HOME-ACTIVITY APPROACH TO MULTI-MODAL TRAVEL CHOICE MODELLING

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Inhoudsopgave

Samenvatting

Onderscheid woning- en activiteitenzijde bij modelleren van multi-modaal reiskeuzegedrag

Traditionele aanpakken voor het modelleren van reiskeuzegedrag in multi-modale netwerken maken onderscheid naar voor- en natransport en niet naar woning- en activiteitenzijde. Onze veronderstelling is dat verschillen tussen woning-en activiteitenzijde met betrekking tot een groot aantal aan de reisgerelateerde aspecten relevant zijn in het reiskeuzeproces en daarom in oogschouw moeten worden genomen bij het modelleren van multi-modale reiskeuzegedrag. In dit artikel laten we zien dat de veronderstelde verschillen tussen woning- en activiteitenzijde daadwerkelijk bestaan en met name tot uitdrukking komen in de beschikbaarheid en het gebruik van multi-modale reisalternatieven en in de kennis die reizigers hiervan hebben. Voor de analyse is gebruik gemaakt van waargenomen multi-modale treinreizen in de Randstad. Daarnaast presenteren we een nieuwe modelaanpak, de zogeheten *home-activity* modelaanpak, waarin expliciet onderscheid gemaakt wordt tussen de woning- en de activiteitenzijde en waarin alle attributen richtingsvrij zijn. De aanpak wordt geïllustreerd middels een Generalised Nested Logit model, waarin op correcte wijze omgegaan kan worden met correlaties tussen vervoerwijzen aan woning- en activiteitenzijde. De analyse laat sterke verschillen zien in de waardering die reizigers voor de karakteristieken aan de woning- en activiteitenzijde hebben. Karakteristieken aan de woningzijde blijken een belangrijkere rol in het plannen van een multi-modal treinreis te maken dan karakteristieken aan de activiteitenzijde.

Summary

Home-activity approach to multi-modal travel choice modelling

Traditional multi-modal travel choice modelling approaches, applicable to single trip data, distinguish access and egress, but make no difference between travellers’ home or activity addresses. We hypothesize that the differences between home-end and activity-end with respect to a number of travel-related factors are relevant in the travel choice process and therefore need be accounted for correctly in multi-modal travel choice models. In this paper, we empirically show that differences indeed exist in availability, use and knowledge of multi-modal trip alternatives. In the analysis, Revealed Preference data of multi-modal train trips in The Netherlands are used. We present a new *home-activity* modelling approach in which the home-end and activity-end are explicitly taken into account in the utility specification and all attributes are direction-free. To illustrate the approach, a Generalised Nested Logit model, suited to capture correlations caused by home-end and activity-end feeder mode types, will be applied to the multi-modal train trip data. We have found that differences in travellers’ valuation of home-end and activity-end characteristics exist. More specifically, home-end characteristics play a more important role in planning multi-modal train trips than activity-end characteristics.

1 Introduction

Modelling multi-modal travel behaviour is a complex task. Travellers make a many choices with respect to modes, services, boarding nodes, transfer nodes and alighting nodes. We hypothesize that the differences between the *home-end* and the *activity-end* of a trip are relevant in the travel choice process and should therefore be properly accounted for in multi-modal travel choice models. This is plausible because first of all, travellers have other modes *available* at the home-end than at the activity-end. Secondly, travellers' level of *knowledge* of transport systems and road networks will be higher in the neighbourhood of their homes than near activity locations. Thirdly, the *modal split* of feeder modes differs between the home-end and the activity-end. All these aspects are likely to influence travellers' appreciation of home-end and activity-end trip characteristics. On top of that, distinguishing the home-end and the activity-end instead of access and egress allows for typical tour-related characteristics, while maintaining the simplicity of analysing single trips. These issues will be discussed in detail in the remainder.

The key questions that will be answered in this paper are:

1. How large are the differences in availability, use and knowledge of feeder mode and railway station alternatives between the home-end and the activity-end of a trip?
2. Do these differences results in different travel behaviour at the home-end and the activity-end?
3. If so, what is the role of the home-end and the activity-end in the multi-modal travel choice process?

To answer these research questions, the following approach has been used. Chosen, known and available multi-modal train trips are analysed, focusing on differences in feeder modes and railway stations at the home-end and the activity-end of a trip. An new multi-modal trip modelling approach explicitly distinguishing the home-end and the activity-end of a trip, is introduced and motivated. Multi-Nomial Logit (MNL) and Generalized Nested Logit (GNL) models are adapted in line with the proposed approach, and are subsequently estimated and interpreted.

Given the estimation results presented in the remainder of the paper, we will show that our hypothesis regarding the relevance of distinguishing the home-end and activity ends is indeed correct. In particular, empirical evidence points towards differences between the home-end and the activity-end with respect to feeder mode use, travellers' knowledge of feeder mode alternatives and availability of feeder mode alternatives. With respect to multi-modal travel behaviour, differences in travellers' valuation of home-end and activity-end trip attributes will be highlighted suggesting a more important role of home-end characteristics.

The paper is structured as follows. First, we define multi-modal trip making. Then, we motivate the importance of explicitly accounting for the home-end and the activity-end of a trip in multi-modal travel choice modelling and the subsequent need for utility specifications that are independent of the direction of the trip. Subsequently, the concept of direction-free utility specifications is introduced. A short description is given of the multi-modal train trip data that is used to analyse home-activity choice behaviour. An empirical analysis of home-end and activity-end characteristics is presented, including use, availability and knowledge of private transport modes and public transport services. Thereafter, MNL modelling results are shown that strongly indicate differences in choice behaviour between the home-end and the activity-end of a trip. Next, a specific type of GNL model, suited to capture correlations between alternatives caused by home-end and activity-end modes, is introduced and applied. The paper concludes with summarizing the main findings.

2 Definition of a multi-modal trip

A *trip* is a sequence of transport modes and transfer nodes connecting a given OD-pair. A trip is *multi-modal* if it involves at least one transfer between - not necessarily different - mechanized modes. A multi-modal trip thus consists of either combinations of multiple public transport modes or combinations of public transport and private modes (e.g. bike and car). A leg is defined as a part of a trip for which a single mode is used (no intermediate transfers).

For inter-urban trips to major cities, the market share of multi-modal alternatives amounts to more than 20%, where train is the most frequently used main mode. In nearly 60% of the cases, train covers the longest distance of the multi-modal trip (*8*). Therefore, the empirical analysis in this paper focuses on inter-urban, multi-modal train trips.

A trip is called *homebound* if either the origin or destination of the trip is the traveller's home address. A homebound trip, in which train is used as main mode, can be divided into three components, namely a *train trip part* and *two non-train trip parts*. A distinction between the non-train trip parts can be made in two ways:

- *access and egress*, where access is defined as the trip part from the origin to the boarding railway station, and egress is the trip part from the alighting railway station to the destination;
- *home-end and activity-end*, where home-end refers to the trip part from / to the railway station near the traveller's home address, and activity-end refers to the trip part from / to the railway station near the traveller's activity address.

In the introduction, we have hypothesized that the classification of the home-end and the activity-end is more important in multi-modal travel choice modelling than the distinction of access and egress. This will be motivated from a theoretical perspective in the next section.

3 Motivation of home-activity, direction-free modelling approach

In this section, we motivate the hypothesized relevance of distinguishing home-end and activity-end in multi-modal travel choice modelling - resulting in a *home-activity* approach - and the inclusion of *direction-free* attributes in the utility specification in case single trip data is used.

3.1 Motivation of distinguishing the home-end and the activity-end

Classical travel choice modelling approaches distinguish access and egress (*7*, *9*). This means that in *access-egress* modelling approaches, it makes no difference whether or not a trip end is the traveller's home or activity address. This implies that differences between the home-end and the activity-end of a trip cannot be properly accounted for in an access-egress modelling approach. We argue that the differences between home-end and activity-end with respect to a number of travel-related factors are relevant in the travel choice process and should therefore be accounted for in travel choice models. The use of the *home-activity* modelling approach, in which the home-end and the activity-end taken into account, is justified from:

1. actual use, availability and knowledge of public transport and private modes near travellers' home and activity addresses;
2. opportunity to account for tour-related characteristics, while maintaining this implicitly of analysing single trip data.

First of all, travellers mostly have other modes *available* at the home-end than at the activity-end, which especially holds for home-bound modes (bike and car). Secondly, travellers' level of knowledge of transport systems (location of stops and timetables) and local road networks (walking, cycling and car routes) will be higher in their neighbourhoods compared to activity locations. Thirdly, the *modal split* of feeder modes differs between the home-end and the activity-end. All these aspects are likely to influence travellers' appreciation of home-end and activity-end trip characteristics. Thus, differences might be expected in travellers' appreciation of mode-related trip attributes (in-vehicle times, walking distances and so on) that should thus kept in mind modelling multi-modal travel choice behaviour.

It is reasonable to assume that travellers keep the return trip in mind when planning the outbound trip, because decisions made for the outbound trip might influence types and number of alternatives that are available for the return trip, and vice versa. This mainly relates to ticket type and availability of home-based transport modes, like bike and car. Seasonal or return tickets for public transport are considerably cheaper than single tickets. However, such tickets often apply to a specific OD-relation. Travellers might use the same transport services between the same boarding and alighting stops to reduce public transport travel costs. With respect to vehicle availability, a traveller, using a car in the morning to go to the railway station, is highly to travels via this railway station on the way home to pick up the car. Therefore, outbound and return trips should not without further thought be modelled independently of one another. Availability of home-based transport modes and use of ticket types are typical characteristics that might be dealt with in a *tour-based* modelling approach in which outbound and return trip are modelled simultaneously. However, modelling multi-modal tours is not an easy task. Planning multi-modal tours involves many different choices, like boarding and alighting railway stations, train service types, transfer stations, and so on. To properly determine the importance of all kinds of relevant characteristics in the multi-modal travel choice process, detailed data on the different transport modes and services (types of modes, line numbers, boarding and alighting stops, departure and arrival times, ticket types, etc.) and transfers (walking distances, waiting times, etc.) are required. In practice, such detailed data is hardly ever available for both outbound and return trips. Distinguishing home-end and the activity-end in trips allows for accounting for typical tour-related characteristics, while maintaining the simplicity of analysing single trips. This is just another argument to adopt the home-activity modelling approach.

3.2 Motivation of direction-free approach

In traditional multi-modal travel choice modelling, transfers are generally accounted for by including *directional* trip attributes in the utility specification, such as types of transfers, transfer-waiting times and transfer-walking times. The value of transfer attributes is often dependent on the direction of the trip, i.e. outbound or return trip. Application of the home-activity modelling approach on single trip data, is based on the assumption that outbound and return trips have the same attribute structure, meaning that similar transport modes and transfer nodes are used, albeit in reversed order. The distinction between home-end and activity-end is leading and whether or not a trip is an outbound or a return trip is not taken into account. Therefore, only direction-free trip attributes can be included in the utility function, such as in-vehicle times, costs, and frequencies.

Although many transfer attributes are directional attributes, this does not mean that transfer characteristics cannot be accounted for in direction-free route choice models. Possible attributes are:

- number of transfers, not distinguishing modal combinations;
- number of legs, possibly distinguishing high-frequency legs and low-frequency legs;
- frequencies for home-end and activity-end trip parts.

For instance, in order to account for expected positive effects of high-frequency services - as opposed to low-frequency services - in a direction-free model, a distinction can be made between the number of high-frequency legs and the number of low-frequency legs, where the number of legs is closely related to the number of transfers. Different definitions of high-frequency and low-frequency legs will be tested later in this paper.

Limited inclusion of transfer attributes might be seen as a drawback of the home-activity modelling approach. Preliminary modelling results (*4*), however, show that the advantage of explicitly accounting for home-end and activity-end characteristics is much larger than the disadvantage of a less detailed specification of a transfer.

4 Home-activity analysis of inter-urban train trips

This section briefly describes the Revealed Preference data that has been collected to estimate the choice models that are presented in the remainder of the paper. Furthermore, characteristics of the home-end and the activity-end of a trip are shown, especially focusing on chosen trips, reported and available multi-modal alternatives.

4.1 Collected data

For the estimation of home-activity models, multi-modal travel behaviour data will be used from a survey conducted among train travellers in an urbanized corridor in The Netherlands, including cities like Dordrecht, Rotterdam, The Hague and Leiden (*4*). The survey focused on used multi-modal trips (which modes were used, what were the transfer nodes, what were the boarding and alighting nodes) and on train-based trip alternatives known by travellers. The survey data was extended with detailed data on all trip components, such as in-vehicle times and costs, as well as with similar data for all other reasonable, non-reported alternatives for the same trip. These reasonable routes were generated using a diachronic-graph representation of the multi-modal transport system (*4*).

The considered sample contains 708 homebound trips. 70% and 30% of the trips are outbound-trips and return-trips, respectively. All trips correspond to different OD-pairs. Travellers' home and activity addresses are located throughout the research area. On average, there is no apparent difference between locations of origin and destination addresses (e.g. with respect to city type, location within the city and public transport supply). The number of reasonable trip alternatives is very large. A more detailed description of the data collection and the data can be found in (*3*, *4*).

4.2 Characteristics of the home-end and the activity-end

Reported chosen trips were analysed for expected differences in feeder mode and railway station use between the home-end and the activity-end of a trip. Figure 1 shows the distributions of feeder modes used at the home-end and the activity-end to travel from / to railway stations. A distinction between regions (i.e. Rotterdam, The Hague and smaller cities) has been made to account for expected differences in feeder mode use due to differences in availability of urban public transport (UPT) and service frequencies between the different regions. Shares of private feeder mode transport are high at the home-end as well as the activity-end (55% - 72%). Shares of public transport modes are slightly higher at the activity-end than at the home-end. Furthermore, supply of UPT services and city size influence use of private and public transport modes. In regions with smaller UPT supply (in terms of services types, service frequencies and line densities), private mode use is considerably larger (± 75%)

than in regions with higher UPT supply (± 50%). Travellers mainly use direct feeder transport to and from railway stations (except for metro-metro in Rotterdam). The low number of home-end trip parts with multiple legs might be explained from the transportation network (many public transport lines offering direct transport services to and from train stations) and from travellers' preferences (travellers do not like to make transfers).

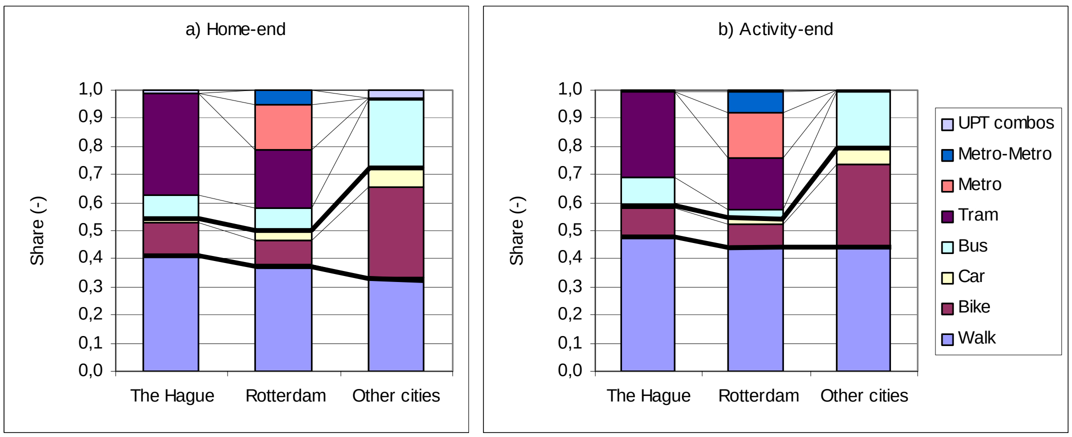

Figure 1: Distribution of used (a) home-end and (b) activity-end feeder modes by region.

Due to limited availability of bike and car at the activity-end, modal split on both trip ends differ considerably. The shares of bike and car are higher at the home-end than at the activity-end. However, the share of walking is higher at the activity-end than at the home-end, resulting in a total share of private transport modes that is higher at the activity-end than at the home-end. This thus implies that UPT use is higher at the home-end than at the activity-end. We emphasize that locations of OD-addresses and characteristics of public transport services are similar for both trip ends, and as such do not cause the observed difference in mode use between the home-end and the activity-end. Furthermore, choices of feeder modes at the home-end and the activity-end appear to be independent of one another, and distributions of feeder mode distances to railway stations as well as UPT service frequencies at the home-end and the activity-end are similar. Opposed to the findings for feeder modes, no differences were found with respect the use of boarding and alighting railway station types between home-end and the activity-end of a trip.

The majority of *reported* (*thus known*) *non-chosen alternatives* are simple variations on reported chosen trips, differing mainly from them with respect to home-end and activity-end feeder modes. As might be expected, the number of known alternatives is larger at the home-end than at the activity-end. This does not only hold for private feeder modes, but for urban public transport as well. Analysis of *available* alternatives shows that the number of available private feeder modes is significantly larger at the home-end than at the activity-end.

The analysis of chosen trips, reported non-chosen alternatives, and other available alternatives clearly shows the expected differences in use and availability of private transport modes between the home-end and the activity-end. Furthermore, travellers' knowledge of public transport systems and of local road networks appears to be larger at the home-end than at the activity-end, being reflected in the number of reported alternatives. These differences in knowledge and availability also become apparent in the use of feeder modes.

5 Multi-nomial logit modelling results

In the previous section we have shown empirical evidence that differences in use, availability and knowledge alternatives between the home-end and the activity-end exist, especially with respect to feeder transport. The question is: 'Do such differences result in differences in travel behaviour?'

We start our modelling with Multi-Nomial Logit (MNL) models. Despite their theoretical shortcomings, MNL-models are known to be robust, justifying their use as a first step in the analysis of multi-modal travel choice behaviour. MNL-models are merely used to explore relevance, i.e. size and significance, of trip attributes. Table 1 shows the best MNL-model that contains 25 direction-free trip attributes, including in-vehicle times per mode, costs for UPT and parking, UPT headway, walking time to UPT-stops, number of high-frequency / low-frequency legs, feeder mode indicators, train service specific indicators, and railway station indicators. All parameter estimates appeared to be all highly significant. Mode and railway station indicators are defined for the home-end as well the activity-end.

5.1 Importance of the home-end and the activity-end

MNL-modelling results strongly indicate differences in choice behaviour between the home-end and the activity-end of a trip. There appears to be a significant and systematic difference between home-end and activity-end (public transport) feeder mode indicators[1]. Activity-end

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[1] Note that the mode-specific indicators in this paper are not alternative-specific constants, but rather mode specific parameters. The utility function includes mode-specific variables (indicators) that sum up to one for each trip end. If a traveller subsequently uses two busses and a tram as home-end feeder transport, the home-end bus specific variable is equal to 2/3, while the home-end tram specific variable is equal to 1/3. All other home-end mode specific variables are equal to zero. Walking is defined to be the base mode and its corresponding parameter value is set to zero at both trip ends.

public transport feeder mode indicators are ± 5 minutes of train in-vehicle time (IVT) larger than the corresponding home-end ones. The ranking of transport modes is the same for both trip-ends and is equal to walk, bike, metro, (car), tram and bus.

Figure 2a shows contributions of home-end, activity-end, and train trip parts to total trip utility of chosen and non-chosen alternatives. Home-end and activity-end utilities are composed of utilities induced by feeder mode indicators, feeder mode-specific in-vehicle times, walking times from / to UPT stops, and UPT headway. Train trip part utility consists of utilities generated by railway station indicators, train service specific indicators and train in-vehicle time. The home-end, the activity-end and train trip parts appear to be equally important in the multi-modal route choice process (equal shares). This implies that 2/3 of total trip utility comes from access to and egress from railway stations, while it only accounts for 50% of the travel time. Accessibility of railway stations thus is an important issue, which should be accounted for adequately.

5.2 Importance of transfer attributes

In the utility specification of the best MNL-model only direction-free attributes are included. Therefore, transfers cannot be modelled using traditional directional transfer attributes, like transfer-waiting times and transfer-walking times. An analysis has been performed on the way transfers can be accounted for using various definitions for the number of legs, while including the frequencies of the home-end and activity-end public transport services. The following options have been analysed:

- total number of legs;
- number of legs with a distinction between of high-frequency and low-frequency legs (4 up to 12 vehicles per hour):
    - for public transport legs only;
    - for public transport legs as well as private mode legs (i.e. car and bike), the latter are assumed to be high-frequency legs;
    - for public transport legs, private mode legs, and walking to and from railway stations.

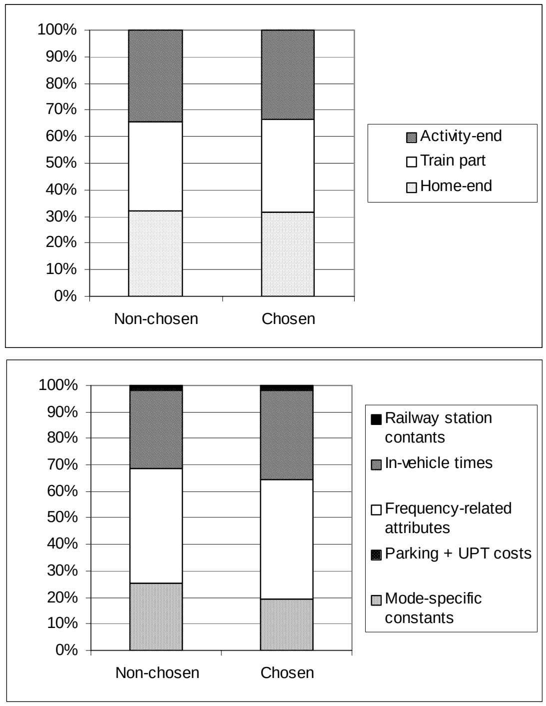

Figure 2: Contributions of a) home-end, activity-end, and train trip parts to the mean utility of chosen and non-chosen alternatives, and b) contributions of mode indicators, train station indicators, in-vehicle times, transfer aspects and costs to the mean utility of chosen and non-chosen alternatives.

Analysing the results of the various MNL-model specifications, we concluded that the best modelling results are obtained if not only high-frequency public transport services but also home-bound transport services and walking to railway stations are considered to be high-frequency legs. This result might be explained from the free time-accessibility of walk, bike and car. Furthermore, travellers seem to consider walking to railway stations as a real part of a multi-modal train trip and as an alternative to for example cycling or UPT. Walking to UPT stops, however, appears to be seen as inevitable to UPT use. Parameter estimates of high-frequency and low-frequency legs appeared to be significantly different from one another with an optimal boundary value of 8 times per hour to differentiate between them.

Figure 2b shows contributions of different trip types of attributes to total trip utility of chosen and non-chosen alternatives. In the analysis, five types of attributes are distinguished, namely mode-specific in-vehicle times, transfer attributes, costs, mode indicators and railway station indicators. The contribution of costs as well as railway station indicators to total trip utility (for chosen and non chosen alternatives) is small (less than 2%). Costs and railway station types are thus relatively unimportant aspects in planning multi-modal train trips. In-vehicle times, transfer aspects and mode indicators contributed considerably to total trip utility. On average, the share of utility induced by in-vehicle times is equal to 30%, while the share of utility induced by mode indicators is equal to 25%. The largest share of utility (43%) is generated by transfer aspects. These findings indicate that in a direction-free home-activity model transfer characteristics can adequately be accounted for, including the frequency aspect, while it sheds a new light on the role of walking as access and egress mode for railway stations.

6 Accounting for correlations In multi-modal trip making

Multi-modal trip alternatives consist of multiple components, such as home-end, train and activity-end legs, each of which may be a source of correlation between alternatives. These correlations cannot be accounted for using MNL-models. Therefore two alternative approaches have been considered: Path-size Logit and Generalized Nested Logit.

6.1 Path size Logit

One way to account for correlation between alternatives, more specifically correlation resulting from common route parts, using a path size modelling approach (*5*, *6*), results in a significant improvement in modelling performance (log likelihood value -1593.76 compared to -1616.39). The path size of an alternative may be considered as the reciprocal of route commonality (*2*). Route commonality in multi-modal route choice requires a specific definition in terms of common transport modes, common transport services and common boarding, alighting and transfer nodes, instead of time or distance. Although the path size modelling approach captures part of the correlation between alternatives, it does not specifically account for the unobserved similarities between home-end and activity-end modes. This can be seen by the fact that, just like the MNL-results, feeder mode indicators still differ between the home-end and the activity-end of a trip. Path Size Logit modelling results are not shown in this paper.

6.2 Generalized Nested Logit

Different groups of alternatives can be distinguished based on either home-end or activity-end characteristics, such as type of railway station and feeder mode transport. However, both distinctions (home-end or activity-end) do not necessarily result in the same grouping of alternatives. An alternative with tram and bicycle as home-end and activity-end feeder mode, respectively, is categorized as ‘public transport’ and ‘private transport’ based on home-end and activity-end feeder mode, respectively. Therefore, Nested Logit (NL) models will not suffice. Generalized Nested Logit (GNL) models, however, offer a means to account for these similarities by combining similar alternatives into nests.

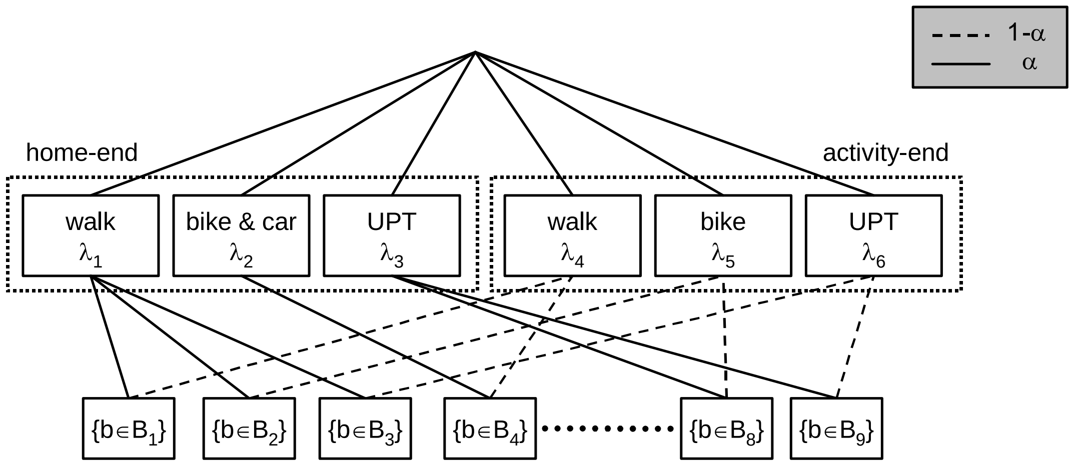

Figure 3: Nesting structure of the GNL-α model, distinguishing walk, bike&car and UPT nests at both the home-end and the activity-end of a trip. Each alternative is allocated to only one home-end (α) and only one activity-end nest (1-α), and logsum parameters are not necessary equal for corresponding nests.

For multi-modal train trip making alternatives can naturally be grouped, such that each alternative belongs to only one home-end and only one activity-end nest. This can be modelled in a special type of GNL-model, called GNL-α, which explicitly accounts for the home-end and the activity-end of a trip. This type of model introduces two types of parameters: allocation factors that define to which extent an alternative belongs to home-end and activity-end nests, and the logsum parameters for each of the nests. Due to the fact that the number of and characteristics of alternatives differ among travellers, the extent to which an alternative is allocated to a home-end and an activity-end nest cannot be estimated, and is assumed to be the same for each alternative (α and 1-α for home-end and activity-end nests, respectively). Since allocation parameters are equal for all home-end nests and for all activity-end nests, it is plausible that setting all logsum parameters equal for all nests does not offer enough flexibility to accommodate the choice problem. Therefore, different logsum parameters are estimated for each nest, simultaneously with attribute parameters in the utility function (see Figure 3). The probability that alternative *i* is chosen can then be written as:

$$P_i = \frac{\alpha e^{V_i/\lambda_h}\left(\sum_{b\in B_h} e^{V_b/\lambda_h}\right)^{\lambda_h-1} + (1-\alpha)e^{V_i/\lambda_{act}}\left(\sum_{b\in B_{act}} e^{V_b/\lambda_{act}}\right)^{\lambda_{act}-1}}{\alpha\sum_{l=1}^{H}\left(\sum_{b\in B_l} e^{V_b/\lambda_l}\right)^{\lambda_l} + (1-\alpha)\sum_{l=1}^{ACT}\left(\sum_{b\in B_l} e^{V_b/\lambda_l}\right)^{\lambda_l}}$$

when alternative *i* belongs to home-end nest *h* and to activity-end nest *act*, where *H* and *ACT* are the sets of all home-end and activity-end nests, respectively, and with λ_h and λ_{act} the logsum parameters of nests *h* and *act*, respectively. For a more elaborate discussion on GNL-models we refer to (*10*). The next section shows Generalized Nested Logit modelling results.

7 GNL-modelling results

Estimating GNL-models is computationally demanding. Therefore, first Nested Logit (NL) models were estimated to determine relevant nesting structures. It was found that nests based on feeder mode types yield a substantial improvement in modelling performance, while nests based on railway station types had no impact at all (*4*). Therefore, GNL-models were estimated having nesting structures based on feeder mode types at the home-end as well as the activity-end. Table 1 shows modelling results of the best GNL-model, where separate walk, bike&car and UPT nests are distinguished. The GNL-model shows a considerable improvement (from -1616.39 to -1584.02) in log likelihood value. Using a χ^2-test, it appears that this improvement in log likelihood value is significant compared to both the best MNL-model and the best NL-models, which are based on either home-end or activity-end transport modes at a 95%-confidence level. NL-modelling results can be found in (*4*).

7.1 Importance of the home-end and the activity-end

The allocation parameter α has been determined by systematically varying it between 0.4 and 0.8, and appears to be equal to 0.65. The finding that α is 0.65 implies that in planning a multi-modal train trip, similarities in nests for home-end feeder modes are twice as important as for activity-end nests. In the GNL-model, feeder mode indicators at the home-end and the activity-end proved not to be significantly different from one another, and were therefore constrained to be equal. Posing this constraint hardly influences the final log likelihood value. The fact that feeder mode indicators at the home-end and the activity-end appear to be not significantly different from one another clearly shows that the GNL-nesting structure indeed accounts for similarities in unobserved characteristics induced by the home-end and the activity-end of a trip. The differences between home-end and activity-end feeder mode indicators for the MNL-model appear to be caused by correlations between home-end and activity-end modes. As a result, the feeder mode indicators in the resulting GNL-model account to a larger extent for pure feeder mode related characteristics, like comfort, privacy and vehicle speeds, than the ones in the MNL-model. Note that other parameter estimates in the GNL-model are of the same order as those in the MNL-model.

8 Conclusions and recommendations

In this paper, a home-activity approach to multi-modal travel choice modelling has been put forward. In this approach, the home-end and the activity-end of a trip are accounted for explicitly and only direction-free trip attributes were included in the utility function, such as in-vehicle times, costs, number of legs and frequencies.

To test the importance of distinguishing the home-end and the activity-end, we have analysed chosen trips, reported non-alternatives and available alternatives from a sample of multi-modal train trips in The Netherlands. This analysis reveals large differences in use and availability of feeder modes and in travellers' knowledge of the public transport system and the local road network. To establish whether or not observed differences in home-end and activity-end attributes result in differences in travel behaviour between both trip ends and to determine their impact on the multi-modal travel choice process, we applied Multi-Nomial Logit (MNL) and Generalized Nested Logit (GNL) models in line with the proposed approach. MNL modelling results suggest that differences in travellers' valuation of home-end and activity-end trip attributes indeed exist. Using a GNL model, distinguishing nests based on home-end and activity-end feeder modes, we found that the home-end appears to be twice as important as the activity-end.

The paper thus clearly showed that choice behaviour differs between the home-end and the activity-end, which makes sense from a behavioural perspective as well as from a modelling perspective. It should therefore be accounted for when modelling travel choice behaviour. Furthermore, transfers can properly be accounted for in a home-activity approach by inclusion of direction-free transfer attributes, like the number of legs and frequencies of UPT services, in the utility specification. The logical question then is, whether direction-free home-activity models lead to a better performance than traditional directional access-egress models. Analysis by Hoogendoorn-Lanser (*4*) indicate that this is indeed true. Direction-free home-activity models appear to be more robust, while having less correlation between the parameters than directional access-egress models. Adjusted rho-squared values are similar. However, more research is needed for a thorough comparison of both approaches.

Table 1: Multinomial Logit model results (#trips = 708 and #alternatives = 23,494) and Generalized Nested Logit model results with nesting structures based on transport modes at the home-end and the activity-end of a trip (parameter estimates are scaled to units of train IVT).

		Multinomial Logit		Generalized Nested Logit α=0.65	
Home-end / Activity-end	Mode indicators	Home-end	Activity-end		
	Walk[2]	0	0	0	
	Bike	-16.99[4]	-16.99[4]	-15.82	
	Car	-24.87	-	-23.16	
	Bus	-33.53	-38.44	-38.55	
	Tram	-25.82	-31.19	-29.81	
	Metro	-17.17	-23.97	-21.41	
	Train station indicators	Home-end	Activity-end	Home-end	Activity-end
	Intercity train station[2]	0	0	0	0
	Express train station	0[3]	-7.26	0[3]	-6.56
	Local train stations	-7.71	-11.66	-9.10	-12.27
	Logsum nests			Home-end	Activity-end
	Walk	n.a.		0.58	0.60
	Bike & car	n.a.		0.32	0.48
	Public transport	n.a.		0.42	0.36
Train	Train indicators				
	Intercity train station[2]	0		0	
	Express train	-5.64		-5.64	
	Local train	-7.02		-7.02	
Whole trip	In-vehicle times (min)				
	Walk	-2.38		-2.52	
	Bike	-2.61		-2.74	
	Car	-4.26		-4.46	
	Bus	-0.40		-0.30[1]	
	Tram	-0.84		-0.80	
	Metro	0[3]		0[3]	
	Train	-1 (-0.104)		-1 (-0.06)	
	Number of legs				
	Low-frequency (<8)	-24.70		-22.91	
	High-frequency (≥8)	-20.55		-18.64	
	Costs (€)				
	Parking costs	-2.55[1]		-4.04	
	UPT-costs	-3.72		-3.94	
	Other (min)				
	Total UPT headway	-0.13[1]		-0.16	
	Walking time to UPT-stops	-2.21		-2.41	
Statistics	Final log likelihood	-1616.39		-1584.02	
	Likelihood ratio test	1531.71		1596.45	
	Free parameters	25		27	

[1] 1.65 ≤ t-statistics ≤ 1.96. [2] The IC train indicator, the walk indicators and the IC railway station indicators were constrained to be zero (base parameters). [3] The express train station indicators at the home-end and the metro IVT parameter appeared not to be significantly different from zero and were therefore constrained to be equal to zero. [4] Bike indicators at home-end and at activity-end appear not to be significantly different from one another and were constrained to be equal.

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