8. Train station access and train use: a joint stated and revealed preference choice modelling study

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8.1 INTRODUCTION

Public transport accessibility depends not only on the places and opportunities that can be reached by transit, but also on accessibility to public transport. The characteristics of access and egress modes influence accessibility patterns but also ridership levels of public transport modes. In particular, public transport companies and city planners in Northern Europe have increasingly recognized the key role that bicycling plays as a feeder and distributor service for public transport (Pucher and Buehler 2008). However, the literature is still limited on how characteristics of access and egress modes influence the choice of the main mode of travel. In this chapter, we examine the key factors that influence access and egress mode choice and their influence on train use in the wider metropolitan area of The Hague–Rotterdam, in the Netherlands.

In this chapter, we estimate mode choice models based on a joint estimation of revealed preference (RP) and stated preference (SP) data to overcome the constraints of each of these two types of datasets (Bradley and Daly 1997). Most of the studies in the literature on feeder modes are based on RP data. In general, RP methods allow the construction of a picture of real situations and patterns, but often do not provide enough information to draw important inferences. As a result, most of the studies in the literature on feeder mode choice did not test the effect of improved service of feeder modes to access the train station. Moreover, variables such as cost and time are often correlated in the RP surveys (Cherchi and Ortúzar 2002). Therefore, one of the major benefits of SP methods is the ability to capture the response to diverse attribute combinations which are not otherwise observed in the market (Hensher 1994). Only a few studies have collected stated preference (SP) data about access mode choice. For example, Hensher and Rose (2007) analysed main mode choice, but included only car, walking

and bus as feeder modes. One of the main limitations of SP experiments in this context is the restricted applicability. The hypothetical scenarios presented in SP experiments can be unrealistic or inconsistent, or the sample can be biased due to self-selection of respondents (Krizek et al. 2007).

In the literature, joint estimations of RP–SP data are advocated in order to overcome these issues. It is argued that RP data can act as a reference point for pivoting the levels of the attributes in the stated choice experiment. The mixing of sources (SP and RP) means the opportunity to position an SP data set relative to an RP data set within the one empirical analysis on the common choice problem. It enables the modeller to extend and infill the relationship between variations in choice response and levels of the attributes of alternatives in a choice set, and hence increase the explanatory power of the RP choice model, as stated in Hensher (1994). The statistical methods to jointly estimate RP–SP can be divided in two main procedures: the nested logit specification and mixed model specification with non-linear effects. The non-linear specification appears to be more suitable as not only does it obtain better model results in other published studies, but also the real distribution of the error terms was revealed (Cherchi and Ortúzar 2002). The nested logit approach is not capable of dealing with the effect of repeating observations, as demonstrated in Hensher et al. (2008).

In this study we use a mixed logit model with a non-linear specification to model mode choice, based on joint RP–SP data. The joint RP–SP estimation allows us to develop more reliable conclusions about access and egress generalized costs to train stations. We develop a set of policy scenarios and estimate the change in probabilities to use train according to the variations of time, cost and quality attributes, and estimate value of travel time savings (VTTS) values and willingness to pay (WTP) for changes in attributes in both access and egress modes. To the authors' knowledge, this study is the first attempt to develop mode-specific VTTS and WTP for access and egress modes to train stations. The results of this chapter are interesting for both researchers and planners. We examine the effect of different model structures and the use of different data types, and examine the effectiveness of different types of measures (for example, bicycle pricing, 'liveliness' of railway stations) to influence train use.

The chapter is structured as follows. We first give a brief overview of the available literature on station access and egress (section 8.2). We discuss the case study and survey design (section 8.3), followed by a description of the econometric framework developed for this research (section 8.4). The results of the joint RP–SP model estimations (section 8.5), VTTS estimations (section 8.6), and the effects of policy measures on market shares are described (section 8.7). Finally, the conclusions from the research are presented (section 8.8).

8.2 LITERATURE ON STATION ACCESS AND EGRESS

The number of studies on station access or egress modes is fairly limited. A number of studies have examined the importance of feeder modes in railway use (Ben-Akiva and Morikawa 1990; O'Sullivan and Morrall 1996; Pucher and Buehler 2009). Specifically in the Netherlands, the bicycle as feeder mode has motivated many studies (Brons et al. 2009; Debrezion et al. 2009; Givoni and Rietveld 2007; Keijer and Rietveld 2000; Martens 2007; Rietveld 2000) based on revealed preference data.

The inclusion of realistic attributes in the SP experiment is important for the interpretation of the hypothetical scenarios. Moreover, when new alternatives are being evaluated, making the attribute levels believable (and deliverable) becomes a primary consideration (Hensher 1994). For example, relevant attributes to consider in the mode choice of station access or egress are: cost, time and mode facilities (Martens 2004), transfer and waiting time (Hensher and Rose 2007), and station environment. Different elements of station environment have received attention in the past decade: Cozens et al. (2003) discussed passengers' perceptions of crime and nuisance at the station and immediate routes. Lee and Lam (2003) investigated the level of service of stairways in mass rapid transit stations. Ampofo et al. (2004) found a correlation between passengers who are dissatisfied due to thermal conditions within the underground railway system. More recently, Cascetta and Carteni (2014) found that train users are more willing to walk nine more minutes to reach a high-aesthetic-quality station. They quantified the 'value of stations quality' in €0.35–€0.50/trip, by train. They suggested that further research could extend the scope to include the specification of mode choice models with specific aesthetic quality parameters. However, the effect of those elements in modes of access and egress has never been analysed, to the authors' knowledge.

As stated in the introduction, only a small number of studies have analysed access and egress mode choice based on stated preferences. Therefore, WTP for the implementation of specific transport policies has received little attention. At the same time, the effect of the value of travel time savings in the station access or egress journey has rarely been studied. Hensher and Rose (2007) estimated VTTS for both access and egress modes. However, the VTTS relate to all public transport modes, rather than specific public transport modes, such as bus and train. Similarly, since the choice set was composed of main modes (that is, new light rail, new bus way, bus, existing and new train, and so on), cost and time attributes were not disentangled by access modes (that is, walking, cycling, bus/tram/metro, car). However, they did demonstrate clear differences between VTTS of access and egress time

(AU\$6–AU\$10/hour and AU\$4–AU\$7/hour, respectively). Similarly, there is no specific and published value of time for access and egress modes to train stations. Finally, the effect of various policy scenarios has rarely been tested over SP data. No scenario has been described combining both quality of station and level of service of feeder modes.

Continuing from the review of research presented above, the objective of this chapter is twofold: (1) to develop a joint RP–SP estimation of access and egress mode, which allows us to estimate more reliable VTTS and WTP for new transport measures; and (2) based on the SP data, to calculate the influence of various policy scenarios on train ridership, and to draw specific conclusions about both access and egress modes in different journey purposes.

8.3 CASE STUDY AREA, DATA COLLECTION AND SURVEY DESIGN

Our case study area is the wider metropolitan area of The Hague–Rotterdam in the Netherlands (see Figure 8.1). The metropolitan region of The Hague–Rotterdam and surroundings comprises 3 million residents and is one of the most urbanized areas in the Netherlands. This area is also known as Randstad South in Dutch policy and planning documents. We conducted an online survey among paid members of an online commercial panel, in the mid-summer and early autumn of 2013. This study involved a total of 1524 respondents. The survey had a response rate of 84 per cent.

Figure 8.1 Case study area: the wider metropolitan area of The Hague–Rotterdam

The recruitment was based on the following three criteria:

- Residential location. We only recruited inhabitants living within a 5 km catchment area of one of the 38 railway stations in the case study area.
- Frequency of travelling by train for both work and non-work purposes. Three types of passenger were established: 'frequent' (a person who travels once per week or more), 'infrequent' (a person who travels once per year up to three times per month), and 'never' (a person who travels less than once per year). The objective was a balanced distribution of user type, but the non-users were very reluctant to complete the survey. As a result, 44 per cent of the respondents who completed the survey belong to the frequent traveller category, 40 per cent are infrequent travellers, and only 16 per cent expressed that they never travel by train.
- Type of departure station. We distinguished between large (inter-city) railway stations (for example, Rotterdam Central Station, The Hague Central Station), medium-sized (intercity) stations (for example, Leiden Central Station) and small (local) railway stations.

The questionnaire comprised two parts: revealed preference and stated preference experiment. The RP part included questions related to the most recent trip in the study area (travel time, purpose, origin, destination, and so on). Table 8.1 shows the variables in the RP context. In the SP part, each respondent completed 12 cards, six for each access and egress mode choice. The cards included five alternatives, differing between access and egress modes. In the access cards, the respondents chose from: bus/tram/metro (BTM), car, walk, bicycle, other mode and non-choice. The non-choice has two sub-options: 'I would not travel by train' and 'I would find another way to go to the station'. In the egress part, the respondent chosen among: BTM, own bicycle, public transport bicycle (PT-bicycle; in Dutch: *OV-fiets*), walk and the non-choice option as in the access experiment. The PT-bicycle is a popular members-only rental scheme in the Netherlands, primarily used at the activity end of a train trip. Users pay a small yearly fee to subscribe (€10, 2013 price) and a rental fee (€2.85 for 24 hrs, 2013 price). The subscription can be linked to the national smart card system (*OV-chipkaart*) to allow for fast identification and easy payment. The PT-bicycles are parked at regular guarded parking facilities or in special bicycle lockers, within easy access of the train platforms, at every railway station in the Netherlands.

Each alternative was assigned with a time attribute. Car, BTM and bicycle were additionally provided with a cost attribute. Car and bicycle

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StedenbaanPlus Enquête

Uw reis van huis naar vertrekstation (1/2)

We leggen u nu 3 denkbeeldige scenario's voor. Stel dat u van huis naar werk gaat en dat de treinreis 241 minuten duurt. Hoe zou u naar het treinstation Boskoop gaan als u de volgende vervoerswijzen kunt kiezen? Als een voorgesteld alternatief niet van toepassing is op uw situatie, dan mag u deze negeren.

U dient op deze pagina 3 afzonderlijke keuzes te maken. Op de volgende pagina zullen nogmaals 4 keuzes gemaakt worden.

Mogelijke modaliteiten	Reistijd	Kosten	Andere karakteristieken	Indicatieve afbeelding
Bus / Tram / Metro	29 minuten	€ 3,60 Per retour		<div>3</div>
Auto passagier	17 minuten			
Fiets	15 minuten	€ 1,25 Per retour	Geen vertraging op de fietsroute naar het station, door onderbrekingen in de route, zoals verkeerslichten	
Lopen	39 minuten		U heeft 2 minuten wachttijd bij verkeerslichten	
Ik zou op een andere manier naar het station gaan of Ik zou niet met de trein reizen				

Figure 8.2 Example of card in the stated choice experiment

parking represent the cost attribute of car and bicycle, respectively. BTM cost belongs to the price of the trip. For both cycling and walking specific statements about route quality were included. An example of choice card is shown in Figure 8.2 (in Dutch). Table 8.1 presents the variables and attributes included in both RP and SP contexts.

It is important to highlight that for both access and egress time is adaptive from the revealed preference part. Travel time was adapted from the RP survey by adding 0, 5 and 10 minutes to the access time indicated in the survey. Similarly, in the SP experiment, bicycle access cost includes three levels: free, €1.25/day and €2.50/day. Both 'free' and '€1.25/day' belong to the current situation. More information about the design of the SP experiment can be found in La Paix and Geurs (2014). Table 8.2 shows the attributes and levels of the SP experiment.

8.4 MODEL SPECIFICATION

8.4.1 Mixed Logit (ML) and Nested Mixed Logit (NML)

This section discusses the econometric structure of the mixed logit model, which is used the estimation with both joint RP–SP and the SP-only data.

Table 8.1 Variables in the RP context

Name	Description	Notation
Socio-economic characteristics (SE)		
Age	Continuous variable. Alternative specific for BTM and non-train user.	β_{age-i}
Gender	Equal to 1 if male. Alternative specific for BTM	$\beta_{gender-i}$
Frequency of trip	1 if equal to four times per week, zero if otherwise.	$\beta_{frequency-i}$ X_6
Work	Alternative specific for BTM and car Dummy variable, equal to 1 if trip purpose is 'work', zero if otherwise. Alternative specific for car and bicycle.	β_{work-i} X_3
Level of service (LOS)		
Access time BTM	Dummy variable. Equal to 1 if travel time is equal to 5–10 minutes	$\beta_{access\ time - btm}$
Access time car	Dummy variable. Equal to 1 if travel time is equal to 10–15 minutes	$\beta_{access\ time - car}$
Access time bicycle	Dummy variable. Equal to 1 if travel time is equal to 10–15 minutes	$\beta_{access\ time - bicycle}$
Access time walk	Dummy variable. Equal to 1 if travel time is equal to 5–10 minutes	$\beta_{access\ time - walk}$
Cost BTM and Bicycle	Continuous variable	$\beta_{costBTMRP}$ $\beta_{costbicycleRP}$

The ML is a highly flexible model that can approximate any random utility model (McFadden and Train 1996), which has been widely applied for many years in the field of transport econometrics (see e.g. Brownstone and Train 1998; Train 2003). The ML probabilities are the integral of standard logit probabilities over a density of parameters, expressed in the following form, as in Train (2003):

$$P_{nj} = \int L_{ni}(\beta) f(\beta) d\beta, \quad (8.1)$$

where $L_{ni}(\beta)$ is the logit probability evaluated at parameters β , $f(\beta)$ is the density function:

$$L_{ni}(\beta) = \frac{e^{V_{ni}(\beta)}}{\sum_{j=1} e^{V_{nj}(\beta)}}. \quad (8.2)$$

Table 8.2 Variables, Attributes and levels in RP and SP context

Attribute	Levels	Description	Notation
Alternatives, access mode	5	Car driver/passenger, BTM, Bicycle (own), Walking, No choice (other mode, non-train use)	
Alternatives, egress mode	5	BTM, bicycle (own), PT-bicycle, walking, no choice (other mode, non-train use)	
Travel time access/egress: adaptive RP	3	+ 0, 5, 10 minutes	
Cost bus	2	Cost per journey €3.6/return journey €2.2/return journey	
Cost car	2	Cost of parking per day €8/day	
Cost bicycle parking	3	Free €1.25/day €2.5/day	
Cost PT-bicycle	2	2.85 €/day 0.5 €/day	
<i>Cyclist infrastructure: delays</i>			
No delays	0	Equal to 1 if quality attribute is 0; and 0 if otherwise	C_{sp}
Addition of 5 minutes in the route by bicycle due to number of interruptions, cyclist	1	Equal to 1 if quality attribute is 1; and 0 if otherwise	C_{sp1}
Addition of 2 minutes in walking from bicycle parking to platform	2	Equal to 1 if quality attribute is equal to 2; and 0 if otherwise	C_{sp2}
Addition of 5 minutes in walking from bicycle parking to platform	3	Reference category	
<i>Pedestrian infrastructure: delays</i>			
2 minutes waiting time for pedestrians at traffic lights on the route to the station bicycle parking to platform	0	Equal to 1 if quality attribute is 0; and zero if otherwise	P_{sp}
5 minutes waiting time for pedestrians at the traffic lights on the route to the station	1	Equal to 1 if quality attribute is 1; and 0 if otherwise	P_{sp1}
Improvement of current station environment for train passengers	2	Equal to 1 if quality attribute is 2; and 0 if otherwise	P_{sp2}
No improvement of current station environment	3	Reference category	P_{sp3}

$V_{ni}(\beta) = \beta x_{ni}$ is the deterministic part of the utility function. The density of β can be specified with mean b and covariance W . Substituting $L_{ni}(\beta)$ and V_{ni} in equation (8.2), the choice probability under this density becomes:

$$P_{ni} = \int \frac{e^{\beta x_{ni}}}{\sum_j e^{\beta x_{nj}}} f(\beta|b, W) d\beta. \quad (8.3)$$

Simulation is normally used to estimate the ML. Given the values that describe the population parameter of the individual parameters, R values of β are drawn from its distribution and the probability in equation (8.3) is calculated conditional on each realization. The simulated probability (SP) is the average of the conditional probabilities over the R draws:

$$SP_n = \frac{1}{R} \sum_{r=1, \dots, R} P_{ni}(\beta^r). \quad (8.4)$$

8.4.2 The Joint Estimation RP–SP

As stated in the introduction, in the joint RP–SP estimation, a scale parameter is estimated. The RP parameters are considered the true parameters which scale the SP parameters. The structure is similar to a nested logit model in which we have two nests: RP and SP alternatives. Therefore, given two sources of data, RP and SP, the random utility functions associated with alternative i can be specified as follows:

$$U_i^{RP} = \beta X_i^{RP} + \alpha Y_i^{RP} + \varepsilon_i^{RP} \text{ and } U_i^{SP} = \beta X_i^{SP} + \gamma Z_i^{SP} + \varepsilon_i^{SP}, \quad (8.5)$$

where α, β, γ are vectors of parameters to be estimated, X_i^{RP} and Y_i^{SP} vectors of attributes common on both data sets, that is, socio-economic characteristics, Y_i^{RP} and Z_i^{SP} are vectors of attributes to each type of data, that is, alternative specific constants (ASCs) and level of service (LOS) parameters. ε_i^{RP} and ε_i^{SP} are the error terms, which take into account multiple responses of the generic individual i . An efficient estimation with two different data sources is to scale one data set to achieve the same variance in both sets (Cherchi and Ortúzar 2006a). Then:

$$\tilde{U}_i^{RP} = \theta U_i^{SP}. \quad (8.6)$$

This means that the standard deviations in RP are equal to the standard deviations in SP multiplied by a parameter ($\theta_{\frac{RP}{SP}}$). The $\theta_{\frac{RP}{SP}}$ parameter is actually the ratio between the scale parameters in the RP and SP, written as:

$$\theta_{SP}^{RP} = \frac{\lambda_{RP}}{\lambda_{SP}}. \quad (8.7)$$

Therefore the likelihood function is L implicitly estimated as the product of the RP and the SP probabilities, which is written as:

$$L = \prod_{RP} \frac{e^{U_i \lambda_{RP}}}{\sum_{i \in J^{RP}} e^{U_i \lambda_{RP}}} * \prod_{SP} \frac{e^{U_i \lambda_{SP}}}{\sum_{i \in J^{SP}} e^{U_i \lambda_{SP}}} \quad (8.8)$$

Additionally, in the SP models, the equations (8.5) and (8.6) are scaled by a nested parameter ϑ_m . Where we have two nests:

- Train users. Given the inherent correlation across the modes of access to the station because all of them can be selected by the train users, the nested structure keeps in the same nest the alternatives related to train use. Those alternatives are the access or egress to the station: car, BTM, bicycle/PT-bicycle, walk and other mode.
- Non-users. The option ‘I would not travel by train’ is more associated with non-train use than with access/egress modes and is placed in a ‘non-users’ nest.

The parameter ϑ_m takes the value 1 if the alternative belongs to the ‘non-users’ nest, and takes the value θ_m if the alternative belongs to the ‘train-users’ nest. θ_m is an estimated parameter in the model. This structure is called mixed nested logit, and it allows the estimation of the more realistic market shares of train users, and it is applied in the scenarios of section 8.6.

8.4.3 Model Structure

In a joint RP–SP estimation, the model structure deserves special attention. In this particular case, the alternatives are not exactly the same in the SP as in the RP data. Moreover, the LOS information about the alternatives (cost, time) is not available in both data sets, or is not measured on the same scale (that is, travel time is either a categorical or continuous variable). This generates additional drawbacks in the joint estimation. Some authors have used only the LOS information available in the SP data and estimate ASC specifically for RP and RP, for example Bhat and Sardesai (2006). Other authors argue that if RP and SP alternatives are not exactly the same, then the ASC should be adjusted to match the market shares of

the base year (Cherchi and Ortúzar 2006b). Additionally, they consider specific LOS parameters for RP and SP, and additionally estimated two different models with specific and generic ASCs. However, the specification of generic or specific ASCs did not have any effect on results. This was certainly an important issue in the estimation because the two data sets are complementary and there is no relation between the mean of the error terms (Cherchi and Ortúzar 2006b). The common parameters will be the socio-economic parameters. In this way, we are allowing each data source to capture those aspects of the choice process for which it is superior, as explained in Cherchi and Ortúzar (2006a).

The utilities for the RP context are specified as:

$$\begin{aligned}
 \text{Car passenger: } V1_{RP} &= ASC_{1RP} + \sum \beta_{SE}^i X_{SE} + \sum \beta_{LOS} X_{LOS} + \zeta_{CAR} \\
 \text{Car Ddriver: } V2_{RP} &= ASC_{2RP} + \sum \beta_{SE}^i X_{SE} + \sum \beta_{LOS} X_{LOS} + \zeta_{CAR} \\
 \text{BTM: } V3_{RP} &= ASC_{3RP} + \sum \beta_{SE}^i X_{SE} + \sum \beta_{LOS} X_{LOS} + \zeta_{BTM} \\
 \text{Bicycle: } V4_{RP} &= ASC_{4RP} + \sum \beta_{SE}^i X_{SE} + \sum \beta_{LOS} X_{LOS} + \zeta_{bicycle} \\
 \text{Walk: } V5_{RP} &= ASC_{4RP} + \sum \beta_{SE}^i X_{SE} + \sum \beta_{LOS} X_{LOS} + \zeta_{walk} \\
 \text{Others: } V6_{RP} &= ASC_{6RP} \\
 \text{Non - train: } V7_{RP} &= ASC_{7RP} + \zeta_{NOTRAINRP}.
 \end{aligned} \tag{8.9}$$

Similarly, the utility equations for SP context are specified as:

$$\begin{aligned}
 \text{BTM: } V0_{SP} &= ASC_{0SP} + \sum \beta_{SE}^i X_{SE} + \sum \beta_{LOS} X_{LOS} + \zeta_{BTM} \\
 \text{Car passenger: } V1_{SP} &= ASC_{1SP} + \sum \beta_{SE}^i X_{SE} + \sum \beta_{LOS} X_{LOS} + \zeta_{CAR} \\
 \text{Bicycle: } V2_{SP} &= ASC_{2SP} + \sum \beta_{SE}^i X_{SE} + \sum \beta_{LOS} X_{LOS} + \zeta_{BIKE} \\
 \text{WALK: } V3_{SP} &= ASC_{3SP} + \sum \beta_{SE}^i X_{SE} + \sum \beta_{LOS} X_{LOS} + \zeta_{WALK} \\
 \text{OTHERS: } V4_{SP} &= ASC_{4SP} + \beta_{bike_{cost4}} X_{bike_{cost4}} \\
 \text{NON - TRAIN: } V5_{SP} &= ASC_{5SP} + \beta_{bike_{time5}} X_{bike_{time5}} + \zeta_{NONTRAIN}.
 \end{aligned} \tag{8.10}$$

where β_{SE}^i indicates a vector of alternative specific parameters of socio-economic characteristics, common for both SP and RP contexts. β_{LOS} is a vector of level of service characteristics (cost and time). Equations (8.9)

and (8.10) show that the error components (ζ_{it}) are also shared by both SP and RP, and these are alternative specific.

8.5 RESULTS OF JOINT RP–SP ESTIMATIONS

This section contains the results of the joint estimation of RP and SP surveys. The alternatives included in the RP context are: car driver, car passenger, BTM, walking, others and non-train use. The alternatives included in the SP context have been already described in section 8.3.

The parameters are either specific or unique for each database. Three parameters of socio-economic (SE) characteristics (gender and age) were estimated common to both RP and SP contexts. In the RP context, Table 8.3 shows six parameters related to travel characteristics, among which three are estimated for frequency of the journey and two parameters of trip purpose. Six parameters of level of service were estimated as dummy variables, among which four parameters belong to access time (BTM, walking, car and bus), and two parameters belong to cost (BTM and bicycle). Car cost was not collected in the survey to reduce the complexity of the questionnaire. Similarly, Table 8.3 shows the estimated parameters in the SP context: three cost parameters (BTM, car and bicycle), four parameters of time (BTM, car, bicycle and walking) and three parameters of cyclist infrastructure.

To obtain an advanced joint RP–SP estimation, the SE characteristics were estimated as generic parameters between RP and SP. LOS parameters are specific to RP and SP because: (1) the scale of travel time variables was categorical in the RP survey, whilst it was continuous in the SP experiment; (2) the information about cost was calculated via geographical information systems (GIS), since the BTM cost was not asked in the RP survey. The standard deviations in the RP survey were not significant, which is reasonable because one person chooses only one RP alternative. By contrast, the standard deviations in the SP data were all relevant. If the value is positive, this indicates that the individuals tend to choose the same alternative across different SP cards. Furthermore, the non-linear specification allows the distribution of the error terms according to possible correlation between modes. As can be observed in the standard deviation of BTM (σ_{BTM}) and bicycle ($\sigma_{Bicycle}$), those modes seem to be either correlated or competing. Consistent with the introductory discussion, the non-linear specification is more suitable for analysing SP data, and also reveals the real distribution of the error terms (Cherchi and Ortúzar 2002).

As can be seen in Table 8.3, the parameter λ_{RP} is statistically significant, which means that alternatives in the RP part are correlated among

Table 8.3 Results for SP and joint estimation RP-SP

Name	SP estimation value	Robust t-test	Joint RP-SP value	Robust t-test	Affected utility
ASC_2_			0.930	2.940	Car driver
ASC_0_SP			7.730	11.160	BTM SP
ASC_IRP			0.960	2.760	Car passenger
ASC_I_SP	-1.36	-3.83	6.110	12.480	Car passenger SP
ASC_2_SP	-0.428	-1.37	6.930	13.960	Bicycle SP
ASC_4RP			1.630	9.500	Bicycle RP
ASC_3RP					BTM-RP
ASC_3_SP	2.02	5.90	1.360	7.930	Walk-SP
ASC_5RP			9.660	18.980	Walk-RP
ASC_4_SP	-4.11	-9.35	2.090	10.850	Other mode-SP
ASC_6RP					Other mode-RP
ASC_5_SP	-3.54	-8.65	4.110	7.570	Non-train SP
ASC_7RP			0.988	8.700	Non-train RP
SE	SP unique		RP-SP generic		
β_{ageBTM}	0.00412	2.92	0.001	0.440	BTM
$\beta_{age-car}$	0.00274	1.81	-0.002	-1.710	Car
$\beta_{age-non-train}$	0.00474	4.82			Non-train
$\beta_{gender-car}$	-0.371	-1.55	-0.481	-3.400	Car
$\beta_{gender-bicycle}$	-0.2	-0.79			Bicycle
Travel related			RP-unique		
$\beta_{frequency_{car}}$			-0.62	-2.11	Car
$\beta_{frequency_{BTM}}$			-0.753	-4.38	BTM
$\beta_{work_{car}}$			-0.66	-2.83	Car
$\beta_{work_{bicycle}}$			0.327	2.81	Bicycle
LOS			RP-specific		
$\beta_{accesstime-bim}$			-1.000	-7.100	BTM
$\beta_{accesstime-walk}$			-2.230	-5.800	Walk
$\beta_{accesstime-car}$			-2.190	-8.680	Car
$\beta_{accesstime-bicycle}$			-1.870	-6.790	Bicycle
$\beta_{contBTMRP}$			0.104	2.650	BTM
$\beta_{contbicycleRP}$			2.000	8.070	Bicycle

LOS	(SP-specific)				
$\beta_{time_{BTM}}$	-6.14	-0.123	-5.050	BTM	
$\beta_{cost_{BTM}}$	-4.12	-0.193	-10.910	BTM	
$\beta_{time_{walk}}$	-11.03	-0.275	-4.750	Walk	
$\beta_{time_{car}}$	-3.27	-0.089	-4.280	Car	
$\beta_{time_{bicycle}}$	-4.81	-0.134	-4.990	Bicycle	
$\beta_{cost_{bicycle}}$	-10.69	-0.357	-10.230	Bicycle	
$\beta_{cost_{bicycle}}$	0.54	1.250	22.910	Other mode	
$\beta_{cost_{bicycle}}$	-3.13			Non-train	
Quality of cyclist and pedestrian infrastructure (SP-unique)					
$\beta_{C_{sp}}$	0.266	0.245	3.09	Bicycle	
$\beta_{C_{sp1}}$	0.548	0.613	3.67	Bicycle	
$\beta_{C_{sp2}}$	0.589	0.531	4.65	Bicycle	
$\beta_{P_{sp}}$	0.0439	0.0495	0.74	Walk	
$\beta_{P_{sp1}}$	-0.214	-0.103	-0.98	Walk	
$\beta_{P_{sp4}}$	-0.366			Other mode	
$\beta_{P_{sp14}}$	-0.833			Other mode	
$\beta_{P_{sp0}}$	-0.372			Non-train	
$\beta_{P_{sp2}}$	-0.368			Non-train	
$\beta_{P_{sp1}}$	-0.401			Non-train	
Standard deviations (error components for panel effects)					
σ_{WALK}		-0.101	-0.030	Walk SP	
σ_{BTM}		2.330	4.670	BTM SP	
σ_{CAR}		-1.440	-3.850	Car SP	
σ_{BIKE}		-2.010	-11.890	Bicycle SP	
$\sigma_{non\ train}$	-1.14	1.750	4.690	Non-train SP	
σ_{WALKRP}	-1.52	-0.035	-0.710	Walk RP	
σ_{BTMRP}	0.983	-0.008	-0.070	BTM RP	
$\sigma_{NOTRAINRP}$	2.29	0.007	0.120	Bicycle RP	
σ_{BIKERP}	-2.63	0.018	0.350	Non-train RP	
λ_{SPRP}		1.610	4.410	All alternatives	

themselves and, at the same time, those alternatives are independent of the alternatives in the SP part. It also means that the choice behaviour on the SP situations can be scaled to the RP data by a factor λ_{RP} . The heterogeneity in taste from the combined RP and SP data can be elicited only with the SP data if this is scaled by λ_{RP} .

The travel-related variables are RP-specific. It means that those variables were only included in the utility function of RP alternatives. As can be seen in Table 8.3, two travel-related variables are included in the specification: frequency and type of journey. Frequency of the trip is included as alternative specific parameter in both car and BTM access modes. Journey frequency is a dummy variable which is set as 1 if the person travels more than four times per week, and otherwise 0. In both cases, users are more likely to choose modes other than the car or BTM for frequent journeys. This is confirmed by the working trips parameter affecting the utility of bicycle (RP). The sign and t-test of this parameter indicates that workers (who are at the same time frequent travellers) tend to choose bicycle as their access mode to the train station.

The LOS parameters are RP and SP specific. Regarding the RP coefficients, the parameters of access time are negative, as expected. However, the parameter of BTM cost is positive, which is not consistent with the expectations. This is associated to the nature of this variable. The BTM cost was calculated based on a kilometre rate. The trip distance was calculated via GIS analysis from the home postcode provided by the respondent, to the departure station. The distance travelled in a journey by BTM tends to be longer than those by non-motorized modes, that is, bicycle. Then the average cost for BTM users is higher than for other modes. Consistently, the sign of the BTM parameter is positive.

The parameters of LOS, pedestrian and cyclist infrastructure keep similar magnitudes in both SP and joint RP-SP estimations. This means that the joint estimation is now improved but the SP estimation is unbiased. The parameter $\beta_{p_{sp2}}$ (improvement of current station environment for train passengers) is acting in the utility function of non-train use. As can be seen, this is a significant attribute for choosing train as main mode, as shown the t-test of the estimated parameter $\beta_{p_{sp2}}$ (improvement of current station environment). Consistent with Cascetta and Carteni (2014), the results show that enhancing the 'liveliness' at the train station (that is, the existence of cafés, restaurants and places to sit and talk) increases the likelihood of using the station. Additionally, regarding the selection of other access modes, the results show that a better quality of station environment encourages both bicycle and public transport use. The parameters $\beta_{p_{sp0}}$ and $\beta_{p_{sp1}}$ are negative, indicating that interruptions along the route deter train users from walking to the station.

8.6 VTTS BY TRIP PURPOSE AND MODEL STRUCTURE

Table 8.4 shows the VTTS for access and egress journeys for BTM and bicycle by trip purpose. Models labelled as ML (mixed logit) assume non-nested alternatives, as explained in section 8.4. θ_m is equal to one; while models labelled as NML (nested mixed logit) estimate a correlation parameter across alternatives in the same nest (θ_m). The correlation parameter is kept in the model structure only if it is statistically significant.

As can be seen, the VTTS in the egress journey by bicycle is higher than the VTTS in the access journey. This is consistent with previous (unpublished) studies by the NS (Netherlands Railways). Furthermore, the VTTS by bicycle is higher than the VTTS by BTM in both working and non-working journeys. This means that travel costs are higher for cyclists, therefore bicycle use is less attractive than BTM as an access mode. Additionally, this result is associated with the asymmetry between bicycle use for access and egress journeys. Bicycle use is substantially more difficult in the egress journey than in the access journey, given the bicycle availability at the train station.

It is interesting to analyse the VTTS of PT-bicycle users. The average price per hour is €6, while the VTTS of own bicycle use is €24 per hour. This result represents the amount of effort that cyclists need to make in using their own bicycle to leave the train station. At the same time, the VTTS of BTM users is €5 per hour, which means that the PT-bicycle is seen as a public transport mode that competes with BTM in the egress journey.

Moreover, the difference between VTTS by journey purposes is large in the egress part, where the VTTS –BTM increases substantially for non-working trips with respect to working journeys. At the same time, the VTTS for access is in overall lower than the VTTS for egress, consistent with Hensher and Rose (2007), who found that VTTS by public transport is higher in the access than in the egress journey of working trips. To the authors' knowledge, this is the first published result on mode specific VTTS in access and egress journeys to the station in the Dutch context.

For the present research, in the case of bicycle access, VTTS-egress is higher than VTTS-access; while in the case of BTM, VTTS-egress is lower than VTTS-access. Table 8.4 also shows the WTPs for better cyclist infrastructure. As can be seen, the WTP for a better infrastructure is higher in the egress journey than in the access journey. The values of WTP for avoiding five minutes of delay in the egress journey double the size of WTP in the access. By contrast, the WTP for a two-minute reduction from bicycle parking to platform is similar for both access and egress journeys.

Table 8.4 VTTS and WTP for access and egress journeys

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Type of model	ML	ML	ML	NML	NML	ML	NML	NML
Journey purpose	All	Working	Non-working	All	Working	All	Working	Non-working
Stage of journey	Access	Access	Access	Access	Access	Egress	Egress	Egress
Number of estimated parameters	37	29	28	38	30	28	28	28
Sample size	9144	3864	5508	9144	3636	9144	3636	5508
Rho squared	0.385	0.385	0.322	0.385	0.366	0.348	0.522	0.499
VTTS BTM (€/hour)	9.84	18.15	22.61	10.05	15.95	5.14	8.46	4.38
VTTS bicycle (€/hour)	15.87	23.15	19.36	15.96	22.18	24.66	24.60	25.11
VTTS PT-bicycle (€/hour)						6.07	4.79	9.10
WTP: no delays (C0) (€)	-0.80	-0.85	-1.11	-0.80	-0.79	-0.25	-0.02	-0.48
WTP: avoid delays 5 mins intersection (C1) (€)	0.85	-0.46	-2.46	-1.98	-1.97	-2.95	-2.49	-3.33
WTP: avoid delays 2 mins from platform (C2) (€)	-1.70	-1.68	-2.03	-1.72	-1.75	-1.88	-1.65	-2.17
ASC/bicycle (€)	-3.37	-0.46	0.919	-3.59	-4.49	-4.39	-6.48	-6.39
ASC/PT-bicycle cost (€)						0.92	-0.37	2.617

Of particular significance here is the high VTTS of non-working trips, for both access and egress journeys. This result is in line with Wardman (2004), who claimed that early walking to public transport is seen as a 'distressing' activity. According to this notion, the access to a railway station before work is more relaxing than during a non-working journey. Also, Wardman (2004) found substantially larger values of VTTS in leisure journeys than business travel by public transport. Particularly, the large VTTS of egress by bicycle in non-working journeys is related to the unavailability of bicycles at arrival stations.

Finally, the results in Table 8.4 highlight the differences in VTTS by model structures, which are the NML and ML. This indicates that omitting important correlations across access mode alternatives leads to overestimation of time valuation by train users. Methodologically, it means that selecting a proper model structure is very important for the accurate economic appraisal of transport measures.

8.7 SCENARIOS AND MARKET SHARES OF TRAIN RIDERSHIP

Using the parameters of Model 4 (access) and Model 6 (egress), we forecast scenarios according to hypothetical improvements in the LOS (cost and time) and station level. We select this model because it is the most generic approach. The scenarios are described as follows:

- Scenario 1: in this scenario, it is assumed that (guarded and unguarded) bicycle parking is free for all the choice situations.
- Scenario 2: improved station environment, only for medium-sized and small stations (less than 10 000 passengers per day), which means more restaurants and cafés that increases the 'liveliness'.
- Scenario 3: in this scenario, in addition to the implementation of free bicycle parking, the access time by BTM is reduced by 15 per cent.
- Scenario 1-egress: in this scenario, free (guarded and unguarded) bicycle parking is provided in the egress part of the SP experiment. It means that free bicycle parking is provided at arrival station.

Figure 8.3 shows the change in both bicycle and non-train user share. The differences are calculated in respect to a baseline scenario. The baseline scenario represents the stated choice experiment as it was conducted. We first compare the results of the baseline scenario with the current scenario. For example, the market share of non-users is 12 per cent, which represents the population that never use the train. The baseline is consistent with

Figure 8.3 Changes in probabilities of train and bicycle use for access and egress scenarios

the Customer Satisfaction Survey (KTO, acronym in Dutch) analysed by Givoni and Rietveld (2007) and Brons et al. (2009).

The differences between scenario 1 and the baseline shows that assuming that free bicycle parking in the access journey is provided, the probability of bicycle use increases by 3.4 per cent on average, while the probability of non-users would be reduced by 0.4 per cent.

The difference between scenario 2 and the baseline shows that by enhancing the 'liveliness' of medium-sized and small stations, the number of train passengers would increase by 2.5 per cent. It means that train ridership is influenced by both bicycle parking cost and station quality. Moreover, the 'liveliness' of station environment plays a role almost as important as the bicycle parking cost in the decision to travel by train or not.

Scenario 3 assesses the importance of improving public transport accessibility to the station. Reducing the travel time by BTM by 15 per cent would increase the train ridership by 0.5 per cent, equivalent to 3100 passengers/day among the 38 stations sampled. The results indicate that investments in public transport connection to the rail station would increase rail use, by making the journey a smoother chain of public transport modes. Consistent with Brons et al. (2009), the results show the effects of a smoother chain of modes in the whole train journey.

Table 8.5 shows the average changes in market shares of access modes by station type. The last column on the right shows the average number of passengers per day depending on the station size. The total increase

Table 8.5 Average change in market shares of access modes by station type

Row labels	Average of S1 Δ BIKE (%)	Average of S2 Δ BIKE (%)	Average of S2 Δ BTM (%)	Average of S1Δ NON- USER (%)	Average of S2 Δ NON- USER (%)	Δ S1 Total # of passengers	Av. passengers/ day
1	3.30	-0.74	1.72	-0.35	-0.21	71	10000
2	3.31	-0.77	1.79	-0.36	-0.22	1404	65000
3	3.31	-0.70	1.60	-0.32	-0.18	258	20000
4	3.27	-0.63	1.44	-0.30	-0.16	127	6000
5	3.27	-0.61	1.40	-0.30	-0.16	121	2500
6	3.24	-0.70	1.61	-0.32	-0.20	19	2000
Total	3.29	-0.71	1.64	-0.34	-0.20	1999	

Note: N = 38 stations.

in passengers is calculated by multiplying the change in non-users by the number of respondents by station type in the sampled network. For scenario 1, a total of 2000 passengers would be added to the 38 stations analysed in the survey.

8.8 CONCLUSIONS

This chapter estimates both joint RP-SP and SP choice models of station access and egress mode in the wider metropolitan area of The Hague-Rotterdam, in the Netherlands. The joint RP-SP estimation allows the verification of unbiased results in the SP models. Moreover, this chapter analyses mode specific VTTS and measure specific WTP. Finally, by developing different attribute combinations, a sensitivity analysis of train ridership is calculated.

The results show that train ridership strongly depends on access time by the different access modes. At the same time, train passengers are attracted by both free bicycle parking costs and low bus, tram or metro fares. The positive effect of free bicycle parking on train ridership is consistent for both access and egress journeys. In addition, improving the 'liveliness' of stations also increases the probability of train use in the small and medium-sized stations.

From a methodological perspective, the results show that the model structure is relevant for the estimation of accurate market shares in modes of access and egress. The estimation of both NML and MNL shows that omitting the correlation across alternatives tends to overestimate the market shares, and also the VTTS and WTP.

In future research, the calculation of VTTS by car for access and egress would complete the mode specific research. In this study, that was not possible because the cost of car access/egress was not available in the SP experiment. In addition, we did not include network effects which are likely to occur when the quality of access and egress transport changes. Changes in station accessibility, however, affect the catchment area of railway stations and are likely to result in network effects. Bicyclists might, for example, choose a larger railway station farther away as a departure station when bicycle parking is improved, instead of choosing the closest local train station. This can be included by incorporating the VTTS and WTP values in a regional or national transport demand model which would also allow a comparison between market shares from discrete-choice models and simulation models to be possible.

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