TIME AND SPATIAL DEPENDENT ACTIVITIES AND TRAVEL CHOICES: RESULTS FROM SANTIAGO DE CHILE

JUSTEN, Andreas: Institute of Transport Research, German Aerospace Center, Berlin, andreas.justen@dlr.de

MARTÍNEZ, Francisco: Department of Transport Engineering, University of Chile, Santiago, fmartine@ing.uchile.cl

CORTÉS, Cristián: Department of Transport Engineering, University of Chile, Santiago, ccortes@ing.uchile.cl

ABSTRACT

Based on the choice for an activity plan (number and sequence of activities) we calculate complete activity trip trajectories, denominated as spatial paths. Each path represents the interdependency of activities and trips and includes choices for locations and modes. We introduce a methodology to reduce the spatial search for secondary activity locations and constrain spatial paths against daily travel time budgets. The application is illustrated for an activity plan of type 'Home-Work-Shopping-Home'. As main information sources we use an existent trip demand model to reproduce the long term decisions for work and education locations and Santiago's Travel and Household Survey to describe the characteristics of conditional secondary activities. We show results of the calculations of spatial paths and validate them against the empirical data base. The approach is currently under development for the area of Greater Santiago, Chile.

Keywords: Activity and Travel Behaviour, Activity Plans, Spatial Paths, Travel Time Budget, Santiago de Chile

INTRODUCTION

This work aims at the introduction of a methodology and application to reproduce choices of activities and trips interdependencies throughout the day. The modelling of interdependent travel behaviour is issue to a great variety of research efforts that finally all try to reproduce more realistic human activity and travel behaviour. We start from a theoretical definition of the individual decision making process and deduce a typology of hierarchies among decisions. We then analyse the available Chilean Travel and Household survey against the background of this typology to work on the implementation in a real world application.

In recent years various research attempts have been dedicated to develop a behaviourally sounder framework than the established trip based models provide. Generally, newer approaches can be summarized under the concept of an activity based travel analysis. These approaches are founded on the common understanding that travel demand is derived from the activities people conduct during the day, that decisions for destinations, modes and times depend on each other and that the household context influences the decisions of its members. Research is underway in various directions, efforts focus on aspects such like activity scheduling, estimation of joint activities and trips with other household members or assuring the spatial dependency between destination and mode choices (Bhat et al., 2008; Bhat, 2009; Bowman and Ben-Akiva, 2000; Jonnalagadda et al., 2001; Bradley et al., 2010). Often the dependency between decisions for activities and trips is realized applying tour based models where a sequence of activities and trips starts and ends at the home location without a home stay in between. The approach presented here is related to a tour based understanding of transport demand, where people start and end the activity trip combination at home. But, in difference to approaches that simulate tours for each individual separately, we estimate tour probability flows for aggregated socioeconomic household clusters.

As mentioned, most of the activity based approaches are implemented as microsimulations, treating each individual as a single agent within the system that decides under a constrained environment. Often the underlying assumption of the simulations is having rational individuals, maximizing their utility within a set of options. The trade off of this approach is that equilibrium conditions, that build part of the traditional 4 step transport models, are eliminated with the benefit of an increase in modelling details. This is due to the common problem of these models to handle the combinatorial number of choices and the dependency among them that arise from activities, spatial location, travel options and scheduling activities for all consumers. Without any doubt the contribution of the new models is their increased detail on activities, destinations and their interdependencies, but again, the more realism provided is at the cost of departing from the equilibrium paradigm; for an overview of transport models under development and in application see Davidson et al., 2007; Iacono et al., 2008; Buliung and Kanaroglou, 2007; Bradley and Bowman, 2006.

In this paper we develop a methodology and show results of a framework that considers aspects of an activity based model type but which from its conceptual design works probabilistic and allows the consideration of equilibrium conditions. The complex combinatorial process as a result of the large amount of possible individual choices is simplified by means of a hierarchical (macro-micro) approach. Naturally, this approach cannot stand the level of information detail microsimulations provide with their perspective on individual choice situations (bottom up approach), as our output are probabilistic flows of activity travel trajectories, denominated spatial paths. The benefit of our hierarchical equilibrium model is that our top down approach provides some detail of the individuals' choices at the same time that we can introduce the time budget constraint in the spatial paths choices. Moreover, the approach, by construction is bound to reproduce observed totals. We demonstrate the calculation process based on an exemplary activity travel sequence, using a classical trip demand model for the macro scale activities (home, work and education), and observed probabilities for secondary activity choices such as shopping or leisure. Hence, the paper shows a methodology based on a hierarchical time equilibrium model which can be applied in a context where classical trip based models are available. It extends their level of detail with the introduction of spatial paths and deals with the combinatorial problem of disaggregated and linked choices by introducing a hierarchical geographic location search.

The paper is structured as follows: chapter 2 introduces the theory of hierarchical decision making and its underlying assumptions, chapter 3 outlines the used input data and models, chapter 4 describes the processing of input data and additionally exemplifies in detail the calculation process; chapter 5 is dedicated to validate the results against empirical observations, in chapter 6 we draw conclusions and give an outlook on the next steps to further improve the framework.

HIERARCHICAL STRUCTURE OF CHOICES

Daily transport related choices can appear extremely complex for human beings due to the large amount of options that define the feasible set: the combination of ordered activities, the decisions for locations and transport modes and the allocation of time. Such complexity means high requirements even for advanced computers when we try to simulate such a process. The number of options increases with the number of ways in which time is allocated, the set and order of activities performed and with the level of detail that describes the geography, i.e. the zoning system. Additionally, any search process reproduced in a model needs to consider the limited amount of resources available in the real world (time, money). In order to introduce a rational but also feasible strategy to reduce complexity, the information needs to be organized into a hierarchical structure of decisions in space and time. The following table is the attempt to order decisions that represent (or do have an impact on) the individual transport behaviour in a hierarchy of time.

Table 1: Time hierarchy for activities

TIME-WINDOWS	TIME-UNITS	CONSUMERS	SUPPLIERS	REGULATORS
Very long-term	Centuries	Cultural factors	Cities building and network structure New cities	
Long-term	Decades to Years	Family structure Education Car-Ownership Residence Job	Infrastructure: Buildings Roads/Tracks Bridges Technology	Plans: Regulations Incentive Policies Infrastructure Plans
Short to very short-term	Years to Months	Time and location of leisure activities Transport Modes	Operations: Level-of-Service	
Very short-term	Days to Hours	Route Choice Local Transport Modes Walking Destinations	Adjustment of Operations: Stops and Delays	

A typology of hierarchies in decision making appears reasonable as we can observe in reality, that decisions are taken in different time windows. Staying with the example of the table above the development of infrastructure (suppliers) takes years and may influence decisions of home and work locations or if a car is purchased (consumers); the level of service (supplier) determines decisions taken in the short term for activity locations and transport modes (consumers); finally, daily circumstances of the operational level (suppliers) that change at a very short term can influence daily route or local location choices (consumers). Again all these decisions happen within boundaries, defined by economic or time depleted resources and the individual's capability to process information. This is consistent with the existence of a maximum amount of feasible effort made by human beings in a search process, be it physically or economically defined. In accordance to the table we formulate the following typology of hierarchies:

Hierarchy between the geographical and temporal scales: The geographical scale is subordinated to the temporal scale. In other words: the decision whether or not to buy a car is a long term (temporal scale) decision that once realized influences decisions of location choice (geographical scale). Hence, decisions associated to the long term temporal scale define the effects that last for the long term, both in terms of the consumption of resources and the level of utility attained. An appropriate geographical scale is utilitarian rather than fundamental, as it is the one that provides an efficient search in a complex set of options, saving efforts and resources, but does not affect fundamentally the long term quality of life. Therefore, this rule univocally defines that the temporal scale determines the geographical scale.

Hierarchy among time: The time spent on long term decisions compared with short term ones is consistent with the corresponding scales. This means that time spent for a long term related decision such as the work duration, ascertains durations of secondary activities. Naturally, time is treated as a depleted resource where for instance daily travel times or daily out of home times vary among user groups but are constrained against a maximum.

Hierarchy among activities locations: Long term decisions for home or work locations determine any subordinated decision of a short to very short term decision, such as the location of a shopping or leisure facility. This typology is related to the argument of limited available resources where the scales between activities coincide with the amount of resources associated to long and short term decisions.

As introduced, the major assumption of the methodology presented here is that choices for activities and later on for related destinations and modes are modelled as they were made hierarchically. In our approach any individual belonging to a socioeconomic cluster chooses an activity plan, concept that refers to the set of activities and their order (see Figure 1). Given the set of activities a spatial path is defined including the locations of activities and the associated transport modes. Each individual is assumed to perform a search and evaluation process for an optimal spatial path. We assume a bi level of macro and micro scales that correspond to a hierarchy between decisions associated to different levels for time, space and activity locations. Macro decisions are mainly influenced by the long term variables such as the household structure or car ownership, micro related decisions for discretionary activities respond to the actual level of services and attractiveness of activity locations. In combination macro and micro decisions represent the spatial path which is constraint against limited time resources. In the current application which is described in the remainder, we constrain the spatial path against the daily travel time budget.

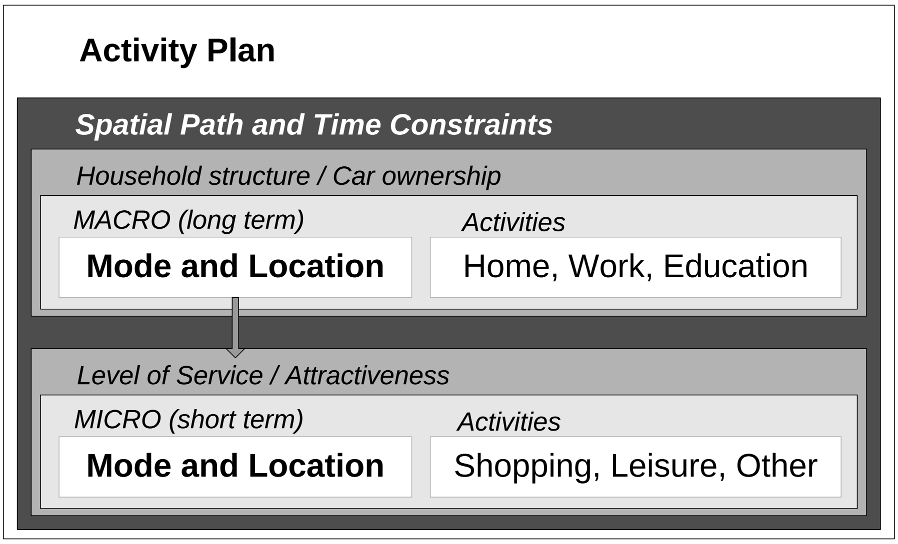

Figure 1: Sequence of Choice Process

Making use of hierarchies among temporal, spatial and activity related decisions, we now focus on the introduction of an efficient hierarchic and strategic search algorithm of spatial paths for individuals. Efficiency simultaneously serves both to reproduce travel behaviour assuming individuals that have limited capacities to search as this is time consuming, i.e. costly, and also to save computing resources. The approach works fully probabilistic, thus the methodology offers a proceeding that stepwise reduces the large amount of combinatorial options making use of the hierarchical decision making rules introduced in this chapter.

MODELS AND DATA

The aim is to assess the value of the hierarchical approach and the potential benefits before developing an implementation of a fully operational model. This allows us to investigate functionality and efficiency of the methodology and validate the results against the empirical sources. As main input sources for the calculations we use Santiago's Travel and Household Survey (EOD) and input/output data of Santiago's modelling suite for transport (ESTRAUS) and land use (MUSSA). Both data and models are related directly to the bi level of macro and micro choices introduced in Figure 1. ESTRAUS provides the (macro) information about OD relations (by mode) between home and either the work or education locations. The data from the EOD is used to calculate (micro) empirical distributions (e.g. sequences of activities, mode choices, daily travel times) and land use model MUSSA delivers the attractiveness of discretionary activity locations. Note that the usage of this information is due to the specific context of available data in Santiago. Especially in the case of the spatial relationship between the home and work (education) locations, other sources – if available – can be considered.

Santiago's Travel and Household Survey – EOD

The EOD was assigned by the Chilean Ministry of Planning in 2001 and conducted by the Catholic University of Santiago. The main objectives were the detailed description of the cities travel patterns that would allow the generation of origin destination matrices and the estimation of the necessary parameters for an urban transport model (DICTUC, 2002; Mideplan and Sectra, 2002). The survey was realized during two time periods (summer, rest of the year) and information was collected both for typical work days and at the weekend. The sample represents 1% of Santiago's population and provides information about approximately 150,000 trips (by purpose, location and mode) as well as sociodemographic and economic characteristics of nearly 60,000 people living in 15,000 households. The survey includes geographic coordinates referenced to the housing block level for all observed trips and related locations. The data was used to generate day plans of activities and trips per person. The day plans describe the complete information of all activities and trips for one person during one day, referring to activity types, starting, ending and duration times of activities and trips, in and out of home durations, used modes and associated person and household related variables like age, sex, household income or number of vehicles per household.

Transport and Land Use Models

The development of both models was funded by the Chilean government and today they are applied to assess strategic infrastructure projects and the cities real estate market. Transport model ESTRAUS belongs to the family of 4 step demand models starting with trip generation (number of trips by household and zone type), applying an entropy model for trip distribution and mode partition and the assignment of origin destination matrices to networks until equilibrium criteria between demand and supply are achieved. From ESTRAUS we adopt the distribution of the population into 13 household types, impedance matrices by mode and the origin destination matrices for the purposes work and education. Further information about transport model ESTRAUS can be found e.g. in Mideplan, 2003 and de Cea, 2003.

Land use model MUSSA was designed to describe, predict, simulate and carry out analysis of the urban real estate market. According to the model all consumers in the urban real estate market, both households and economic activities, are located where they are highest bidders among all others in the market, so that real estates are assigned to their use according to a rule of an auction. In Santiago, MUSSA is applied to analyze policies of urban management that stimulate (subsidies) or not (taxes, regulations) the location of activities in the city. MUSSA interacts with transport model ESTRAUS by estimating the localization of the population at the Traffic Analysis Zone (TAZ) level which serves as input to the trip generation step in ESTRAUS. Conversely, MUSSA considers the level of service given by ESTRAUS when describing the attractiveness of zones. We use the location and size of economic activities predicted by the model to describe the attractiveness at the TAZ level. For a more comprehensive description of MUSSA refer to e.g. Martínez, 1996 and Martínez, 2007.

CALCULATION OF ACTIVITY TRIP TRAJECTORIES

Remarks on the model structure

Several elements of the existing modelling framework in Santiago were adopted such like the city's TAZ structure of 630 zones and the categorisation of the population into 13 household types, classified by 5 income and 3 car ownership categories.[1] The following remarks are preceded by the introduction of structural elements and major information sources used for the calculations:

1. we consider 5 activities (alternatively travel purposes): WORK ('W'), EDUCATION ('E'), SHOPPING ('S'), LEISURE ('L') and OTHER ('O') and

2. 5 modes: CAR DRIVER ('ach'), CAR PASSENGER ('aac'), PUBLIC TRANSPORT ('tpub'), WALKING ('cam') and BICYCLE ('bici'),

3. defined primary and secondary activities, denominating WORK and EDUCATION as of primary, all other activities as of secondary importance,

4. grouped the population into 13 household type categories according to the segmentation given by existing transport and land use models (see above),

[1] The 13 household types are segmented as follows: **01** (0 cars, 0-150.000 CHP), **02** (1+ cars, 0-150.000 CHP), **03** (0 cars, 150.001-300.000 CHP), **04** (1+ cars, 150.001-300.000 CHP), **05** (0 cars, 300.001-600.000 CHP), **06** (1 car, 300.001-600.000 CHP), **07** (2+ cars, 300.001-600.000 CHP), **08** (0 cars, 600.001-1.200.000 CHP), **09** (1 car, 600.001-1.200.000 CHP), **10** (2+ cars, 600.001-1.200.000 CHP), **11** (0 cars, > 1.200.000 CHP), **12** (1 car, > 1.200.000 CHP), **13** (2+ cars, > 1.200.000 CHP).

5. use the origin destination matrices for the relation home to work (divided by modes and household types) and impedance matrices of ESTRAUS

6. and include information about economic activities given by MUSSA (industry, commercial, service, education, other) in m² of constructed space per TAZ.

Note that the segmentation given by the transport and land use models is adopted due to the situation of reduced information availability. The methodology presented is designed in such way that it is not conditioned by the currently existing information. Once other sources about e.g. the home and workplace relation exist, different household types, i.e. more disaggregated types, can be determined.

Travel Purposes and Modes

After the generation of activity plans[2], we grouped the 12 travel purposes given in the EOD to 5 main purposes as mentioned above. The aggregation of travel purposes was due to two reasons: first, some purposes showed only very few cases in the survey which creates difficulties when trying to achieve statistically valid distributions; second when defining the activities treated in the model one needs to consider from a practical point of view which activities can be represented adequately by the land use. The grouping of travel purposes is not described in detail here but was principally based on the calculation of a weighted Euclidean distance measurement considering activity duration times, travel times and modal split reported for the 12 travel purposes in the EOD. With regard to modes, the current transport model in Santiago considers also shared taxi and taxi as mode alternatives, whereby bicycles are not yet part of the demand estimation. The calculation process presented here concentrates on the 5 main modes mentioned above due to the comparably small shares of shared taxi and taxi and to reduce combinatorial complexity. As data for bicycle travel behaviour is practically not available, spatial paths based on this mode can not be calculated, nevertheless the approach considers the mode in its conceptual design.

Prioritization of Activities

The introduction of priority between activities is defined such that compulsive activities receive higher priorities than discretionary activities. According to our time scale hierarchy work and educational purposes are understood as those of primary importance since time consumption is large compared to other activities, like shopping, leisure or errands which are classified as of secondary importance. The differentiation of activities into primary and secondary ones is important due to the following reasons: first, giving priority is thought to influence the order in which activities are scheduled (Buliung and Kanaroglou, 2007). From a behavioural point of view it seems reasonable to assume that activities of secondary

[2] The building of coherent day plans refers particularly to the preparation and validation of the EOD data. This work includes for instance the testing for complete time information (activities, trips) and consistency (all plans starting and ending at home, not having two or more consecutive home stays, etc.). The respective transformations and newly created variables that are used for the calculation of empirical probabilities are not explained in detail here.

importance are arranged conditional and around a primary one. For example, decisions associated to a recreational activity like visiting a gym (duration time, mode, location) will depend on at what time the individual can leave work. Second, the consideration of primary activities and their locations as anchor points for secondary activities eases the reproduction of their location decisions as some activity locations (work, education, home) are – at least spatially – fixed.

Unfortunately, the EOD did not ask people explicitly which activities in their travel diary were of primary and secondary importance. However, to avoid ad hoc prioritization we checked whether the assumption that work and education are of major importance due to the amount of activity time spent compared with the secondary ones holds against empirical observation. This is in line with the approach of Bowman and Ben-Akiva that applied this rule to assign higher priority to activities of longer duration (Bowman and Ben-Akiva, 2000), and consistent with our underpinning theoretical argument of hierarchical choices. Thus, we applied the rule and checked if the individual's major daily time investment reflects the order of the assumed activity importance. The following figures show the share of activities ordered by the longest duration.

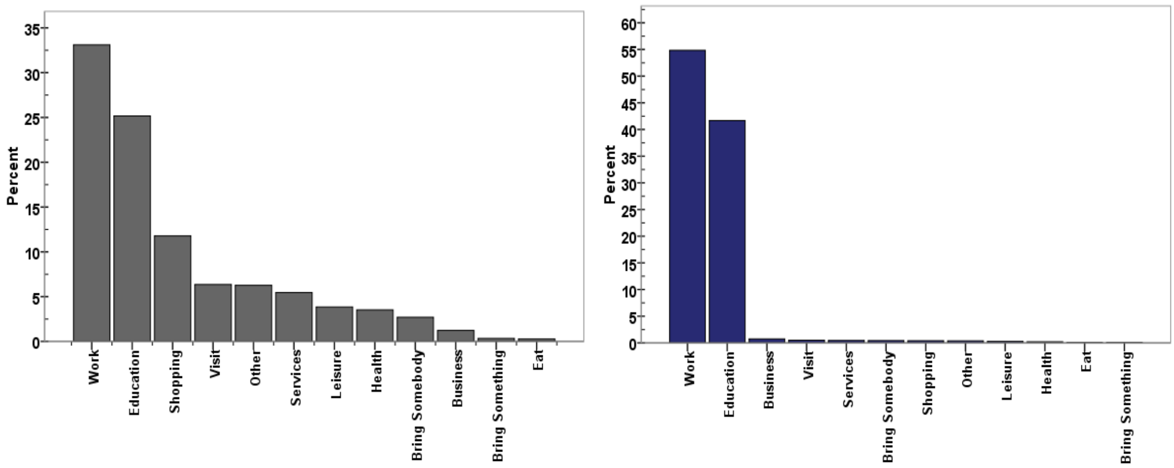

Figure 2*: EOD: Order of activities by duration
left: (Monday to Friday), N 31.992 plans
right**: (Monday to Friday), N 19.314 plans
*12 EOD travel purposes are considered
**given the condition that either work or education activity appears within the plans

The figure on the left side indicates that regarding time durations, the dominance of the work and education activities over all other activities can be confirmed. In nearly 60% of all observed activity plans either the work or education activity was reported as the longest activity in duration. In the figure on the right side we pushed this analysis forward and analyzed only those plans that contain a work or education activity and checked for the longest activity duration among these plans, obtaining that in almost every case (98%) when a work or education activity appears within the plan it was the most important activity of the day.

Daily Activity Plans for Santiago

The analytical interest in generating activity plans from the EOD was to investigate the degree of behavioural complexity that the plans represent. With complexity we refer to the number and order of activities and for instance, how often home stays occurred in between separate tours. Generally, we expected that a great share of the daily behaviour was covered by very few activity plans. To evaluate behavioural complexity we denominate primary activities (work, education) with 'X' and secondary activities (shopping, leisure, other) with 'Y'. The home location is represented by 'H'. For instance, an activity plan with the activity sequence, Home-Other-Leisure-Home is assigned to the activity plan type 'HYYH' and Home-Work-Shopping-Home is represented by 'HXYH'. Figure 3 shows all activity plan types derived from the EOD according to the applied rules for their categorisation.

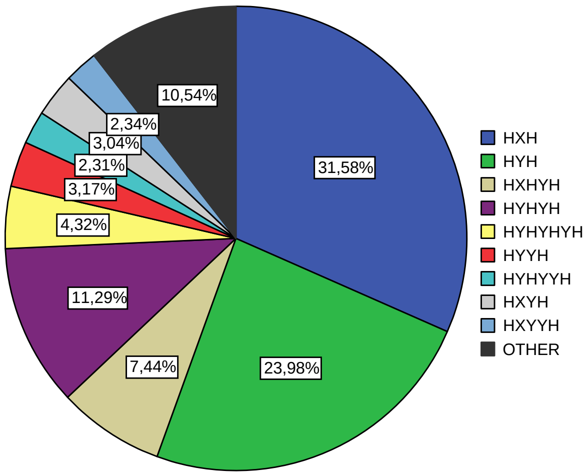

Figure 3: Frequency distribution of activity plan types in Santiago / Source: EOD, N 41.922 plans

Note that only 9 activity plan types represent almost 90% of the observed large variety of activity plan types. The category 'Other' (10.54% of all plans) comprises all activity plan types that occur with a share of less than 2%. Remember that e.g. the activity plan type 'HYHYH' counts for a great variety of plans as all combinations of secondary activities are possible, for instance 'HSHLH' or 'HOHSH', etc. The intuitive belief that only a few plan types represent a great share of behavioural variability could be confirmed by this analysis. Another interesting outcome was that about 56% of all plans are single trip home based plans ('HXH', 'HYH'). Staying with Figure 3 we can also record that nearly 79% of all activity plan types are based upon plans with one or more single trips getting back home after every activity. This is important as it shows that for a great share of plans the interdependency between activity locations and modes is not an issue due to their single trip simplicity. But in these cases, still time expenditure is relevant and makes choices dependent, as for instance, time spent both for the activity and trips of a first single trip tour influences adjacent decisions taken on a second tour conducted the same day.

In what follows we choose plan type 'HXYH' for the next calculation steps. This is due to the following reasons: the analysis showed that beside the single trip home based plans, all other plans rarely consist of more than two consecutive activities in between home stays;

and, 'HXYH' is a good reference as it represents the interdependency of decisions for modes, locations and timing and requires a more sophisticated treatment than single trip home based plans. The at the first sight rather simple example of an activity plan of type 'HXYH' (e.g. going to work and afterwards to a shopping facility before getting back home) increases tremendously in complexity when taking into account the number of possible decisions associated to execute such a plan. Theoretically a freedom of choice exists for the 'X' location, the mode used to get to any 'X'; from any 'X' there is once again the same freedom of choice (modes, locations) for the 'Y' activity. Additionally, the decisions depend on further aspects such as car availability or the household context and, most important, the resources (time, money) available and the geographical space considered.

Mode Choice Probabilities

Staying with the example of plan type 'HXYH', three trips are realized. Considering four transport modes this leads to a theoretically possible number of 81 (3^4) mode combinations. But analogously to the observations made regarding the activity plan types, it does not seem necessary to consider the complete variety of mode combinations. It can be expected that certain mode combinations are preferred options and hence, show higher frequencies of occurrence. For instance, if the first trip is realized by car (as driver), only in very few cases the following trips will be realized by other modes as the necessity to bring back the car after finishing the complete plan determines behaviour and associated decisions.

Again plan type 'HXYH' is used to exemplify the concentration of observed transport mode combinations. The decision to select only a share of possible mode combinations is done considering the following criteria: for each principal transport mode (public transport, car, walking and bicycle) there should at least be one mode combination included. Furthermore, for each of the principal modes we include at least one 'pure' mode combination, referring to the use of the same mode throughout the complete plan. Finally, the number of mode combinations incorporated should represent a target majority of the overall observed variability. The distribution of mode combinations associated to plan type 'HXYH' is shown in the following figure.

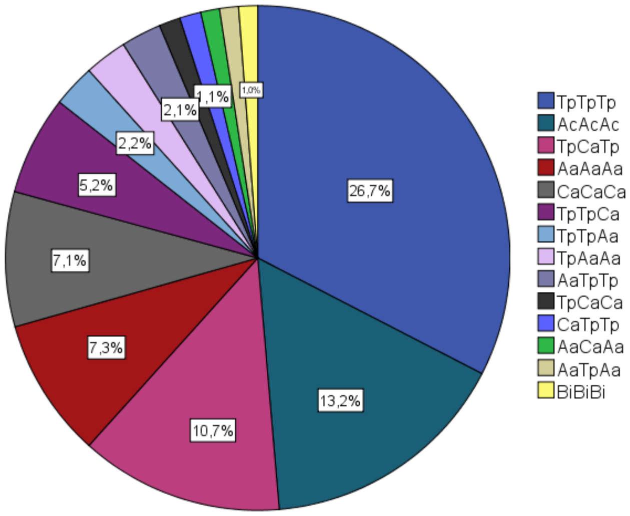

Figure 4: Share of mode combinations, plan type 'HXYH', N 805 plans
Legend: Ac (Car Driver), Aa (Car Passenger), Tp (Public Transport), Ca (Walking), Bi (Bicycle). The 14 mode combinations selected here represent 82% of all reported mode combinations for plan type 'HXYH'.

By far dominant and almost reflecting a 40% of the overall variability are the 'pure' mode combinations of TpTpTp and AcAcAc. The selection shown in Figure 4 accomplishes the criteria mentioned above: every mode is included, for each mode a 'pure' mode combination is considered and regarding the overall variability, the target majority of combinations is reproduced (82%).

Based on the empirical observation a total number of 14 mode combinations are included in the calculation. Later, any trip realized from home to work – which in the current transport model ESTRAUS is interpreted as a single and independent event – will be disaggregated regarding the identified probabilities for mode combinations. For example, if the trip to the primary activity work is realized by public transport, several possibilities open up that the following trips are realized by different modes (according to Figure 4, six mode combinations are possible). Naturally, in the case of public transport the probability to choose one of the six mode combinations is not equal for each of them. Hence, we had to identify internal modal split values for each combination defined. The following Figure 5 shows the distribution of principal modes into mode combinations and the related internal modal split values.

Public Transport		**Car Driver**		**Car Passenger**		**Walking**		**Bicycle**	
TpTpTp	55,4%	AcAcAc	100%	AaAaAa	64,1%	CaCaCa	86,4%	BiBiBi	100%
TpCaTp	22,2%			AaTpTp	18,5%	CaTpTp	13,6%		
TpTpCa	10,8%			AaCaAa	8,7%				
TpTpAa	4,7%			AaTpAa	8,7%				
TpAaAa	4,6%								
TpCaCa	2,3%								

Figure 5: Internal Modal Split Values by disaggregated mode combination

It is important to note that the probabilities shown for each mode combination are based on empirical observations, they are determined once and remain static during the calculation procedure. Nevertheless, the use of transport model ESTRAUS can reflect variations in modal split values for the principal modes, caused e.g. by policies or projects.

Algorithm and Implementation for activity plan type 'HXYH'

We use activity plan type 'HXYH' as an example and calculate the complete activity trip trajectory constrained by resources (time) and with an emphasis on the estimation of probabilities for secondary activity choices such like mode and location of a shopping or leisure activity (see Figure 1). The calculation algorithm was implemented using the statistical software package SPSS and is exemplified by the following tables.

Table 2: Calculation Step 1

Orig	Dest	P_OD_Work_06_aac	P_OD_Work_06_ach	P_OD_Work_06_cam	P_OD_Work_06_tpub	P_OD_Work_07_aac	...
3	4	3,4	6,6	9,7	4,3	*4,7*	...
3	9	2,7	10,7	0,5	0,2	*0,8*	...
3	15	0,8	2,6	0,7	5,8	*3,4*	...
3	23	4,5	4,2	3,6	11,3	*16,4*	...
3	103	1,4	7,3	3,5	1,2	*3,6*	...
3	245	2,1	0,9	11,5	0,5	*8,2*	...
4	8	*0,5*	*8,5*	*7,6*	*4,8*	*2,8*	...
4	45	*3,2*	*3,3*	*5,3*	*1,9*	*3,4*	...
4	76	*5,6*	*0,9*	*2,7*	*3,7*	*10,1*	...
...	...	...	...	...	...	...	...

Starting point is the origin destination matrix for the relation home to work (see columns *Orig, Dest*) provided by transport model ESTRAUS. The header *P_OD_Work_06_mode* represents the probability (multiplied by 100) that a trip from home to work is realized by household type 06 with mode aac (car passenger), ach (car driver), cam (walking) or tpub (public transport). We interpret the traffic flow matrix of ESTRAUS for the relation home to work as input probability for the calculation of the spatial path of 'HXYH'. Doing so, we actually calculate the spatial path for the sequence of 'HWYH', with 'Y' still representing a secondary activity of any type. Generally, the calculation steps are similar independent if estimating a spatial path for plan type 'HEYH' (education as primary activity) or 'HWYH'. For the moment we do not differ 'Y' by a specific secondary activity, nonetheless this is possible according to the data available to describe the land use. Note that mode bicycle ('bici') is not considered here. It is included in the algorithm but not calculated as the current version of ESTRAUS does not consider bicycle as mode and the information about its use in the EOD is quite sparse (only 2.3% of all trips in the EOD were realized by bicycle).

Table 3: Calculation Step 2

Travel Times first leg (TT1)						Travel Times second leg (to all Dest2) (TT2)						Travel Times third leg (from all Dest2) (TT3)					
Orig	Dest	cauto	ctpub	ccam	bici	Dest	Dest2	cauto	ctpub	ccam	bici	Dest2	Orig	cauto	ctpub	ccam	bici
3	4	2,4	9,9	16,5	5,5	4	1-630					1-630	3				
3	9	4,0	12,6	25,7	8,6	9	1-630					1-630	3				
3	15	8,1	26,9	69,1	23,1	15	1-630					1-630	3				
3	23	3,9	8,8	30,5	10,2	23	1-630					1-630	3				
3	103	12,4	28,1	107,8	35,9	103	1-630					1-630	3				
3	245	9,2	22,9	62,1	20,7	245	1-630					1-630	3				
4	8	4,4	10,2	14,5	4,8	8	1-630					1-630	4				
4	45	4,8	18,5	36,2	12,1	45	1-630					1-630	4				
4	76	13,4	33,1	109,7	36,6	76	1-630					1-630	4				
...	...	...	...	...	...	...	...					...	...				

The next step adds the travel times by modes for all zone combinations *(Orig, Dest).* This refers to the travel time for the first trip leg *(TT1),* the second trip leg from the work destination (*Dest*) to all possible secondary destinations (*Dest2*, *TT2* for 630 TAZ in the case of Santiago) and the third trip leg from all possible secondary destinations to the home location *(Orig, TT3).* The 'c' in front of each mode stands for costs (in minutes travel time), for instance in the case of public transport the travel time is composed by access, waiting and in vehicle times. With the availability of all travel times by modes for all zone combinations, all theoretically possible spatial paths can be calculated. We now use this large amount of information to define the number of relevant spatial paths that are feasible according to a set of criteria which are introduced successively in the following explanations.

A summed travel time for a spatial path, denominated as the sum of *TT1, TT2* and *TT3* is only calculated when the location of the secondary activity – respectively the travel time necessary to reach this zone – is within a given time limit. The calculation of the total daily travel time *(DTT)* for a spatial path is only realized if one of the following conditions is fulfilled:

If ($TT2_m$ < $TT3_m$ & $TT2_m$ <= X_m), then calculate DTT
If ($TT2_m$ >= $TT3_m$ & $TT3_m$ <= X_m), then calculate DTT

X_m refers to the definition of a maximum search space defined in minutes of travel time by mode. The search space is then the number of TAZ reachable within the given travel time. For instance, the assumption of a maximum search space of 20 minutes for walking trips to the secondary activity will eliminate all zones beyond this time limit. In case the travel time exceeds the criteria set by X_m, no summed travel time is calculated, hence no spatial path created. With the control whether *TT2* is less/greater than *TT3*, we define if the search space in X_m minutes is calculated from the location of the secondary location *(TT2 < TT3)* or the home location *(TT2 >= TT3).* This is an important rule which allows us to define univocally from which anchor point (the home or work location) the secondary activity location is selected. Without a doubt, the spatial decision for the location of a secondary activity is not only bounded either to the work or home location, but may lie in a corridor between both activities. For the moment we apply the search space around the anchor points, having in mind that an extension of the methodology is pending to include a geographical corridor for the secondary location choice.

The calculation of *DTT* allows the consideration of another important constraint. Until now, we only limited the travel time to the secondary activity. But, some paths still might have too high values for *DTT* when other trips of the plan show very long travel times. We now compare the calculated *DTT* with the empirically documented *DTT* in the EOD. For instance, it is most likely that combinations realized throughout by public transport in average show different *DTT* than those realized by car. Respectively, we eliminate all spatial paths with a *DTT* above the observed maxima in the EOD. The range of accepted *DTT* is between 80 minutes for the mode combination TpCaCa and 220 minutes for TpTpTp. As in the EOD some cases still exceed these ranges we apply a 90% threshold, meaning that in the case of TpCaCa 90% of all plans were realized within the 80 minutes limit.

Table 4: Calculation Step 3

Orig	Dest	Dest2	ModeType	DTT	Relation	Dest2	Land Use (LU)	∑ LU by OD	psuelo (LU / ∑ LU)
3	4	53	TpTpTp	66,6	1	53	4981,7	33405,4	0,149
3	4	53	AaTpAa	39,1	1	53	4981,7	33405,4	0,149
3	4	53	AcAcAc	24,1	2	53	4981,7	33405,4	0,149
3	4	53	AaTpTp	59,1	1	53	4981,7	33405,4	0,149
3	4	16	TpTpTp	41,2	2	16	6739,3	33405,4	0,202
3	4	16	CaCaCa	90,5	1	16	6739,3	33405,4	0,202
4	8	12	TpCaTp	54,5	2	12	*7637,2*	*84209,7*	*0,091*
4	8	12	AcAcAc	26,0	1	12	*7637,2*	*84209,7*	*0,091*
4	8	45	TpTpTp	59,3	1	45	*42795,5*	*84209,7*	*0,508*
...	...	...	...	...	...	...	...	...	...

The result of the constrained selection of feasible spatial paths is illustrated in the table above. For every origin destination combination *(Orig, Dest)* several secondary destinations are feasible *(Dest2).* Note that any secondary destination is differentiated by its respective mode combination *(ModeType).* The example indicates that the number of possible mode location combinations depends strongly on the definition of X_m and the marginal values for *DTT*. By introducing a rule to define whether a plan is home or work related and having the travel time by mode to the secondary activity location, we are able to define univocally the pivot relation of each spatial path *(If Relation = 1 → home related path / If Relation = 2 → work related path).*

So far the fact that a secondary location might be more attractive than another because of differences in the supply of land use characteristics is not considered. We now add for every secondary location *(Dest2)* the land use *(LU in m² of constructed space for service and commercial use provided by land use model MUSSA),* build the sum of *LU* by OD pair (*Orig, Dest)* and calculate the proportion of land use for each secondary location *(psuelo).* The values of *psuelo* sum up to 1 for each origin destination pair.

Table 5: Calculation Step 4

Orig	Dest	Dest2	...	psuelo (p)	weight (w)	p*w (pw)	ModeType	ModeAgg	∑ pw by ModeAgg	pw2 = (1/∑ pw * pw)
3	4	53	...	0,149	0,26	0,0387	TpTpTp	Tp	0,0771	0,5019
3	4	53	...	0,149	0,48	0,0209	AaTpAa	Aa	0,0596	0,3507
3	4	53	...	0,149	0,56	0,0834	AcAcAc	Ac	0,0834	1,0000
3	4	53	...	0,149	0,26	0,0387	AaTpTp	Aa	0,0596	0,6493
3	4	16	...	0,202	0,19	0,0384	TpTpTp	Tp	0,0771	0,4981
3	4	16	...	0,202	0,18	0,0364	CaCaCa	Ca	0,0364	1,0000
4	8	12	...	*0,091*	*0,19*	*0,0173*	TpCaTp	Tp	...	...
4	8	12	...	*0,091*	*0,48*	*0,0437*	AcAcAc	Ac	...	...
4	8	45	...	*0,508*	*0,19*	*0,0965*	TpTpTp	Tp	...	...
...	...	...	...	...	...	...	...	...	...	...

Next a joint factor *(pw)* is calculated based on land use proportions *(psuelo)* and specific weighting factors *(w).* The weighting factors *w* are calculated from the EOD considering mode and travel time to secondary activity locations. Each weight *w* represents the probability that a trip (by mode) takes place within a given time slot. Thus, these factors allow evaluating and ordering all secondary activity locations by OD pair according to their better/worse accessibility by mode. Then the product of *psuelo* (representing the attractiveness defined by the land use) and *w* (the accessibility by mode) can be calculated *(pw)*. The time slots are predefined and in 10 minutes intervals. For instance, a trip by car to a secondary activity location may take between 0 and 30 minutes. In this case three probabilities, or weights *(w)* that together sum up to 1, are extracted from the EOD for the three time slots. Before the assignment of *w* and the calculation of *pw* we check for the pivot relation of the spatial path and its mode and travel time to the secondary location, following these rules:

If (Relation = 1 & ModeType = Y) & ($TT3_m(Y)$ <= Z_m & > W_m), then weight = V_1
If (Relation = 2 & ModeType = Y) & ($TT2_m(Y)$ <= Z_m & > W_m), then weight = V_2

Y represents one of the 14 mode combinations; $TT3_m(Y)$ the travel time to the secondary location using a specific mode of mode combination *Y*; Z_m and W_m represent travel time slots by mode (0 to 10 min, 11 to 20 min, 21 to 30 min, 31 to 40 min), V_1, V_2 are the respective empirical probabilities/weighting factors derived from the EOD.

The joint probability *pw* is then normalized to 1 *(pw2)* considering the aggregated values of *pw* by principal mode *ModeAgg.* The variable *ModeAgg* represents the mode choice for the primary activity, which in our example is a commuting trip between home and work. In the example of Step 4 any given demand of realizing trips to work by public transport, would be divided with a probability of 0.5019 into one path leading to secondary location zone 53 and another path with a probability of 0.4981 leading to secondary location zone 16 – in both cases using the mode combination TpTpTp.

Up to this point, the criteria X_m and *DTT* for secondary locations have been applied, the attractiveness by land use was included, the specific travel time to the secondary location was used (accessibility) for weighting and the joint probability of land use and travel time was calculated. Now, based on the information if a spatial path is either home or work related, we can apply another selection criterion corresponding to the spatial orientation (pivot relation) of each path. The empirical information given by the EOD indicates the number of plans of type 'HXYH' and mode combination *Y* that are either home or work related. In practice, this means we observed in the EOD that for instance, 57% of all plans realized by mode combination AcAcAc are home related and 43% work related. We then apply these proportions to the overall number of calculated spatial paths and eliminate those paths with the lowest joint probability *(pw)* in such way that the empirical proportion of home and work related paths documented in the EOD is exactly reproduced. Afterwards, the remaining spatial paths and associated joint probabilities are normalized to 1 for each aggregated mode as indicated before.

Table 6: Calculation Step 5

Orig	Dest	Dest2	Orig	user_06	P_OD_Work_06_aac	P_OD_Work_06_ach	P_OD_Work_06_cam	P_OD_Work_06_tpub	pw2	ModeAgg	ModeType
3	4	53	3	367	3,4	6,6	9,7	4,3	0,5019	Tp	TpTpTp
3	4	53	3	367	3,4	6,6	9,7	4,3	0,3507	Aa	AaTpAa
3	4	53	3	367	3,4	6,6	9,7	4,3	1,0000	Ac	AcAcAc
3	4	53	3	367	3,4	6,6	9,7	4,3	0,6493	Aa	AaTpTp
3	4	16	3	367	3,4	6,6	9,7	4,3	0,4981	Tp	TpTpTp
3	4	16	3	367	3,4	6,6	9,7	4,3	1,0000	Ca	CaCaCa
4	8	12	4	15	0,5	8,5	7,6	4,8	...	Tp	TpCaTp
4	8	12	4	15	0,5	8,5	7,6	4,8	...	Ac	AcAcAc
4	8	45	4	15	0,5	8,5	7,6	4,8	...	Tp	TpTpTp
...	...	...	...	...	...	...	...	...	...	...	...

Finally, the probability for a secondary mode location choice combination *(pw2)* is brought together with the overall demand (product of the number of households and the proportion of plan type 'HXYH' of the overall variability of plan types defined) and the initial probability for the first trip leg of home to work (origen destination matrix from transport model ESTRAUS). In the table of Step 5, *user_06* represents the demand.[3] Remember that the probabilities indicated by *P_OD_Work_06_mode* sum up to 100 for all modes and by origin (see Table 2). Respectively, the probability for each spatial path is denominated as the product of *user_06, P_OD_Work_06_mode* and *pw2*.

Table 7: Calculation Step 6

Orig	Dest	Dest2	Orig	Path_06	ModeType
3	4	53	3	7,92	TpTpTp
3	4	53	3	4,38	AaTpAa
3	4	53	3	24,22	AcAcAc
3	4	53	3	8,10	AaTpTp
3	4	16	3	7,86	TpTpTp
3	4	16	3	35,6	CaCaCa
4	8	12	4	...	TpCaTp
4	8	12	4	...	AcAcAc
4	8	45	4	...	TpTpTp
...	...	...	...	...	...

Calculation of path probability by user group

P_OD_Work_06_mode * pw2 * user_06 / 100
EXAMPLE first row: 4,3 * 0,5019 * 367 / 100

We exemplify the calculations for the first row with the respective values shown in the box on the right side of Table 7. *Path_06* represents the spatial path probability that a member of household type 06 makes a trip to work from origin 3 to destination 4, continues for a secondary activity location to zone 53 and uses for all related trips public transport.

[3] This calculation step is not shown here. It is basically a trip generation step, based on the proportion of the respective plan type and the number of households that will probably execute this plan during a normal workday.

RESULTS AND VALIDATION

In the chapter before we illustrated the methodology along a reduced example. The application with real data leads to much more combinations of spatial paths which are gradually reduced according to the introduced constraints. An example of how to demonstrate and check the results based on real data is given by the following table.

Table 8: Aggregated Spatial Paths Flows by Mode and Household Type

Orig	Dest	ModeAgg	…	pPath04	pPath05	pPath06	…	pPath13
1	**25**	Public Transport	…	0,3914	17,9862	0,6295	…	0,0001
		Car Driver	…	1,0100	0,0000	1,4563	…	0,0008
		Car Passenger	…	0,2594	0,5632	0,3640	…	0,0002
		Walking	…	0,1750	7,1805	0,2416	…	0,0000
		Bicycle	…	-	-	-	…	-
110	**243**	Public Transport	…	0,0954	5,3070	0,1394	…	0,0000
		Car Driver	…	0,1911	0,0000	0,2732	…	0,0001
		Car Passenger	…	0,0584	0,0672	0,0737	…	0,0000
		Walking	…	0,0000	0,0000	0,0000	…	0,0000
		Bicycle	…	-	-	-	…	-
550	**393**	Public Transport	…	0,0172	0,2513	0,4232	…	1,0955
		Car Driver	…	0,0401	0,0000	0,9452	…	9,5155
		Car Passenger	…	0,0115	0,0050	0,2480	…	2,2347
		Walking	…	0,0000	0,0000	0,0000	…	0,0000
		Bicycle	…	-	-	-	…	-

For three OD pairs of the relation home to work the spatial paths flows by mode and 4 of the 13 household types are shown. Staying with household type 06 *(pPath06),* as in the simplified example before, we see that e.g. based on the commuting trip from Origen 1 to Destination 25, in sum 1.5 (1.4563 indicated in the table) spatial paths (paths per household type per day) with the mode 'Car Driver' were calculated (column *pPath06*, row *'Car Driver'*).

We initially explained that we use the OD matrix for the purpose work from transport model ESTRAUS and interpret the matrix as the probability for the home to work relation. The calculation of spatial paths is then the disaggregation of this initial probability into manifold options of subsequent mode and location choices. This means, the product of the initial OD probability given by ESTRAUS and the number of households needs to equal the sum of all calculated spatial paths. Table 8 allows for this plausibility check. The probability of 1.4563 reflects the sum of 246 spatial paths estimated for the OD relation 1 to 25, with mode 'Car Driver'. The product of the initial OD probability (3.8104 trips for household type 06 between OD relation 1 to 25 with mode 'Car Driver', not shown here) and the number of households in zone 1 (38, not shown here) matches approximately – considering a rounding error – the spatial paths probability (3.8104 * 38 / 100 = 1.4480).

Besides the plausibility check of the calculation procedure itself, we validate the results against the empirical data of the EOD. For this purpose, we compare if possible indicators between the calculation results and the EOD, otherwise we evaluate results given by the calculation that can not be validated against the EOD. For validation we defined the following indicators:

1. Share between home and work related plans by mode combination

2. Average daily travel time by mode combination

3. Average number of feasible secondary locations by OD pair and mode combination

4. Travel time to secondary activity locations in time slots and by mode combination

Table 9: Travel Related Indicators, Model and EOD

Public Transport (40) / Car (30) / Walking (20)*		**MODEL**		**EOD**		**MODEL**	**EOD**	**MODEL**
Mode Combinations		Relation		Relation		Daily Travel Time (Mean)		Number of Secondary Locations (Mean)
TypeNr	ModeType	home related	work related	home related	work related			
1	TpTpTp	63,2	36,8	63,0	37,0	100	121	129
2**	TpCaTp	50,0	50,0	*50,0*	*50,0*	104	106	10
3	TpTpCa	8,8	91,2	9,0	91,0	137	111	43
4	TpAaAa	81,2	18,8	81,0	19,0	71	92	221
5	TpTpAa	52,8	47,2	53,0	47,0	98	126	95
6	TpCaCa	50,0	50,0	*50,0*	*50,0*	57	62	6
7	AcAcAc	57,0	43,0	57,0	43,0	52	89	262
8	AaAaAa	81,2	18,8	81,0	19,0	52	68	223
9	AaTpTp	63,2	36,8	63,0	36,0	82	91	130
10	AaCaAa	50,0	50,0	*50,0*	*50,0*	74	71	7
11	AaTpAa	52,8	47,2	53,0	47,0	74	75	95
12	CaCaCa	50,0	50,0	*50,0*	*50,0*	57	42	5
13	CaTpTp	63,2	36,8	63,0	37,0	134	97	103
14***	BiBiBi							

*The results are based on a maximum search space for secondary locations by modes as indicated: 40 minutes for public transport, 30 minutes for car (driver, passenger) and 20 minutes for walking.
**In cases of italic shares for the differentiation between home and work related plans, we assumed a 50/50 distribution because of little sample sizes in the EOD.
***There were now spatial paths calculated for mode combinations with bicycle use.

The share between home and work related plans matches the references given by the EOD. This is due to the use of the empirical shares of the EOD and their application as fixed adjustment parameters (see Step 4, above). Regarding the summed daily travel time the strongest deviations (overestimations) are observable when a walking trip is realized in combination with two public transport trips. There is also a tendency of underestimating daily travel times when car based trips are realized, especially in the case of the ‘pure’ car mode combinations. The average number of secondary locations, i.e. the number of spatial paths, varies strongly dependent on the mode combination. Up to 226 combinations (in average) are estimated in the case of AcAcAc, whereas the smallest number of 5 combinations is related to CaCaCa.

The differences in the daily travel times are most probably related to two aspects: we constrained the spatial path by a limited travel time for the secondary location choice and by a limit for the overall daily travel time. We do not yet weight separately each trip leg and its associated travel time. Thus, larger travel times for the first and last trip leg – especially in the case of the mode combinations TpTpCa and CaTpTp – can be responsible for an at average higher daily travel time. Additionally, and most evident in the cases of underestimated daily travel times for TpAaAa, AcAcAc and AaAaAa, an explanation might be found in the respective information itself which was used for the calculation. The EOD represents reported travel times of surveyed individuals for point to point travel given the situation of Santiago's infrastructure and associated levels of services from 2001. The calculation of the spatial paths was made based on the information available which basically are impedance matrices given by transport model ESTRAUS from 2007, representing the morning peak hour and based on zone to zone measurement. Which effect finally causes the deviations in calculated and surveyed travel times can not be answered definitely (errors of respondents in the EOD, the averaged zone to zone time matrices or infrastructural and operational changes of the transport system in Santiago between 2001 and 2007). But the results at least indicate that car related travel times given by ESTRAUS seem to be too low in comparison to the city's trips demand situation as reported in the EOD.

Important indications about the model performance are also given by the average number of secondary locations by mode type. This number can not be compared to the EOD as the survey reports the specific choice for a secondary location (see Table 9) and not the total of feasible spatial paths. We can clearly identify the relevance of spatial units and travel times by mode on the number of selected secondary locations. Using the car leads to a more extended search space than using public transport although we applied a less restricted travel time limit for public transport related trips. When the secondary location is reached walking, the number of options decreases significantly. This effect is caused by the rather rough TAZ level, respectively only very few secondary locations can be reached within the 20 minutes travel time criteria.

Further insight to the results is given by comparing the travel times to secondary locations reported in the EOD and those calculated (see the following table).

Table 10: Travel Time to Secondary Locations, Model and EOD

Travel Time to Secondary Locations in % of time slots									
Public Transport (40) / Car (30) / Walking (20)		**MODEL**							
		Relation							
Mode Combinations		home related (in min)				work related (in min)			
TypeNr	ModeType	0 to 10	11 to 20	21 to 30	31 to 40	0 to 10	11 to 20	21 to 30	31 to 40
1	TpTpTp	2,1	23,5	39,3	35,1	5,7	26,0	43,6	24,6
2	TpCaTp	0,2	11,6	56,0	32,3	39,1	60,9		
3	TpTpCa	52,9	47,1			4,5	26,2	40,3	29,0
4	TpAaAa	31,6	40,6	27,8		55,0	30,9	14,1	
5	TpTpAa	20,7	43,2	36,1		9,0	37,5	36,8	16,7
6	TpCaCa	68,9	31,1			62,8	37,2		
7	AcAcAc	34,0	41,2	24,8		41,3	40,4	18,3	
8	AaAaAa	31,5	40,5	28,0		54,7	30,9	14,4	
9	AaTpTp	2,1	23,5	39,3	35,1	5,7	26,0	43,6	24,6
10	AaCaAa	15,4	47,8	36,8		56,5	43,5		
11	AaTpAa	20,7	43,3	36,0		9,0	37,6	36,8	16,5
12	CaCaCa	67,1	32,9			58,9	41,1		
13	CaTpTp	3,4	30,4	36,5	29,7	7,2	30,7	41,7	20,4
14	BiBiBi	23,7	41,3	35,0		24,4	37,7	37,9	

Public Transport (40) / Car (30) / Walking (20)		**EOD**							
		Relation							
Mode Combinations		home related (in min)				work related (in min)			
TypeNr	ModeType	0 to 10	11 to 20	21 to 30	31 to 40	0 to 10	11 to 20	21 to 30	31 to 40
1	TpTpTp	42,0	29,6	14,8	13,6	46,2	28,2	16,7	9,0
2*	TpCaTp	42,0	29,6	14,8	13,6	68,7	19,4	*10,4*	*1,5*
3	TpTpCa	61,9	16,7	*11,9*	*9,5*	46,2	28,2	16,7	9,0
4	TpAaAa	58,5	30,2	7,5	*3,8*	57,5	25,0	12,5	*5,0*
5	TpTpAa	58,5	30,2	7,5	*3,8*	46,2	28,2	16,7	9,0
6	TpCaCa	61,9	16,7	*11,9*	*9,5*	68,7	19,4	*10,4*	*1,5*
7	AcAcAc	58,5	30,2	7,5	*3,8*	57,5	25,0	12,5	*5,0*
8	AaAaAa	58,5	30,2	7,5	*3,8*	57,5	25,0	12,5	*5,0*
9	AaTpTp	42,0	29,6	14,8	13,6	46,2	28,2	16,7	9,0
10	AaCaAa	58,5	30,2	7,5	*3,8*	68,7	19,4	*10,4*	*1,5*
11	AaTpAa	58,5	30,2	7,5	*3,8*	46,2	28,2	16,7	9,0
12	CaCaCa	61,9	16,7	*11,9*	*9,5*	68,7	19,4	*10,4*	*1,5*
13	CaTpTp	42,0	29,6	14,8	13,6	46,2	28,2	16,7	9,0
14	BiBiBi								

*In difference to the model, shares for travel times above the defined limits (40, 30 and 20 minutes) are documented in the EOD and displayed in italic.

The empirical data shows the general decreasing tendency of trip shares in time slots with increased travel times. As expected this tendency is even more distinctive for walking trips where between 60% and 70% of all trips are realized within the 10 minutes time slot. The calculations can capture this tendency only partially. Especially the shares of public transport trips are much too low for trips in the direct surrounding (0 to 10 minutes time slot). The same applies for car related trips but to a minor extent. The explanation is once again related to geography and the underlying TAZ structure. There are simply too few options within reach in 10 minutes travel time for public transport. Thus, secondary locations are mainly found within 10 to 30 minutes travel time distance.

CONCLUSIONS AND OUTLOOK

The presented methodology is of relevance as it opens up a possibility to calculate interdependent activities and trips trajectories based on regularly available input information. We employ an OD matrix to reproduce the relation between the home and the work (or educational) location and use the Chilean Travel and Household Survey EOD for the estimation of empirical probabilities for activity plans, mode combinations and timing issues. The implementation of the methodology was shown using an example based on activity plan type 'HXYH', representative for plans such like 'Home-Work-Shopping-Home'.

It could be shown that the application works plausible given the used information and the spatial zoning considered, nevertheless several shortcomings need to be addressed. First of all, the methodology applied to establish the search space must be refined. For the moment, a secondary location is selected either around the home or the work (education) place. The so defined search space is limited by the travel time imposed to reach the secondary location and by the summed daily travel time for the complete path. There is still a geographical limitation missing that permits to reduce the search space around the anchor points and at the same time expands it to a corridor between them. Especially for car based travel still too many secondary locations are within reach. This does not seem reasonable from the argument that the information about options is limited for the individual and creates difficulties for the calculations because of the large number of combinations considered. Another problem is caused by working on the city's TAZ level. For slower modes (walking, partially public transport) only very few spatial options for secondary locations are selected. A possibility to handle this would be the introduction of a spatially more disaggregated level for those trips with location choices in the nearer surrounding.

For the moment, the methodology works for plans of type 'HXYH'. As was demonstrated, these plans represent only a minority of the overall variability observed in the EOD. The challenge now is to transfer parts of the established methodology to other plan types. In the case of single trip home based plans an even simplified approach will be sufficient. But as soon as a plan is composed of several tours with home stays in between, another constraint needs to be considered which was excluded from the analysis conducted so far: the influence of the time already spent on activities and trips on the number and duration of subsequent activities and trips. Although not implemented yet, the EOD offers the possibility to calculate interdependent time windows for activities. By that, we refer to the observed probabilities that e.g. if a work activity took 8 hours, the following secondary activity will take 1, 2 or more hours. In the case of plan type 'HXYH' we can use this information to check each spatial path and the respective calculated total path travel time against a summed activity and travel time. For example, if the spatial path indicates a summed travel time of 3 hours and we add a time window probability which sums up to 12 hours, we can once again check against the EOD if the overall activity and travel time of 15 hours is within the observable margins.

Another issue that can be addressed is the – at the moment – consideration of 13 household types to estimate the number of plan types executed by each group. Actually, the use of these household types is due to the availability of OD matrices from ESTRAUS to replicate the relation between home and work locations. As long as no other information is available to reproduce the relation between anchor points, this level of disaggregation seems sufficient. Nevertheless, from a methodological point of view the approach allows to substitute the household types by a different categorisation which then can include aspects of household size or household constitution (number of adults and children).

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