Competition Among Egress Transport Modes: A Stated Choice Model Incorporating Availability-effects

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SAMENVATTING

Concurrentie tussen natransport modaliteiten: Een stated choice model met aanwezigheids-effecten

Dit paper beschrijft de resultaten van een stated choice experiment dat is uitgevoerd om de substitutie en synergie effecten tussen de verschillende mogelijkheden van natransport beter te begrijpen. In het stated choice experiment wordt de aanwezigheid van de alternatieve natransport mogelijkheden gevarieerd, waardoor het mogelijk is om na te gaan welke modaliteiten elkaar beconcurreren voor hetzelfde marktaandeel. Er hebben 996 respondenten deelgenomen aan het onderzoek. De resultaten tonen dat hoogfrequent openbaar vervoer grotendeels substitutie effecten heeft op andere modaliteiten, vooral op trein taxi en ov fiets, terwijl laagfrequent openbaar vervoer grotendeels synergie effecten heeft, vooral op taxi en lopen. Taxi en train taxi hebben substitutie effecten op autogebaseerde modaliteiten, terwijl ze synergie effecten hebben op de meeste andere modaliteiten. De drie onderscheiden fiets alternatieven hebben geen significante aanwezigheidseffecten, dus elk heeft zijn eigen markt.

SUMMARY

Competition among egress transport modes: A stated choice model incorporating availability-effects

This paper describes the results of a stated choice experiment that was conducted to better understand substitution and synergy effects among various options for egress transport modes. The stated choice experiment that was designed varies the availability of alternative transport modes and thus allows us to identify which modes compete for the same market share. The survey consisted of 996 respondents in the Netherlands. The results show that high-frequency public transport services largely have substitution effects on other modes, especially on train taxi and public transport bicycle, whereas low- frequency public transport services largely have synergy effects, especially on taxi and walking. Taxi and train taxi have substitution effects on car-based transport modes, while they have synergy effects on most other modes. The three distinguished bicycle alternatives have no significant availability-effects, so each has its own market

1 INTRODUCTION

In many European and Asian countries and in certain parts of the USA trains compete with cars, especially for longer distance travel. Transportation planners, public government officials and transport authorities would like to see greater market shares of the train. However, whereas the car allows door-to-door transport, the train requires additional before- and after-transport. This means that in terms of marketing, pricing and service provision, before and after transport is highly important. When traveling to the train station, travelers can often use private transport modes such as car or bicycle. However, on the egress side of the train trip, travelers depend on the supply of transport modes provided at the destination station. If the alternatives offered at the destination station do not satisfy travelers' preferences, they may be less inclined to choose the train. It is, therefore, in the interest of transport providers to get to know travelers' preferences for egress transport modes.

In the Netherlands, Dutch railways has fully realized this market potential and stimulated the provision of a wide variety of transportation modes at train stations. For example, they introduced the *train taxi* in the past, which is a shared taxi of which more details are provided in the next section. This was, however, not introduced in the four largest cities as regular taxi providers feared severe competition. More recently, Dutch railways introduced *public transport bike (PT bike).* When this means of transport was introduced, some policy makers were afraid that the PT bike would draw too many customers from urban public transport. This effect was considered unfavorable as urban public transport already faced low ridership. The question therefore is to what extent adding or removing an egress transport mode influences the use of other egress transport modes.

To put it more generally, these examples illustrate the need to examine in more detail the effects of the availability of various means of egress transport on mutual market shares. For example, does the market share of a new mode draw proportionally from the market share of all existing modes, or does it draw specifically more from particular modes? To what extent will the introduction of these various egress options increase the use of trains, or is there evidence of cannibalization among the various forms of public transport?

In estimating market shares of transport modes, routinely the multinomial logit (MNL) model has been used (e.g. Ben-Akiva and Lerman, 1985). By definition, however, this model will predict that the introduction of a new egress transport model will draw market shares in direct proportion to the market share of the existing modes. The reason is that the MNL model is based on the so-called independence from irrelevant alternatives (IIA) assumption, which states that the utility and odds of choosing any choice alternative does not depend on the existence and attributes of any other choice alternative an individual traveler may choose. This implies that the MNL model and any stated choice experiment being based on the MNL model does not allow one to study the effects of the (non-)availability of particular transport modes on the market shares of the various modes driven by processes of asymmetric competition, synergy and cannibalization.

To estimate availability-effects, Oppewal and Timmermans (1991) suggested estimating the universal logit model that McFadden *et al.* (1977) proposed as a test of the IIA-property. In addition, they indicated how conventional stated choice experiments should be elaborated to produce unbiased estimates of availability-effects. The universal logit model can be viewed as an extension of the multinomial logit model in that it assumes that the utility of an alternative does not only depend on the attributes of that alternative, but also on the availability and/or the attributes of the other alternatives in the choice set. To that effect, so-called cross effects, which indicate to what extent the utility of an alternative changes by the availability of another alternative, are estimated.

This methodology was used in the present study on egress transport modes. In order to estimate availability-effects, a stated choice experiment carried out among 996 Dutch train travelers in the spring of 2005. This paper presents and discusses the results of the analyses, which shed light on the significance of the availability of various egress transport modes on egress mode choice.

The remainder of this paper is organized as follows. First, we will describe the applied methodology in more detail. Then, the data collection will be discussed, which is followed by a presentation of the modeling results. Finally, some conclusions are drawn and policy implications will be discussed.

2 METHODOLOGY

2.1 Multinomial and universal logit models

Stated choice (SC) experiments differ from the more commonly stated preference experiments in that the response involves a choice between alternatives instead of ranking or rating all alternatives. Choice experiments have some potential advantages over ranking and rating tasks. It may be argued that choice is a more natural task than ranking or rating tasks (Louviere, 1988). More important, choice experiments allow one to simultaneously test both the specification of the utility function and the assumed functional form of the relationship between utility and choice.

Most choice experiments in transportation research (e.g. Louviere et al 2000) assume an MNL model to represent the choice process. Hence, the probability of choosing a particular choice alternative is given by the following equation:

$$p_j = \frac{\exp(\sum_k \beta_k X_{jk})}{\sum_{j'} \exp(\sum_k \beta_k X_{j'k})}$$

where p_j is the probability that choice alternative (say transport mode) j will be chosen, X_{jk} represent the attributes k of choice alternative j and the β's denote the impact of these attributes on the choice probability. Because the MNL model is based on the IIA-assumption, the design of a choice experiment allowing the estimation of this model is straightforward. First, the choice alternatives are selected and the attributes that characterize each alternative. Next, an orthogonal fractional factorial design is constructed to vary the attributes of interest for each choice alternative separately, usually allowing the estimation of a main-effects utility function. Next, the common smallest denominator of these designs dictates the number of choice sets, which are created by randomly assigning, without replacement, for each cycle the choice alternatives to a choice set. Respondents are then requested to choose the choice alternatives, each described by a bundle of attributes they like best.

As discussed in the introduction, the (non-)availability of any other choice alternative in the choice set might increase or decrease the utility of the choice alternative of interest. Whether this condition is met can be empirically tested, but alternatively the size of the effect can also be estimated, leading to the mother or universal logit model. This model for the problem at hand can be expressed as:

$$p_j = \frac{\exp(\sum_k \beta_k X_{jk}) + \sum_{j' \neq j} \lambda_{j'j} Z_j}{\sum_{j'} \exp(\sum_k \beta_k X_{j'k}) + \sum_{j''} \lambda_{j''j'} Z_{j''}}$$

where the lambda represents availability-effects and Z denotes whether an alternative is present or not. If λ is larger than 0, then the utility of choice alternative *j* will be higher in the presence of *j'*. This is a synergy effect. In contrast, if $\lambda < 0$, there is evidence of substitution. Note that $\lambda_{j'j''}$ is not necessarily equal to - $\lambda_{j''j'}$; that is, availability is not necessarily symmetric. By examining all these effects for pair of choice alternatives, the full pattern of substitution and synergy becomes apparent.

To estimate availability-effects, it is needed to construct an SC experiment that allows the unbiased estimation of this set of availability-effects beyond the estimation of the usual attribute effects. One way to achieve this is to construct choice sets of varying size according to a 2^J design to vary the available *J* alternatives orthogonally. Anderson and Wiley (1992) demonstrate that it is more efficient to take an orthogonal fraction from the 2^J design and its foldover. The latter means that the availability of alternatives in a choice set is mirrored: an alternative available in a choice set is not available in its foldover, and likewise an alternative not available in a choice set is available in its foldover. For example, if the availability of 7 choice alternatives is varied, the smallest orthogonal fraction of a 2^7 full factorial design involves 8 choice sets. Adding the foldover would result in 8+8 = 16 choice sets, only 1/8 of the number of choice sets implied by the full factorial design.

2.2 Choice alternatives

In this study the availability of the following seven egress modes was varied in the SC experiment: public transport (PT), taxi, train taxi, public transport bike, bike in train, bike at station, and Greenwheels (rental car based on shared car principles).

Although some studies found utility differences between diverse PT vehicles (e.g. Hoogendoorn-Lanser, 2005), it was decided not to make such a distinction as we did not found utility differences between bus, metro and tram in a pilot project in which we applied the same methodology as in the present paper. This reduced the size and complexity of the choice task. Probably more important is the frequency of the PT service, as for a low-frequency service the probability that one has to wait increases, which may induce the traveler to choose another egress transport mode. However, to avoid dominant choices we did not include low- and high-frequency services as full egress mode alternatives. Instead, we specified the public transport alternative in the choice sets as a high-frequency service departing every 5 minutes and in their foldovers as a low-frequency service departing every 25 minutes. This breakdown of the public transport alternative in a low and high-frequency service came at the cost of the fact that moderate correlations were introduced between the availability of high and low public transport alternatives with the availability of some of the other transport alternatives. As these correlations did not exceed .5, the separate availability-effects of low and high-frequency PT services on other transport modes can still be estimated. However, it was not possible to estimate the separate availability-effects the other modes have on high and low-frequency PT services.

Bicycle as an egress mode has as least three different variants, which are all distinguished in the experiment. A first possibility is *bike in train:* travelers take their own bicycle in the train, which costs 6 euros per day. While one can bring a folding bike all day, it is not allowed to bring a regular bicycle during rush hours. A second possibility is *bike at station*: commuters and students who have to make regular trips to the same destination, often park a bicycle at the station at the activity end of their train trip. Open-air bike-racks are commonly placed in front of train stations and are free to use, while the usually guarded railway station shelters charge about 10 euros a month or 87 euros a year. The final option, *public transport bike,* is a relatively new concept: travelers can rent a bicycle at a train station for only 2.75 euros a day. However, travelers have to subscribe in advance to this service and pay a fee of 7.50 euros per year. This service is now rolled out throughout the Netherlands, but not yet available at every station.

A next category is the taxi. In front of major train stations regular taxi vehicles are usually waiting for passengers; at smaller stations, however, taxis are usually not waiting, they have to be called. Taxi rides in the Netherlands are not so cheap: more than 5 euros to start with plus 2 euros for every kilometer and about 0.5 euro per minute for waiting, for instance at a red traffic light. Therefore, the Dutch railways introduced a cheaper taxi alternative, the train taxi, which is a shared taxi at a fixed price, charging about 4 euros for each ride. The train taxi must wait maximally 10 minutes for more passengers after the first one gets in. As Dutch railways subsidize this service, to reduce costs, they cut down the number of stations where train taxi is available.

A final egress mode that is varied in the experiment is Greenwheels. This is a rental car based on shared car principles, for which one has to subscribe in advance to use it. There are several packages of fixed – variable cost combinations, but the cheapest subscription fee is 5 euros per month. Then one can make reservations for a car and pays 10 cents per kilometer and between 2.50 and 5 euros per hour, depending on the type of subscription. It is a general car-sharing system, with cars parked at various fixed places all over town. In the experiment it is possible to board Greenwheels cars at the train station.

2.3 Choice experiment

The availability of the seven alternatives was systematically varied in the choice experiment as described before. Three basic options were added to each of these choice sets. Firstly, walking was added as, for most travelers, this is always an option to reach the final destination. Secondly, the option traveling by other means of transport than train was added. It may be that travelers consider the egress modes offered in the choice set to be not sufficient and therefore decide not to travel by train but by another transport mode, which will probably most often involve the car. Finally, travelers may consider the offered egress transport modes in a choice set to be insufficient and therefore choose not to travel at all, so stay at home. The latter option was chosen as the reference choice and is given a utility of zero by definition. Hence, the utilities of the other modes are relative to the utility of this reference option.

Respondents were invited to choose from each choice set the transport option they like best. They made choices for all 16 choice sets, the order of which was randomly varied across respondents to avoid order effects. Respondents were requested to make their choices for a specified hypothetical travel context, which was also varied by design. The travel contexts described the travel motive (recreational, business), knowledge of route (knows route or not), size of luggage (none or small, large), distance towards destination (1, 5 kilometers), weather (dry, rain), travel company (alone, with others), time of day (day, night). Due to space limitation, the effects of these travel contexts on mode choice will not be presented in this paper. However, including the contexts in this experiment has influenced the effects presented in this paper in the following way. The occurrence of the context levels in the experiments is completely balanced, meaning that they all appear an equal number of times, which does not necessarily reflect the number of times each travel context level appears in reality. Thus the alternative specific constants do not reflect the constants observed in reality, but apply only for the hypothetical situation where all context levels appear an equal number of times.

2.4 Data collection

The stated choice experiment was included as the middle part of a written questionnaire. The experiment was preceded by questions on the availability of modes and the travelers' mode choice at their destination station and by a brief explanation of the egress transport modes for those travelers who are less familiar with some modes. The questionnaire ended by some questions on personal characteristics.

Passengers in intercity trains were requested to fill out the questionnaires in the spring of 2005. As the questionnaire took approximately 15 to 20 minutes to complete, sections were selected with about 30 minutes' travel time between two stations, all in the centre of the Netherlands. Interviewers handed out the questionnaires in the first 10 minutes of each trip and recollected these just before the next stop. About one out of two train travelers agreed to respond. Of the 1014 recollected questionnaires, 18 respondents did not make any choices in the stated choice experiment. Of the remaining 996 respondents, 11.3% had missing values in the stated choice experiment. This is in line with previous data collections including SC experiments in trains in which we also observed relatively large percentages of random missing values in the choice sets. This is probably caused by the movements of trains that induce respondents to overlook one or more choice sets. In total, 14460 valid choices are observed among the 996 respondents.

Table 1 presents some respondent characteristics, which will also be used for the segmentation. It can be seen that more females than males were among the respondents. Closer examination revealed that gender did not correlate with any of the other segmentation variables. In addition, it can be observed that the younger age group is far more represented than the older age group. This is probably because students in the Netherlands have a free public transport card at their disposal and therefore many train travelers are students. This is reflected by the large percentage of respondents that indicated that school is their most important daily activity. Furthermore, almost all respondents that have a season ticket for the bus are students. Thus, the segmentation variables *age group*, *daily activity* and *season ticket bus* are highly correlated. Finally, it can be observed that almost half of the respondents have a higher vocational or university education, while more than half of the respondents has a lower level of education.

TABLE 1 Distribution of segmentation variables

gender		**age group**		**level of education**	
females	60.0%	< 30	64.1%	< = middle vocational	54.8%
males	40.0%	30 +	35.9%	higher vocational & university	45.2%
daily activity		**season ticket bus**			
work	32.0%	yes	53.9%		
school	54.4%	no	46.1%		
otherwise	13.6%				

3 ANALYSIS AND RESULTS

3.1 Analysis

The universal logit model is estimated with Nlogit, a specialized module for estimating discrete choice models of the econometric software package LIMDEP. Effect coding was applied to code the availability-effects. More specifically, the availability-effect of alternative A on alternative B was coded as follows. Code +1 was included if the alternatives A and B were both available in the choice set, code –1 was included if B was included while A was not, and finally, code 0 was included if alternative B was not available. Applying effect coding implies that the availability-effects are all expressed as deviations from the alternative specific constant. Hence, as discussed before, the availability-effect of alternative A on B indicates how much the utility of alternative B should be corrected due to the (non-)availability of alternative A.

The loglikelihood of the model of only alternative specific constants is equal to –21986. If the model is extended to include all 66 availability-effects, the loglikelihood is equal to –21798, which is a statistically significant improvement. Thus, including the availability-effects in the model significantly improves the model fit.

3.2 Alternative specific constants

The first column of Table 2 presents the alternative specific constants. Recall that market shares based on these alternative specific constants do not necessarily reflect real market shares due to the systematic variations of contexts as discussed in the choice experiment subsection. Recall further that 'not traveling', so staying at home, was chosen as the base alternative and thus has a utility of zero by definition. Public transport received the highest utility and clearly is the most popular egress transport mode. Utility of public transport increases 0.13 when it concerns a high-frequency service and decreases –0.13 when it concerns a low-frequency service (not presented in the table). However, this difference is not statistically significant at the 0.05 level, meaning that the differences in departure time of once every five minutes and once every 25 minutes is not as important as expected.

TABLE 2 Alternative specific constants

	all	**gender**		**age**		**education**		**daily activity**			**season ticket bus**	
		male	female	< 30	>= 30	high	low	work	school	otherw.	yes	no
PT	2.59	2.45	2.67	2.89	2.02	2.66	2.56	2.13	2.88	1.33	2.92	2.13
Greenwheels	-1.01	-0.61	-1.14	-0.82	-1.11	-0.97	-0.83	-1.20	-0.69	-2.90	-0.45	-1.54
taxi	2.11	2.06	1.92	2.13	1.76	2.13	1.89	1.88	2.07	1.07	2.06	1.85
train taxi	2.06	2.12	2.08	2.08	2.11	2.27	2.00	2.15	2.06	1.45	2.10	2.06
PT bike	-0.81	-0.20	-0.68	-0.27	-0.68	-0.39	-0.51	-0.64	-0.28	-1.56	-0.29	-0.67
bike station	1.10	1.25	1.09	1.46	0.42	1.23	1.15	0.43	1.56	0.04	1.44	0.73
bike train	0.05	0.06	0.06	0.12	-0.05	0.37	-0.20	-0.14	0.22	-0.67	0.15	-0.09
walking	1.96	2.04	1.65	2.07	1.49	2.03	1.71	1.57	2.04	0.64	1.98	1.63
not by train	1.23	1.03	1.42	1.26	1.22	1.72	0.89	1.40	1.16	0.15	1.19	1.30

[yellow] Significant effect at the 0.05 level

Next in popularity come taxi and train taxi, both being about equally popular. Apparently the fact that a regular taxi is more expensive is largely compensated for by the fact that it does not have to wait for additional passengers and does not make detours like the train taxi does.

After public transport and taxi, walking is the next egress transport mode chosen quite often. Walking is followed by the category 'not by train', which means that the trip is not made by train as the main mode of transport, but with another mode, usually the car. Hence, this 'not by train' alternative is chosen relatively often, which indicates that train travelers are not stuck to public transport, but do consider other alternatives. Closer examination indicated that 40% of the respondents had a car available for the trip they were currently making. Thus if travel conditions change and the availability of egress transport modes is not optimal, a large group of travelers can - and part of them certainly will - change from train to car.

Of the bicycle alternatives, bike at the station is the most popular one. This option has (relatively low) constant costs and negligible variable costs for additional use. Bike in train is the next popular bike alternative, whereas the PT bike clearly is the least popular bike alternative. Perhaps many travelers are still not familiar with this relatively new egress mode concept. Another reason may be that one has to subscribe in advance and pay an annual fee in order to be allowed to use PT bike. Both reasons may also explain the low utility derived from Greenwheels, which clearly is the least popular egress transport mode alternative.

3.3 Alternative specific constants by segments

Table 2 also presents the results broken down by the various categories of background variables. The results for gender show that males, more than females, have a higher preference for walking while they less often choose to travel by another alternative than by train. Closer examination learns that more males than females (46% versus 36%) have a car at their disposal, which therefore cannot explain the latter difference. Possibly a selection effect caused this result: males who prefer less to travel by train already did so and are, thus, to a lesser extent found among the respondents.

More differences are found between the age groups. Young travelers (younger than 30 years) have a higher utility for all transport modes, which indicates that they, less often than older travelers, choose the base alternative ‘not travel at all’. The differences between younger and older travelers with respect to public transport, taxi, bike at station, and walking are statistically significant. Young travelers choose more often public transport because most young travelers are students who have a ‘free’ public transport card at their disposal while they are studying. Moreover, they choose more the active modes like walking and bike at station, possibly because they are, on average, in a better condition than the older travelers. That they also opt more for the taxi comes as a surprise as, on average, they have less income than older travelers. Perhaps this is a selection effect: older travelers who are inclined to spend more money on travel, are less to be found in trains as they travel more by car.

The higher educated derive a higher utility from bike in train. This is probably related to folding bike ownership, as closer examination indicated that more higher educated own such a bike (8.5% vs. 2.9%). Moreover, the higher educated also opt more often for walking. Finally, the higher educated more often choose to travel by other means of transport than the train. Closer examination learns that indeed more higher educated people have a car at their disposal (49% versus 33%).

Concerning the daily activity, distinguishing work, school and otherwise. Table 2 learns that the 'other' group makes less use of all means of transport. Hence, they are more inclined not to travel. Furthermore, the differences between work and school exactly reflect the differences between the age groups. Finally, these results are also reflected in the differences between bus season ticket holders and non-season ticket holders, except that the difference for Greenwheels is additionally significant.

3.4 Substitution and synergy effects

Table 3 presents the estimated availability-effects. An availability-effect of alternative A on alternative B equal to zero indicates that the utility of B will not change if A is available. This means that the (non-)availability of alternative A changes the choice probability of alternative B as a function of the utility of alternative A, which is completely in accordance with the IIA assumption. A negative value of alternative A on alternative B indicates that if alternative A is available in the choice set, the utility of alternative B decreases. This is an indication of *substitution*: alternative B substitutes alternative A, at least to some extent. On the other hand, a positive availability-effect indicates that the utility of B increases if A is available in the choice set. This effect is an indication of *synergy*: the joint availability of two alternatives increases the likelihood of choice.

TABLE 3 Availability-effects

	PT high freq	PT low freq	Green-wheels	taxi	train taxi	PT bike	bike station	bike train
PT			-0.07	0.13	0.09	-0.02	0.03	-0.01
Greenwheels	0.00	0.09		-0.22	-0.20	0.07	-0.03	0.05
taxi	-0.02	0.16	-0.13		-0.10	0.00	0.08	0.03
train taxi	-0.21	0.06	-0.01	-0.10		-0.07	0.01	-0.04
PT bike	-0.50	0.02	0.03	0.10	-0.09		-0.17	-0.06
bike station	-0.14	-0.04	-0.02	0.13	0.15	0.05		0.00
bike train	0.00	-0.04	-0.04	0.19	0.13	-0.01	0.00	
walking	0.05	0.14	-0.04	0.17	0.17	-0.01	-0.03	-0.01
not by train	-0.12	0.07	-0.01	0.01	0.03	0.02	-0.02	0.04

[yellow box] Significant effect at the 0.05 level

Table 3 presents the estimated availability-effects. The table shows that high-frequency PT services have substitution effects on most other modes. The largest substitution-effect is on PT bike (-.50), which indicates that once high-frequency PT is available, PT bike utility drops dramatically. Likewise high-frequency PT has a significant substitution effect on regular taxis. Of all transport modes high-frequency PT also has the largest substitution-effect on *other main modes of transport than train*, although this effect is not statistically significant. This involves that if high-frequency public transport is available as an egress transport mode, one is more inclined to travel by train. The availability of low-frequency PT, on the other hand, mainly has synergy-effects on other modes, of which two are statistically significant: on regular taxi and on walking. Low-frequency PT has substitution-effects, though small and not significant, on bike at station and on bike in train, which suggests that once low-frequency PT is available, one is less inclined to use one's own bike transport.

Greenwheels mainly has substitution-effects on other transport modes, of which only the effect on regular taxis is statistically significant. The latter result is plausible as both alternatives involve the car and are relatively expensive options. The taxi has substitution-effects on both Greenwheels and train taxi, both other car-based modes, but has synergy effects on all other transport modes. The substitution-effect of taxi on train taxi is statistically significant, and though the substitution-effect on Greenwheels is relatively large, it is not statistically significant, probably due to the few observed choices for Greenwheels. The synergy-effects of taxi on PT, bike at station, bike in train and walking are all statistically significant. The same substitution- and synergy-effects observed for taxi are also found for train taxi, with the exception that train taxi competes more with PT bike, although this effect is not significant. Also the synergy-effect on bike in train is not significant. Overall, it can be concluded that each of the car-based alternatives has substitution effects on the other car-based alternatives, while they have synergy effects on the other transport modes. Thus, the car-based alternatives compete for the same market-share.

The three bicycle alternatives have less consistent availability-effects among themselves as observed among the car-based alternatives. Bike at station has a relatively great substitution-effect on PT bike, and to a lesser extent, also bike in train has a substitution-effect on PT bike. However, both effects are not statistically significant, due to the relatively few observed choices for PT bike. As some expected that the introduction of PT bike would have substitution-effects on bike at station, the opposite seems to be true: a synergy effect is observed, although not statistically significant. The other availability-effects of the bicycle alternatives are rather small, do not seem very systematic and none of these effects are statistically significant. Hence, perhaps with the exception of the competition of bike at station and PT bike, there seems to be no competition among the bicycle alternatives and between the bicycle alternatives and the other modes. So, each bicycle alternative seems to have its own market.

Overall, it can be concluded that the substitution and synergy can be interpreted well and are plausible.

3.5 Substitution and synergy effects by segments

It was examined whether the availability-effects vary between the various segment categories. To that effect, interaction variables between effect-coded segment variables and availability-effects were estimated. A formal test whether extending the model with the availability-segment-interactions improves the model fit cannot be given, as extending the model with these effects exceeds the number of coefficient (100) that can be estimated simultaneously with Nlogit. However, as the availability-effects are largely orthogonal and consequently also the interactions with the segments, separate models for each segmentation variable including only the interaction-effects and the alternative specific effects will give fairly comparable results. Significant available-interaction-effects indicate which segments are statistically significant.

For each of the 5 five segmentation variables 64 availability-interaction-effects were estimated, thus in total 320 effects. Only 12 of these 320 effects, that is 3.75%, are significant at the 5% significance level. Hence, less statistically significant differences are found than can be expected based on pure chance. Of the 12 significant differences, 7 appear to be effects on PT bike and 1 on Greenwheels. These two transport modes have received only very few choices from all respondents as discussed before and thus even fewer choices per segment category. This makes the segmentation estimations for these transport modes relatively unstable and they probably do not reflect systematic differences. Furthermore, the 4 remaining significant differences do not seem to be very systematic and give the impression to be random. Guided by the parsimony criterion, we decided not to extend the model to include differences in availability-effects between the segments. Consequently, the results are not presented and discussed. Overall, it is concluded that the availability-effects do no differ between the segments.

3.6 An Illustration

The impact of the availability-effects on market shares will be illustrated by predicting the market shares for two choice sets. In the first choice set, the following egress transport modes are available: low-frequency PT, taxi, train taxi, PT bike and walking, while one can also choose not to travel, so stay at home. The second choice set is basically the same, except that train taxi is no longer available. Table 4 presents the market shares for both choice sets predicted without and with availability-effects, thus based on the estimated MNL and the estimated Universal Logit Model.

TABLE 4 Market share prediction with and without availability-effects

	train taxi is available		**train taxi is not available**	
	prediction without availability-effects (MNL)	prediction with availability-effects (Universal Logit)	prediction without availability-effects (MNL)	prediction with availability-effects (Universal Logit)
low-frequency PT	31.4%	32.3%	39.7%	35.0%
taxi	22.1%	20.9%	27.9%	33.3%
train taxi	20.9%	14.6%		
PT bike	1.2%	1.1%	1.5%	1.7%
bike in train	2.8%	3.1%	3.5%	3.1%
walking	19.0%	25.9%	24.0%	24.1%
staying at home	2.7%	2.2%	3.4%	2.8%
total	100.0%	100.0%	100.0%	100.0%

The results for choice set one clearly demonstrate the differences in predicted market shares between the two models, with the largest differences for train taxi and walking. If utility is not corrected for availability-effects (MNL model), a greater market share for train taxi is predicted. As we noticed that taxi and, to a lesser extent, also PT bike and bike in train have substitution effects on train taxi, taking these availability- effects into account (Universal Logit Model) results in a lower predicted market share for train taxi. On the other hand, the predicted market share for walking becomes higher if the availability-effects are taken into account. This is caused by the relatively high synergy effects the availability of low-frequency PT, taxi and train taxi have on walking. From Table 4 it also becomes clear that in this total package of egress transport modes the synergy effects dominate, as only 2.2% of the travelers choose not to travel if the availability-effects are taken into account, whereas it is predicted that 2.7% of the travelers choose not to travel if the availability-effects are not taken into account.

Comparing the MNL model predictions for the choice sets 1 and 2, shows that all market shares increase once the train taxi is removed from the choice set. The market share of the train taxi is distributed over all remaining alternatives in proportion to their utilities, due to the IIA assumption. Hence, this implies that the ratio between the market shares of any two choice alternatives is not affected by removing the train taxi from the choice set. For example, the ratio between low-frequency PT and taxi in the first choice set is 31.4% / 22.1% = 1.42, which is equal to the ratio in the second scenario: 39.4% / 27.9 = 1.42.

However, if the availability-effects are taken into account in choice set 2, proportionally greater market shares are predicted for the taxi, because the taxi no longer competes with the train taxi. The same applies for the PT bike. On the other hand, lower market shares are predicted for low-frequency public transport and bike in train, as the synergy effects of the train taxi no longer apply. Absence of train taxi synergy effects also causes that the market share predictions for walking are now practically equal for both models.

4 CONCLUSIONS AND DISCUSSION

A good supply of egress transport modes seems of paramount importance if the train has to compete successfully against other transport modes. However, because in many local situations too many options and alternatives may compete for the same market share, it may be relevant to better understand cannibalization and synergy effects among egress transport modes.

This study reports the main findings of the stated choice experiment to get more insight into this research question. In particular, it is based on estimating availability-effects in a non-IIA choice model. The effects pick up the change, if any, in the utility of a particular choice alternative as a function of the (non-)availability of transport modes.

The results of this study suggest that cannibalization is strongest for high-frequency public transport on public transport bike and train taxi and among the three car-based alternatives: taxi, train taxi and Greenwheels. On the other hand, this study has produced evidence of synergy effects from low-frequency public transport, taxi, and train taxi on other transport modes. The results further suggest that the three bicycle alternatives do not have systematic cannibalization or synergy effects, and thus all have their own markets.

The main results of the segmentation analysis reveal that students, and consequently also young travelers and bus season ticket holders, as these variables are highly correlated, to a larger extent choose public transport, bike at station and walking. However, no systematic differences are found in availability-effects between the various segments based on personal characteristics.

Based on the results presented in this paper better-informed recommendations can be given to transport providers on the complete package of egress transport modes at train stations. For example, the following recommendations can be provided to Dutch railways with respect to the further introduction of the PT bike. As the availability of high-frequency public transport negatively influences the utility of the PT bike, they should not give high priority to the introduction of the PT bike at the stations from which many destinations can be reached with high-frequency public transport. On the other hand, as the taxi has synergy effects on the PT bike, the availability of taxis at stations is an advantage. Furthermore, as train taxi and PT bike partly compete for the same market share, PT bike use will be higher at stations where the train taxi is withdrawn.

Transport mode choices in this study were observed for different travel conditions, which are completely balanced in the experiment. This means that the market shares presented in this paper only reflect those in reality if in reality all context levels apply an equal number of times. As this is likely not the case, the market shares as presented should be interpreted with care. Future analyses on these data will reveal how alternative specific constants of egress transport modes and availability-effects vary with travel contexts and potentially produce more realistic market shares.

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