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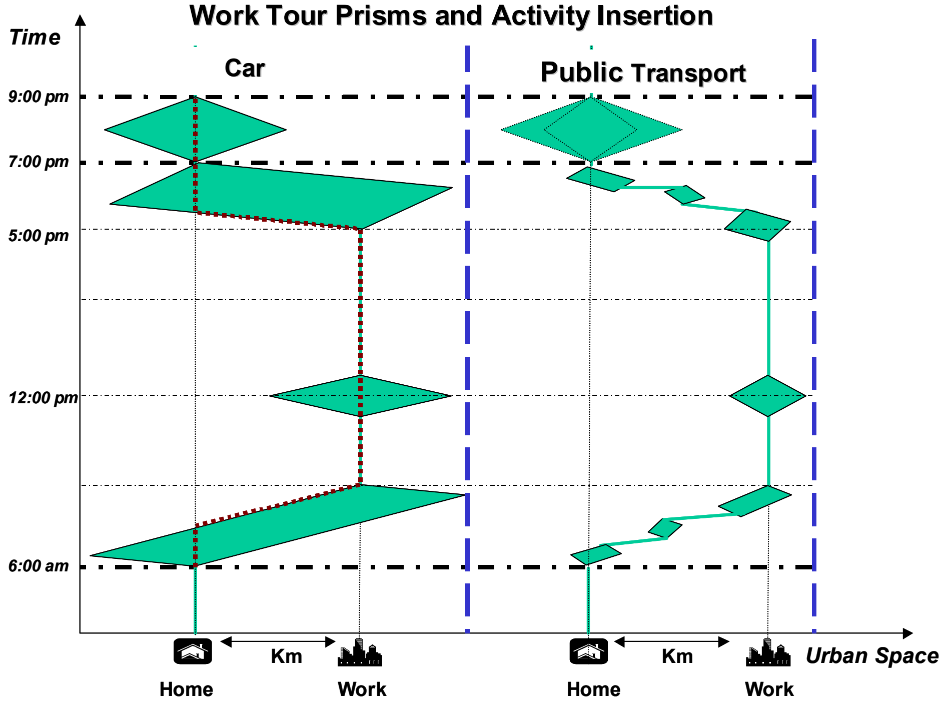

Capturing interdependencies in tour mode and activity choice: a co-evolutionary logit modelling approach

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Capturing Interdependencies in Tour Mode and Activity Choice: A Co-Evolutionary Logit Modelling Approach

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Abstract

The paper aims to analyse the interdependencies in work-tour choice facets, specifically mode and activity choice. Activities may be inserted before, in-between and/or after the work activity resulting in complex work tours. Traditional modelling approaches assume that tour decisions are being made simultaneously or in some predefined order. Both these assumptions have inherent shortcomings such as defining a discrete set of choice alternatives or wrong estimation of parameters in the case of hierarchical estimation. To address the questions of interdependent tour choice facets, the paper proposes the co-evolutionary methodology. The methodology holds implications for both the estimation and prediction phase. Separate utility models are estimated for each choice facet with the other choice facets used as independent variables. Estimated parameters thus represent the influence of the other choice facets. Prediction involves interactively updating predicted possibilities until a pre-defined convergence is reached (which solves the problem of circularity between linked decisions). Under the assumptions that individuals make least uncertain decisions first, the methodology provides for clarification on the order of decisions.

The empirical analysis uses detail, disaggregate travel-activity dairy collected in the Utrecht – Almere – Amsterdam region, The Netherlands (2001). The results reveal that mode choice is significantly influenced by intermediate activities while intermediate activities are less influenced by mode choice. Also, before, in-between and after intermediate activities correlate with distinctly different transport, land use and socio-demographic characteristics. Considering the order of decisions, it was found that, in the majority of cases, intermediate activity choice rank higher up in the decision hierarchy while transport mode ranks rather low. The finding lends support to the hypothesis that intermediate activities might not be as discretionary as sometimes believed and that mode choice is determined, in most cases, by activity choice and not vice versa.

Keywords

Tour choice facets, co-evolutionary methodology, Logit models, Choice Hierarchy, International Conference on Travel Behaviour Research, IATBR

Preferred citation

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"Life is a Journey - not a Destination", Author unknown

1. Introduction

Activity-based travel demand models are characterized by a plethora of choice facets covering activity and travel issues such as activity frequency, start time, duration, location, transport mode, etc. (Adler & Ben-Akiva, 1979; Alves & Axhausen, 1994; Arentze & Timmermans, 2000b; Kitamura, Kostyniuk, & Uyeno, 1981; Kondo & Kitamura, 1987; Nishii, Kondo, & Kitamura, 1988; Wen & Koppelman, 2000). An important feature of contemporary activity-based models is their recognition of the interdependent nature of these choice facets. Nowhere are these interlinked travel and activity choice facets more evident than on the home-based tour. Home-based tours are simply defined as a sequence of movements that begins and ends at the home location (Alves & Axhausen, 1994; Timmermans et al., 2003)[1]. Given the prominence of the work as a mandatory activity, the home-based work tour (or simply work-tour) is important in shaping daily activity and travel behaviour with the home and work location acting as pegs around which daily activity and travel behaviour is organised (Cullen & Godson, 1975; Forer & Kivell, 1981; McGuckin & Murakami, 1998). Many researchers have pointed to the secondary role of the work tour, i.e. providing an opportunity to link activities (Nishii, Kondo & Kitamura, 1988). The possible linking of intermediate activities to the work tour clouds our understanding of the influence of policy and planning measures to entice users to shift from environmentally unsustainable transport modes, such as the car, to more sustainable public transport alternatives for their commute trip (Hensher & Reyes, 2000). Clearly, certain modes, such as the car, are more 'suited' to inserting activities on the work-tour by virtue of the mode's spatial and temporal flexibility.

The causal relationship, however, between additional activities on the work-tour and tour mode choice has not yet been well clarified. This results in problems when specifying models of decision chains such as the arbitrary choice of the sequence in which decisions are made. Any pre-defined order pre-supposes a decision structure that might not reflect actual circumstances and result in erroneous predictions. The alternative of assuming a discrete choice between all combinations of choices in the tour is also theoretically inadequate. The problem is aggravated in cases were intermediate activity and mode choice

[1] In general, tours are defined as round trips that start and end at the same location and may include home, work or other activity location.

may be mutually interdependent. Identifying the decision structure underlying the insertion of intermediate activities (or trip chaining behaviour) may suggest a method for evaluating transportation policies more effectively (Dueker, Strathman & Bianco, 1998; Nishii & Kondo, 1992).

The main objective of this paper is to address the nature of the causal relationship between the work-tour choice facets using the co-evolutionary methodology. The methodology holds implications for both the estimation and prediction phase. Separate utility models are estimated for each choice facet with the other choice facets used as independent variables. Estimated parameters thus represent the influence of the other choice facets. Prediction involves iteratively updating predicted possibilities until a pre-defined convergence is reached (which solves the problem of circularity between linked decisions). Assuming that least uncertain decisions are made first, the relative degree of uncertainty for a particular choice facet will determine the position of the decision in the choice hierarchy. The co-evolutionary modelling methodology has been previously introduced and applied by Arentze and Timmermans (2001) to predict linked decision rules of activity scheduling and profiling decisions (Arentze & Timmermans, 2001). This application differs in that logit models are used (as opposed decision trees) and the technique is extended to also predict the order of decisions.

The paper is structured as follows: The following section briefly reviews the literature on the relationship between intermediate activities and mode choice as well as the specific methodologies applied to assess these intrinsically linked decisions. This is followed by a discussion of the co-evolutionary and nested logit modelling methodology applied in this paper. The data collection and choice sets for estimation are subsequently discussed. The results of the models are presented in the following section before the paper is concluded with a discussion of the transport policy and land-use planning implications.

2. Tour choice facets in the literature

The importance of tours in explaining travel and activity behaviour has long been recognised by the transport modelling fraternity and significant conceptual, methodological and empirical advances have been made.

Strathman and Dueker (1995) used the United States Nationwide Personal Transportation Survey data (NTPS, 1990) to derive a trip chain typology and relate this trip chain typology to various socio-demographic, metropolitan structure and transport characteristics (Strathman & Dueker, 1995). Using cross-tabulations and binomial logit models (with the dependant variable the probability of a complex commute), they found that changing household composition and structure, higher incomes and the entrance of women in the labour force results in more complex work chains. Support for their findings is provided by McGuckin and Murakami (1998) who also found that women are more likely to form complex-work trip travel chains (McGuckin & Murakami, 1998). The changing social and economic role of women (especially the increasing participation in the labour force) over the past three decades has had equally significant changes on travel behaviour and particular on trip chaining. The difference between men and women, however, seems to be amplified by the household composition and gender roles, in specific child-care responsibility.

In a series of articles dealing with the specific impacts of the spatial-temporal constraints on the propensity to chain activities to the work tour, Nishii, Kondo and Kitamura (1988), Kondo and Kitamura (1987) and Nishii and Kondo (1992) showed that the likelihood of pursuing a non-work activity in a separate, home-based trips chain will increase with the speed of travel, i.e. faster modes. A pre-condition of this finding, however, is that the marginal benefit of in-home activity diminishes (Kondo & Kitamura, 1987). Should the marginal benefit not diminish the above relationship actually reverses with more activities inserted on the tour as speed of travel increases. Furthermore, propensity to chain activities to the work tour increases as the commuting distance (and thus trip duration), travel cost or the density of opportunities increase and for train users if the number of transfers increase (Kondo & Kitamura, 1987; Nishii & Kondo, 1992; Nishii, Kondo & Kitamura, 1988).

Finally, Kondo and Kitamura (1987) state that the same principles do not apply to all three prisms (at least for the before and the after work prism) when it comes to intermediate activity engagement. Intermediate activities of short duration seems to be conveniently linked to the work trip in the morning prism but that the afternoon prism impose less stringent time-space constraints on intermediate activities thus allowing for longer duration activities.

In addressing the issue of interdependencies of tour decisions, Adler and Ben-Akiva (1979) treat tour choice facets as a single joint choice of a complete travel pattern (travel pattern being defined as a set of tours – and included on tours the number of stops, mode choice etc., - made by an individual within a fixed time period). Using the utility maximising framework, they relate the optimum travel pattern (measured in terms of the number of tours travelled on a given day and in terms of the number of stops made on each tour) to transport expenditure. They found that disincentives on travel (i.e. increase in travel expenditure for example) caused an overall decrease in the average number of sojourns per tour. This was found to be caused by the general reduction in the number of sojourns per household, which results in fewer opportunities for a household to link trips together in multiple-sojourns (Adler & Ben-Akiva, 1979).

Wen and Koppelman (2000) addresses the issue of interdependencies of tour choice facets by adopting a linked model methodology (Wen & Koppelman, 2000). They use a two-stage logit modelling approach system to model short-term travel and activity decisions. The first stage includes (a) the generation of daily maintenance activities (stops) and (b) the allocation of stops/auto's among household members. The second stage includes the individuals' choice of travel patterns including selection of the number of tours and assignment of stops to the tour. The expected utility of the second stage models (tour formation models) is used in the estimation of the first stage models while the second stage model is conditional on the estimated number of stops (form the first stage model). Using a 2-day travel and activity dairy from Portland, Oregon (1994) they found that the expected utility on the individuals' tour pattern has an influence on the generation of maintenance stops and the allocation of maintenance stops and autos' among household members.

In general, most studies agree that the forces behind formation of complex work chains are related to household composition, urban form and spatial temporal constraints. Considering the choice process, earlier studies have adopted a simultaneous choice model, i.e. the decision consists of a single choice of all choice facets (e.g., Adler & Ben-Akiva, 1979, Strathman, Deuker and Davis 1994), a nested choice model, i.e. lower-level choices are nested within higher level choices in some pre-defined hierarchy (e.g., Wen and Koppelman, 2000) or a sequential choice model, i.e. decisions are made sequentially in some pre-defined order (e.g., Borgers, et al, 2002, Fujii et al. 1998). Notwithstanding their obvious valuable contribution, all of these approaches have shortcomings. Assuming a (subjective) pre-defined order, as is done in nested and sequential approaches, presupposes a decision structure that might not reflect actual circumstances in all cases and hence results in erroneous or biased predictions. The alternative of assuming a simultaneous discrete choice between all combinations of choices in the tour is also troublesome as the number of choice alternative increases tremendously with the number of choice facets and individuals may evaluate alternatives at the choice-facet level.

3. Methodological approach and disaggregated travel data

3.1 The choice problem

Faced with their daily activity programs (sets of activities to be included during the day) and available means of transport, individuals can organise their travel in individual trips and/or trip chains (or tours). This research is concerned with scheduling of out-of-home activities (i.e. intermediate activities) on the work-tour (work is assumed the primary subsistence activity and other daily activities are assumed to be scheduled around this). Activities available for insertion on the work-tour include, in order of importance, *non-leisure* activities (church, medical and other planned personal and other household non-leisure activities), *serving passengers or goods* (pick-up/drop-off persons or goods), *maintenance* activities (shopping and services), *leisure* (social, recreational and cultural purposes) and other (i.e. remaining activities)[2]. Individuals can insert no additional activities on the work-tour in which case the work tour is referred to as a simple tour or can insert intermediate activities before, in-between and/or after work in which case the work tour is referred to as complex tour. The before, in-between and after intermediate activity are modelled as separate (discrete) choices as they do not refer to mutually exclusive categories. In the case of multiple intermediate activities on the same position (before, in-between, after) in the tour, the choice is defined based on the primary intermediate activity. The primary intermediate activity is selected on the basis on the hierarchy above, i.e.; Non-Leisure, Serve Passenger, Maintenance and Other in order of importance. The models thus refer to the primary intermediate activity on the work-tour.

An important property of the co-evolutionary approach is the assumption that the other choice facets are known for each decision. That is, for the mode choice decision, the observed intermediate activity choice are known while for the intermediate activity choice models, the mode choice and other intermediate activity choices are assumed known. This assumption implies that the availability of alternatives is defined as follows; an activity is defined available for insertion on the tour if two conditions are met. Firstly, an activity must occur on the day, i.e. it is included in the activity program for that day. Secondly, after taking into consideration the other intermediate activities of same type on the tour (i.e. before, in-between and after), if any, there are still activities left for inserting for

[2] The order of importance of activities is derived form the requirement to serve the needs of the household and the possibility – or not – to schedule the activity at another time.

this particular choice. As such, the intermediate activity choice models (before, in-between and after main activity) refer to the choice of inserting an activity only when that activity is available for inserting on the tour. When no activity is available, either because it is not in the daily activity program and/or this type of activity has been inserted on the tour in the other prisms, the option is excluded from the choice set.

Considering the main transport mode of a tour, the mode has been defined based on a hierarchy of modes; train, bus/tram/metro, car driver, car passenger, bicycle, walking and other in hierarchical order. For example, any tour involving a train trip for any of the tour trips is defined as a train tour[3]. Use of public transport modes as tour main mode does not preclude other modes from being used on the tour, for example the use of slow modes during the lunch hour. The model, however, predicts the main tour mode used. The choice set for the mode choice logit model is defined as car driver, car passenger, train, bus/tram/metro and slow (the latter includes both walking and the bicycle). A nested structure is adopted with Private, Public and Slow defined as the primary nests. Secondary nodes for private are car driver and car passenger. For public, the train and bus, tram, metro (BTM = one category) are the nodes. Slow was selected as the reference category. The car driver alternative was only available to people with a drivers' license. No other availability criteria were specified.

3.2 Co-evolutionary modelling methodology

The co-evolutionary approach has implications for both the estimation and prediction phase. The process is initiated by estimating separate models for mode choice and intermediate activity choices (before, in-between and after). These four models are individually estimated using the traditional multinomial/nested logit-modelling framework (Ben-Akiva & Lerman, 1985; Lerman & Ben-Akiva, 1975; Richards & Ben-Akiva, 1975)[4]. In

[3] Arguably, this deterministic rule does favour public transport modes and discriminate against slow modes and the definition might result in a higher number of public transport tours. In some cases private transport may be used in combination with public transport and the traveller might consider public transport as the secondary mode with private transport the main tour mode. There was, however, no other satisfactory rule to detect the primary tour main mode. An alternative rule considers travel time on the different modes as an indication of main mode. Descriptive analysis on travel time did reveal that the longest travel time very often (in fact nearly always) corresponded to the hierarchy and as a result it was decided to adopt the hierarchy as decision rule.

[4] The HieLow modelling software was used to estimate the parameters (Bierlaire, 1995).

each model, the choice outcomes of the other choice facets are included as independent variables. The estimated parameters for these choice facets thus indicate interactions between these choices. During the *predictive* phase, the co-evolutionary method involves an iterative procedure. Initially, the choice probabilities for the four decisions ($P_{ki}^{t=0}$ *where k = choice facet, i = alternative within choice facet and t = iteration*) are set equal (*i.e.* $P_{k1}^{0} = P_{k2}^{0}$ *for each k*). The models are subsequently used to predict the probability distribution P_k^t assuming P_j^{t-1} for each decision $j \neq k$. The process is iterated until a convergence criterion is met, whereby convergence is measured as the *sum of absolute differences between updated probabilities and probabilities of the last iteration*. Once convergence is achieved, the choice facet with the lowest level of uncertainty is selected and a decision is made and fixed in the iterative process. Uncertainty is measured as the entropy of the choice probability distribution and a decision involves choosing the alternative that has the highest choice probability. Since a decision changes the choice probability, the same process is repeated and so on until all decisions have been made.

The outcome of the above is a set of decisions for the choice of tour main mode, before intermediate activity, in-between intermediate activity and after intermediate activity choice as well as the order of the decisions. We emphasize that, in this procedure, the sequence of the decisions is predicted and case dependent rather than a-priory defined and constant across cases. Since the co-evolutionary approach assumes full information about the outcomes of related choices in the estimation stage, it may improve the predictive performance of the model as well. The main reason, however, for using the approach in the present study is that it allows the researchers to establish the nature of the interdependence between activity and (multi) tour mode choice. If the mode decision is made prior to the activity choice in the majority of cases there is evidence that activity choice is conditional on mode choice rather than the other way round (in most cases).

3.3 Data

The data used in this study comes from an extensive 2-day travel and activity diary survey undertaken during April to September 2000 in the Utrecht-Almere-Amsterdam urban region, The Netherlands (Arentze et al., 2001b)[5]. Neighbourhoods within the region were pre-classified according to public transport accessibility (i.e. stratified sample) in order to increase the share of public transport users. Within these selected neighbourhoods activity diaries were distributed to all household members over the age of 12. A total of 1966 households, representing 4246 individuals, completed and returned useable diaries. Information on +/- 24 000 trips and 12459 tours (i.e. average 2.1 trips per tour) were recorded. Of these, 1331 (10.7%) tours involved a public transport mode while 11164 (89.3%) tours involved only private transport modes. The survey data were combined with extensive data on the transport system and land-use system. For each tour, objective travel times were derived for slow, car and public transport modes using the national road and public transport network (i.e. 'basisnetwerk'-file and 'Randstad Model'-file, 2000) of The Netherlands. Land use data, which included accessibility measures, were derived for all 6-position postcode areas (the chosen spatial unit) in the study area[6].

Work tours were selected (n = 3980) and some additional selection criteria were applied which included selection of "closed tours" (tours that start and end at the home location on the same day), and where travel times could successfully be derived (sometimes it was not possible to derive travel times as home and work locations where not coded correctly) and only tours were selected where the main mode was clearly identifiable. After all the selections, the dataset contained 2757 home-based work tours. Table 1 shows the cross-tabulation of modes and intermediate activities for the data set. The three columns, i.e. at least one intermediate activity before, in-between and after work, refer to tours where at least one intermediate activity occurred and are not mutually exclusive (thus they do not add up to complex tours).

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[5] The research program, for which the data was collected, is referred to by the acronym AMADEUS, which stands for "Assessing the time varying effects of Multimodal transportation systems on Activity and Destination choices in Urban Systems". The research was commissioned by the Dutch government in an attempt to clarify multimodal travel and activity patterns (Arentze, Dijst, et al. 2001b).

[6] The Netherlands counts a total of +/- 430 000 6 PCA's. Each 6-PCA contains +/- 17 persons and the given a 6-PCA location for a household, the location can be determined up to between 50 – 500 meters of accuracy depending on development density.

Table 1: Tour mode choice and intermediate activity occurrence

Tour Mode	No Intermediate Activity *(%)* ***Simple Tours***	*At least* one IA before work (%)	*At least* one IA in-between work *(%)*	*At least* one IA after work *(%)*	***Complex tours*** *(%)*	Total
Car Driver	633 *(56)*	196 *(17)*	122 *(11)*	285 *(25)*	499 *(44)*	1132
Car Passenger	35 *(65)*	10 *(19)*	3 *(5)*	10 *(19)*	19 *(35)*	54
Train	346 *(72)*	30 *(6)*	33 *(7)*	86 *(18)*	133 *(28)*	479
Bus/Tram/Metro	121 *(68)*	12 *(6)*	8 *(5)*	45 *(25)*	58 *(32)*	179
Slow: walk & bike	529 *(58)*	146*(16)*	110 *(12)*	252 *(28)*	384 *(42)*	913
Total	**1664** ***(60)***	**394** ***(14)***	**285** ***(10)***	**678** ***(25)***	**1093** ***(40)***	**2757**

The dataset contains, seemingly, more intermediate activities compared to other studies, whom often found only +/- 15 % of all tours to be complex (Alves & Axhausen, 1994; Arentze & Timmermans, 2000a; Strathman & Dueker, 1995; Strathman, Dueker & Davis, 1994). A possible explanation lies in the fact that for the AMADEUS dataset a relatively high percentage of bring/get persons/goods activities (termed serve passenger in this paper) were observed. The latter might be a result of the different dairy format used in the study (Arentze et al. 2001a). Table 2 below shows the type of intermediate activity inserted on the tour associated with the different transport modes.

Table 2: Tour mode and Intermediate Activity differentiated according to activity type

Tour Mode	No Intermediate Activity (IA) (%)	At least one Non-Leisure	*At least one Serve Pass./Goods*	*At least* one Maintenance	*At least* one Leisure	At least one Other
Car Driver	633 *(56)*	31	*340*	82	67	14
Car Passenger	35 *(65)*	1	*13*	3	2	1
Train	346 *(72)*	4	*49*	57	28	3
Bus/Tram/Metro	121 *(68)*	2	*22*	22	11	3
Slow: walk & bike	529 *(58)*	27	*222*	107	64	6
Total	**1664** ***(60)***	65	646	271	172	27

Table 3 shows the frequency distribution of intermediate activity type for the three intermediate choice models. There are relative few cases for the activity categories maintenance, leisure and other in the before model. The few number of cases is probably due to the fact that most work tours commence in the morning and that (in The Netherlands at least) many shops and business do not open before 9-10am. Similarly, for the in-between model there are fewer intermediate activity cases overall compared to the other two alternatives. Few cases hamper the estimation of coefficients and it was decided to group some of the intermediate activity choices together. The results are shown in Table 4.

Table 3 Frequency distribution of choices for intermediate activity choices on work mode tours

Model Nr.	**1**		**2**		**3**	
	Intermediate activity before work		Intermediate activity after work		Intermediate activity in-between work	
Choice Categories	**#**	**%**	**#**	**%**	**#**	**%**
No IM	2363	85.7	2079	75.4	2481	90.0
Non-leisure out	35	1.3	17	.6	16	.6
Bring Get	337	12.2	334	12.1	121	4.4
Maintenance	*9*	.3	195	7.1	80	2.9
Leisure	*6*	.2	123	4.5	46	1.7
Other	7	.3	9	.3	13	.5
Total	**2757**	**100**	**2757**	**100**	**2757**	**100**

Table 4 Frequency distribution of grouped choices for intermediate activity choice

Model Nr.	1						
	Intermediate activity before work			Intermediate activity after work		Intermediate activity in-between work	
Choice Categories	#	%	**Choice Categories**	#	%	#	%
No IM	2363	85.7	No IM	2079	75.4	2481	90.0
Bring Get	337	12.2	Bring Get	334	12.1	121	4.4
Non-leisure out	35	1.3	Maintenance	195	7.1	80	2.9
			Leisure	123	4.5	46	1.7
Other	22	0.8	Other	26	.9	29	1.1
Total	2757	100	Total	2757	100	2757	2757

4. Modelling results

The results of the four logit models are presented in appendices A to D. In as much as the data allowed, the same independent variables have been used in the three models of intermediate activity choice to facilitate comparison. For the tour mode choice model, four categories of variables have been used, i.e. transport level-of-service, socio-demographic, intermediate activity and urban form variables. Descriptions of the variables are given in the first column of Appendix A. Considering the intermediate activity choice models, transport level-of-service, activity program, other intermediate choice, socio-demographic, land use and urban form variables were used. Similarly, variable definitions are shown in the first column of Appendix B.

4.1 Mode choice model

In general, the results obtained for the mode choice models are in-line with traditional mode choice models. Travel time, estimated as a generic coefficient, is appropriately signed and in order of magnitude of travel time estimates in other models. Unfortunately, estimating mode specific travel times proved unsuccessful. The train travel time ratio is correctly signed (negative) implying that a larger differential between train and the car travel time leads to a decrease in the utility of the train.

Considering the socio-demographic variables, the utility of public transport modes decrease with an increase in the number of cars per worker. An increasing household size leads to decrease in the utility for all modes, however, the disutility is much smaller for the car modes compared to the public transport modes. As the reference category is slow modes, the results imply that more household members will rely on slow modes with an increase in household size. Given that larger households generally contain more children, this finding is understandable. The male-dummy variables reveal that the utility of public transport modes declines while it increases for car driver.

The insertion of before and after intermediate activities on the tour leads to a decrease in the utility of public transport modes. The coefficients are particularly strong for the before intermediate activity choice, which might reflect the especially strong time regimes and schedules public transport travellers face on the trip to work in the morning time period. Fixed public transport schedules, fixed work start times, as well generally limited free time in the morning leads to an inability to undertake intermediate activities on the morning trip. In general, public transport travellers are not able to terminate their trip and deviate from the fixed public transport network.

On the other hand, none of the in-between intermediate activity variables showed up as significant. As the model estimates the main mode used on the tour, the use of public transport does not exclude individuals from using slow modes (the reference category) in-between work activities to insert intermediate activities on the tour. Public transport users may conduct in-between intermediate activities by switching to walk (or the bicycle) if activity locations are within easy reach given their available time.

Two urban form variables were included, i.e. an origin and destination central business district (CBD) dummy indicating whether a person resides or work in a CBD location respectively. Whereas none of the origin CBD variables are significant, all of the destination CBD variables are significant. Individuals, who work in the central business districts, have a preference for public transport while the utility of the car is lower. The later being likely to relate to limited and/or expensive parking as well as congestion problems. Public transport networks are traditionally designed to converge on the CBD with good services running to and from the CBS.

4.2 Intermediate activity before main activity

Transport mode specific dummies were estimated for car driver and slow mode only meaning that public transport and car passenger together formed the base. As there were too few cases for public transport and car passenger it was not possible to estimate separate effects for the two. Use of the car (driver) increases the utility of inserting non-leisure intermediate activities. Neither the car driver nor slow mode significantly increases the utility for inserting a passenger serving activity.

Travel-time parameters were first estimated as alternative specific (the reference No Choice). No significant and/or interpretable results where obtained. An alternative specific parameter was subsequently estimated only for the No Choice alternative but the result was not significant. This is slightly counter-intuitive (and contrary to the literature), as one would expect longer trips and tours to be associated with a higher activity-chaining propensity. However, as this model refers to the "before main activity" alternative, it might be that many people do not have time before the main activity commence to insert an intermediate activity. Furthermore, longer trips and tours generally begin earlier on the day when fewer businesses are open. The relationship between trip duration and activity insertion may thus be more a function of trip start times. A similar argument also holds for the car distance variable with only one distance variable (i.e. serve passenger/goods) being significant. A longer trip distance leads to a lower propensity to insert a serve passenger/goods activity. Considering the peak period travel dummy, the models reveal that inserting a passenger/goods serve activity on the tour is positively associated with travelling during the peak period while negatively associated with inserting other activities. This might indicate that passenger/goods serve is a mandatory activity which cannot be scheduled during less congested travelling periods.

The following two variables categories, number of activities in the activity program (excluding the main tour activity, i.e. work) and duration of the main tour activity (i.e. work) represent the time pressure faced by the individual. No significant coefficients were found for the number of activities in the daily activity program. Work activity duration was found to be significant for serve passenger/goods activity. The results seem to indicate that people, whom face much time pressure, do not compensate by inserting activities on the way to work. The exception being to serve passenger/goods, which is often a compulsory activity and the longer duration of the main activity the more likely are people to chain this activity to the tour, as time for a separate tour will be limited. Short duration work activities will allow people to undertake a separate tour for the activity as opposed to chaining the activity to the work tour.

The following four variables refer to whether or not a similar activity was inserted on the tour (i.e. the other intermediate choice variables). That is, “After choice (Non-Leisure)” refers to the case where a non-leisure activity was inserted after the main activity while in-between refers to whether a similar activity was inserted in-between the main activity. Very obvious is the very strong coefficient for the After Choice (serve passenger/goods) variable. The positive coefficient implies that when this activity is inserted after the main activity, it very strongly increases the propensity that the activity will be inserted before the main activity and points to the relationship between serve passenger/goods and the need to repeat that activity in the evening. The positive coefficient also implies that the same person assumes responsibility for serve passenger/goods before and after work as opposed to the activity being shared.

Of the socio-demographic variables, the gender variable is relatively strong and significant for the serve passenger/goods, implying that males are much less likely to take responsibility for this activity. Higher income people are more likely to chain passenger serving activities to their work tour (higher income is also associated with longer work duration). The negative coefficient for lower income and non-leisure activities is particularly strong. It is quite possible that lower income people are less likely to participate in these types of activities (particularly cultural activities) or that because of the correlation with activity duration, lower income people have more time to conduct separate tours for these activities. Dual income households and the presence of a young child (< 6 years of age) significantly increase the propensity to chain a passenger/goods serving activity to the work tour.

Of the land use and urban form variables, the dummy indicating whether trip originate in the central business district (CBD) significantly increases the utility to insert non-leisure and maintenance intermediate activities on the work tour. In central business districts many businesses are more likely to be open in the morning while activity locations are often much more favourably located (in terms of accessibility). Individuals living in the CBD's have much more opportunity to chain these activities to their work tour.

4.3 In-between main activity

Of the transport mode dummies, car driver and slow mode leads to an increase in the utility of maintenance activities in-between work. Private transport modes are readily available at the work location and allow individuals to make full use of their free time window.

Travel time is positively associated with maintenance activities in-between the main activity. People who travel very long will more likely undertake their maintenance activities in-between the main activity as (probably) they arrive too late or have to depart too early to conduct these activities at the origin or destination.

The activity program and work duration are mostly significant and negatively associated with the insertion of intermediate activities in-between the main activity. The more activities during the day, the less utility for a passenger serving and maintenance activity in-between the main activity. Similarly, the longer the work duration, the less the utility for inserting any of the activities in-between the main activities. At first this might seem counter-intuitive. However, this might imply that the main activity gets preferences and that people faced with many activities will rather undertake separate trips from home as opposed to inserting these activities on the tour. Conversely, it also implies that people with fewer activities, are more likely to chain their activities on the main tour. The negative relationship between work duration and the insertion of an intermediate activity should be treated with some caution due to the inherent relationship between work duration and the availability of free time during, for example lunch. Arguably people that insert an intermediate activity in-between the work activities will have an shorter work duration (i.e. as they are away from work during the in-between main activity). People that do not insert an intermediate activity in-between work activities are thus much more likely to work longer.

Considering the other choice variables, only after-choice maintenance is significant and positive. A positive coefficient for the after-choice maintenance activity leads to an increase in utility for the in-between maintenance choice (this is then given that more than one maintenance activities exists on the tour). Thus, people with many maintenance activities and who have already inserted maintenance activities on the tour will tend to continue to add (insert) maintenance activities on the tour rather than undertaking new tours.

Considering the socio-demographic results, the male dummy is positive for leisure and other activities. It is frequently acknowledged that men are much more likely to participate in leisure activities (such as sporting activities) during the lunch hour. Low income leads to a lower utility to insert intermediate activity in-between main activities. This might be because lower income people tend to work shorter hours and have more time after work to insert a passenger serving activity. Whether an individual comes from a dual income household increases the utility of inserting a serve passenger/goods and leisure activity in-between the main activity. People from dual incomes generally have tight time schedules and time for leisure activities, in specific, is very limited and the lunch break, for example, might allow people to insert leisure activities.

The urban form and land use variables, specifically whether or not the work location is within the CBD or not, significantly increases the utility of inserting an intermediate activity on the tour. The CBD offers more opportunities in close proximity and allow people, within the small free time window, to insert an intermediate activity.

4.4 After main activity

Considering the transport variables, distance is positively associated with inserting a maintenance activity after work. The peak time period dummy show similar findings as for the before choice models with serve passenger having a positive coefficient while leisure is negative (and very significant) associated with peak period tours. This implies that leisure trips are much more likely to be chained outside the peak period or undertaken as separate tours and that leisure activities might be more sensitive to congestion compared to other activities.

More activities in the daily activity program leads to a lower utility for inserting leisure activities on the tour. This is in accordance with general theory that suggests that leisure activities tend to fall away when people are confronted by a heavy activity task schedule. This might indicate that leisure activities receive a lower priority on the tour and other activities are scheduled before attention is paid to the leisure activity. A second plausible conclusion is that leisure activities are scheduled later on the day when other activities have been conducted and implemented. Late scheduled activities are more likely to be undertaken on separate tours.

As with the before results, the duration of the work activity is positively associated with the insertion of a serve passenger/goods activity and a leisure activity on the tour, again a plausible result. People are much more likely to chain leisure activities to the tour, should their work activity be of long duration. Conversely, assuming that many leisure activities are pre-planned for the evening and/or after work, it is plausible that individuals remain at the work location until it is time to leave for the leisure activity.

Concerning the other choice variables, when a serve passenger activity is inserted on the way to work (before), the utility of inserting this activity after work significantly increases. Again, this supports the finding that the intermediate activity serve passenger/goods is scheduled for the same tour and undertaken by the same person. Somewhat surprising is the positive association with the before choice-maintenance. The positive coefficient implies that inserting this activity on the way to work increases the utility of this activity being inserted after work. Given that availability definition above, this result implies that different episodes of a maintenance activity tend to be scheduled for the same tour.

Considering the socio-demographic variables, men are less likely to insert passenger/goods serving activity on the tour (as for the before mode choice model). The presence of young children (i.e. < 6 years) leads to a decrease in the utility of leisure activities on the return trip from work. Arguably children demand time and care after work, impacting on the ability to insert leisure activities on the return home leg of the tour.

Finally, considering the land use and urban form variables, only one variable, the destination CBD variable is significant and implies that the utility of inserting a maintenance activity on the tour after work increases if the destination (i.e. home) is within the CBD.

4.5 Co-evolutionary model (CEM) results

The co-evolutionary model converged in all of the 2757 cases. On average 7.54 iterations with a standard deviation of 1.65 iterations were needed to establish a decision on all four choice facets. If the choice facets were fully independent, then 1 + n iterations would suffice to reach n decisions. The higher number of iterations indicates that interdependencies played a role in the process. Table 5 shows the frequency distribution of the observed tour choice facets (column 1) and the predicted frequency distributions using the co-evolutionary model (column 2). As it appears, predicted frequencies closely match the observed frequencies. The only exception is that dominant choices are slightly over predicted. This is what we would expect given the used decision rule, which selects the highest-probability alternative in every case. For the purpose of the present analysis, however, the decision outcomes are less relevant than the decision order, provided that biases at the level of outcomes are limited. Table 6 shows the order of the decisions in the CEM.

Table 5 Choice set predictions

	Tour Choice Facet	Observed	CEM
Mode	Car Driver	0.41	0.54
	Car Pass.	0.02	0.02
	Train	0.17	0.09
	BTM	0.07	0.04
	Slow	0.33	0.30
Before	Non-Leisure	0.01	0.01
	Serve Passenger/goods	0.12	0.13
	Other	0.01	0.01
	No intermediate activity	0.85	0.85
In-Between	Other	0.01	0.01
	Leisure	0.02	0.02
	Maintenance	0.03	0.02
	Serve Passenger/good	0.04	0.06
	No intermediate activity	0.90	0.89
After	Other	0.01	0.01
	Leisure	0.05	0.04
	Maintenance	0.07	0.10
	Serve Passenger/good	0.12	0.14
	No intermediate activity	0.75	0.71

Table 6 Tour decision hierarchy

	Choice Order	Frequency	%	Cum. %
Mode	First	94	3	3
	Second	228	8	12
	Third	250	9	21
	Fourth	2185	79	100
	Total	***2757***	***100***	
Before	First	1709	62	62
	Second	639	23.2	85
	Third	341	12.4	98
	Fourth	68	2.5	100
	Total	***2757***	***100***	
In-Between	First	843	31	31
	Second	1473	53	84
	Third	299	11	95
	Fourth	142	5	100
	Total	***2757***	***100***	
After	First	843	4	4
	Second	1473	15	19
	Third	299	68	87
	Fourth	142	13	100
	Total	***2757***	***100***	

As shown (Table 6), mode choice is nearly always chosen last, while intermediate activities rank much higher up. Before intermediate activity choice is in 62% of the cases the first tour decision made. In-between intermediate activity choice is in 31% of the cases the first tour choice but in 53% of the cases the second tour decision. After intermediate activity choice features later in the hierarchy but still ahead of mode choice; it is 87% of the time the third, or higher, most important decision while mode choice is in 80% of the cases, the last tour decision. At the same time, it is important to note that considerable variation in decision order exists between cases. The latter finding supports the hypothesis that the assumption of a pre-defined and fixed decision order is in conflict with reality, at least in this case.

The estimation results of the logit models seem to support the co-evolutionary results. First, whereas the tour mode choice (Appendix A) is very much influenced by intermediate activities (both in terms of the number of significant intermediate activity dummies and the strength of these dummies), the intermediate activity choice models show less relationship with the transport mode dummies. This might suggest that the decision to insert an intermediate activity is not so much a function of the mode but that the chosen mode is determined by the presence of intermediate activities on the tour.

5. Discussion and conclusions

This paper addressed the issue of interaction in tour choice facets (i.e. mode choice, before, in-between and after intermediate activity choice). The co-evolutionary methodology is proposed to clarify the nature of these possible causal relationships. As illustrated, the methodology combines very well with the logit-modelling framework. It involves estimating separate choice models using full information about the outcomes of the related choices and then deriving predictions simultaneously based on an iterative procedure of updating choice probabilities. Assuming that least uncertain decisions are made first, a decision order can be derived from the model dependent on the utility distributions of the specific case.

In general, the results show that for complex transport modes involving mode chaining and many transfers such as public transport modes, the utility for insertion of intermediate activities on the tour decreases. Simple private transport modes are more readily associated with intermediate activities on the tour. This supports the general notion that complex transport modes lead to simple activity chains while simple transport chains leads to complex activity chains. However, although this relationship holds in general, the relationship between intermediate activities and mode choice seems to be magnified or muted by the location on the tour of the intermediate activity. The result showed that before and after intermediate activities are particularly negatively influenced by public transport modes while private transport modes are associated with an increase in the utility when inserting intermediate activities before or after. Inserting intermediate activities in-between the work activity, however, seems much less influenced by public transport. While factors such as density of opportunities and available time are, obviously, important, the results suggests that public transport users are not overly constrained by limited private mode availability and may rely on slow modes for intermediate activities in-between the main activity.

Considering the socio-demographic, land use and urban form characteristics, the results of the empirical analysis reaffirms existing findings. In general, women remain responsible for most complex tours. Specifically, the serve passenger/goods activity predominantly remains a woman (wife's) responsibility. Furthermore, the same person assumes responsibility for both serve passenger activities during the day as opposed to distributing the activities between household members. Both these activities are also scheduled for the same tour as opposed to being inserted on separate tours. While these general findings hold for the before and after work intermediate activities, the in-between intermediate activities show some distinct differences. For one, men are much more likely to insert intermediate activities in-between main activities (in specific leisure and maintenance activities). Longer trip durations (negative for before and after), increase the utility for in-between intermediate activities. In-between intermediate activities thus show some distinct different socio-demographic and transport properties compared to before and after.

The co-evolutionary model successfully converged over the 2757 cases and provides for additional information not previously available with standard utility-based approaches. Furthermore, the CEM does not impose additional data needs and, as demonstrated, can be used successfully with the utility maximising framework.

An important benefit of the model is the information on the hierarchy of tour choice facets. The CEM showed intermediate activities choices are made before mode choice in most cases. In these cases, the decision of inserting an intermediate activity before work is least uncertain and therefore supposedly the first tour choice. Mode choice, on the contrary, is most uncertain and assumed the last tour decision. In conclusion, the co-evolutionary approach may not only improve the predictive performance of the model, but also allows one to establish the nature of the interdependencies between intermediate activity and tour mode choice if one is willing to make the rationality assumption involved.

The order of the intermediate activity decisions also seem to correlate to the temporal and spatial constraints placed on individuals during the three prisms on the work tour. Clearly, engaging on activity participation on the way to work is subject to more temporal and spatial constraints than after work. Possibility of arriving late for work and opening hours of activity locations for example is arguably more severe in the morning prism than in the evening prism. Discretionary activities are thus much more likely to be scheduled for the evening prism while only mandatory activities will be inserted in the morning prism. The presence of mandatory activities in the morning prisms will demand much spatial and temporal flexibility of the transport mode and, again, modes will be chosen based on the presence and nature of intermediate activities.

The above findings do hold significant transport and land use planning implications. Clearly household structure and individual role within the household (both which are endogenous variables in transport and land use policy) remains significant factors influencing the propensity to insert intermediate activities on the work tour. The increasing entry of women onto the labour market and their continuing responsibility for traditional household tasks such as caring and chaperoning young children will clearly impact on their trip-chaining propensity. Furthermore, given that these tasks are often inserted during peak periods, its impact on congestion is to be expected. As household care tasks tend to be mandatory and, as demonstrated by the co-evolutionary methodology, the intermediate activity before work dominates the tour choice facets, it is likely that the transport mode will be chosen to suit the intermediate activity requirements of women and not the other way around. Women's requirement to combine household and facility responsibilities with the work tour makes it likely they will increasingly rely on the flexibility of private transport modes to satisfy their trip chaining needs. Transport policy should keep track of socio-demographic trends and target appropriate public transport market segments.

Furthermore, the effect public transport policies aimed at decreasing public transport travel time between home and work will be muted if the specific market segments are faced with much intermediate activity requirements. The improvement in public transport travel time will be partly offset by the additional travel time required to travel to intermediate activity location, which is often inadequately served by the inflexible public transport network and service schedule.

In conclusion, the results suggest that the temporal and spatial properties of the prisms on the work tour, the household structure and individual responsibility and the flexibility of available transport modes will collectively influence the work tour formation. Public transport authorities can benefit much by considering more appropriate market segments for which the constraints of public transport are less binding and the intermediate activity insertion requirement are more flexible.

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Appendix A: Work Tour Mode Choice Model

Variable definition	Coefficient	Estimation	Std.Er	T-ratio	Multinomial
ASC: Ref. Slow Mode	Constant-BTM	-5.626	1.693	-3.324	-0.477
	Constant-Train	-7.018	1.723	-4.074	-1.206
	Constant-Car Passenger	-5.297	0.812	-6.523	-3.643
	Constant-Car Driver	-2.281	0.627	-3.637	-0.715
Transport Variables					
Train time / Car time	Train TTR	-0.145	0.043	-3.341	-0.038
(Access + egress) / Trip Time	Catchment Ratio (Train)	0.048	0.840	0.057	-0.106
Road Distance between home and work	Home-Work Distance (Train)	0.099	0.010	9.583	0.044
	Travel Time	-0.042	0.002	-19.110	-0.018
Socio-Demographic Variables					
# cars in households / # of workers	Cars/Worker-Train	-2.123	1.185	-1.792	-0.291
	Cars/Worker-BTM	-2.540	1.188	-2.137	-0.570
	Cars/Worker-Car Driver	2.133	0.435	4.903	1.059
	Cars/Worker-Car Passenger	2.295	0.548	4.187	0.992
# persons in household	Household Size-BTM	-2.472	0.634	-3.898	-0.198
	Household Size-Train	-2.473	0.633	-3.905	-0.163
	Household Size-Car Passenger	-0.664	0.206	-3.224	-0.165
	Household Size-Car Driver	-0.567	0.136	-4.160	-0.196
Female Reference	Male Dummy-BTM	-3.143	1.148	-2.737	-0.378
	Male Dummy-Train	-3.178	1.149	-2.766	-0.379
	Male Dummy-Car Passenger	-0.101	0.419	-0.241	-0.083
	Male Dummy-Car Driver	0.159	0.265	0.600	0.163
Income in excess of 55 k E per year	Hi Inc-BTM	-1.626	1.256	-1.295	-0.226
	Hi Inc-Train	-0.980	1.243	-0.788	0.093
	Hi Inc-Car Passenger	0.005	0.477	0.011	0.096
	Hi Inc-Car Driver	-0.044	0.285	-0.153	0.102
Income lower than 35 k Euro per year	Li Inc-BTM	-0.353	1.234	-0.286	0.237
	Li Inc-Train	-0.828	1.238	-0.669	-0.037
	Li Inc-Car Passenger	-0.101	0.495	-0.204	0.369
	Li Inc-Car Driver	-0.620	0.316	-1.963	-0.270
Presence of child < 6 years in household	YoungChild-BTM	-0.483	1.470	-0.329	-0.579
	YoungChild-Train	-0.105	1.453	-0.073	0.120
	YoungChild-Car Passenger	-0.671	0.614	-1.093	-0.702

	YoungChild-Car Driver	-0.089	0.332	-0.268	0.039
Household with 2 income earners	Dual Inc-BTM	0.419	1.102	0.380	0.002
	Dual Inc-Train	0.870	1.102	0.789	0.601
	Dual Inc-Car Passenger	0.398	0.437	0.911	0.098
	Dual Inc-Car Driver	0.388	0.273	1.424	0.314
Intermediate Activity Variables					
IM = Intermediate activity (IA) before work	IM-BTM	-3.522	1.667	-2.113	-0.692
	IM-Train	-3.198	1.646	-1.942	-0.816
	IM-Car Passenger	1.606	0.553	2.903	0.748
	IM-Car Driver	1.304	0.383	3.409	0.427
MI = Intermediate activity (IA) after work	MI-BTM	-2.458	1.201	-2.046	-0.141
	MI-Train	-2.455	1.196	-2.053	-0.433
	MI-Car Passenger	-0.483	0.474	-1.019	-0.501
	MI-Car Driver	0.138	0.263	0.525	0.038
MIM = Intermediate activity (IA) in-between work	MIM-BTM	-1.591	1.554	-1.024	-0.527
	MIM-Train	-2.125	1.560	-1.362	-0.401
	MIM-Car Passenger	-0.592	0.711	-0.833	-0.482
	MIM-Car Driver	0.103	0.360	0.285	-0.044
Urban Form Variables					
CBD = 1; Non-CBD = 0	Origin CBD-BTM	-0.783	1.516	-0.516	0.028
	Origin CBD-Train	-1.025	1.523	-0.673	-0.050
	Origin CBD-Car Passenger	-1.107	0.749	-1.478	-0.773
	Origin CBD-Car Driver	-0.605	0.381	-1.589	-0.315
	Destination-BTM	2.815	1.103	2.552	0.840
	Destination-Train	2.865	1.104	2.595	0.909
	Destination-Car Passenger	-1.793	0.609	-2.943	-0.593
	Destination-Car Driver	-2.177	0.450	-4.838	-0.996
	Theta0		0.137	0.016	-54.360
	Theta1		0.499	0.068	-7.376
General results of the estimation					
	Number of coefficients:	58			
	Final log-likelihood:	-2417.68			
	Log-likelihood of multinomial model:	-2691.74	Test : 548.116		
	Log-likelihood of model with zero coefficients:	-4387.24	Test : 3939.11		
	Rho squared (zero):	0.45			
	Rho bar squared (zero):	0.44			

Appendix B: Before work intermediate activity choice

Variable Definitions	*Independent Variables*	*Coefficient*	*Std. Error*	*T-Ratio*
Alternative Specific Constant: NO = Reference	ASC (Non-leisure out)	-1.310	1.763	-0.743
	ASC (Serve_Pass./Goods)	-2.292	0.584	-3.923
	ASC (Other)	-2.420	1.239	-1.953
Transport mode				
Transport Mode: Car Driver	Car_Driver (Non-leisure out)	1.871	0.911	2.054
	Car_Driver (Other)	1.428	0.910	1.569
	Car Driver Serve (Pass./Goods)	0.172	0.318	0.542
Transport Mode: Slow	Slow (Non leisure out)	0.467	0.307	1.520
	Slow (Serve_Pass./Goods)	-0.550	0.709	-0.776
	Slow (Other)	0.188	0.636	0.295
Travel Time (Specific to No Intermediate Activity)	Travel Time	-0.003	0.003	-1.151
Car Distance between home and work	Road Distance-Non-leisure_out	-0.022	0.015	-1.435
	Road Distance (Serve_Pass./Goods)	-0.010	0.005	-2.000
	Road Distance (Other)	-0.005	0.011	-0.451
Tour start in peak period: 6:30 - 9:00 am	Peak Period : Non-Leisure out	0.170	0.617	0.275
	Peak Period : Serve Pass./Goods	1.084	0.218	4.977
	Peak Period : Other	-1.484	0.498	-2.982
Activity Program				
Activity Program: # of activities per day	AP-Non-leisure_out	0.137	0.160	0.858
	AP-Serve_Pass./Goods	0.008	0.071	0.107
	AP-Other	0.192	0.152	1.267
Duration of work activity	Act._Duration-Non-leisure_out	-0.001	0.002	-0.824
	Act._Duration-Serve_Pass./Goods	0.001	0.001	1.769
	Act._Duration-Other	-0.001	0.002	-0.936
Other Intermediate Choices				
Intermediate activity choice after the main activity	After_Choice-Non-leisure_out	1.509	1.678	0.900
	After_Choice-Serve_Pass./Goods	1.157	0.228	5.064
	After_Choice-Other	0.432	0.618	0.699
Intermediate activity choice in-between the main activity	In-between_Choice-Serve_Pass./Goods	0.434	0.392	1.108
Socio-demographic				
Male Dummy	Gender-Non-leisure_out	-0.385	0.595	-0.647
	Gender-Serve_Pass./Goods	-0.542	0.202	-2.676
	Gender-Other	0.865	0.529	1.636
Income in excess of 55 k Euro per year	High_Income_Dummy-Non-leisure_out	0.034	0.689	0.049

	High_Income_Dummy-Serve_Pass./Goods	0.523	0.218	2.395
	High_Income_Dummy-Other	-0.586	0.613	-0.955
Income lower than 35 k Euro per year	Low_Income_Dummy-Non-leisure_out	-2.201	0.804	-2.739
	Low_Income_Dummy-Serve_Pass./Goods	-0.301	0.225	-1.335
	Low_Income_Dummy-Other	-0.001	0.612	-0.002
Ind. from household where both people work	Dual_Income_Dummy-Non-leisure_out	-0.015	0.546	-0.027
	Dual_Income_Dummy-Serve_Pass./Goods	0.545	0.195	2.799
	Dual_Income_Dummy-Other	-0.468	0.460	-1.017
Household with young child (younger < 6 years)	Young Child Dummy-Non-leisure out	0.055	0.635	0.086
	Young Child Dummy-Serve/Pass./Serve Goods	0.460	0.180	2.548
	Young Dummy-Other	-0.213	0.786	-0.271
Land use & urban form				
LOG (Floor space of daily & non-daily shop.and 'dienst'	Origin_Access-Non-leisure_out	0.003	0.101	0.033
within 1.25 km of home travel distance with slow modes)	Origin_Access-Serve_Pass./Goods	0.031	0.035	0.877
	Origin_Access-Other	-0.060	0.084	-0.716
CBD Dummy	Origin_CBD-Non-leisure_out	3.043	1.013	3.005
	Origin_CBD-Serve_Pass./Goods	0.184	0.277	0.662
	Origin_CBD-Other	1.105	0.530	2.084
General results of the estimation				
	Number of coefficients:	**47.00**		
	Final log-likelihood:	**-556.58**		
	Log-likelihood of multinomial model:	-556.575	Test : -0	
	Log-likelihood of model with zero coefficients:	-1125.87	Test : 1138.58	
	Rho squared (zero) :	0.51		
	Rho bar squared (zero) :	0.46		

Appendix C: In-between work intermediate activity

Coefficient	*Estimation*	*Std. Error*	*T-ratio*
ASC-Serve_Pass./Goods	2.379	1.099	2.165
ASC-Maintenance	-2.668	1.321	-2.020
ASC-Leisure	-2.323	1.222	-1.901
ASC-Other	-1.595	2.393	-0.667
Transportation Variables			
Car_Driver-Serve_Pass./Goods	0.320	0.707	0.452
Car_Driver-Maintenance	1.995	0.667	2.989
Car_Driver-Leisure	0.062	0.661	0.094
Car_Driver-Other	-0.792	0.824	-0.960
Slow_Mode-Serve_Pass./Goods	0.322	0.719	0.449
Slow_Mode-Maintenance	1.895	0.651	2.912
Slow_Mode-Leisure	0.405	0.627	0.646
Slow_Mode-Other	-0.738	0.891	-0.829
Train-Serve_Pass./Goods	0.651	0.783	0.832
Travel_Time-Serve_Pass./Goods	0.001	0.005	0.221
Travel_Time-Maintenance	0.012	0.005	2.347
Travel_Time-Leisure	0.006	0.004	1.378
Travel_Time-Other	-0.010	0.008	-1.196
Activity Variables			
Activity_Program-Serve_Pass./Goods	-0.369	0.115	-3.203
Activity_Program-Maintenance	-0.340	0.126	-2.687
Activity_Program-Leisure	-0.184	0.145	-1.271
Activity_Program-Other	-0.150	0.168	-0.893
Work_Duration-Serve_Pass./Goods	-0.006	0.001	-6.584
Work_Duration-Maintenance	-0.006	0.001	-5.695
Work_Duration-Leisure	-0.007	0.001	-5.997
Work_Duration-Other	-0.008	0.002	-4.107
Other Choice Variables			
Before_Choice-Serve_Pass./Goods	0.371	0.358	1.038
After_Choice-Serve_Pass./Goods	0.137	0.343	0.400
After_Choice-Maintenance	1.058	0.470	2.252
Socio-demographic Variables			
Gender-Maintenance	0.491	0.324	1.512
Gender-Leisure	1.495	0.462	3.234
Gender-Other	2.874	0.884	3.252
Gender-Serve_Pass./Goods	0.405	0.288	1.408
High_Income_Dummy-Serve_Pass./Goods	0.121	0.287	0.419
High_Income_Dummy-Maintenance	-0.165	0.359	-0.459
High_Income_Dummy-Leisure	0.071	0.450	0.158
High_Income_Dummy-Other	-0.102	0.695	-0.147
Low_Income_Dummy-Leisure	0.443	0.489	0.907

Low Income Dummv-Other	0.206	0.841	0.244
Low_Income_Dummy-Serve_Pass./Goods	-0.838	0.325	-2.582
Low_Income_Dummy-Maintenance	-0.387	0.355	-1.091
Dual_Income_Dummy-Serve_Pass./Goods	0.575	0.273	2.109
Dual_Income_Dummy-Maintenance	-0.101	0.296	-0.340
Dual_Income_Dummy-Leisure	1.392	0.412	3.378
Dual_Income_Dummy-Other	-0.740	0.501	-1.479
Young_Child_Dummy-Serve_Pass./Goods	-0.504	0.321	-1.571
Young_Child_Dummy-Maintenance	-0.425	0.429	-0.990
Young_Child_Dummy-Leisure	0.209	0.551	0.380
Age1-Maintenance	1.409	0.883	1.596
Age2-Serve_Pass./Goods	-0.920	0.517	-1.780
Age2-Maintenance	0.987	0.861	1.146
Age2-Leisure	0.423	0.590	0.717
Age2-Other	-0.741	0.767	-0.966
Age3-Serve_Pass./Goods	-1.078	0.474	-2.272
Age3-Maintenance	0.418	0.822	0.509
Age3-Leisure	0.068	0.507	0.134
Age3-Other	-1.823	0.625	-2.915
Age4-Serve_Pass./Goods	0.696	0.650	1.070
Urban Form & Transportation Variables			
Des. CBD-Serve pass./goods	0.638	0.296	2.159
Des. CBD-Maintenance	0.888	0.329	2.697
Des. CBD-Leisure	1.369	0.383	3.578
Des. CBD-Other	-0.086	0.696	-0.123
Des Acessibility-Serve Pass./Goods	-0.146	0.060	-2.451
Des. Accessibility-Maintenance	0.068	0.085	0.803
Des. Accessibility-Leisure	-0.094	0.080	-1.169
Des. Accessibility-Other	0.275	0.213	1.287
General results of the estimation			
Number of coefficients:	65		
Final log-likelihood:	-581.937		
Log-likelihood of multinomial model:	-581.937	Test : -0	
Log-likelihood of model with zero coefficients:	-1141.45	Test : 1119.02	
Rho squared (zero):	0.49		
Rho bar squared (zero):	0.43		

Appendix D: After work intermediate activity

Coefficient	*Estimation*	*Std. Error*	*T-ratio*
ASC-Serve_Pass./Goods	-0.559	0.758	-0.738
ASC-Maintenance	-0.878	0.925	-0.950
ASC-Leisure	0.104	1.328	0.078
ASC-Other	-0.419	1.296	-0.323
Transportation Variables			
Car_Driver-Serve_Pass./Goods	0.320	0.647	0.495
Car_Driver-Maintenance	0.378	0.854	0.442
Car_Driver-Leisure	0.163	1.244	0.131
Car_Driver-Other	0.074	0.663	0.112
Slow_Mode-Serve_Pass./Goods	0.619	0.661	0.937
Slow_Mode-Maintenance	0.519	0.858	0.605
Slow_Mode-Leisure	0.344	1.243	0.277
Slow_Mode-Other	0.119	0.726	0.164
Bus-Serve_Pass./Goods	0.943	0.811	1.163
Bus-Maintenance	1.178	0.910	1.294
Bus-Leisure	1.314	1.300	1.011
Train-Serve_Pass./Goods	-1.049	0.744	-1.409
Train-Maintenance	1.202	0.884	1.359
Train-Leisure	0.530	1.278	0.415
Car_Distance-Serve_Pass./Goods	0.009	0.005	1.685
Car_Distance-Maintenance	0.011	0.006	1.907
Car_Distance-Leisure	0.008	0.006	1.233
Car_Distance-Other	0.004	0.011	0.318
Travel_Time_(NO)	0.002	0.002	0.638
Peak Period Serve. Pass./Goods	0.395	0.184	2.147
Peak Period Maintenance	0.266	0.209	1.278
Peak Period Leisure	-2.978	0.304	-9.787
Peak Period Other	-0.675	0.497	-1.358
Activity Variables			
Activity_Program-Serve_Pass./Goods	-0.050	0.071	-0.704
Activity_Program-Maintenance	-0.125	0.090	-1.378
Activity_Program-Leisure	-0.458	0.131	-3.497
Activity_Program-Other	-0.095	0.163	-0.581
Work_Duration-Serve_Pass./Goods	0.002	0.001	3.471
Work_Duration-Maintenance	0.001	0.001	1.116
Work_Duration-Leisure	0.002	0.001	2.164
Work_Duration-Other	-0.001	0.002	-0.575
Other Choice Variables			
Before_Choice-Serve_Pass./Goods	1.219	0.228	5.352
Before_Choice-Maintenance	2.223	1.247	1.782
In-between_Choice-Serve_Pass./Goods	0.652	0.419	1.556
In-between_Choice-Maintenance	0.646	0.474	1.364

Socio-Demographic			
Gender-Serve_Pass./Goods	-1.077	0.203	-5.301
Gender-Maintenance	-0.163	0.225	-0.726
Gender-Leisure	0.071	0.262	0.272
Gender-Other	0.067	0.582	0.114
High_Income_Dummy-Serve_Pass./Goods	0.223	0.233	0.959
High_Income_Dummy-Maintenance	-0.138	0.258	-0.533
High_Income_Dummy-Leisure	0.030	0.285	0.105
High_Income_Dummy-Other	0.241	0.616	0.391
Low_Income_Dummy-Serve_Pass./Goods	-0.142	0.224	-0.634
Low_Income_Dummy-Maintenance	0.077	0.253	0.304
Low_Income_Dummy-Leisure	-0.199	0.314	-0.633
Low_Income_Dummy-Other	0.121	0.631	0.191
Dual_Income_Dummy-Serve_Pass./Goods	0.142	0.191	0.744
Dual_Income_Dummy-Maintenance	-0.188	0.200	-0.939
Dual_Income_Dummy-Leisure	-0.366	0.239	-1.532
Dual_Income_Dummy-Other	0.637	0.548	1.162
Young_Child_Dummy-Serve_Pass./Goods	0.044	0.229	0.193
Young_Child_Dummy-Maintenance	-0.164	0.315	-0.519
Young_Child_Dummy-Leisure	-0.447	0.462	-0.969
Young_Child_Dummy-Other	0.428	0.603	0.711
Age2-Serve_Pass./Goods	-0.566	0.306	-1.851
Age2-Maintenance	-0.476	0.292	-1.631
Age2-Leisure	-0.385	0.336	-1.145
Age2-Other	-1.218	0.677	-1.798
Age3-Serve_Pass./Goods	-0.458	0.272	-1.683
Age3-Maintenance	-0.489	0.244	-2.002
Age3-Leisure	-0.433	0.285	-1.522
Age3-Other	-1.787	0.576	-3.104
Urban Form & Land Use			
Destination_CBD-Serve_Pass./Goods	-0.027	0.241	-0.113
Destination_CBD-Maintenance	0.417	0.238	1.751
Destination_CBD-Leisure	0.152	0.289	0.527
Destination_CBD-Other	-0.509	0.693	-0.735
General results of the estimation			
Number of coefficients:	71		
Final log-likelihood:	-1015.83		
Log-likelihood of multinomial model:	-1015.83	Test: -0	
Log-likelihood of model with zero coefficients:	-1365.76	Test: 699.87	
Rho squared (zero) :	0.26		
Rho bar squared (zero) :	0.20		