Is there a ‘Stick’ Bonus? A Stated Choice Model for P&R Patronage incorporating Cross-Effects

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This paper presents a universal logit model for P&R patronage. This model was estimated from a Stated Choice experiment, in which 805 car drivers chose among car, P&R and public transport alternatives. In addition to main-effects, attribute cross-effects were estimated denoting the utility change of an alternative due to changes in the attribute levels of another alternative. The results indicate that improving the levels of the P&R related attributes has a negligible effect on the utility of the car alternative, whereas worsening the levels of the car-related attributes increases the utility of the P&R facility. Considering the estimated main-effects as well as the estimated cross-effects suggests that ‘stick’ (push) policy measures are more effective to stimulate P&R patronage than ‘carrot’ (pull) policy measures. The paper further reports that the extension of the model by adding cross-effects to the main-effects resulted in a better model fit and that the resulting model could more accurately predict the choices for new observations.

Keywords: P&R, universal logit model, stated choice, push and pull policy measures

1. Introduction

Park and Ride (P&R) facilities are often introduced to cope with accessibility problems in urban areas where there are congestion and parking difficulties. However, not all implemented P&R facilities attract the expected number of car drivers (Bos, 2004). To increase P&R patronage, policy measures have to be developed. Then the question arises which type of policy measures will attract more P&R users: pull or push measures, also called 'carrot' or 'stick' measures. 'Carrot' measures involve upgrading the quality of P&R and the connecting public transport, and aim at inducing travellers to use P&R. 'Stick' measures involve making the car alternative less attractive, for example increasing parking costs in city centres. To answer this question, the preferences and choices of car drivers regarding P&R facilities have to be examined.

In previous papers (Bos, 2004; Bos et al., 2003; Bos et al., 2004) we reported on the results of a Stated Choice experiment, in which respondents were requested to choose among P&R, car and public transport alternatives. The P&R and the car alternative both varied across choice sets with respect to a number of 'stick'- and 'carrot'-related attributes, while the public transport was chosen as base alternative that did not vary among the choice sets and referred to the car drivers' public transport alternative for the complete trip. The model results indicated that car drivers are more sensitive to changes in costs and time attributes related to P&R than to changes related to the car alternative. This suggests that 'carrot' type policy measures would be more effective in increasing P&R patronage than 'stick' policy measures, although Ghali et al. (1997) and O'Fallon et al. (2004) found that 'sticks' would generally have a greater influence on stated mode choice than 'carrots'.

These results were based on an MNL model, a model that is routinely applied when modelling transport mode choices (e.g. Ben-Akiva and Lerman, 1985). An important assumption of this model is the independence from irrelevant alternatives (IIA)-property. This means that the ratio of the choice probabilities of any two alternatives is entirely unaffected by the systematic utilities of any other alternative. This assumption implies that decreasing the utility of the car alternative, for example by increasing parking fees in inner cities, would result in the same increase in P&R and public transport patronage in proportion to their utilities. The question is whether this assumption holds. In this paper it is tested whether the MNL assumption holds by estimating the universal logit model McFadden et al. (1978) proposed as a test of the IIA-property. This implies that the utility function is extended with so-called cross-effects, indicating to what extent the utility of an alternative changes when attributes in another alternative are taking a different value. The aim of this paper is to estimate these cross-effects and to examine whether these are systematically related to 'stick' and 'carrot' policy measures concerning P&R patronage.

This paper is organized as follows. In the next section the MNL model and the universal logit model are explained in more detail. This is followed by a discussion of experimental design, and the presentation and interpretation of the cross-effect results. Additionally, it is examined whether the model including cross-effects predicts new observations better than the MNL model. The final section draws some conclusions and discusses policy implications.

2. Methodology

Most choice experiments in transportation research (Ben-Akiva and Lerman, 1985) assume that an MNL model represents the choice process. This model can be described as follows. Let *j* denote an alternative in the choice sets used in the choice experiment and let U_j denote the utility of *j*. It is typically assumed that utility is stochastic, implying

$$U_j = V_j + \varepsilon_j \tag{1}$$

where:
U_j = utility of alternative *j*;
V_j = structural utility component of alternative *j*;
ε_j = random utility component.

The random utility component captures non-systematic variance in choice, i.e. variance that is not related to the attributes presented. If it is assumed that the structural component of the utility function is compensatory, i.e. a weighted additive function is assumed, then the function that is estimated can be expressed as:

$$V_j = \alpha_{0j} + \sum_{i=1}^{I} \sum_{l=1}^{L_i - 1} \alpha_{ijl} X_{ijl} \tag{2}$$

where:
α_{0j} = alternative-specific constant of alternative *j*, included in the experiment;
α_{ijl} = coefficient for indicator variable of rating level *l* of attribute *i*;
X_{ijl} = indicator variable for rating level *l* of attribute *i* describing alternative *j*.

Assuming that the error terms ε_j are independent and distributed across choice alternatives the probability of choosing alternative *j*, being a function of structural utilities V_j in a choice set, is expressed by the well-known multinomial logit (MNL) model of the following form:

$$p_j = \frac{e^{V_j}}{\sum_{j' \in S} e^{V_{j'}}} \tag{3}$$

where:
p_j = probability of choosing alternative *j*;
S = choice set of *j* alternatives;

The MNL model is based on the assumption that model errors are independently and identically distributed (IID) Gumbel across alternatives having the consequence that the IIA-assumption is assumed. The implication of this property is that the ratios of the probabilities of all alternatives will remain the same even if a single alternative is removed or added.
An approach to test for potential violations of the IIA-assumption is the universal logit model (McFadden, 1975; see also McFadden et al., 1978). This model relaxes the MNL cross-

elasticity properties by including attributes of competing alternatives in the utility function for some or all alternatives in the choice set (McFadden et al., 1978).
In order to use the universal logit model and thus to include cross-effects in the choice model, equation 2 has to be extended as follows:

$$V_j = \alpha_{0j} + \sum_{i=1}^{I}\sum_{l=1}^{L_i-1}\alpha_{ijl} X_{ijl} + \sum_{k=1}^{K}{}_{k \neq j} \sum_{i=1}^{I}\sum_{l=1}^{L_i-1}\lambda_{ikl} X_{ikl} \qquad (4)$$

where:
λ_{ikl} = coefficient for indicator variable for cross-effects of rating level *l* of attribute *i*;
X_{ikl} = indicator variable for rating level *l* of attribute *i* describing alternative *k* (other alternatives than alternative *j*)

The appearance of significant cross-effects for the effect of alternative *k* would imply that the IIA-assumption no longer holds, so the utility of an alternative depends on the attributes of another alternative. A positive cross-effect involves that the utility of an alternative increases due to the fact that an attribute in another alternative takes a different value. The result is that the choice probability of that alternative increases more than proportionally. Likewise, a negative effect decreases the utility with a proportionally lower choice probability as a result.
The estimated cross-effects can be interpreted in the context of the discussion on 'carrot' or 'stick' measures. For example, imagine that a 'stick' policy measure is applied which increases parking costs in inner cities. Further, imagine that a positive cross-effect for increased car costs on the P&R alternative would be found. In that case this would indicate that the utility of P&R increases and consequently the choice probability of P&R increases more than expected under the IIA-assumption. As this is an additional effect, on top of change induced by the decreased utility of the car alternative due to the increased car costs, this effect could be interpreted as a 'stick' bonus. Likewise, if a positive cross-effect would be found for attributes related to 'carrot' policy measures, this could be interpreted as a 'carrot' bonus.
The universal logit model has not very often been applied in the transportation literature to interpret cross-effects. This may be due to lack of consistency with regard to utility maximization in some cases, the potential to obtain counter-intuitive elasticities, and the complexity of search for a preferred specification as suggested by Ben-Akiva (1974). As doubts on the validity of this model have been raised in the past, this paper will especially pay attention to the soundness of the results by carefully examining the face validity of the estimated cross-effects, the model fit, the predictive ability, and discussing the replication of the results in a second study.

3. Experimental design

3.1 Experimental design

To estimate cross-effects, one needs to construct a stated choice experiment that allows the unbiased estimation of the set of cross-effects beyond the estimation of the usual attribute effects. To estimate these effects in an efficient way, not only the attributes of each alternative need to be orthogonal but also the attributes across the alternatives. In case of two choice alternatives with varying attribute levels and the included current public transport alternative treated as a base alternative, this can be achieved by constructing choice sets according to an L^{M*N} design, where L refers to the number of levels per attribute, M to the number of alternatives and N to the number of attributes per alternative. With such a design one constructs simultaneously the attribute levels for all alternatives included in the choice set (Louviere et al., 2000).

Table 1. Selected attributes and their levels

P&R		**Car**	
attributes	**levels**	**attributes**	**levels**
Quality P&R	4	Delays by car	0 min
	6		20 min
	8		40 min
Quality PT	4	Car costs at destination	€ 0.50
	6		€ 3.50
	8		€ 6.50
Time loss P&R	0 min		
	10 min		
	20 min		
Costs of P&R	€ 0.--		
	€ 2.--		
	€ 4.--		

Table 1 presents the attributes and their levels that were selected to vary the P&R and car alternatives. The quality of P&R and the quality of public transport are expressed as levels on a ten-point scale. Respondents had to imagine that a P&R facility with connecting public transport was realized, which they would evaluate with the level presented in the alternative. How these quality levels can be explained, hence which configuration of the attributes describing the quality of the P&R facility and the connecting public transport, is discussed in detail in previous publications (Bos, 2004; Bos et al., 2004), and will therefore not be further discussed here. Note that policy measures aiming at increasing the quality of the P&R facilities and the connecting public transport and minimizing time loss to P&R use and P&R costs, can be classified as 'carrot' policy measures, whereas policy measures aiming at increasing the time delay and the costs of the car alternative can be classified as 'stick' policy measures.

This selection of six attributes all varied in three levels would require a 3^6 full factorial design. By assuming that all interaction-effects are equal to zero, we selected the smallest possible fractional factorial design by which all main-effects can be estimated. This resulted in the construction of 18 choice sets. Two examples of the choice task are provided in figure 1.

Example 1

Quality P&R facility	**6**	**Extra time using car**	**40 min**	**Current PT without delays**
Quality connecting PT	**6**	**Extra costs using car**	**€ 0.50**	
Extra time using P&R	**0 min**			
Extra costs using P&R	**€ 4**			
P&R		CAR		PT

Example 2

Quality P&R facility	**6**	**Extra time using car**	**0 min**	**Current PT without delays**
Quality connecting PT	**6**	**Extra costs using car**	**€ 6.50**	
Extra time using P&R	**20 min**			
Extra costs using P&R	**€ 0**			
P&R		CAR		PT

Figure 1. Examples of choice task

3.2 Data collection

The choice experiment was integrated in a questionnaire, distributed among car drivers living outside the city of Nijmegen and working or spending their free time in Nijmegen on a regular basis. Nijmegen, a medium-sized city situated in the east of the Netherlands, has been chosen because of its accessibility problems, especially from the north side of the 'River Waal'. From that side, the city is only to be reached by the bridge 'Waalbrug', which leads to a dense stream of traffic.

The target group was approached in two different ways. Firstly, in the historical centre of Nijmegen and in another major, suburban, shopping centre in Nijmegen, car drivers who just parked their car were approached by interviewers and asked whether they were willing to fill out a questionnaire. If they said they were, interviewers checked whether they belonged to the target group, and if so, they were asked to provide their home address. The questionnaire was mailed to this address, together with a self-addressed envelope. Secondly, car drivers working in Nijmegen and living outside the city were approached through a selected number of big companies. These companies could choose between sending an email address with a link to an Internet questionnaire or sending a paper version by mail to the home address. The data collection took place in the second half of June 2002.

In total, 805 people filled out the questionnaire; 500 completed the paper version, and 305 completed the questionnaire on the Internet. The characteristics of the response group are listed in table 2, showing that (1) as many men as women filled out the questionnaire; (2) as many higher-educated people filled out the questionnaire as middle- or lower-educated people; (3) most respondents were between 30 and 50 years old, but the younger and older groups were substantially represented as well; (4) most respondents have a (compact) middle class car; (5) almost all respondents have owner-occupied cars; (6) most respondents have no experience with P&R facilities, and (7) 7 out of 10 respondents have experience with public transport in general. From these results, there are no reasons to believe it was an untypical group of respondents.

Table 2. Response group characteristics

	Absolute (N=734)	Relative (100%)
1 Sex		
Male	439	54.5
Female	356	44.2
Missing values	10	1.2
2 Education level		
Bachelor's/master's degree	445	55.3
Lower or intermediate education	351	43.6
Missing values	9	1.1
3 Age		
18-30	154	19.1
31-50	448	55.7
51+	166	20.6
Missing values	37	4.6
4 Category of car		
City car / compact class	253	31.4
Middle class	439	54.5
Higher middle-class / Top class / Others	101	12.5
Missing values	12	1.5
5 Car ownership		
Own car	730	90.7
Leased car	66	8.2
Missing values	9	1.1
6 Experience with P&R facilities		
Experience	285	35.4
No experience (rarely or never used)	503	62.5
Missing values	17	2.1
7 Experience with PT in general		
Experience	567	70.4
No experience (rarely or never used)	232	28.8
Missing values	6	0.7

4. Analysis and results

4.1 Model estimation

To estimate the universal logit model of P&R choice, the choices for each choice set were aggregated to arrive at choice frequencies. To determine whether extending the main-effects only model with cross-effects improves the model fit, the log-likelihood values of both models are compared. The log-likelihood of the main-effects-only model is equal to –9742 and improves to –9622 after extension with the cross-effects. Hence, the value of the Likelihood Ratio Statistic is equal to 120. For a difference of 12 degrees of freedom, the Chi-square test gives a p-value equal to 0.000, from which can be inferred that extending the model with the cross-effects results in a statistically significant improvement of the model fit.

4.2 Main-effects

The estimated main- and cross-effects are presented in table 3. Although the main-effects have been presented and discussed in detail in Bos (Bos, 2004; Bos et al., 2004), we provide a summary of the results here to form a base reference for understanding the cross-effects. Effect coding (-1, 0, 1) was applied to code the attribute-levels, which means that part-worth utilities can be derived from the estimated coefficients that denote the contribution of an attribute level to the overall utility of an alternative.

Because the current public transport alternative constituted the base alternative, travellers' utility of public transport is given a utility of zero by definition, which forms a base reference for the utilities of the other alternatives. The positive value of the intercepts of both P&R and car suggests that, on average, these two alternatives are preferred to the public transport alternative. The intercept of the car is higher than the intercept of the P&R alternative, indicating that, on average, the car is preferred to the P&R alternative.

Table 3. Estimated main and cross-effects for Nijmegen

		Main-effects		**Cross-effects**	
Attribute	**Level**	**Coeff.**	**P[Z>z]**	**Coeff.**	**P[Z>z]**
ASC P&R		0.251	0.00		
Quality P&R	4	-0.651	0.00	0.017	0.67
	6	0.061	0.18	-0.018	0.65
	8	0.590		0.001	
Quality PT	4	-0.517	0.00	0.086	0.04
	6	0.020	0.67	-0.037	0.35
	8	0.497		-0.049	
Time loss P&R	0 min	0.529	0.00	0.127	0.00
(compared to free-flow car trip)	10 min	0.239	0.00	0.008	0.84
	20 min	-0.768		-0.135	
Costs of P&R	€ 0.--	0.505	0.00	-0.033	0.43
	€ 2.--	0.032	0.49	0.124	0.00
	€ 4.--	-0.537		-0.091	
ASC car		1.222	0.00		
Delays by car	0 min	0.820	0.00	-0.491	0.00
(compared to free-flow car trip)	20 min	-0.038	0.33	0.110	0.02
	40 min	-0.781		0.381	
Car costs at destination	€ 0.50	0.415	0.00	-0.053	0.27
	€ 3.50	0.028	0.48	-0.245	0.00
	€ 6.50	-0.443		0.298	

All main-effects are in expected directions. Improving the quality of the P&R facilities and the connecting public transport, decreasing time loss due to P&R use and lowering P&R costs, all increase the P&R utility. Likewise, decreasing car costs and limiting the delays by car increases the utility of the car. The utilities are related in a linear way with all the attributes, except for time loss when using the P&R alternative. This can be concluded from examining the significance of the second level of each attribute. If this attribute level is not statistically significant, this means that it is actually equal to zero, implying that changing the attribute level from the lowest level to the middle level leads to an equal change in utility as a further change from the middle level to the highest level. This does not apply for time loss due to the use of the P&R alternative. An increase of no time loss to 10 minutes time loss decreases the utility with 0.290 (= 0.239 - 0.529) utility points, while a further increase from 10 to 20 minutes results in a utility decrease of 1.058 (= -0.768 - 0.239) utility points. Hence, time loss up to 10 minutes results in limited utility decrease, while P&R utility decreases more than 3 times as much if time loss becomes greater than 10 minutes.

Comparing the utility ranges of the attributes gives an indication of the total influence each attribute has on the choice of the alternatives. The two time-related attributes seem to have the highest impact on utility. However, it has to be taken into account that the ranges in the levels of the time attributes differ between the P&R and car alternative. On average, each minute extra travel time due to P&R use decreases the utility with 0.065 (=1.296/20) points, while each minute extra travel time per car decreases the utility with 0.040 point (=1.601/40). Additional analyses indicated that this difference is statistically significant. Likewise, it can be calculated that each extra euro travel costs related to P&R decreases the utility with 0.261 points, while each extra euro related to car only decreases the utility with 0.143 points. Thus, comparing the time- and cost-related attributes between P&R and cars indicates that travellers are more sensitive to changes in the P&R alternative than to changes in the car alternative. This suggests that implementing ‘carrot’ policy measures aiming at improving the P&R alternative would have a greater effect on the P&R choice than implementing ‘stick’ policy measures aiming at making the car alternative less attractive. Whether this is true indeed will be investigated next by examining the cross-effects and predicting the choice behaviour for different ‘carrot’ and ‘stick’ policy packages.

4.3 Cross-effects

The cross-effects are also presented in table 3. The greatest cross-effects are observed for the attribute *travel time delays by car*. The cross-effect for the attribute level *no delays by car* is equal to –0.491. This means that when travel time of the car alternative takes this value, the utility in P&R drops by 0.491. If, on the other hand, the attribute level 40 minutes delay is present in the car alternative, the utility of the P&R alternative increases by 0.381 utility points. Hence, due to 40 minutes delay, the utility of P&R increases, whereas the utility of the public transport alternative does not. The result is that proportionally more travellers than predicted under the IIA-assumption will switch from car to P&R and a less than a proportional amount will switch from car to public transport. Likewise, if the car costs are increased with 6.5 euros, the attractiveness of P&R will also increase more than proportionally. These results suggest that if ‘stick’ policy measures are applied, and thus the car alternative is made less attractive, P&R profits more than proportionally. Apparently, car drivers prefer to use the car for the longer part of the trip, and are thus more likely to switch at the P&R facility than choosing the door-to-door public transport alternative when the car alternative becomes less attractive. As the cross-effects come on top of utility difference caused by the main-effects, this can be considered to be a ‘stick’ bonus.

While the greatest cross-effect is plausible, the negative cross-effect for 3.5 euros increase in car costs is less easy to understand. This effect implies that the P&R alternative profits less than proportionally if car costs are increased with a moderate amount of money.

Compared to the cross-effect estimated for the car-related attributes, the cross-effects estimated for the P&R related attributes are much smaller. The greatest effect is observed for the attribute *time loss due to use P&R*. If there is a loss of 20 minutes, public transport seems to profit more than proportionally while, if there is no time loss, the car seems to profit more than proportionally. The latter result suggests that improving the P&R alternative in the sense of severely limiting the time loss due to using P&R results in a car bonus, which is considered to be an undesired effect.

Improving the quality of the connecting public transport leads to a more than proportional decrease in the car alternative, which can be considered to be a 'carrot' bonus; however, the effect is rather small. Finally, the cross-effects for costs or P&R reveal a mixed result: the car alternative seems to profit more from a modest increase from 0 to 2 euros, while public transport seems to profit more from a further increase to 4 euros. In sum, the cross-effects estimated for the P&R alternatives show mixed results. This raises the question whether these effects are consistent or whether these are just random effects. A replication of this study sheds some light on this question.

4.4 A replication of cross-effects

In order to tackle concerns about the generalizability of the model, an additional data collection has been conducted. In this replication the same methodology was applied as in the first study, but instead of selecting only respondents in the Nijmegen region, they are selected all over the country. In total 364 respondents completely filled out the questionnaire via the Internet. From the response characteristics of this sample, there are no reasons to believe it was an untypical group of respondents. In a comparison of both studies, we concluded that the attribute-main-effects are largely comparable, except for the fact that they are consistently smaller in the second study. We refer to Bos (2004) for a more detailed description of the second study and the comparison of the main-effects between both studies.

The universal logit model estimated for the second study is presented in table 4. Considering the cross-effects for the attributes describing the P&R alternative, differences are observed compared with the first study. The cross-effects for the quality of P&R are now significant, while these effects were not significant in the first model. On the other hand, the cross-effects for the remaining P&R related attributes are not significant in the second study, while these effects were significant in the first study. Moreover, some effects change signs. Hence, this comparison shows that the cross-effects for the P&R related attributes are not very consistent and therefore not very trustworthy. It is therefore probably better not to base any substantial conclusions on these results.

On the other hand, the cross-effects for the car-related attributes reveal the same tendency as in the first model. Also in this model these cross-effects have the greatest influence. The similarity in these results enhances our trust in the cross-effects of the first model. Overall, it may be concluded that there are significant cross-effects for the car-related alternatives. P&R profits more than proportionally in case the car alternative becomes less attractive due to higher costs and time loss. Hence, as these attributes are related to 'stick' policy measures, it can be concluded that there is a 'stick' policy bonus.

Table 4. Estimated main and cross-effects for the Netherlands as a whole

		Main-effects		Cross-effects	
Attribute	**Level**	**Coeff.**	**P[Z>z]**	**Coeff.**	**P[Z>z]**
ASC P&R		-0.132	0.02		
Quality P&R	4	-0.398	0.00	-0.135	0.01
	6	0.015	0.84	0.083	0.12
	8	0.383		0.053	
Quality PT	4	-0.179	0.02	-0.039	0.47
	6	-0.137	0.06	0.020	0.70
	8	0.316		0.018	
Time loss P&R	0 min	0.368	0.00	0.078	0.15
(compared to free-flow car trip)	10 min	-0.012	0.87	-0.018	0.74
	20 min	-0.356		-0.060	
Costs of P&R	€ 0.--	0.453	0.00	0.034	0.52
	€ 2.--	-0.027	0.70	-0.006	0.91
	€ 4.--	-0.426		-0.029	
ASC car		1.718	0.00		
Delays by car	0 min	0.489	0.00	-0.295	0.00
(compared to free-flow car trip)	20 min	-0.091	0.08	0.014	0.84
	40 min	-0.397		0.281	
Car costs at destination	€ 0.50	0.201	0.00	-0.059	0.42
	€ 3.50	-0.058	0.27	-0.160	0.03
	€ 6.50	-0.144		0.219	

4.5 Predictive ability

In addition to the discussion of the face validity and generalizability of the results, we examine whether the extension of the MNL model with cross-effects improves the prediction for new observations. To that effect, two holdout choice sets were included in the questionnaire. These holdout choice sets are additional choice sets with the same lay-out as the other choice sets which are not used to estimate the model. The choice probabilities predicted by the MNL model and by the universal choice model are compared with the choice probabilities for the holdout sets being based on observations.

Table 5 presents the results for these comparisons. Comparing the predictive success of both models, it can be observed that the extension of the MNL model with cross-effects results in lower absolute deviations than when the MNL model is used. Thus, it can be concluded that the extension of the MNL model with cross-effects not only leads to a better model fit, as discussed before, but also improves the predictive ability of the model to predict the market share for new observations.

Table 5. Predictions of modal splits for the holdouts choice sets by both the model without cross-effects and the model including cross-effects for the Nijmegen case

				MNL (without cross-effects)		extended MNL (with cross-effects)	
		Hold-out (HO) profile	**Reported**	**Predicted**	**Deviation**	**Prediction**	**Deviation**
HO1	P&R	Quality P&R is 6 Quality PT is 6 Extra time 0 min Extra costs € 4	40.9	32.3	-8.6	36.7	-4.2
	Car	Extra time 40 min Extra costs € 0.50	38.6	46.1	7.5	44.2	5.6
	PT	Base alternative	20.5	21.6	1.1	19.1	-1.4
Mean absolute difference					5.7		3.7
HO2	P&R	Quality P&R is 6 Quality PT is 6 Extra time 20 min Extra costs € 0	21.2	17.4	-3.8	15.1	-6.1
	Car	Extra time 0 min Extra costs € 6.50	59.4	70.2	10.8	67.8	8.4
	PT	Base alternative	19.4	12.4	-7.0	17.1	-2.3
Mean absolute difference					7.2		5.6

4.6 An illustration

The impact of the cross-effects is illustrated by comparing the modal splits predicted by the MNL model and by the universal logit model for two rather extreme 'carrot' and 'stick' policy measure packages, all based on the Nijmegen case. To enable comparison, a base-scenario is introduced in which the quality of the P&R facility and the quality of connecting public transport are of medium quality (evaluated with a 6 on a ten-point scale), the P&R fee is € 4 and the extra time loss due to using the P&R facility is 20 minutes. No time delays occur when using the car and no car fees are charged when entering the urban area, hence only additional fuel costs are included.

In this illustration it is assumed that the package of 'carrot' measures results in decreasing time loss when using the P&R facility from 20 to 0 minutes (for example by realizing a free (bus) lane for the connecting public transport) and decreasing the P&R fee from € 4 to € 0. It is further assumed that the package of 'stick' measures results in increasing car delays from 0 to 40 minutes (for example by reducing the number of parking lots, resulting in longer walking distances or longer times required to find a parking lot indeed) and increasing the car costs at destination side from € 0.50 to € 6.50.

Both the MNL model and the universal logit model are applied to predict the 'carrots' and 'sticks' package effects on the modal split between P&R, car and current public transport. Because we do not trust the cross-effects estimated for the attributes describing the P&R alternative as discussed before, these cross-effects are excluded when applying the universal logit model.

The impact of including cross-effects in the prediction is presented in table 6. The model without cross-effects, the estimated MNL model, predicts that the 'carrot' package results in a higher P&R patronage than the 'stick' measure package. However, if the model with cross-effects is applied, i.e. the estimated universal logit model, the order is reversed due to the ‘stick’ measure bonus. This illustrates that incorrect conclusions concerning the impact of possible policy measures may be drawn when predictions are based on the conventional MNL model. Thus, this illustration shows the potential of estimating cross-effects in order to take the competition between choice alternatives into account.

Furthermore, the cross-effect model predictions also indicate that implementing exclusively ‘carrot’ measures partly goes at the expense of PT. On the other hand, implementing exclusively ‘stick’ measures hugely increases public transport patronage. It is obvious that P&R patronage will benefit most from a combination of ‘carrot’ and ‘stick’ policy packages, which is in agreement with the findings by Papoulias and Heggie (1975), the UK government’s travel plan guide (1999), Rye (2002) and Hole (2004). Hence, the ‘combined carrot and stick’ measure package reduces car usage most. If this package is implemented, most car drivers will switch to P&R, whereas only a relatively small will switch to public transport for the complete trip. Although the gain in public transport patronage is small, these results suggest that combining ‘stick and carrot’ policy measures will not be at the expense of public transport patronage but rather improves it, which is a very relevant finding for policymaking.

Table 6. Illustration of impact of cross-effects on modal split

	Without cross-effects (MNL model)			**With cross-effects (universal logit model)**		
	P&R	**Car**	**PT**	**P&R**	**Car**	**PT**
Base-scenario	2.9	89.4	7.7	1.7	90.5	7.8
‘Carrot’ measure package	23.6	70.3	6.0	15.2	78.1	6.7
‘Stick’ measure package	15.9	42.0	42.1	27.2	36.4	36.5
‘Combined’ measure package	66.2	16.9	16.9	79.1	10.6	10.2

5. Conclusions

In this paper a universal logit model was estimated for P&R patronage. This model was based on the choices observed for 805 car drivers in a stated choice experiment among P&R, car, and current public transport alternatives. The attribute-main-effects suggest that car drivers are more sensitive to changes in the travel time and costs of the P&R facilities than to changes in the same attributes related to the car alternative. This suggests that ‘carrot’ policy measures aiming at improving the P&R alternative would be more effective than ‘stick’ policy measures aiming at making the car less attractive. However, the estimated attribute-cross-effects suggest that changing the levels of car-related attributes, i.e. increasing travel time and car costs, results in increased utility of P&R. Considering both main- and cross-effects, it becomes clear that ‘stick’ policy measures outweigh the effects of ‘carrot’ policy measures on P&R patronage. The results of this study therefore suggest that applying ‘stick’ policy measures to discourage car use in congested urban areas may be more effective to increase P&R patronage than applying ‘carrot’ policy measures by making the P&R alternatives as attractive as possible.

It goes without saying that combining both types of measures will be most effective. This is also the most elegant policy to apply: making the car alternative less attractive in problem areas, as for example inner cities, while at the same time offering high-quality alternatives. This is illustrated by applying the model to predict market shares for car, P&R and public transport use after introducing several policy measure packages. The illustration also suggests that increased P&R patronage due to implementing combined 'carrot and stick' policy measures will not be at the expense of public transport patronage choice for the complete trip, but rather improves it, which is a very relevant finding for policymaking.

Although the universal logit model has not often been applied in transportation studies to estimate cross-effects and sometimes found to produce counterintuitive results, in this study the estimated cross-effects could be interpreted very well and were plausible. The substantial cross-effects could also be replicated in a second data set. Furthermore, adding cross-effects to the main-effects estimated from a conventional MNL model significantly improved the model fit and the extended model was found to predict the choices for new observations better than the conventional MNL model. This rather successful application of the universal model may add to the reconsideration of the application of the universal logit model in stated choice transportation studies to relax the IIA-assumption. The more so as it requires a simple, straightforward estimation procedure and imposes only limited additional requirements to the experimental design.

The model estimated in this paper also has some limitations. Because respondents were presented choice sets always including a car, a P&R and a PT alternative, cross-effects could only be estimated at the attribute level and not at the alternative level. Hence, from these observed choices cannot be tested whether adding or deleting an alternative from the choice set has a more or less proportional effect on the choice of the available alternatives. This model therefore cannot shed any light on a finding presented in the literature (Parkhurst, 1995) that introducing P&R in a given situation abstracts more users from public transport than from cars. The model presented in this paper could be extended to predict such effects; however, this requires an extension of the experimental design and thus additional observations. In addition to choice sets that include all three alternatives (car, P&R and PT), choice sets should then be designed that include only two alternatives: only a car and a PT alternative and only a P&R and a PT alternative. The alternative availability effects that can then be estimated indicate possible deviations from the IIA-assumption at the alternative level. This extension would also require that current public transport users would be recruited as respondents, whereas the focus of this paper was on the switching behaviour of car drivers. The model estimated from these extensions could answer the policy-relevant question whether or not the introduction of a P&R alternative draws proportionally more users from PT than from cars.

Another limitation of the model in fact applies to all stated choice models and refers to the stated nature of the observed choices: one is never entirely sure to what extent stated choices reflect choices in the real world. Therefore, one should be careful to interpret predicted market shares in absolute terms, although interpretations in qualitative terms to compare effects of several policy packages, as is done in this paper, are reasonable. In order to improve the validity of the market shares, one could additionally observe revealed choices in areas where P&R facilities are already implemented. These revealed choices could be used to validate the stated choices. In specific circumstances, both types of observations could be pooled to arrive at combined stated and revealed choice models that potentially produce more valid modal split predictions.

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