STUDENT AWARDS

QPARK Quality in parking

PARKING CHOICE BEHAVIOUR

INFLUENCE PARKING CHOICE BEHAVIOUR

Student information
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Providing information to influence dynamic parking choice behaviour in urban areas

This thesis discusses how information should be provided to support the optimisation of dynamic urban parking choice behaviour.

To influence motorists' dynamic parking choice behaviour the right information should be provided at the right moment in time.

By means of survey based research, it is studied what information sources are typically utilised, what factors influence parking choice behaviour and at what moment in the decision making process, motorists make their parking choice.

To bridge the gap between academic knowledge and practical questions, the theoretical findings are applied to the current parking situation in Leeuwarden.

Eventually recommendations for investing in information supply infrastructure for the municipality of Leeuwarden are provided, and an experiment is designed to measure the success of the recommendations based on actual behaviour.

EFFECTS OF AVS ON PARKING CHOICE

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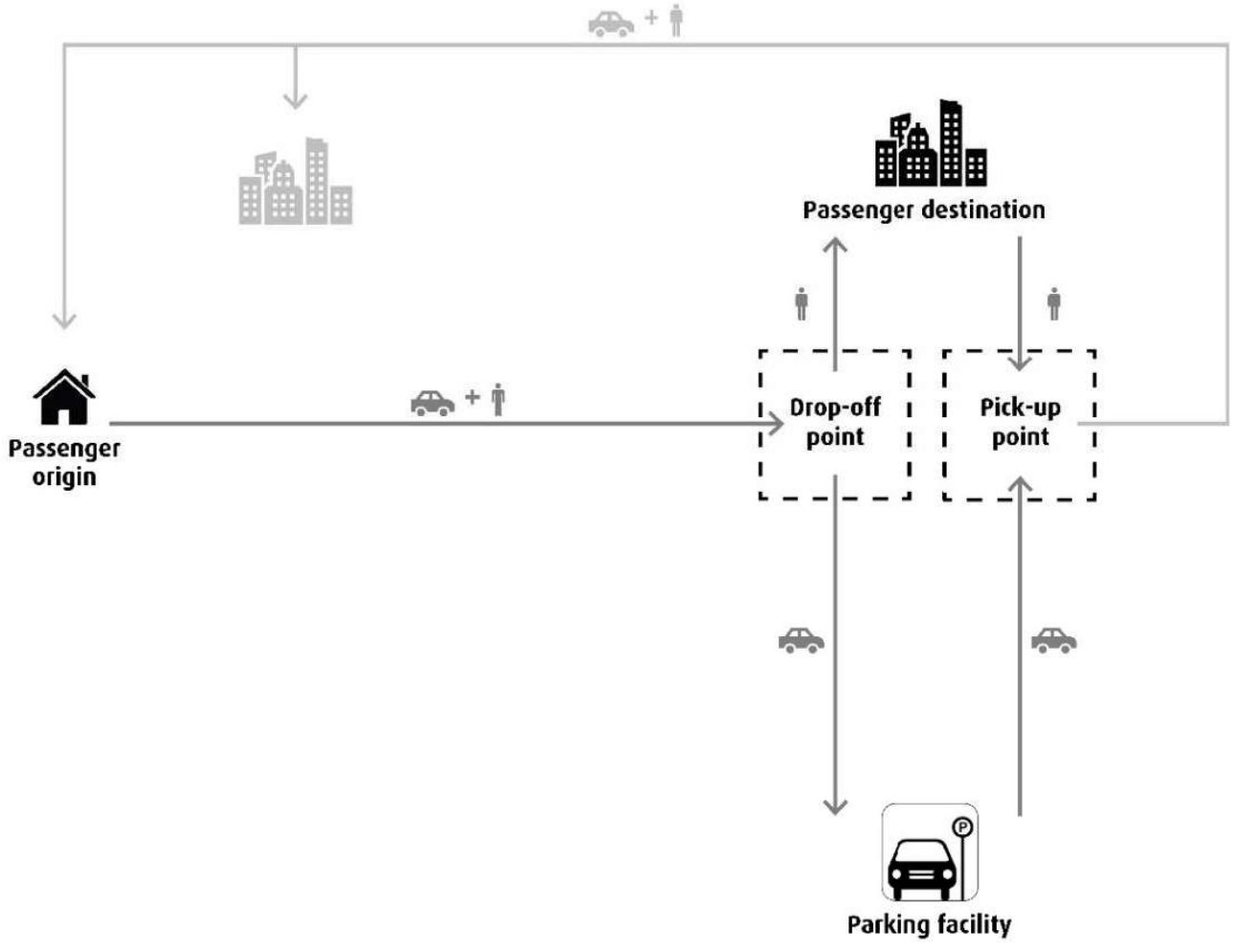
An empirical study into the effects of private automated vehicles on motorists' parking location choice: an application to the city of The Hague

Automated vehicles (AVs) have been receiving increased attention all over the world, since the first fully AVs are already operating on the public road network. AVs could not only have a tremendous impact on the urban environment but also on human travel behaviour. With the capability of AVs to ride and park themselves instead of being operated by a human driver, it is likely that parking choice behaviour will change when conventional vehicles (CVs) are replaced by AVs. In order to make investment decisions, it is important for governments to gain insight into the impacts of AVs. The objective of this research is to find the importance of different factors and constraints that could influence drivers' parking location choice for a future situation in which private highly AVs will become available for passenger transport. The results of this study have been used to provide guidelines for governments on how to develop their parking policy for this future situation. The main research question of this thesis is formulated as follows:

Figure 1: Schematic overview of the different steps of a trip with a private highly AV



'' What is the effect of private highly automated vehicles on drivers' parking location choice, based on parking constraints? ''

AVs can either be privately used or shared with others. This research is focused on the private use of AVs. A schematic overview of a trip with a private highly AV is visualised in Figure 1. The trip with a private highly AV starts from the 'passenger origin' and develops in the direction of the 'passenger destination'. Space to drop-off the passenger is needed to avoid congestion caused by dropping-off passengers on the road itself. On-street parking space is used for the drop-off manoeuvre. When the passenger is dropped-off at a drop-off point, the passenger walks to the destination.

Simultaneous to this walking leg, the private highly AV drives empty from the drop-off point to a parking facility. The two considered parking locations are 1) parking in the inner city (PIC) and 2) parking at the edge of the city (PEC), both at off-street parking facilities. When the passenger's activity has ended, he/she walks to a pick-up point. On-street parking space is used for the pick-up manoeuvre. Simultaneously, the private highly AV drives empty from the parking facility to the pick-up point. When the passenger and the private highly AV have both arrived at the pick-up point, the vehicle trip from the pick-up point to the passenger's home or to another destination starts.

A literature review and brainstorm sessions with experts were conducted to define factors and constraints that could influence drivers' parking location choice. Factors and constraints for the Stated Preference (SP) experiment were selected by means of a Multi-Criteria Analysis (MCA). The selected factors and constraints can be divided into different categories: context factors, attributes, perceptions and exogenous variables. A SP data collection method was used in this research to examine which factors and constraints, and to which extent, influence a driver's parking location choice. Private highly AVs as described in this study are not operating on the public road network yet, which makes the need for hypothetical choice situations necessary. SP data is based on individuals' reactions to hypothetical situations: it is asked what an individual would choose in a specific situation. In this research the environmental conditions, road network configuration and parking constraints of the city of The Hague are used specifically, however, the generic methodology applied in this study could be applied to any large scale city.

Two pilot surveys were conducted in order to design the final questionnaire. An orthogonal design was used to create the hypothetical choice situations for both pilot surveys, because there is no information on prior parameter values. The aim of both pilot surveys was to test if the respondents understood the questionnaire and the concept of automated driving. Furthermore, the results of both pilot surveys were used to find prior parameter values. A final survey was made, based on the results of both pilot surveys. The final survey consists of introduction questions, hypothetical choice situations (part 1), statements on automated driving (part 2) and general questions on personal characteristics (part 3).

In the introduction questions, respondents' fill in the trip characteristics (trip purpose, trip duration and trip reimbursement) of their most recent trip to the inner city of The Hague. The trip characteristics are the context factors that apply for the hypothetical choice situations which were asked in the first part of the survey. Preferences regarding the attributes were collected via the different hypothetical choice situations. Attributes included in the design are: 'parking cost', 'surveillance of the parking facility', 'risk of extra waiting time' and 'risk of parking fee'. The two latter attributes are new concepts for individuals, describing respectively the result of the vehicle arriving too early at the pickup point and the vehicle arriving too late at the pick-up point. An efficient design was used to create the hypothetical choice situations, because the pilot survey provided information on the prior parameter values. In the second part of the survey, statements were presented in order to receive information on respondents' perceptions on automated driving. Information about respondents' exogenous factors was collected via general questions in the third part of the survey.

In total, 421 respondents filled in the online questionnaire. 388 responses were valid and used for the data analysis. Results of the descriptive analysis showed that 16.2% of the respondents have a fixed preference for PIC, compared to 11.6% of the respondents that have a fixed preference for PEC. Trip characteristics explain the fixed preference for either PIC or PEC. Results of the Multinomial logit (MNL) model estimation on the hypothetical choice situations show that all attributes are significant, which means that these attributes are of influence on drivers' parking location choice. From the results of the hypothetical choice situations, it can be concluded that in general PIC is preferred over PEC. The 'parking cost', the 'risk of extra waiting time' and the 'risk of parking fee' have a negative influence on drivers' parking location choice. 'Personnel surveillance' has a positive influence on drivers' parking location choice. The parameter for 'camera surveillance' is not significant, which means that individuals are not sensitive for the presence of cameras in a parking facility. Personal characteristics (exogenous factors), trip characteristics (context factors) and perceptions resulting from the MCA were included in the MNL model as interaction effects to test if these characteristics affect the attributes that influence drivers' parking location choice. Results of the MNL model estimation on the interaction effects showed that only a few interaction effects are significant. Despite their significance, several of these interaction effects are based on a small sample and others cannot be explained. The following interaction effects are based on a large sample and can be explained:

- Individuals with a high income are more sensitive for 'risk of extra waiting time'. This was expected, since the research pointed out that on average, individuals with a higher income have a higher Value of Time (VoT) and Value of Reliability (VoR).
- Individuals with a relatively high purchase value of the car are less sensitive for 'risk of extra waiting time'. A reason for this might be that individuals with a high purchase value of the car find it more important that the car arrives safely at the passenger's destination. In this case, the individual accepts the 'risk of extra waiting time'.
- Individuals who consider safety during the empty vehicle trip to be important, are less sensitive for the 'risk of extra waiting time' and the 'risk of parking fee'. Apparently, these individuals care more about the safety circumstances during the empty vehicle trip than about extra time and costs.

When a large amount of interaction effects do not play a role, a more generic model can be estimated that works for the same conditions. Therefore, it was chosen to conduct the scenario analysis based on a model without interaction variables. This means that the same model applies for individuals with different characteristics, trip purposes and perceptions.

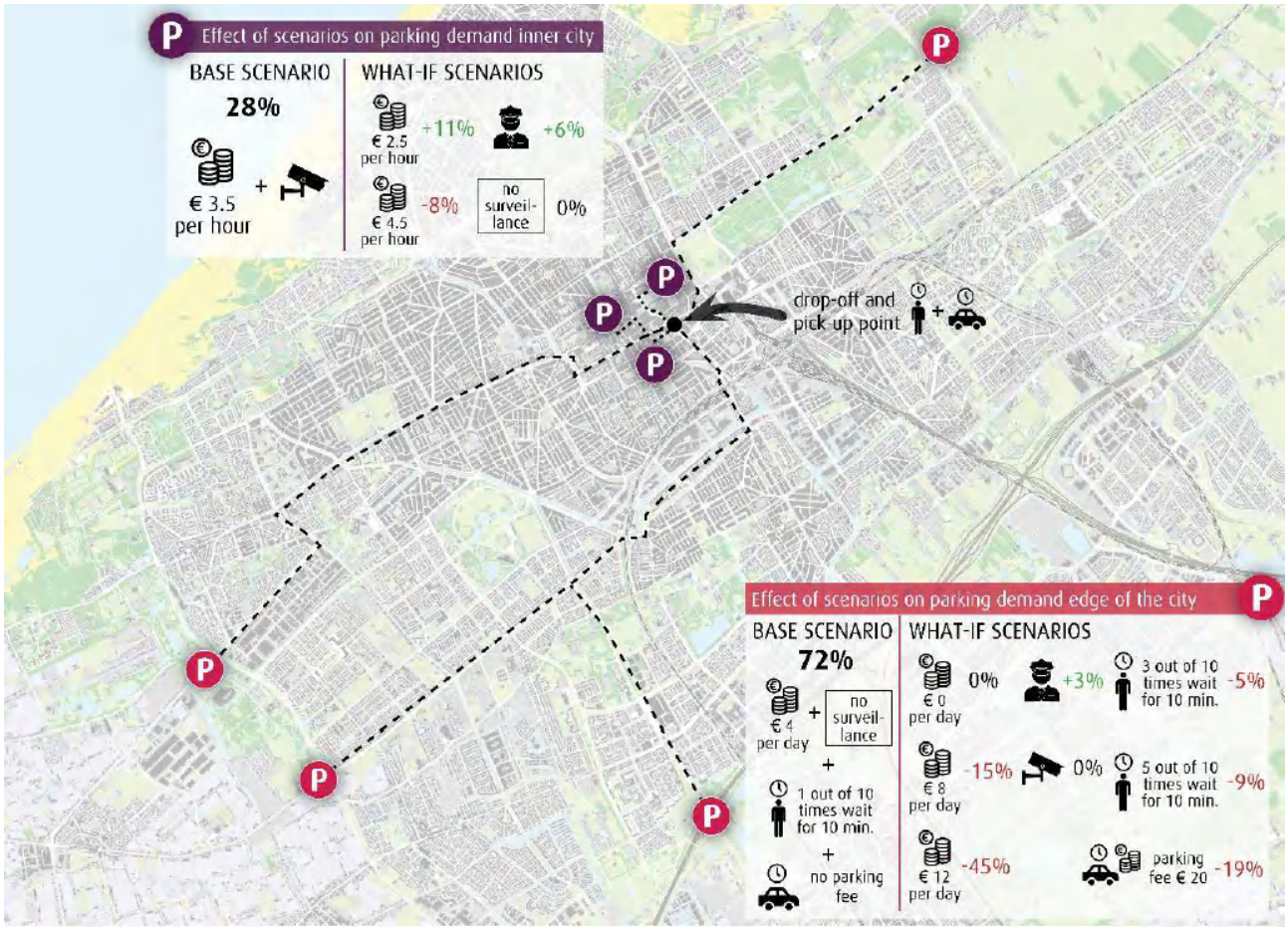
The results of the scenario analysis are visualised in Figure 2. From the results of the scenario analysis can be concluded that individuals are most sensitive for a change in direct costs, i.e. the 'parking cost' at the parking facility and the 'parking fee' for temporary parking the highly AV at an on-street parking place near the passenger's destination. When the parking cost in the inner city is decreased with €1 per hour, parking demand will increase with 11%. Furthermore, it could be expected that when the parking cost in the inner city will be increased with €1 per hour, parking demand will decrease with 8%. When there are no parking costs for parking at the edge of the city, parking demand will remain the same. When the parking cost at the edge of the city will be increased from €4 per day to €8 per day or €12 per day, it is expected that parking demand will drastically decrease with 15% and 45% respectively. When a parking fee of €20 is implemented for temporary parking the highly AV at an on-street parking place near the passenger's destination, parking demand at the edge of the city will decrease with 19%. This has the same effect as increasing the parking cost at the edge of the city from €4 to approximately €8.50 per day. From the results of the scenario analysis can be concluded that individuals are less sensitive for 'personnel surveillance' and 'risk of extra waiting time'. The presence of personnel surveillance has a positive influence on drivers' parking location choice. When

personnel surveillance will be available at a parking facility, parking demand will increase with 6% in the inner city, compared to 3% at the edge of the city. From the results of the model, it was concluded that camera surveillance is not significant, which means that camera surveillance is valued the same as no surveillance. This means that when the parking facility is supervised by means of cameras, it is expected that this will not lead to an increase or decrease in parking demand. The risk of extra waiting time (for 10 minutes) during the off-peak period is 1 out of 10 times. When no separated lanes for highly AVs exist, the risk of extra waiting time during the peak period is likely to be higher. When the risk of extra waiting time is increased to 3 out of 10 times or 5 out of 10 times during the peak period, and no separated lanes for highly AVs are available, the parking demand at the edge of the city will decrease to 5% and 9% respectively.

Directions for parking policies are related to different topics regarding parking regime, parking price and parking capacity. The directions for parking policies are visualised in Figure 3.

1. First, in order to reduce the number of on-street parking spaces, it is advised to forbid the parking of highly AVs at on-street parking spaces. Consequently, released space could be used for drop-off and pick-up manoeuvres. It is not expected that all on-street parking space is needed for drop-off and pick-up manoeuvres. Similar to the current situation, it might be considered that inhabitants of the city of The Hague are allowed to park their highly AV

Figure 2: The influence of the what-if scenarios on the distribution of parking demand

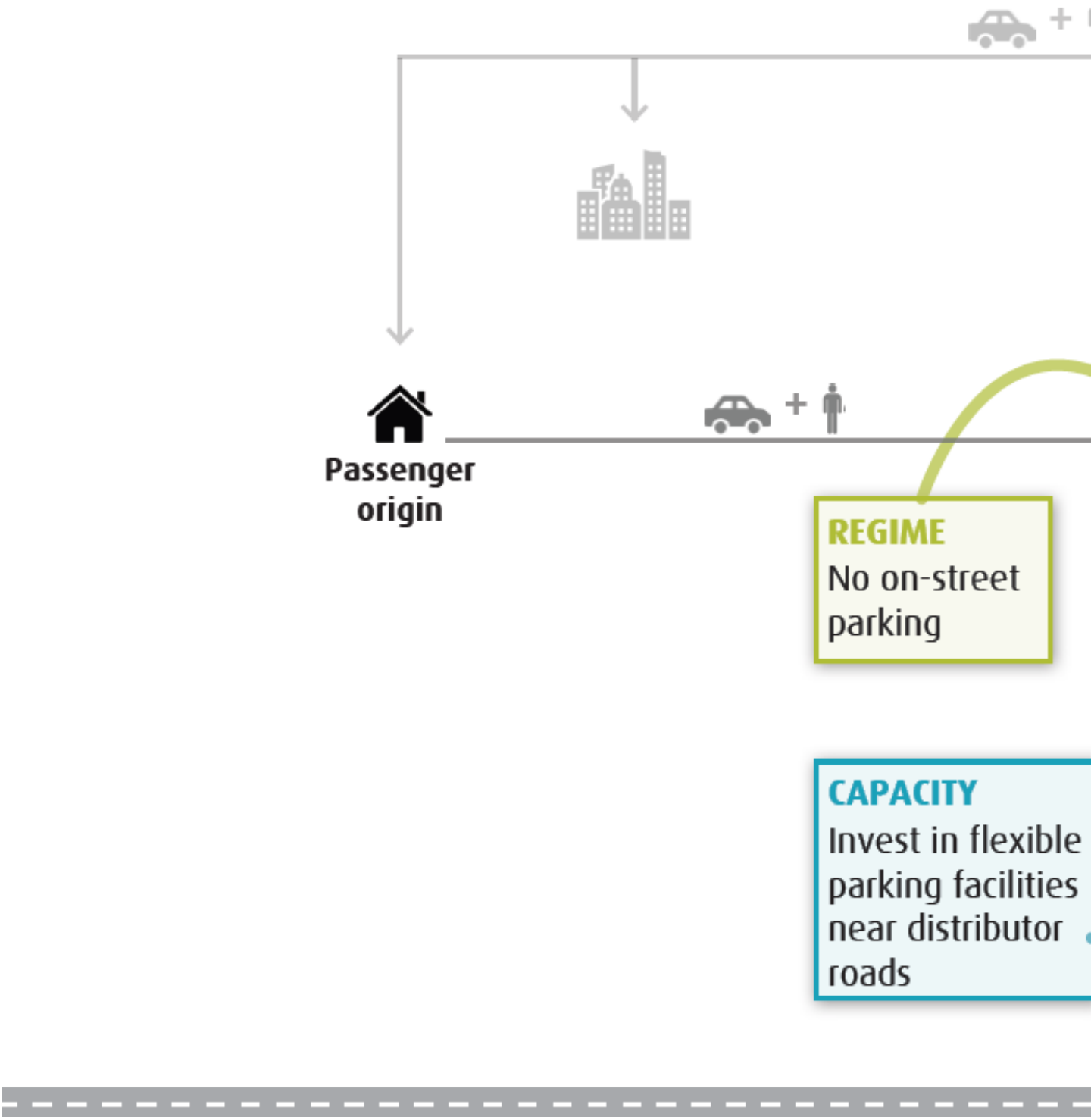


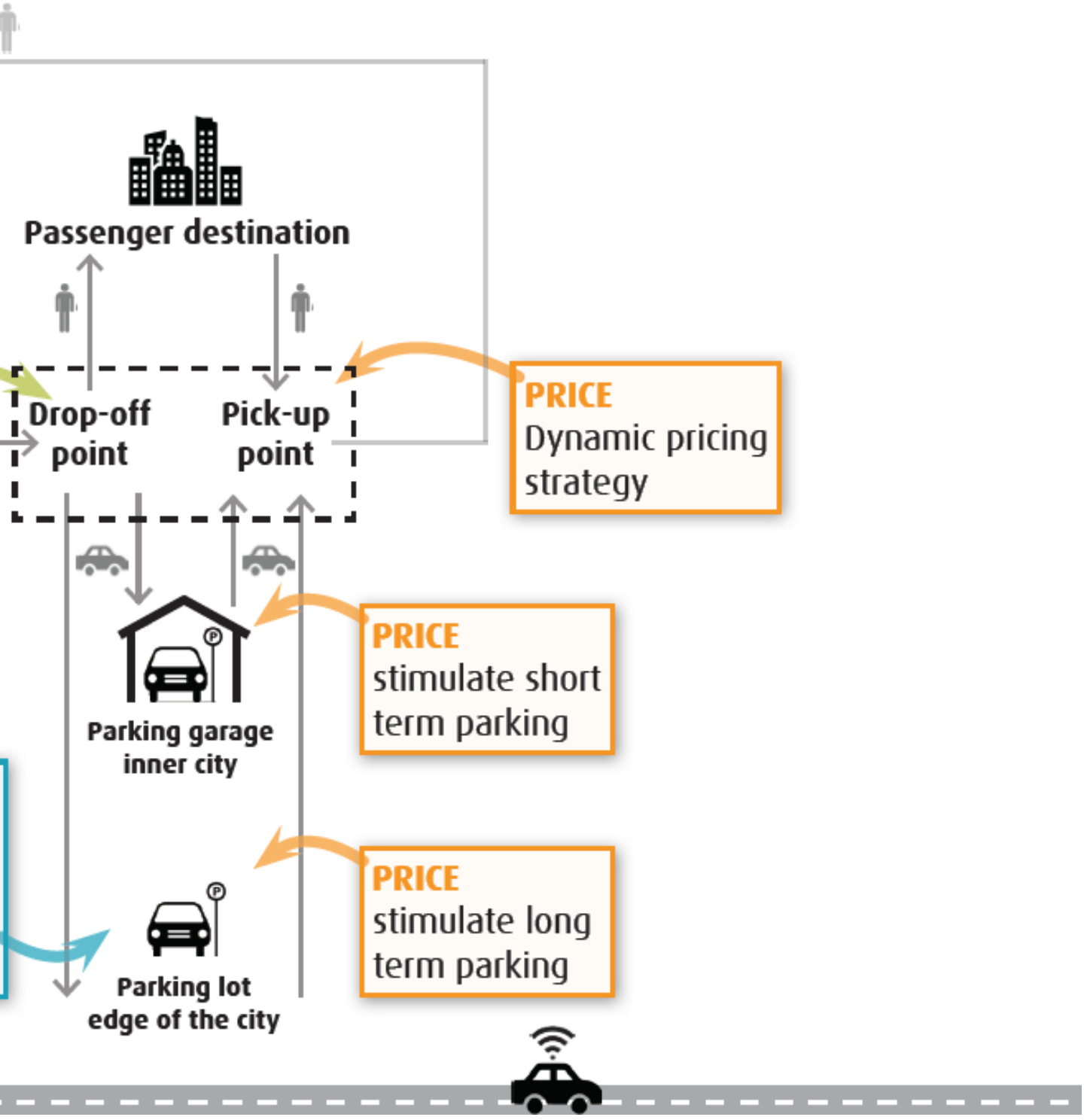
on-street with a parking permit. Furthermore, released on-street parking space could be used for greenery or extra space for bicyclists and pedestrians.

2. Second, in order to minimize the number of empty vehicle kilometres, it is advised to stimulate short term parking of highly AVs in the inner city and stimulate long term parking of highly AVs at the edge of the city. This could be done by increasing the parking cost of parking at the edge of the city from €4 to €10 per day. Consequently, approximately 55% of the individuals would park their highly AV in the inner city, compared to 28% that parked their highly AV in the inner city in the base scenario.
3. Third, it is advised to implement a dynamic pricing strategy for the parking fee that is asked for temporary parking the highly AV at an on street parking place near the passenger's destination, when the highly AV arrives too early. When implementing a dynamic pricing strategy, the municipality is able to 1) control supply and demand, 2) account for competitor pricing and 3) account for external factors (e.g. peak periods). When a parking fee of €20 is implemented, approximately 47% of the individuals would park their highly AV in the inner city, compared to 28% that parked their highly AV in the inner city in the base scenario. Fourth, when more parking capacity is needed, it is advised to invest in flexible parking facilities at the edge of the city near distributor roads. When the parking facility is supervised by personnel, parking demand will only increase with 3%. To increase the attractiveness of parking highly AVs at the edge of the city, it is advised to reserve space for additional services (e.g. pick-up point for groceries and day-care).

Further research is needed to examine which services positively influence drivers' parking location choice. Recent studies show that automated vehicles could induce an increase of travel demand due to changes in destination choice, mode choice and mobility (Milakis, Arem, & Wee, 2017). Hence, more parking capacity might be required. Furthermore, the level of sharing and the penetration rate of AVs should be taken into account when making policy decisions, because these developments might have an influence on the number of parking spaces required. This research succeeded in capturing the change of drivers' parking location choice in the case when private highly AVs will become available for passenger transport. As a result of choices made by respondents in the hypothetical choice situations, insight was gained in individuals' preferences and trade-offs. The presented results and guidelines can be used in future research on the effects of highly AVs on parking location choice where, at the same time, it can be used by governments to develop their parking policy for this future situation.

Figure 3: Visualisation of the directions for promising parking policies




Passenger destination
Drop-off point
Pick-up point
PRICE
Dynamic pricing strategy
Parking garage inner city
PRICE
stimulate short term parking
Parking lot edge of the city
PRICE
stimulate long term parking

PARKING CHOICE AND SOCIAL INFLUENCE

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Parking choice and the role of social influence

Objectives and methodology

The implementation of parking policies has provided limited success in terms of meeting the goals set out by municipalities such as reducing congestion and pollution (Shoup, 2006). Models trying to predict the behaviour of car drivers often only include attributes of the parking facility as predictors. One of the factors that may play a role in the decision making process is the influence of an individual's social circle which has not yet been commonly discussed topic in the field of parking research (Sunitiyoso, Avineri, & Chatterjee, 2011). This research aims to contribute to the possibility that social influence may be a factor in the decision for an individual to choose for a certain parking facility.

Data from an earlier study by (Iqbal, 2018) was gathered with the use of a web-based questionnaire which featured four attributes relating to the characteristics of the parking facility itself being: parking tariff, walking distance to the final destination, type of parking space and type of security. Also included were the advices of four groups that may exist in one's social network being: family, friends, colleagues and experts. Respondents were asked to choose between five ranking option that indicated the likelihood of choosing to park at the presented parking facility.

Data of 377 respondents that completed the survey have been included in the estimation of three different logit models: multinomial logit (MNL), latent class (LC), and mixed logit (ML). The differences in these models allow for more insight in the preferences of respondents regarding the attributes that have been used in the survey. MNL models are restricted in the sense that the interpretation of the results can only be ascribed to the average opinion of the sample of respondents. LC models allow for a distinction of respondents in latent classes with response patterns determining the differences between the classes. The likelihood of a respondent belonging to a certain class can then be derived by matching the estimated parameters of one class with the parameters from a single respondent. ML models are used to identify whether heterogeneity is present for certain attributes which in turn can be further investigated by using, for example, sociodemographic characteristics to see whether these can be defined as the source of the heterogeneity being present.

Results and conclusions

The MNL model showed that the most influential attribute regarding the choice to park at a given location is the parking tariff. The second most influential attribute was found to be the security measures being present with a large preference for security staff over security cameras. Latent classes were not able to be estimated with the inclusion of all attributes. This indicates that respondents were either too homogenous in their responses or that no regularity could be based on response patterns. Estimating latent classes when only including alternative-specific constants (ASC's) showed that there is a group of respondents that rarely stated they were unlikely to park at the described parking facility given in the survey. Because no more information could be derived with the use of the LC model further analysis has been done with the use of the MNL model with data being separated based on socio-demographic characteristics of the respondents which were: age, gender, educational level, nationality and family situation (whether respondents had children or not).

Of these five characteristics, two were further investigated as they were estimated to show differences when separated into two groups. Four MNL models were estimated, two based on gender and two based on nationality of the respondents. The MNL model that included only male respondents showed more significant parameter estimates for different attributes indicating that they were either more homogenous in

their taste preferences or considered more attributes to be of importance. Differences showed that male respondents were more likely to prefer a short walking distance to their final destination compared to women and that they disliked on-street-parking more than women as the latter attribute was not found to be significant for the model with only female respondents. Social influence was found to be significant for the positive ranking options. The male only model showed three significant parameter estimates concerning advice from family, friends and experts for the "very likely" ranking option with the latter two stating the parking facility was the cheapest and advice of family being that the parking facility was the safest. The female only model only showed one significant parameter estimate concerning social influence which was an expert stating that the parking facility was the safest for the "very likely" ranking option.

Comparing the models whereby the response sample was based on region of origin (one model for EU citizens and one model for non-EU citizens) showed that parking tariff was less likely to be of importance for non-EU citizens compared to EU-citizens. If the described parking facility was on street, the probability that a positive ranking option was chosen decreased according to the model with only non-EU respondents whereas the same attribute was not estimated to be significant for the model with only EU-citizens. Similarly to the models comparing gender, social influence seemed to play a role for the positive scoring options whereby the model with only EU-citizens estimated advice from all four included groups to be significant. Non-EU citizens were most likely concerned with the advice of their family. Both models also show that whenever the advice is concerned, the likelihood of a positive ranking option being chosen increased whenever their family stated the parking facility was the safest. The mixed logit model confirmed that heterogeneity was present for all ranking options as was also found in the MNL and LC models. Estimated standard deviations were found to be significant for the ASC's for all ranking options indicating that not only the model did not capture all attributes that would explain the reason why a certain ranking option was chosen but also that respondents have different reasons for choosing said option. Other attributes with a significant standard deviation estimate were the parking tariff, walking distance, parking type and security level. Further analysis whereby socio-demographic characteristics of respondents were taken into account confirmed the findings as done with the MNL model that heterogeneity was present for regional differences concerning the importance of parking tariffs and walking distance.

With regards to the significance of the models each addition proved to be significant in terms of model fit according to the four goodness-of-fit methods used in this study. The MNL model although limited in its use did prove to be of worth, especially when manually separating respondents into groups based on socio-demographic characteristics and comparing the models. Comparing the MNL and ML model it is clear that the interpretation of the MNL model is easier but it also lacks the depth of taking heterogeneity into account which was found to be present in the dataset. The ML model performed better but also required much more parameters complicating the interpretation of results and also making the model less parsimonious, i.e. less likely to be practical for other datasets. Future research should take into consideration if individual tastes are needed to be investigated or whether taste preferences based on groups are good enough for the model.

PERSPECTIVE ON RESIDENTIAL PARKING

Student information
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A new perspective on residential parking policy: A multiple regression model to explain visitor parking demand in Dutch urban residential areas.

As cities expand, municipalities face mobility challenges to keep their cities sustainable, liveable and accessible. In Europe, individual mobility focuses on personal car use, which makes the availability of car parking spaces an essential and challenging aspect in development projects.

This thesis aims to identify factors which explain visitor parking demand and what this means for the visitor parking standards. The conceptual framework developed showed that visitor parking demand depends on the demographic, geographic and policy characteristics of the residential areas of both the host and the visitor.

The traditional CROW standard makes a distinction between type of dwelling and socio-economic differences, but for visitor parking a universal mark-up of 0.3 parking spaces per dwelling unit applies. With declining car ownership per household, this fixed component is becoming an increasingly large proportion of the parking spaces to be realised in urban new build projects, and is consequently driving up costs and housing prices.

Literature advocates implementing context-specific parking standards related to the local residential area conditions. However, these studies lack insight into actual usage and neglect the visitor parking standards. In practice, there is often an oversupply of visitor parking.

Visitor parking needs were analysed based on the actual use of visitor permits in Eindhoven per postcode zone. Using regression analysis, this data was then linked to:

- geographical data (density, function, accessibility and housing types),
- demographic data of residents in the area (family composition, income and education level),
- parking facilities (on-street, off-street, tariffs).

Surprisingly, it transpired there was hardly any relationship between the number of visitor parking transactions and the number of residents or households. Areas in or near the city centre attract more visitor parking. Residents of larger, owner-occupied, dwellings attract more visitors and, finally, accessibility by car, measured by the number of parking spaces available and proximity to the main road network, has a positive influence on the number of visitors wanting to park.

The study concludes that visitor parking demand is very complex and therefore visitor parking standards should be based on local conditions rather than defining a national uniform value per dwelling. In addition, limiting the number of visitor parking spaces may possibly lead to reduced demand from visitors. However, this needs further practical research to establish new, more specific guidelines.

LIVING WITHOUT A CAR

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Living without a car: an analysis of the car-sharing landscape in Belgium

This research is in two parts. The first part focuses on understanding the group of households without a car and the advantages and disadvantages they experience as a result of not owning a car.

In the context of this study, a zero-car household was viewed as not owning a car. However, zero-car households may still use a car. To understand the issues concerning not owning a car, a literature review was conducted. This revealed that the group of zero-car households is diverse. The group can be subdivided based on the underlying reasons for not owning a car:

- **car-free** households who do not own a car by choice.
- **car-less** households who do not own a car due to external factors.

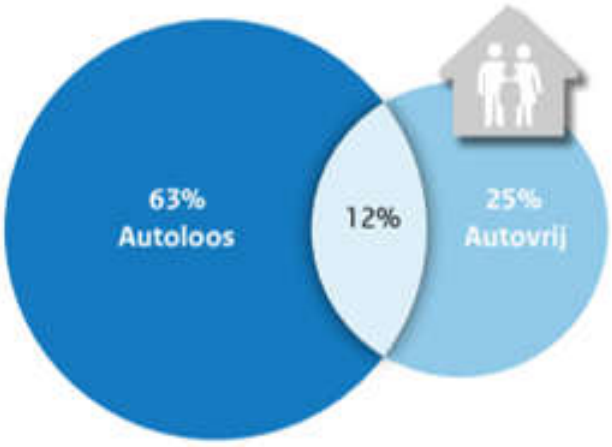
In this context, the label was applied according to the disadvantages experienced by the car-free and car-less households. Reasons for a household being car-less are mainly economic, however, depending on the residential location a household may be forced into car ownership to participate in economic, political, and social life of the community.

Car-free households are mainly located in more densely populated areas with better public transport coverage than car-less households. These car-less households therefore tend to experience more mobility disadvantages than car-free households.

The second part of this research focuses on the car-sharing landscape in Belgium as a possible solution for car-free and car-less households. This involved comparing the various organisations regarding general operation, geographical locations, additional facilities, and cost price.

The car-sharing industry is competitive and still developing, while the lack of standardisation makes comparison difficult. The car-sharing providers distinguish themselves mainly by the region in which they operate, the facilities offered and the conditions for users. Car-sharing organisations which specifically target sparsely populated areas may offer a solution for the group of car-less households.

Figure 4: Car-free versus car-less households



RESIDENTIAL URBANISM AND AGING

Student information
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The impact of residential urbanism and aging of young adults on car travel demand in the Netherlands

Travel demand in the Netherlands has been decreasing over the past two decades. This applies particularly to car travel by young adults and urban residents. Despite this, over 50% of all trips in the Netherlands are still made by car. The impact of urbanisation on car travel demand and the development of car travel by young adults in the longer term is still not clear.

This research examines the role of residential urbanism in car travel behaviour for different types of household composition in the Netherlands. It also explores the development of car travel behaviour among young adults.

Two waves of data from the Dutch Mobility Panel, from 2013 and 2019, were selected. Participants from waves, aged 18 and over, were asked to complete a three-day trip diary. This enabled changes in demographic characteristics together with changes in car travel behaviour within this group to be analysed.

The analysis revealed that residential urbanism is an important factor for determining car travel behaviour. However, residential urbanism does not affect all household types in the same way. It's clear that households with children travel by car more frequently whereas singles, especially in cities, are more inclined no to travel by car.

The results imply that urbanisation has the potential to decrease car travel demand among single person households and couples. However, as young adults age, they exhibit similar car travel behaviour to older adults.

	Residents of the most urban areas (2500 or more inhabitants/km^2)			**Residents of the least urban areas (1000 or less inhabitants/km^2)**		
Household type	Singles, N = 251	Couple, N = 154	Couple + children, N = 57	Singles, N = 123	Couple, N = 303	Couple + children, N = 202
License holding	205 (82%)	134 (87%)	53 (93%)	109 (89%)	276 (91%)	195 (97%)
Car ownership	122 (49%)	133 (86%)	53 (93%)	93 (76%)	288 (95%)	190 (94%)
Preferred transport mode to work						
Bike	73 (29%)	38 (25%)	12 (21%)	21 (17%)	46 (15%)	39 (19%)
Car	50 (20%)	36 (23%)	30 (53%)	38 (31%)	88 (29%)	122 (60%)
Not applicable	75 (30%)	48 (31%)	9 (16%)	43 (35%)	157 (52%)	26 (13%)
Public transport	19 (7.6%)	12 (7.8%)	2 (3.5%)	5 (4.1%)	1 (0.3%)	3 (1.5%)
Walking	6 (2.4%)	0 (0%)	0 (0%)	0 (0%)	1 (0.3%)	0 (0%)
Preferred transport for groceries						
Bike	73 (29%)	38 (25%)	8 (14%)	44 (36%)	103 (34%)	41 (20%)
Car	41 (16%)	42 (27%)	26 (46%)	32 (26%)	108 (36%)	109 (54%)
Not applicable	29 (12%)	20 (13%)	4 (7.0%)	11 (8.9%)	21 (6.9%)	11 (5.4%)
Public transport	1 (0.4%)	0 (0%)	0 (0%)	0 (0%)	1 (0.3%)	0 (0%)
Walking	52 (21%)	19 (12%)	4 (7.0%)	7 (5.7%)	16 (5.3%)	5 (2.5%)
Home to work travel by car	64 (25%)	43 (28%)	31 (54%)	45 (37%)	93 (31%)	129 (64%)
Average number of trips	13.0 (7.1)	12.2 (7.1)	11.9 (6.2)	10.7 (5.6)	10.1 (4.8)	11.2 (5.2)
Average distance travelled (km)	229.8 (346.2)	149.8 (248.4)	217.1 (282.9)	142.2 (211.3)	107.1 (144.1)	147.6 (172.8)
Average number of trips by car	3.1 (3.9)	4.4 (4.1)	6.9 (5.4)	4.8 (3.9)	5.2 (4.0)	6.8 (4.8)
Average number of PT trips	3.9 (6.8)	3.0 (7.1)	1.4 (4.0)	1.2 (3.4)	0.2 (1.3)	0.1 (0.8)

INTENTION TO USE MAAS

Student information
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Vehicle-owners' intention to use Mobility-as-a-Service

A latent class cluster analysis identifying factors behind the intention to use MaaS in the Netherlands

Increasing urbanisation and challenges regarding global sustainability mean that restructuring of current mobility and transportation systems is inescapable. One concept regarded as an answer to the changes needed is Mobility-as-a-Service (MaaS): an online platform which enables users to put together their optimal trip from a variety of transport modes, conventional and shared. MaaS only requires a single payment and provides up-to-date information about the desired trip. MaaS increases flexibility and ease of travelling, which is expected to have a positive effect on contemporary (urban) mobility.

As a relatively novel concept, MaaS has received considerable attention in academia as well as policy-making. In this body of literature, on the one hand MaaS is expected to improve the transport system, combat negative externalities of transportation, and positively impact social equity. On the other, the smart mobility solution is speculated to potentially be counterproductive by mostly replacing trips made by public transport and active transport modes. In this case, MaaS does not provide a solution to the changes needed in the current mobility and transportation systems, but contributes to the increasing number of vehicles on the road and related negative externalities.

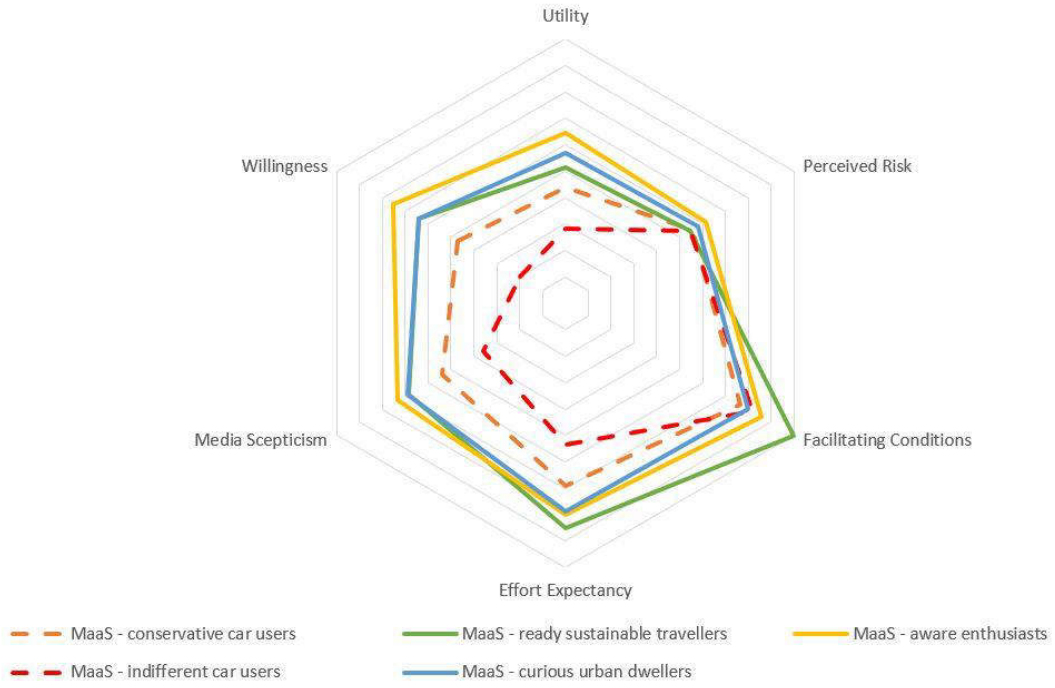
Previous studies on the adoption potential of MaaS in the Netherlands have identified private vehicle owners as unlikely to adopt MaaS while individuals using environmentally-friendly transport modes are likely to adopt. In that case, MaaS might be more likely to negatively affect the Dutch transport system and society. Despite the discussions on the expected potential impacts of MaaS, uncertainties still remain about the impact on the transport sector and on the potential for individuals to adopt MaaS.

Successful implementation of MaaS, where the concept positively impacts the transport system and society as a whole, relies on public acceptance. As vehicle owners are currently identified as unlikely to use MaaS, insight into their motives which could influence their intention to use MaaS and contribute to its successful implementation were examined.

For this, a conceptual model was created in this research to provide an overview of potentially influential factors. Data was collected using a self-administered questionnaire which was distributed among individuals living in the Netherlands and owning or jointly owning a car. The constructs and relationships of the conceptual model were analysed and resulted in five factors, plus a sixth factor representing the vehicle owners' willingness to use MaaS.

The research findings indicate that the overall willingness to use MaaS among vehicle owners is relatively low. The factor scores per cluster (see figure) show that clusters with a higher Willingness value also have a higher perceived utility and effort expectancy of MaaS. These clusters are consequently identified as intending to use MaaS. The perceived benefits in terms of convenience, travel time and travel costs of MaaS over current modes of travelling, similarities between MaaS and individuals' habits as well as the perceived ease of using MaaS thus indeed influence the intention to use MaaS.

The results also show that vehicle owners intending to use MaaS have a higher concern about potential risks and more scepticism of external evaluations.



Cluster factor scores

The factors identified, as well as personal characteristics which influence vehicle owners' intention to use MaaS, are mainly in line with previous research on the adoption potential of MaaS. Namely, clusters with a higher Willingness value have more younger vehicle owners, whereas clusters with a lower Willingness value have more vehicle owners aged 45 years or older.

An individual's main mode of transport affects their intention to use MaaS. Vehicle owners whose main mode of transport is public transport, walking or cycling are better represented in the clusters intending to use MaaS. As also shown in previous studies, those with a higher level of education and living in a larger municipality also indicate a higher intention to use MaaS.

From the findings, it can be distilled that vehicle owners might not be the first in line to use MaaS once introduced, but this does not mean that vehicle owners will completely disregard the option of MaaS. The cluster profiles show that personal characteristics, such as the age, education level or experience with MaaS(-like) services also play a role.

Recommendations from this research include increasing individual familiarity with MaaS, for example with car-sharing services, as positive experiences with such services have a positive influence on intentions to use MaaS. Efforts in less densely populated areas have the most potential as the research results show that clusters not intending to use MaaS contain a large share of vehicle owners living in smaller municipalities, those inexperienced with vehicle-sharing schemes and who are unfamiliar with MaaS.

RESIDENTIAL SELF-SELECTION AND TRAVEL BEHAVIOUR AND ATTITUDES

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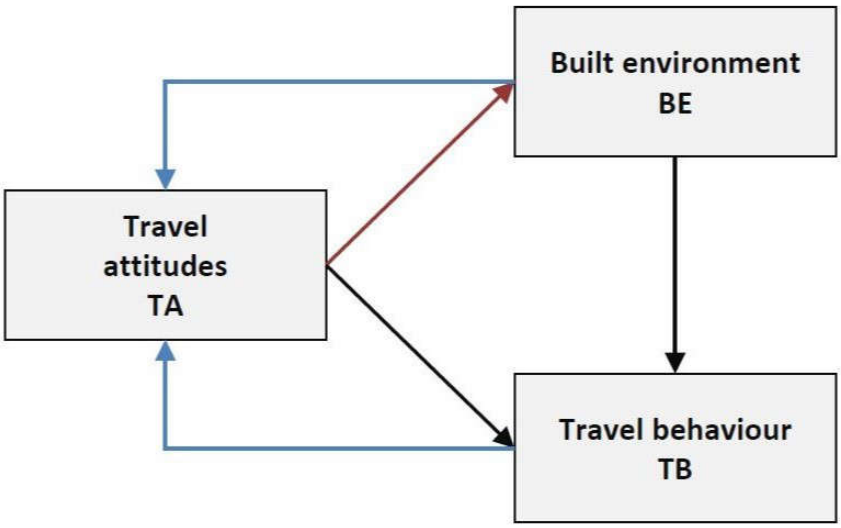
With the transition to more sustainable transport systems, many different concepts and innovations have arisen. One of these is the car-free neighbourhood, which discourages car use through an urban design that favours active modes of transport, and leaves less space for private cars.

Developers aim to create urban and rural environments that encourage sustainable transport, in line with the wider objectives of reducing transport emissions and improving urban liveability. Achieving this transition requires a nuanced understanding of the complex urban planning relationships between the built environment (BE), travel attitudes (TA) and travel behaviour (TB).

Research in this area has consistently shown that the built environment has a significant impact on travel behaviour. The consensus is that mixed-use neighbourhoods equipped with sustainable transport options encourage residents to travel less by car and more by public transport or active modes of transport such as walking and cycling. However, the impact of the built environment on travel behaviour is intertwined with individuals' travel attitudes (TA). This relationship introduces the concept of residential self-selection (RSS), where people not only adapt to their environment but also select an environment which is consistent with their travel preferences and attitudes.

This study focuses on the relationship between the built environment (BE), travel behaviour (TB), and travel attitudes (TA) of people who move home. Using data from the Netherlands Mobility Panel(MPN), the study uses a basic cross-lagged panel model (CLPM) and a random intercept cross-lagged panel model (RI-CLPM) to identify the causal relationships between BE, TA, and TB and public and private transport before and after moving home.



Relationship between TA, TB and BE

The three-day travel diary extracted from the MPN data was used to specify travel behaviour through a variable derived from the total car kilometres driven. Questions on mode of transport preference for different travel purposes were used to identify travel attitudes. The built environment was defined by an urbanisation indicator provided by Statistics Netherlands. The data sample was created from MPN respondents with complete data points in three consecutive waves between 2014 and 2019, and who had moved home between their first and second data wave. This resulted in a data sample consisting of 347 respondents.

Both models showed that residential self-selection (RSS) is a significant factor. It suggests that people tend to move to environments that match their pre-existing travel attitudes. The RI-CLPM introduces a reverse causality effect, suggesting that the built environment after moving can influence travel attitudes one year later. However, there is also a reciprocal effect from travel attitudes after moving to the built environment.

Surprisingly, the RI-CLPM does not identify any effects on changes in travel behaviour, such as changes in car kilometres driven, that can be attributed to the built environment or travel attitudes. On the other hand, the CLPM does find relationships between travel attitudes and behaviour, suggesting these are influenced by stable, time-invariant third variables that the RI-CLPM most likely factors out.

Despite its valuable findings, the study acknowledges limitations related to the operationalisation of variables and the sample size. Further research into more reliable specifications of travel behaviour, exploring different types of relocation, and considering the influence of time-varying third variables is recommended.

In particular, the study highlights the theoretical advantage of the RI-CLPM and recommends its use in future research. It emphasises that conclusions drawn from CLPM studies may lead to erroneous conclusions about causal mechanisms.

Policy implications are highlighted in the context of limited evidence to explain changes in travel behaviour. The study suggests that facilitating opportunities for people with a lower preference for travel by car to relocate to dense neighbourhoods with reliable alternative transport options, may encourage more sustainable travel behaviour. However, the need for more robust evidence poses a challenge in translating these findings into concrete policy recommendations.

The lack of evidence to explain changes in travel behaviour makes it difficult to translate the findings into policy recommendations. One recommendation is to encourage people with a lower car preference to relocate to densely populated neighbourhoods with reliable alternatives, so they can self-select and practice more sustainable travel behaviour.

If future research confirms that changes in travel attitudes after relocating do lead to changes in behaviour, policymakers should target recent movers to dense areas, and inform them about sustainable travel options. This approach aims to reduce car preference by encouraging residents to seek and adopt alternative modes and change their travel behaviour.