.0704	4.0695
		110%	**-0.2028**	0.0696	-2.9120
		120%	-0.5711		
	Depreciation	5%	0.0072	0.0421	0.1703
		10%	-0.0072		
	Monthly costs	decrease by 35%	**0.2079**	0.0727	2.8587
		decrease by 20%	**0.1552**	0.0708	2.1927
		decrease by 5%	**-0.1572**	0.0717	-2.1912
		increase by 10%	-0.2059		
Latent-attitude variables	N/A				

I1.3: Results of the second alternative

Alternative 2: shared autonomous vehicle

			Estimate	Std.err.	t-ratio(0)
Alternative-specific constant	N/A				

Standard deviation of the random panel effect parameter			**-1.5353**	0.3615	-4.2473
Socio-demographic variables	N/A				
Alternative-attribute variables	Monthly membership fee	€ 0	**0.9336**	0.0736	12.6913
		€ 20	**0.4452**	0.0707	6.2927
		€ 40	**-0.4147**	0.0713	-5.8170
		€ 60	-0.9641		
	Price per km	€ 0.10	**0.5760**	0.0716	8.0492
		€ 0.20	**0.1767**	0.0707	2.4975
		€ 0.30	**-0.2305**	0.0706	-3.2670
		€ 0.40	-0.5222		
	Waiting time	1 minute	**0.4069**	0.0715	5.6916
		4 minutes	-0.0087	0.0701	-0.1240
		7 minutes	**-0.2018**	0.0714	-2.8269
		10 minutes	-0.1965		
	Reliability 1	80% - 20%	-0.0252	0.0409	-0.6155
		60% - 40%	0.0252		
	Reliability 2	2 min too early - 2 min late	-0.0492	0.0406	-1.2111
		on time - 4 min late	0.0492		
Latent-attitude variables	Sustainability		**0.4450**	0.2081	2.1385

I1.4: Results of the latent variable

Latent-attitude results

			Estimate	Std.err.	t-ratio(0)
Sustainability	Constant		-0.0165	0.0238	-0.6952
	Standard deviation		**0.6712**	0.0390	17.2122
	Lambda	Indicator 1	1		
		Indicator 2	**1.1502**	0.0708	16.2532
		Indicator 3	**1.1881**	0.0694	17.1165
		Indicator 4	**1.1782**	0.0700	16.8388
		Indicator 5	**1.1947**	0.0697	17.1480
	Standard deviation	Indicator 1	1		
		Indicator 2	**0.6374**	0.0186	34.3228
		Indicator 3	**0.4690**	0.0168	27.9459
		Indicator 4	**0.5205**	0.0169	30.7837
		Indicator 5	**0.4727**	0.0168	28.1547

I2: Process of finding best model

Model	Removed(-)/added(+) variable	-/+	Other adjustments
Model 1			
	Usage of the scooter	-	
	Usage of walking	-	
	Usage of shared mobility	-	
	Car ownership	-	

	Lease car	-	
	Nr. of driving license in the household	-	
	Household car ownership	-	
Model 2			
	Usage of car as a passenger		
	Driving license		
	Household composition	-	
	Level of education	-	
	Income level	-	
Model 3			
	PT membership	-	
Model 4			
	Usage of the train	-	
	Usage of the bus/tram/metro	-	
Model 5			
	Usage of the bike	-	
Model 6			
	Occupation	-	
Model 7			
	Usage of the train	+	
	Usage of the bus/tram/metro	+	
Model 8			
	Level of education	+	
	Income level	+	
	Usage of the train	-	
	Usage of the bus/tram/metro	-	
Model 9			
	Usage of the train	+	
	Level of education	-	
	Income level	-	
Model 10			
	Occupation	+	
Model 11			
	Usage of the bike	+	
Model 12			
	Usage of the bus/tram/metro	+	

	Usage of the bike	-	
Model 13			
	Usage of the train	-	
	Usage of the bus/tram/metro	-	
	Income level	+	
Model 14			
	Income level	-	
	Reliability 1		The attributes reliability 1 and 2 are merged to one attribute (with 4 categories)
	Reliability 2		
Model 15			Final model (almost the same as model 6)

I3: Extended model summary of final model

Results of the SCE		
Number of individuals	822	
Number of observations	6576	
Number of draws	500	
LL start	-10141.48	
LL whole model	-7208.432	
LL indicator 1	-1147.027	
LL indicator 2	-1160.62	
LL indicator 3	-1094.296	
LL indicator 4	-1113.715	
LL indicator 5	-1099.295	
LL choice	-2798.139	
AIC	14512.86	
BIC	14838.84	
Estimated parameters	48	
Iterations	74	
ρ^2	0.289	
ρ2 adjusted	0.284	
	Alt 1: buy AV	Alt 2: share AV
Times available	6576	6576
Times chosen	3599	2977
Percentage chosen overall	54.7%	45.3%
Percentage chosen when available	54.7%	45.3%

Appendix J – Results of the SACE

J1: Results starting model

J1.1: Model summary

Results of the SACE

Number of individuals	765
Number of observations	2846
Number of draws	500
LL start	-7280.974
LL whole model	-5562.780
LL Statement 1	-1024.039
LL Statement 2	-1045.766
LL Statement 3	-969.916
LL Statement 4	-985.134
LL Statement 5	-964.361
LL choice	-1677.649
AIC	11423.560
BIC	12316.360
Estimated parameters	149
Iterations	174
R square	0.236
R square adjusted	0.216

J.1.2: Results of the first alternative

Alternative 1: Shared autonomous vehicle

			Estimate	Std.err.	t-ratio(0)
Alternative-specific constant			**2.8566**	1.1983	2.3840
Standard deviation of the random panel effect parameter?			**1.3245**	0.2577	5.1399
Socio-demographic variables	Gender	Male	**1.1857**	0.4865	2.4370
		Female	-1.1857		
	Age	18-34 year	-0.8086	0.6649	-1.2161
		35-54 year	-0.1627	0.5787	-0.2811
		55-74 year	-0.1971	0.5110	-0.3857
		>75 year	1.1684		
	Education	Low	1.2839	0.6922	1.8548
		Middle	-0.6608	0.4437	-1.4893
		High	-0.6230		
	Income	€0-€20.000	0.9730	0.5178	1.8791
		€20.001-€40.000	0.2194	0.4201	0.5223
		€40.001 or more	0.1208	0.5080	0.2378

		"I prefer not to answer"	-1.3132		
	occupation	Student	0.9186	0.7422	1.2377
		Work	**1.2248**	0.4687	2.6132
		Unemployed, disability or other	**-1.3320**	0.6109	-2.1803
		Retired	-0.8114		
	Living environment	Urban	0.1304	0.5543	0.2353
		Slightly urban	0.1781	0.7091	0.2512
		Village	**1.5429**	0.6645	2.3219
		Rural	-1.8515		
	Household composition	Single without child(ren)	9.1920	57.4115	0.1601
		Couple without child(ren)	-5.0595	19.1436	-0.2643
		Single/couple with child(ren)	-3.3921	19.1438	-0.1772
		Other	-0.7404		
	Nr. driving licenses in the household		**-0.7270**	0.2730	-2.6634
	Household car ownership	None	4.1282	19.1464	0.2156
		One car	3.6402	19.1422	0.1902
		Two or more cars	3.3070	19.1587	0.1726
		One person household	-11.0754		
Travel characteristics	Driving license	Yes	0.5620	0.3831	1.4670
		No	-0.5620		
	PT membership	PT Membership	-0.0536	0.3201	-0.1676
		None	0.0536		
	Car ownership	One car	0.4287	0.6111	0.7016
		Two or more cars	0.9835	1.1487	0.8562
		None	-1.4122		
	Car lease	Lease car	-0.7025	0.4298	-1.6347
		None	0.7025		
	Usage of car as driver	4 or more days per week	**-1.4484**	0.5791	-2.5011
		1-3 days per week	-0.7412	0.4857	-1.5261
		1-4 days per month	**1.0890**	0.4993	2.1811
		10 times per year - never	1.1006		
	Usage of car as a passenger	1 or more times per week	**1.1506**	0.4620	2.4907
		1 to 4 days per month	-0.4342	0.4153	-1.0456
		1 to 10 days per year	**-1.1530**	0.4518	-2.5522
		Never	0.4366		
	Usage of train	1 or more times per week	-0.2860	0.5995	-0.4770
		1 to 4 days per month	-0.2710	0.5855	-0.4628
		1 to 10 days per year	-0.2771	0.5459	-0.5075
		Never	0.8340		
	Usage of bus/tram/metro	1 or more times per week	-0.4767	0.4726	-1.0088
		1 to 4 days per month	0.0012	0.4579	0.0027

		1 to 10 days per year	0.5685	0.4631	1.2274
		Never	-0.0930		
	Usage of bike	4 or more days per week	-0.3731	0.4035	-0.9249
		1 to 3 days per week	0.2524	0.5074	0.4974
		1 to 4 days per month	0.0388	0.7144	0.0543
		Never	0.0819		
	Usage of walking	4 or more days per week	-0.4584	0.3824	-1.1986
		1 to 3 days per week	-0.4890	0.4382	-1.1159
		1 to 4 days per month	0.3154	0.5542	0.5692
		Never	0.6319		
	Usage of shared mobility	Using shared mobility	0.2905	0.2964	0.9801
		Never	-0.2905		
Reference trips variables	Transportation mode	Car	**0.5262**	0.1803	2.9182
		Train	-0.4265	0.2190	-1.9472
		Bus	-0.0202	0.2280	-0.0886
		Shared mobility	-0.0794		
	Travel purpose	Work	0.0926	0.3757	0.2464
		Social/leisure	**-0.5829**	0.2912	-2.0016
		Shopping/doing groceries	0.3739	0.4434	0.8431
		Other	0.1165		
	Travel distance	Unit: kilometer	-0.0047	0.0064	-0.7433
	Travel time	Unit: minutes	-0.0148	0.0081	-1.8242
	Travel pressure	Not in a hurry	-0.2413	0.2922	-0.8260
		A bit in a hurry	-0.1385	0.3202	-0.4326
		In a hurry	0.3798		
	Travel companion	Alone	-0.0646	0.2233	-0.2895
		With others	0.0646		
	Travel with kids	With kids	0.5697	0.5448	1.0458
		No kids	-0.5697		
Alternative-attribute variables	Price per km	€ 0.10	**1.5243**	0.1196	12.7478
		€ 0.20	**0.3404**	0.0983	3.4618
		€ 0.30	**-0.8190**	0.0984	-8.3264
		€ 0.40	-1.0457		
	Waiting time	1	**0.2640**	0.1001	2.6364
		3	**0.3065**	0.0995	3.0796
		5	-0.1067	0.0969	-1.1010
		7	-0.4638		
	Travel time*	Low	0.0709	0.0561	1.2645
		High	-0.0709		
	Seating comfort	Economy	-0.0459	0.0584	-0.7865
		Business	0.0459		
Latent-attitude variables	Sustainability		-0.4718	0.3739	-1.2618

J1.3: Results of the second alternative

Alternative 2: Shared autonomous ride

			Estimate	Std.err.	t-ratio(0)
Alternative-specific constant			1.3035	1.2017	1.0847
Standard deviation of the random panel effect parameter?			**-1.3650**	0.2683	-5.0881
Socio-demographic variables	Gender	Male	**1.0086**	0.4842	2.0831
		Female	-1.0086		
	Age	18-34 year	-0.6454	0.6615	-0.9757
		35-54 year	0.0035	0.5797	0.0061
		55-74 year	-0.2169	0.5119	-0.4236
		>75 year	0.8588		
	Education	Low	**1.3642**	0.6909	1.9745
		Middle	-0.6238	0.4437	-1.4059
		High	-0.7405		
	Income	€0-€20.000	**1.3955**	0.5174	2.6970
		€20.001-€40.000	0.2365	0.4198	0.5633
		€40.001 or more	-0.2165	0.5086	-0.4257
		"I prefer not to answer"	-1.4155		
	occupation	Student	0.5366	0.7378	0.7273
		Work	**1.2514**	0.4685	2.6711
		Unemployed, disability or other	-0.8127	0.6088	-1.3348
		Retired	-0.9754		
	Living environment	Urban	0.0971	0.5524	0.1757
		Slightly urban	0.0928	0.7166	0.1295
		Village	**1.5402**	0.6630	2.3231
		Rural	-1.7300		
	Household composition	Single without child(ren)	9.5586	57.4076	0.1665
		Couple without child(ren)	-4.6922	19.1422	-0.2451
		Single/couple with child(ren)	-3.2173	19.1425	-0.1681
		Other	-1.6491		
	Nr. driving licenses in the household		-0.5262	0.2741	-1.9194
	Household car ownership	None	3.9731	19.1450	0.2075
		One car	3.6854	19.1408	0.1925
		Two or more cars	3.1589	19.1575	0.1649
		One person household	-10.8175		
Travel characteristics	Driving license	Yes	0.4176	0.3809	1.0964
		No	-0.4176		
	PT membership	PT Membership	0.0204	0.3237	0.0629
		None	-0.0204		
	Car ownership	One car	0.1943	0.6106	0.3182
		Two or more cars	0.6655	1.1501	0.5787

		None	-0.6655		
	Car lease	Lease car	**-0.8735**	0.4240	-2.0602
		None	0.8735		
	Usage of car as driver	4 or more days per week	**-1.2167**	0.5785	-2.1034
		1-3 days per week	-0.1018	0.4898	-0.2077
		1-4 days per month	0.5637	0.4978	1.1324
		10 times per year - never	0.7548		
	Usage of car as a passenger	1 or more times per week	**0.9627**	0.4598	2.0935
		1 to 4 days per month	-0.4504	0.4122	-1.0927
		1 to 10 days per year	**-1.3550**	0.4563	-2.9692
		Never	0.8427		
	Usage of train	1 or more times per week	-0.3608	0.5948	-0.6065
		1 to 4 days per month	0.1965	0.5879	0.3343
		1 to 10 days per year	-0.5548	0.5470	-1.0142
		Never	0.7190		
	Usage of bus/tram/metro	1 or more times per week	-0.0656	0.4676	-0.1403
		1 to 4 days per month	-0.0938	0.4638	-0.2023
		1 to 10 days per year	0.5467	0.4626	1.1818
		Never	-0.3873		
	Usage of bike	4 or more days per week	-0.1502	0.4013	-0.3743
		1 to 3 days per week	0.0380	0.5082	0.0747
		1 to 4 days per month	-0.1026	0.7127	-0.1440
		Never	0.2149		
	Usage of walking	4 or more days per week	-0.2618	0.3848	-0.6805
		1 to 3 days per week	-0.5060	0.4369	-1.1580
		1 to 4 days per month	0.3007	0.5541	0.5427
		Never	0.4671		
	Usage of shared mobility	Using shared mobility	0.5147	0.2942	1.7494
		Never	-0.5147		
Reference trips variables	Travel purpose	Work	0.4767	0.3747	1.2723
		Social/leisure	-0.3786	0.2905	-1.3032
		Shopping/doing groceries	0.2121	0.4427	0.4791
		Other	-0.3102		
	Travel distance	Unit: kilometer	-0.0023	0.0063	-0.3688
	Travel time	Unit: minutes	**-0.0175**	0.0080	-2.1833
	Travel pressure	Not in a hurry	-0.0731	0.2904	-0.2516
		A bit in a hurry	-0.1745	0.3179	-0.5490
		In a hurry	0.2476		
	Travel companion	Alone	-0.0260	0.2212	-0.1174
		With others	0.0260		
	Travel with kids	With kids	0.2527	0.5506	0.4589
		No kids	-0.2527		

Alternative-attribute variables	Price per km	€ 0.05	**0.9608**	0.0988	9.7251
		€ 0.10	**0.2134**	0.0955	2.2349
		€ 0.15	**-0.3602**	0.1010	-3.5663
		€ 0.20	-0.8141		
	Waiting time	4	**0.2373**	0.0955	2.4849
		6	0.1525	0.0966	1.5791
		8	-0.0961	0.0996	-0.9648
		10	-0.2938		
	Travel time*	Low	**0.1516**	0.0562	2.6958
		High	-0.1516		
	Number of strangers	1	**0.3551**	0.0959	3.7010
		2	-0.1542	0.0997	-1.5469
		3	0.0156	0.0970	0.1611
		4	-0.2165		
	Seating comfort	Economy	**-0.1224**	0.0564	-2.1712
		Business	0.1224		
Latent-attitude variables	Sustainability		-0.3306	0.3772	-0.8763

J1.4: Results of the third alternative

Alternative 3: Autonomous public transportation

			Estimate	Std.err.	t-ratio(0)
Alternative-specific constant	N/A				
Standard deviation of the random panel effect parameter			**-2.4113**	0.4342	-5.5533
Socio-demographic variables	N/A				
Alternative-attribute variables	N/A				
Latent-attitude variables	N/A				

J1.5: Results of the latent variable

Latent-attitude results

			Estimate	Std.err.	t-ratio(0)
Sustainability	Constant		-0.0026	0.0245	-0.1072
	Standard deviation		**0.6434**	0.0399	16.1062
	Lambda	Statement 1	1		
		Statement 2	**1.1570**	0.0768	15.0568
		Statement 3	**1.1963**	0.0746	16.0250
		Statement 4	**1.2062**	0.0757	15.9306
		Statement 5	**1.1730**	0.0736	15.9476
	Standard deviation	Statement 1	1		
		Statement 2	**0.6493**	0.0196	33.1502
		Statement 3	**0.4488**	0.0169	26.4898
		Statement 4	**0.4744**	0.0171	27.7946
		Statement 5	**0.4614**	0.0169	27.3797

J2: Process of finding best model

Model	Removed(-)/added(+) variable	-/+	Other adjustments
Model 1			
	Usage of walking	-	
	Usage of shared mobility	-	
	Car ownership	-	
	Household car ownership	-	
	PT membership	-	
Model 2			
	Usage of the train	-	
	Usage of the bus/tram/metro	-	
	Usage of the bike	-	
	Travel companion	-	
	Travel with kids	-	
Model 3			
	Driving license	-	
	Usage of car as driver	-	
	Lease car	-	
	Travel distance	-	
	Travel pressure	-	
Model 4			
	Number of driving license in the household	-	
Model 5			
	Income level	-	
	Travel purpose	-	
Model 6			
	Usage of car as a passenger	-	
Model 7			
	Living environment	-	
Model 8			
	Occupation	-	
Model 9			
	Living environment	+	
Model 10			
			Latent variable: SAR and APT
Model 11			
	Living environment	-	
Model 12			
	Occupation	+	
Model 13			
	Occupation	-	
	Travel time	-	

	Interaction between travel time (RT) and seating comfort (3 categories)	+	
	Interaction between number of people and seating comfort	+	
Model 14			
	Interaction between number of people and seating comfort	-	
Model 15			
	Interaction between travel time (RT) and seating comfort (3 categories)	-	
	Interaction between travel time (RT) and seating comfort (2 categories)	+	
Model 16			Final model

J3: Extended model summary of final model

Results SACE

Number of individuals	765
Number of observations	2846
Number of draws	500
LL start	-7250.924
LL whole model	-5618.593
LL Statement 1	-1019.106
LL Statement 2	-1040.33
LL Statement 3	-966.043
LL Statement 4	-981.1508
LL Statement 5	-960.5592
LL choice	-1754.138
AIC	11355.19
BIC	11708.49
Estimated parameters	59
Iterations	93
R square	0.225
R square adjusted	0.217

Appendix K – Results of model 12 (related to the SACE)

K1: Model summary

Results SACE

Number of individuals	765
Number of observations	2946
Number of draws	500
LL start	-7280.974
LL whole model	-5636.800
LL Statement 1	-1028.879
LL Statement 2	-1046.272
LL Statement 3	-970.7698
LL Statement 4	-986.0222
LL Statement 5	-965.1041
LL choice	-1748.422
AIC	11391.6
BIC	11745.12
Estimated parameters	59
Iterations	98
R square	0.226
R square adjusted	0.218

K2: Results of fist alternative

Alternative 1: Shared autonomous vehicle

			Estimate	Std.err.	t-ratio(0)
Alternative-specific constant			**1.8363**	0.6120	3.0006
Standard deviation of the random panel effect parameter			**-1.9228**	0.1322	-14.5429
Socio-demographic variables	Gender	Male	0.9766	0.4985	1.9589
		Female	-0.9766		
	Age	18-34 year	0.0621	0.5307	0.1170
		35-54 year	-0.3029	0.5248	-0.5772
		55-74 year	-0.1963	0.5335	-0.3680
		>75 year	0.4371		
	Education	Low	**2.0520**	0.7117	2.8834
		Middle	**-1.1390**	0.4591	-2.4811
		High	-0.9130		
	Household composition	Single	**-0.8487**	0.4011	-2.1159
		Couple	**-1.2488**	0.4306	-2.9005
		Family (with children)	**1.0986**	0.5573	1.9715

		Other	0.9989		
Reference trips variables	Transportation mode	Car	**0.7388**	0.1635	4.5183
		Train	**-0.6605**	0.2077	-3.1795
		Bus	-0.1596	0.2158	-0.7395
		Shared mobility	0.0813		
	Travel time	Unit: minutes	**-0.0196**	0.0043	-4.5594
Alternative-attribute variables	Price per km	€ 0.10	**1.5128**	0.1180	12.8165
		€ 0.20	**0.3180**	0.0966	3.2910
		€ 0.30	**-0.8022**	0.0966	-8.3038
		€ 0.40	-1.0286		
	Waiting time	1	**0.2292**	0.0985	2.3255
		3	**0.2886**	0.0979	2.9483
		5	-0.0867	0.0954	-0.9093
		7	-0.4310		
	Travel time*	Low	0.0961	0.0552	1.7419
		High	-0.0961		
	Seating comfort	Economy	-0.0392	0.0573	-0.6835
		Business	0.0392		
Latent-attitude variables	N/A				

K3: Results of second alternative

Alternative 2: Shared autonomous ride

			Estimate	Std.err.	t-ratio(0)
Alternative-specific constant			**1.2226**	0.5836	2.0951
Standard deviation of the random panel effect parameter			-0.0688	0.4223	-0.1630
Socio-demographic variables	Gender	Male	0.7902	0.4791	1.6494
		Female	-0.7902		
	Age	18-34 year	0.4453	0.5110	0.8714
		35-54 year	-0.1441	0.5075	-0.2840
		55-74 year	-0.3460	0.5197	-0.6658
		>75 year	0.0449		
	Education	Low	**2.1265**	0.6942	3.0634
		Middle	**-1.1104**	0.4491	-2.4725
		High	-1.0160		
	Household composition	Single	-0.4556	0.3803	-1.1979
		Couple	**-1.1623**	0.4153	-2.7990
		Family (with children)	0.8448	0.5388	1.5680
		Other	0.7731		
Reference trips variables	Travel time	Unit: minutes	**-0.0189**	0.0043	-4.4576
Alternative-attribute variables	Price per km	€ 0.05	**0.9132**	0.0964	9.4762
		€ 0.10	**0.2197**	0.0933	2.3536
		€ 0.15	**-0.3162**	0.0985	-3.2084
		€ 0.20	-0.8167		
	Waiting time	4	**0.2356**	0.0940	2.5064
		6	0.1570	0.0945	1.6611

		8	-0.1111	0.0974	-1.1408
		10	-0.2815		
	Travel time*	Low	**0.1398**	0.0551	2.5367
		High	-0.1398		
	Number of strangers	1	**0.3385**	0.0941	3.5983
		2	-0.1302	0.0976	-1.3349
		3	0.0025	0.0950	0.0263
		4	-0.2108		
	Seating comfort	Economy	-0.1045	0.0552	-1.8932
		Business	0.1045		
Latent-attitude variables	Sustainability		**0.4013**	0.1494	2.6859

K4: Results of third alternative

Alternative 3: Autonomous public transportation

			Estimate	Std.err.	t-ratio(0)
Alternative-specific constant	N/A				
Standard deviation of the random panel effect parameter			**3.2186**	0.4777	6.7378
Socio-demographic variables	N/A				
Alternative-attribute variables	N/A				
Latent-attitude variables	Sustainability		**0.4118**	0.3796	1.0849

K5: Results of latent variable

Latent-attitude results

			Estimate	Std.err.	t-ratio(0)
Sustainability	Constant		-0.0138	0.0243	-0.5658
	Standard deviation		**0.6758**	0.0421	16.0591
	Lambda	Statement 1	1.0000		
		Statement 2	**1.1576**	0.0768	15.0721
		Statement 3	**1.1951**	0.0745	16.0367
		Statement 4	**1.2061**	0.0756	15.9455
		Statement 5	**1.1726**	0.0734	15.9790
	Standard deviation	Statement 1	1.0000		
		Statement 2	**0.6485**	0.0195	33.2047
		Statement 3	**0.4497**	0.0169	26.5395
		Statement 4	**0.4739**	0.0172	27.5853
		Statement 5	**0.4613**	0.0167	27.5562