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PARKING CHOICE BEHAVIOUR

INFLUENCE PARKING CHOICE BEHAVIOUR

Student information
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Graduation year: 2016

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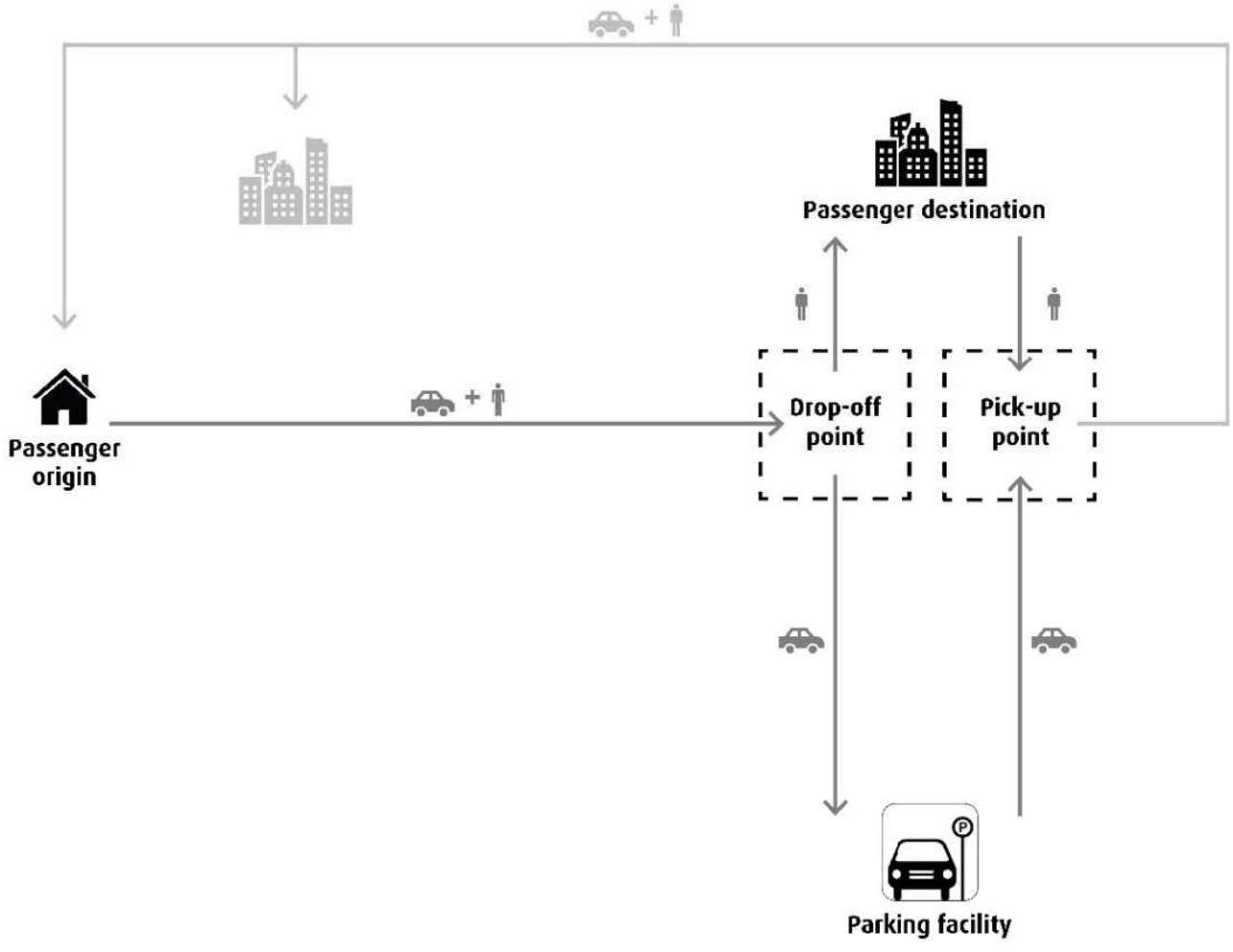
An empirical study into the effects of private automated vehicles on motorists' parking location choice: an application to the city of The Hague

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.

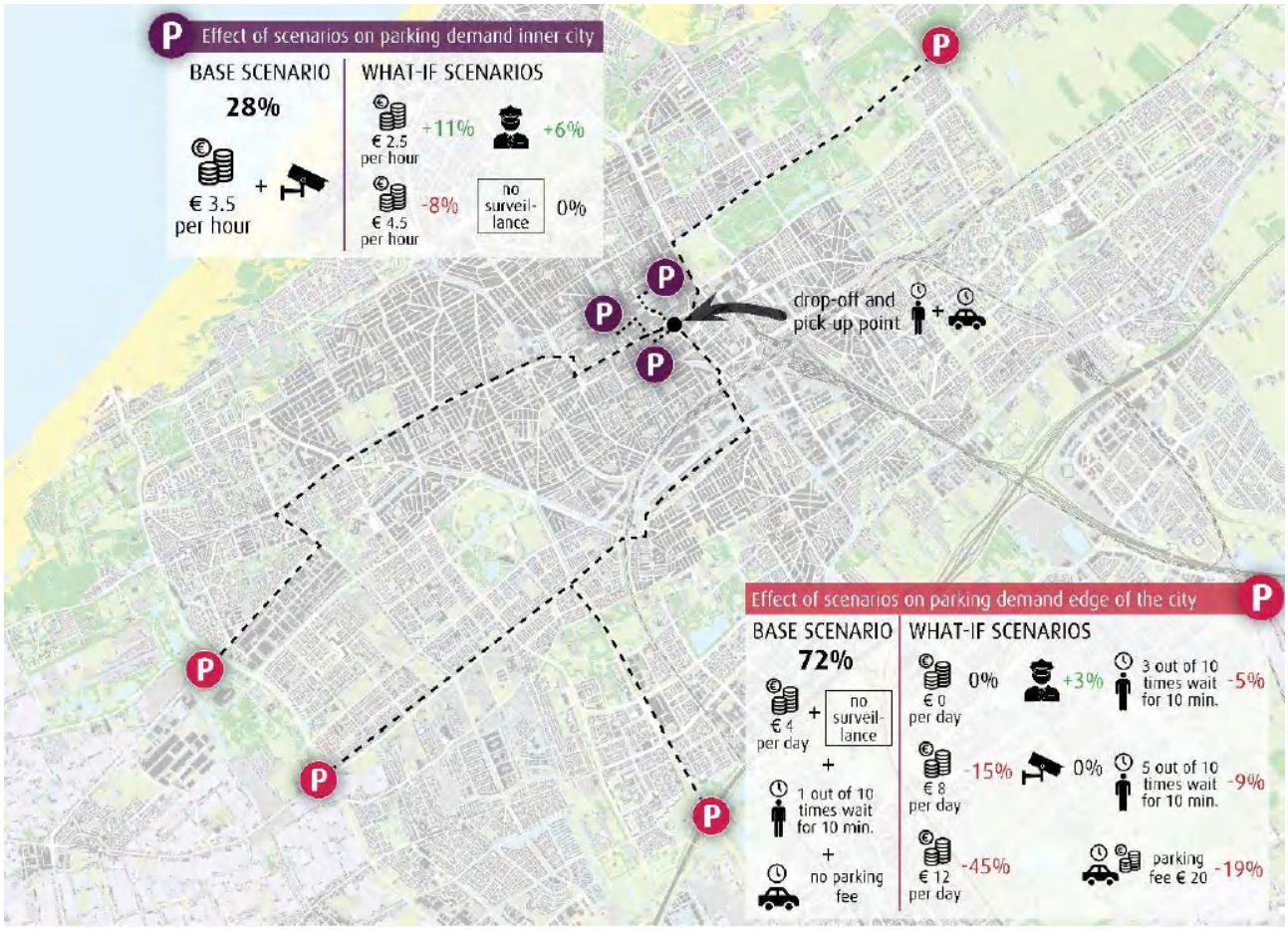
The results of the scenario analysis are visualised in Figure 2. From the results of the scenario analysis can be concluded that individuals are most sensitive for a change in direct costs, i.e. the 'parking cost' at the parking facility and the 'parking fee' for temporary parking the highly AV at an 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

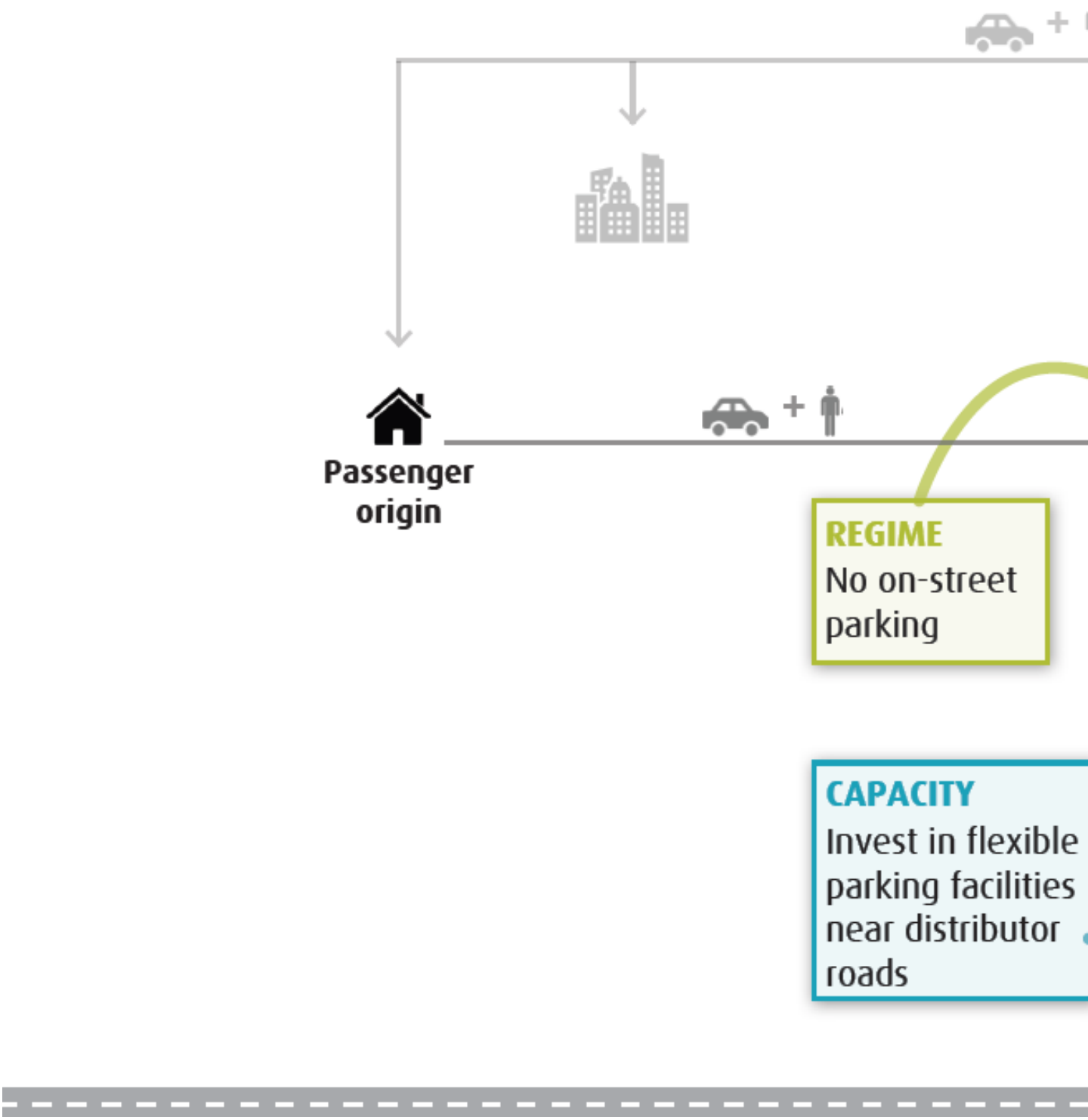


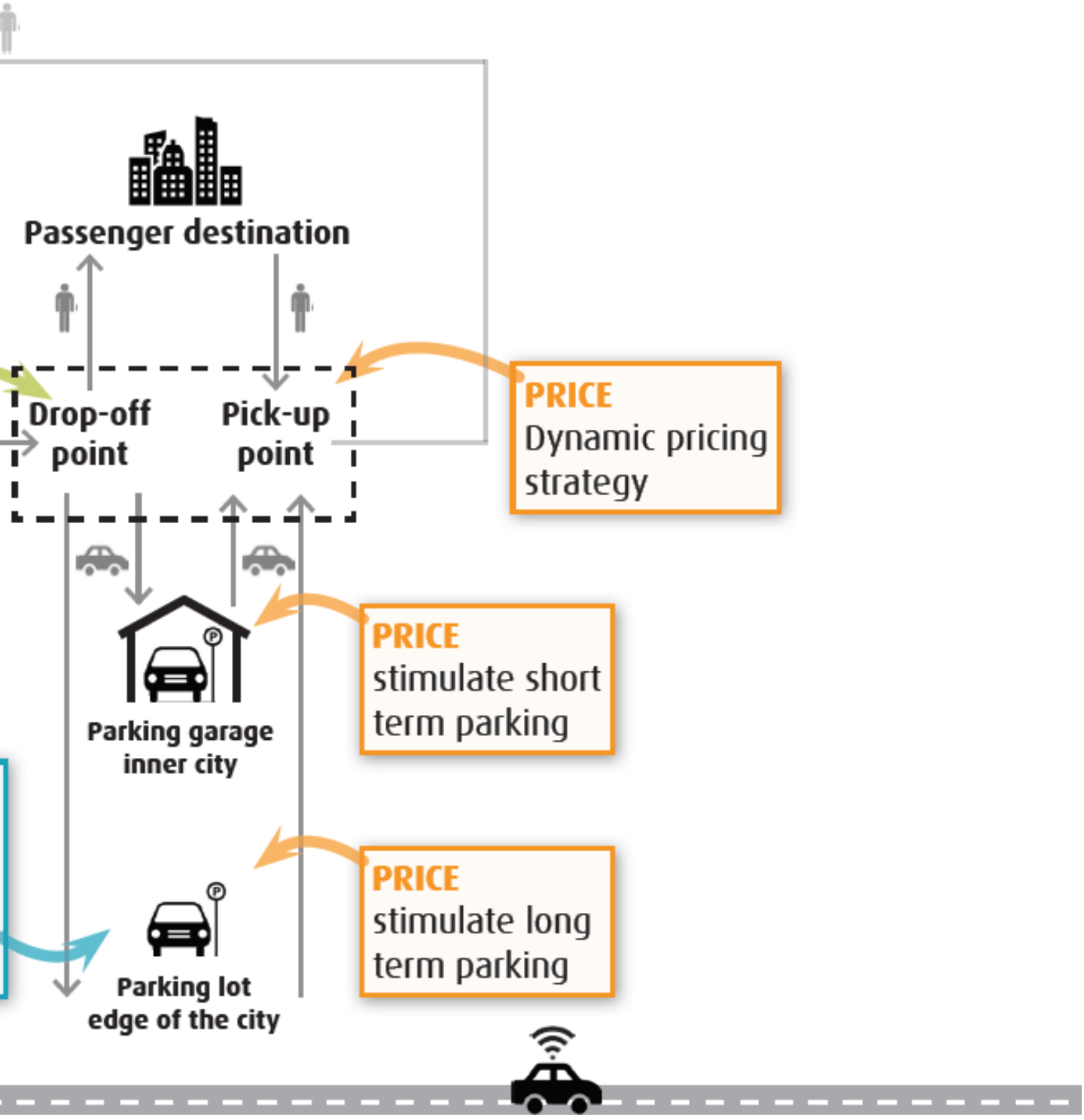
on-street with a parking permit. Furthermore, released on-street parking space could be used for greenery or extra space for bicyclists and pedestrians.

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.