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TOPIC 15
TRAVEL CHOICE AND
DEMAND MODELLING

MODELLING THE COMBINED CHOICE OF PARKING LOT AND SHOPPING DESTINATION

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Abstract

Parking is a key-element in modern transportation planning at local, regional and national levels. Transportation planners on all levels use a variety of parking measures to reduce car use for shopping, work trips, social visits and recreational trips. Many measures focus on the parking situation in the vicinity of shopping centres in inner-cities.

INTRODUCTION

Most European cities suffer from innercity congestion due to an ever increasing car use. A recurring issue in the definition of policies to alleviate the congestion problem is how to maintain or improve the accessibility of the innercity shopping area. Planners try to control the accessibility with a variety of infrastructural measures, including parking measures. Parking measures may involve changing the number of parking spaces, the parking costs, the maximum parking duration, or the location of parking spaces. More recently, there has also been a focus on increasing the diversity in the supply of parking spaces (Axhausen and Polak 1991; Matsoukis 1993). In order to be able to select a parking policy, planners need to anticipate their effects. Therefore, they need to know how motorists will react to the various possible parking measures. Motorists can respond to parking measures by changing the parking location, the starting time for the trip, the selected mode and trip destination, or by abandoning the trip (Feeney 1989).

The ways in which motorists react to infrastructural measures will have their effects on the economic performance of shopping areas and individual stores. Consequently, these effects are a major concern to innercity retailers. Retailers particularly fear that consumers will choose to visit other centres and stores in response to the new parking measures (eg Timmermans, Van der Heijden, and Westerveld 1984; Burt and Sparks 1991; Skinner and Hayes 1992; Matsoukis 1993). Other parties, in particular residents in the fringe of the city-centre, fear that consumers will only choose to park their cars further away from the centre, thus congesting the city fringe areas. A relevant question therefore is *to which extent do consumers choose to visit other shopping destinations and to which extent do they choose to park at other available parking areas if parking measures are taken at a particular parking area?*

Currently available models are of little help to answer this question. First, models of consumer choice of shopping destination do not allow a detailed specification of the parking situation at destinations. Typically, in these models the number of attributes representing the parking lots in the surrounding of the shopping destinations is limited to one or two. Also, the potential availability of different parking lots is mostly neglected. Secondly, models of choice of parking lot have no specific link to destination choice models. Parking lot choice models are mainly based on a given number of arrivals at a destination.

Therefore, *the aim of this paper is to propose and illustrate a way in which the combined choice of parking lot and shopping destination can be modelled using a stated choice approach.* The suggested approach allows one to answer the question mentioned above and, in a more general sense, to get more insight into the influence of characteristics of parking areas on the competitive position of alternative parking areas and shopping centres. The approach in this study is based on the specification of a choice task with both destination and parking choice in the context of shopping trips.

To achieve the aim as described above the paper is organised as follows. First, the way in which parking situation is used in destination choice models is described. Next, attention is paid to the link between existing parking lot choice models and destination choice. Then a combined destination and parking lot choice task and model is specified. The results of an application of our approach to the city of Boxtel are presented. The paper ends with some concluding remarks.

PARKING SITUATION, DESTINATION AND PARKING LOT CHOICE

Destination choice is an important component of travel choice and provides an opportunity for developing closer links between land use and transport planning (Jones 1978). To get a better insight into the relation between destination choice and parking situation, attention should be paid to the ways in which both elements are connected to each other.

However, the parking situation in the vicinity of most shopping areas is very complex. We define the parking situation as the whole of parking lots in the vicinity of the shopping centre. Hence, the parking situation may involve multiple parking lots. Each of these parking lots may be different in terms of scale, location, type, pricing, regulation, design, and accessibility. In their attempt to simplify and model this complex structure, most researchers have focused on either destination choice, leaving little room for parking situation aspects, or on parking aspects, ignoring the destination aspects. It nevertheless repeatedly appears that the parking situation is an important factor in destination choice (see Polak, Axhausen and Errington 1990).

In destination choice research, the parking situation is mostly represented by averages of parking attribute values (for example average walking distance between available parking lots and destination). In the case of parking choice behaviour, the parking situation is mostly defined in terms of groups or types of parking lots. For example, Axhausen and Polak (1991) distinguished five types of parking facilities: free-on-street parking, metered on-street parking, off-street surface, multi-storey facility and illegal parking. Skinner and Haynes (1992) defined four types of 'parking links': public car park links, on-street parking links, heavy vehicle and private parking links, and external parking links located outside the parking choice area. Other researchers only use a subset of existing parking lots to represent the parking situation of a destination (Matsumoto and Rojas 1994).

Examples of attributes that are often used in shopping destination choice models are 'distance from home to destination', 'assortment/choice range', 'store convenience', 'price of goods', and 'quality of products' (for an overview see Oppewal 1995). Mostly, the parking situation at a shopping destination is defined by one, sometimes two attributes. For example, Oppewal (1995) uses the attributes parking convenience (easy and difficult) and parking costs (free, 1 NGL/hr, 2 NGL/hr and 3 NGL/hr). Examples of more general specifications used in both revealed and stated choice studies, are 'parking search time' (Timmermans, Van der Heijden and Westerveld 1984), 'quality of parking facilities' (Timmermans and Van der Waerden 1992), 'availability of parking facilities' (Timmermans 1995) and 'number of parking spaces' (Timmermans, Borgers and Van der Waerden 1992).

Most existing parking lot choice models do not describe the relationship between parking situation and destination choice either. The models mainly describe the distribution of arriving cars across available parking lots at one destination. The models just started with a given number of cars arriving at the studied destination(s). These information is extracted from traffic counts (eg May, Jones and Rigby 1989), observed or estimated origin-destination tables (eg Skinner and Haynes 1992) or parking surveys (eg Van der Goot 1982). None of these approaches can take into account the influence of a changing parking situation on the attractiveness of a destination and therefore on the number of arrivals at this destination.

In transportation research, stated choice experiments are increasingly used to get insight into the influence of the attributes of the parking situation on the destination choice behaviour of consumers. In this approach, respondents choose from a set of hypothetical alternatives that are described by pre-specified levels of attributes (eg Hensher 1994). In general, a choice task is constructed so that all defined alternatives have the same structure, representing a product or service which may or may not be observed in the market. To study the effect of both the number and the attributes of parking lots at one destination on the attractiveness of the destination, a special kind of alternative is required. Destination alternatives should be defined with a variable number of parking lots which are complete specified by relevant attributes.

THE CHOICE EXPERIMENT AND MODEL STRUCTURE

In our approach, alternatives are defined as specific combinations of shopping centres and parking situations. Parking situations consist of either one or two parking lots. Shopping centres and parking lots are described in terms of relevant attributes. For the present application, attributes were selected from the literature as follows (cf. Axhausen and Polak 1991; Oppewal 1995).

Shopping centres were defined by:

- the number of clothing stores (levels: 5, 15 and 25 shops);
- the travel time between the home and the shopping centre (levels: 10, 15 and 20 minutes).

Parking lots were represented by:

- maximum parking duration (levels: none and 2 hours);
- parking costs per hour (levels: free, 1 NGL/hr and 2 NGL/hr);
- walking distance between parking lot and shops (levels: 50, 200 and 350 meters).

SHOPPING CENTRE	CENTRE I	CENTRE II		CENTRE III
# clothing shops	15 shops	15 shops		50 shops
travel time H -> C	10 mins	15 mins		50 mins
PARKING LOT	LOT I	LOT IIa	LOT IIb	LOT III
max. parking duration	none	2 hours	none	none
parking costs / hour	free	1 NGL/hr	2 NGL/hr	4 NGL/hr
distance to shops	350 m	200 m	350 m	500 m
CHOICE SHOPPING CENTRE	☐	☐		☐
PREFERENCE FOR PARKING LOT		☐	☐	

Figure 1 **Example choice set of parking lot and shopping centre combinations**

A fraction of the $2^3 * 3^{10}$ factorial design was used to design 36 choice sets of parking lot and shopping centre combinations. These choice sets consist of two shopping centres, one of which always has one parking lot while the other always has two parking lots available, as shown in Figure 1. A fixed third centre with one parking lot was added to each choice set to serve as a constant base alternative.

Two responses were collected for each choice set. First, respondents had to choose which of the three available shopping centres they would visit if they would want to purchase clothes. Next, they had to indicate which of the two parking lots of shopping centre II they would most prefer.

In this paper, we conceptualize the choice process induced by this task structure as an extended multinomial logit model structure. Respondents choose from among the four available parking lots, but they may recognize that two of these belong to the same shopping centre. We expect that the similarity between these two lots will lead to violations of the Independence of Irrelevant Alternatives (IIA) characteristic that underlies the standard MNL model. These violations can be modelled by including cross-effect terms in the utility specification of the MNL model (eg Oppewal and Timmermans 1991). Because our design strategy implies that the shopping centre and parking lot attributes are independent within and between the two shopping centres and three parking lots, it allows us to estimate the relevant cross-effects. In our approach, the cross-effects specification allows us to describe and test the effects of changes in one parking lot on the utility of the complementary lot at the same centre and of the lot located at the other shopping centre. In this way, we get insight into the way in which a parking lot competes with other lots at the same centre and with parking lots at other shopping centres.

DATA COLLECTION AND MODEL ESTIMATION

For the present application, the 36 designed choice sets were randomly distributed across 12 blocks, such that each block contained 3 choice sets. Each respondent received one such block, after having been introduced to the task. This introduction involved an explanation about the hypothetical nature of the task, the attributes and their levels, and a practice trial. The total task was included in a mail-back questionnaire.

In October 1993, one thousand of these questionnaires were randomly distributed among households in Boxtel, a small city in the south of the Netherlands that considered introducing parking fees. 159 respondents completed the experimental choice part. The returned questionnaires are evenly distributed across the 12 blocks of choice sets.

The parameters of the model were estimated with iteratively reweighted least square analysis as implemented in the NTELOGIT software (IMS 1992). Effect coding was used to represent the effects of the attributes on the utility of an alternative. This means that the two level attribute was coded as (-1) or (1), while the three level attributes were coded as vectors (1 0), (0 1) and (-1 -1) for the first, second, and third levels, respectively.

Table 1 Estimation results for the specified destination and parking lot choice models

Model	Parameters	LL(0)/ LL(B)	RhoSqr	RhoSqr (AIC)
0. null model	0	-370.904		
1. specific constants	2	-326.117	0.121	0.115
2a. generic attributes	11	-194.859	0.475	0.445
2b. generic attributes with cross effects	16	-184.163	0.503	0.460
3a. specific attributes	20	-175.291	0.527	0.473
3b. specific attribute with cross effects	25	-165.702	0.553	0.486

Table 1 presents the estimation results of the various model specifications. First, the log likelihood value 'LL(0)' for the random choice, or null model is presented. Next, the table presents the estimation results for five different models: the log likelihood value at convergence 'LL(B)', McFadden's RhoSquare, and the 'adjusted' McFadden's RhoSquare; the latter measure adjusts for the number of estimated parameters and is based on the Akaike Information Criterion (AIC).

Model 1 contains only two constants, one for each (non-base) shopping centre. Model 2a includes generic attributes for the two shopping centres and for the three parking lots. In model 2b, cross-effects are added to this specification. Model 3a contains alternative specific attributes for the two centres and three parking lots; this specification is extended with cross-effects in model 3b.

The statistical significance of the model differences can be tested with the likelihood ratio test statistic, which is defined as minus two times the difference between the log likelihood values of the compared models and which is chi-square distributed with degrees of freedom equal to the difference in numbers of parameters (see Ben-Akiva and Lerman 1985). It appears that the all relevant model differences (models 1 vs. 0; 2a vs. 1; 2b vs. 2a; 3a vs. 2a; 3b vs. 3a; 3b vs. 2b) are statistically significant at the conventional 5% significance level. For example, the test statistic for the difference between models 3a and 3b equals -2 * 9.59, which is 19.18, and model 3b has five more parameters than model 3a. With 5 degrees of freedom, the critical chi-square value equals 11.07, hence the models are significantly different.

Table 2 Parameters of the shopping destination and parking lot choice model (model 3b)

Attributes	Levels	Parameter[1]	t-statistics
constant for centre I		+1.5020	8.177
constant for centre II		+0.8125	4.297
# clothing shops centre I	5	-1.0800	-5.447
	15	+0.2131	1.157
	25	*+0.8669*	
travel time centre I	10 mins	+0.7064	3.886
	15 mins	+0.0065	0.038
	20 mins	*-0.7129*	
max. parking duration lot I	none	+0.3339	2.447
	2 hrs	*-0.3339*	
parking costs lot I	free	+1.1603	6.269
	1 NGL/hr	-0.3406	-1.879
	2 NGL/hr	*-0.8197*	
walk distance lot I	50 m	+0.7398	3.921
	200 m	-0.1177	-0.665
	350 m	*-0.6221*	
# clothing shops centre II	5	-0.6213	-3.617
	15	-0.3924	-2.253
	25	*+1.0137*	
travel time centre II	10 mins	-0.1656	-0.953
	15 mins	+0.6667	3.763
	20 mins	*-0.5011*	
max. parking duration lot II	none	+0.4981	4.463
	2 hrs	*-0.4981*	
parking costs lot II	free	+1.0296	6.750
	1 NGL/hr	+0.1201	0.831
	2 NGL/hr	*-1.1497*	
walk distance lot II	50 m	+0.6575	4.653
	200 m	-0.8065	-4.523
	350 m	*+0.1490*	
cross-effects of i on j[2]			
maximum parking duration lot	none	-0.3223	-3.052
	2 hrs	*+0.3223*	
parking costs	free	-0.1545	-0.914
	1 NGL/hr	+0.0153	0.110
	2 NGL/hr	*+0.1392*	
walk distance	50 m	-0.1194	-0.789
	200m	-0.3028	-1.905
	350m	*+0.4222*	

Notes:

[1] Parameter estimates are equal to part-worth utilities; for each attribute, the utility of the remaining level is added in italics.

[2] where, if *i* concerns parking lot IIa, then *j* concerns lot IIb and vice versa, if *j* concerns a, then *i* concerns b. So, if attributes of *i* change, cross-effects represent the resulting utility change in *j*.

So, model 3b performs best in terms of fit. The above tests indicate that models with alternative specific attributes for the two shopping centres and three parking lots perform better than models with generic attributes. Similarly, models with cross-effects perform better than models without cross-effects. This means that the four parking lots were not perceived as completely separate alternatives. Parking lots IIa and IIb were similar in that they both belonged to shopping centre II. This explains why, as shown in Table 2, the constant for centre II is much smaller than the constant for centre I and, similarly, why the effect of the number of clothing stores attribute is much smaller for centre II than for centre I. It appears that the travel time parameters are much more similar across centres I and II. This is in line with our argument because trips to one shopping centre differ in travel time, depending on the parking lot that is chosen.

Table 2 presents all the parameter estimates for model 3b, that is, the model with alternative specific attributes and cross-effects. It shows that most of signs and values of parameters are as expected. For the attribute 'number of clothing shops' the parameter value for the first level is smaller than for the second level. For the other three level attributes, the reverse is true. The signs of 'maximum parking duration' are also in the anticipated direction. Only the parameter values of the attributes 'travel time from home to shopping centre II' and 'walking distance from a parking lot of shopping centre II' result into some unexpected utilities.

Table 2 also shows the estimates for the cross-effects. Though our tests indicate that cross-effects contribute significantly to the fit of the model, it appears that this effect is due to one cross-effect parameter only: the effect of the maximum parking duration of the parking lots at shopping centre II on the other lot at this same shopping centre. Apparently, if maximum parking duration is introduced in one of the lots at shopping centre II, this has a particular large positive effect on the attractiveness of the other lot at shopping centre II. Remarkable is that there are no significant cross-effects of parking costs.

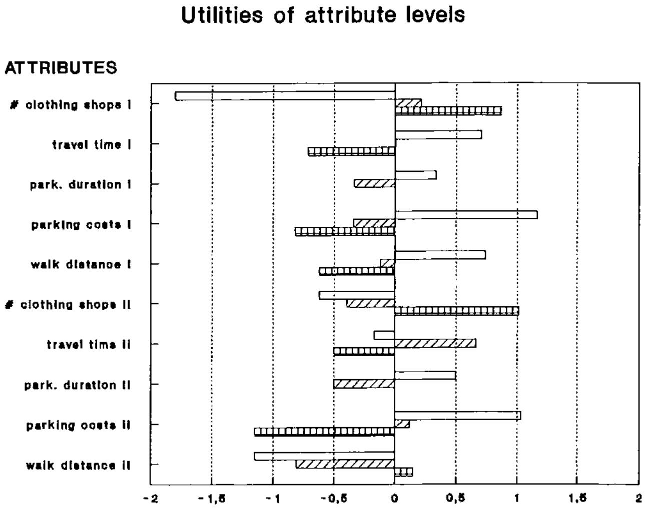

Figure 2 Partworth utilities of attribute levels

Figure 2 shows the partworth utilities presented in Table 2. In stated choice studies the ranges of partworth utilities are relevant because in this kind of studies relative importance of attributes are often assessed from these ranges: the relative importance of an attribute is derived from the maximum utility difference between the levels of an attribute. It appears that the most important attributes for shopping centre I are the number of clothing shops and parking costs. The other attributes are less important but still significant. For centre II, the most important attributes are the number of clothing shops, parking costs, and walk distance. However, care should be taken when comparing the attributes of centre II because of the IIA-violations that were found.

CONCLUSION

The current paper proposed and illustrated a stated choice approach to model the combined choice of parking lot and shopping destination can be modelled. The main concern of the study was the role of the parking situation at shopping centres in relation to shopping destination choice behaviour. Hypothetical alternatives were defined as specific combinations of shopping centres and parking situations. Parking situations consisted of either one or two parking lots. Shopping centres and parking lots were described in terms of relevant attributes. Specific elements in the approach used in this study, were the existence of shopping destination alternatives with varying numbers of parking lots, and the number of parking lot attributes in a destination choice model.

Several models were specified and analyzed. The best fitting combined parking lot and shopping destination choice model contained one constant for each (non-base) shopping centre, the following attributes of shopping centre and parking lots (number of clothing shops, travel time between home and shopping centre, maximum parking duration, parking costs and walk distance between parking lot and shopping area), and cross-effects for the parking lots being part of the same shopping centre. The most important attributes of shopping centre and parking lot combinations were the number of clothing stores and parking costs. The estimates obtained for the shopping centre constants suggest that different parking lots at one centre were perceived to a large extent as one single alternative. This is an indication that, if an additional lot is added to an existing centre, this additional lot will compete with the existing lot, much more than with the other available shopping centres.

In addition, the estimated parameters for the cross-effects suggest that if there are multiple parking lots at one centre, these lots tend to compete in particular on 'convenience' aspects like maximum parking duration. This means that changes in these kind of attributes lead in particular to changes in the number of visits at the centre's other parking lot. In contrast, if parking fees are changed at only one of the lots of a shopping centre, this change results in a proportional large number of consumers switching to other shopping centres in the region.

This paper presented only a first attempt to model and link destination and parking choice. The further analysis of the present data will focus on using a nested logit structure. A point of future interest will be the number of destinations in the choice task, and the number of parking lots per destination. The complexity of the real world shopping destinations and parking situations require more attention to this issue.

Finally, it should be acknowledged that our conclusions are based on stated choice data only. Future research should relate the model to actual behaviour.

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