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Modelling of household time constraints

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Abstract

The paper describes an activity based model for Copenhagen, introducing the concept of 'Primary Family Priority Time' (PFPT). We postulate that for pre-agreed workdays all family members spend time together at home in shared activities, e.g. dinner or childcare, and that PFPT has higher priority than each person's own related activities, such as work and leisure. The conference paper presents the concept of PFPT and discusses how it fits into our demand model. Model estimation results are presented, including sub-models for PFPT participation, as well as its impacts in the model estimation results of the other model components.

1. Introduktion

The main objective of the paper is to promote a model for, so called, Primary Family Priority Time (PFPT). This model is part of the day pattern demand model for the Copenhagen region. By definition, the PFPT is the time spent at home by all household members in a workday. The minimum length required is 20 minutes for activity types such as child care and social, e.g. dinning.

There are two major reasons for defining the PFPT model. First, household decisions on a day level put time constraints on activity planning and execution of its members. This is to say that household model(s) should be placed at the top of person day pattern models. Second, time spent together within the household is important for the household members. Therefore in a day where the PFPT is scheduled a working parent would continue working at home first after the family time is over.

The paper is scheduled as following. Chapter 2 describes the research project for which the PFPT model is part of. Chapter 3 describes the data to be applied in the model estimations, while the modelling results are described in Chapter 4.

2. ACTUM

Most European regional traffic models, including Danish models for the greater Copenhagen, the OTM model (Vuk and Hansen, 2006), and the National Traffic Model (Brems, 2012), are tour based models. They focus on individual travelers and thereby neglect family decision-making dynamics and task allocation social interactions within the household even though that they influence the daily activity-travel patterns of household members. In particular, both individual and joint activities and travel patterns are related to the role of the individual as a family member, defined by intra-household interactions in the attempt to satisfy the welfare needs of all household members and enhancing the unity of the family.

Danish Strategic Research Council has appointed DTU Transport to organize and lead a five year research project in activity based modelling, the ACTUM project, starting January 1st 2011. The current study takes a first step in closing this gap, by unveiling the joint activity and travel patterns of household members in the Copenhagen area for the development of a new generation of behaviourally realistic activity based models. In-depth analysis was conducted in order to understand the role of escort activities in individual travel, and the households' joint activities and joint travel patterns at a household level. In particular, the household coordination and constraints are considered as important, i.e. a mother escorting a child to school imposes time and spatial constraints on the mother, but this action also requires coordination with the father regarding the allocation of the car at the household level. Another important aspect is the concept of PFPT, the time spent at home by all household members in activities such as child care or social (e.g. having dinner together). By definition the PFPT has a minimum length of 20 minutes and it is related to a workday. We postulate here an a priori assumption that family/household, puts time constraints on its members, so that the person day travel demand needs to be modelled in function of family characteristics. That means that in the hierarchy of person day pattern models the PFPT model is placed at the top of the tree structure. That is to say that the family does not plan nor execute activities – the family agrees on actions, which might be long-tern decisions, such as home location or car ownership, or short-term decisions, such as who will escort the child to school tomorrow. However, it is the household members that plan and execute day activities for the good of the family, but also for their own sake (say playing tennis once a week) – they in that way maximise their own and the family overall activity pattern utility on a day level.

The ACTUM research project embraces a prototype of the first operational activity based traffic model for the Greater Copenhagen Area (GCA), the so called COMPAS[1] model. Some of the pressing traffic planning problems in the GCA, in the recent years, are i) dramatic increase in traffic congestion on the incoming

[1] COMPAS stands for Copenhagen Model for Person Activity Scheduling

motorways - some solutions include differentiated road pricing, environmental city zones and restricted parking policy, ii) increase in slow mode traffic, especially bicycling, and iii) optimal strategy for infrastructure development in the region, e.g. Copenhagen Metro, Ring Road 5 and the Harbour Tunnel project.

The COMPAS model proposes an entirely disaggregated approach to modelling of travel demand. It rests on the micro-economic theory where each individual plans and executes daily activities - some of them demand travel activities - by maximising his/her personal utility within the choice set and on different levels. Apart of including the context of the PFPT in its structure, the COMPAS model offers the following novelties:

- Denmark is among leading countries that promote bicycling. Biking is therefore included in all levels when modelling individual day pattern activities, with special emphasis on escorting activities.
- Formulation of impact of budget constraints on person day activity planning and execution.
- Estimation of simultaneous mode, destination and time of day sub-models on the tour level. Even further, estimations of new values of travel time (VoT) are to be undertaken, where different formulations, e.g. non-linear coefficients for time and cost, are tested.

3. Data analysis

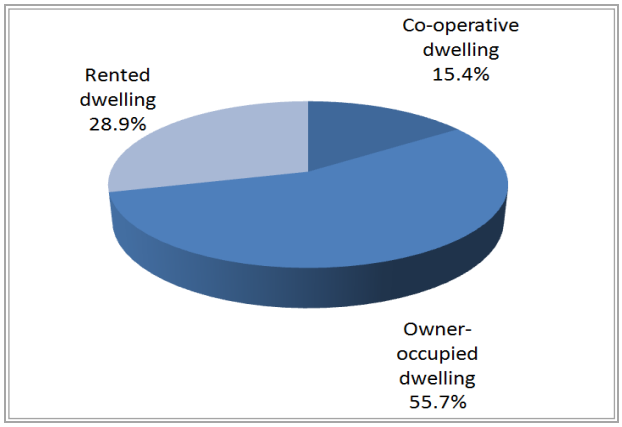
In more than twenty years we have been collecting travel data across the whole country – the so called TU survey. It is a person based survey and it covers only one day. The structure of the TU questionnaire (e.g. definitions of travel purposes, modes, travel times) served as base for the household based travel survey that has been designed and completed in the ACTUM project. Some more questions were added plus that all household members were now involved in the survey. One of the household adults answered questions related to the household (e.g. car ownership, household income) while every person completed an activity/travel diary for the same day – diaries of the small children were completed by one of the parents. The households included in the survey were sampled across the greater Copenhagen but mostly in the central municipalities of Copenhagen and Frederiksberg. The sample was taken from the internet panel of the surveying company, and the sampling procedure was based on family structure, age and geography.

In total, 2.467 individuals were interviewed, which correspond to 903 households. In 162 cases it was a single person household and in 180 cases it was a household with two adults and no children. 237 households has one child, 273 households had two children, while only 51 households had more than two children.

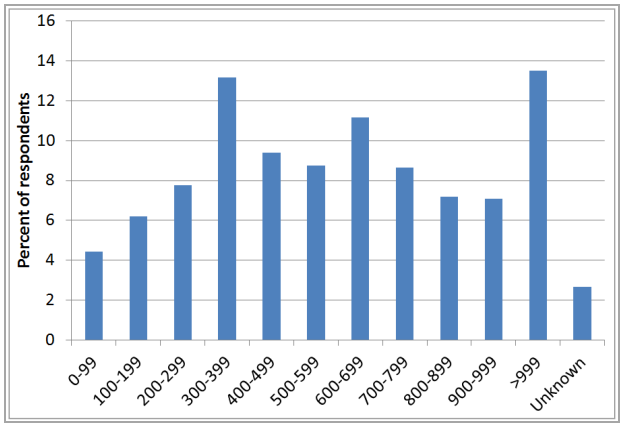
The home ownership, household income, household size, and car ownership are presented in figure 1. The average household size is 2.8 persons per household. 49% of the sample consists of families with two adults and children, while 12% involve a single adult and children under the age of eighteen. A small share of the households (4%) consists of more than two adults, possibly grown-up children. 56% are home owners,

which is slightly lower than home ownership at the national level (63%). Home ownership is related to household size. As expected, a large percentage of small households prefer rented dwelling units, while large households prefer by and large owner occupied house. The share of cooperative dwelling also decreases as the household size increases. In terms of income, 14% of the sample earn up to DKK 200.000, while 40% of the households in the sample have an income of up to DKK 500.000, and 30% have a household income above DKK 800.000.

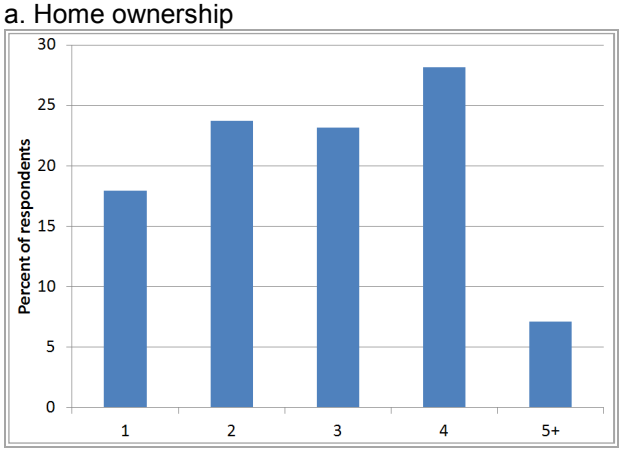
Figure 1: Household socio-economic characteristics



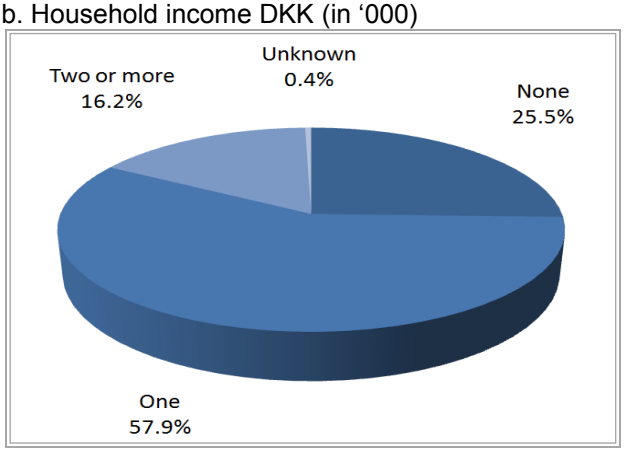
a. Home ownership



b. Household income DKK (in '000)



c. Household size (number of persons)



d. Car ownership

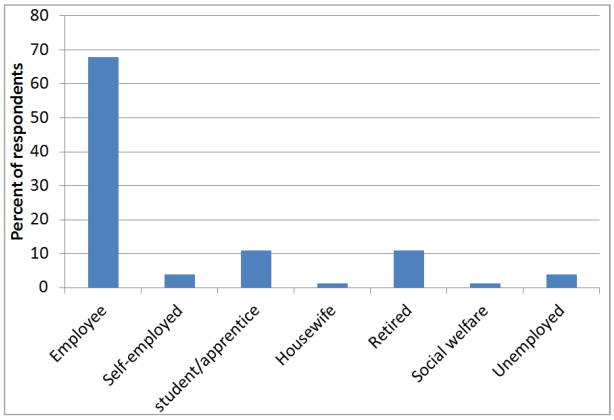
In terms of mobility resources, in 93% of the households there is at least one person with a driver license, and 74% of the households have at least one car. The car ownership rate in the project sample is higher than the ownership rate at the national level (56%). Only 12% of the sample has a parking place at home, 30% can park in a parking facility reserved for residents, while the majority of the sample (i.e. 58%) can park on street only (free or paid parking). Car ownership in the sample is related to household size as presented in table 1. As expected, car availability and number of cars dramatically increase with the increase of household size and presence of children in the household.

Table 1: Household car ownership by household size, %

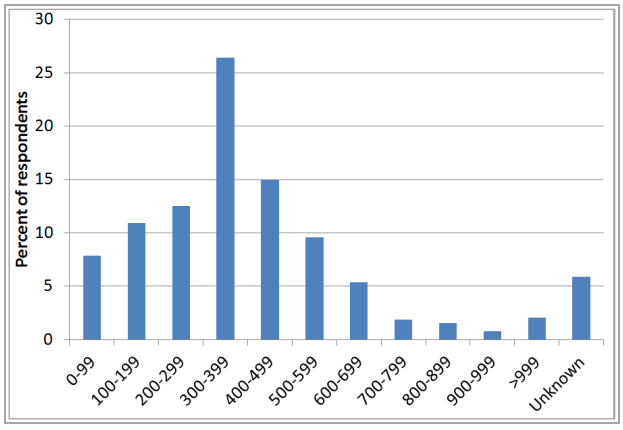
	1	2	3	4	5
No available car	58.6	30.4	19.6	9.1	9.4
One car	41.4	60.7	61.7	61.8	62.5
Two cars of more	0.0	8.9	17.7	28.3	28.1
Unknown	0.0	0.0	1.0	0.8	0.0
Total	100.0	100.0	100.0	100.0	100.0

There is approximately the same share of male and female respondents in the sample while some 62% of the respondents are adults. Of the adults, 15% are in their twenties, 17% are in their thirties and 33% are in their forties. 14% of the sample is persons above 60 years of age. 75% of the adults in the sample are involved in a relationship, while 19% are single. In terms of education, more than two-thirds of the adult respondents (67%) have post-secondary higher education, while 29% of the respondents have secondary education (i.e., 10th form, higher preparatory certificate, technical, commercial and business education, vocational secondary education and other schooling), and only 4% have compulsory primary education. The employment status, income, working hours and working-hour flexibility are presented in Figure 2. In terms of employment status, 68% of the respondents are employees, while only 4% are self-employed. Only the employees and the self-employed (72%) among the adult respondents specified the number of working hours. As expected, the majority of the respondents work between 30-40 hours (75%), although a significant share of 20% have longer working hours. About 82% earn a personal yearly income of up to DKK 500.000. Interestingly, half of the respondents work fixed hours and there seems to be no specific dominant arrangement in terms of work-time flexibility. This percentage is much higher than the share of flexible working hours in Denmark at the national level which is around 25%.

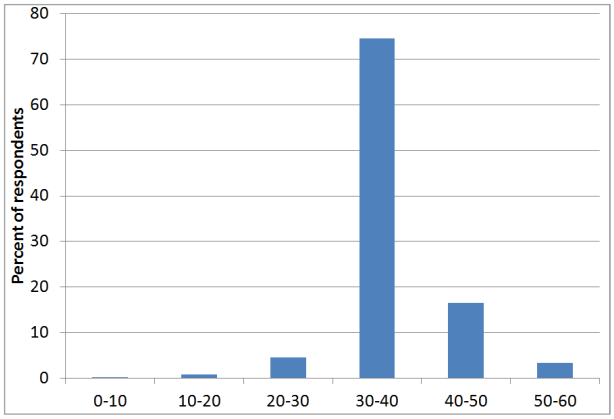
Figure 2: Individual socio-economic characteristics



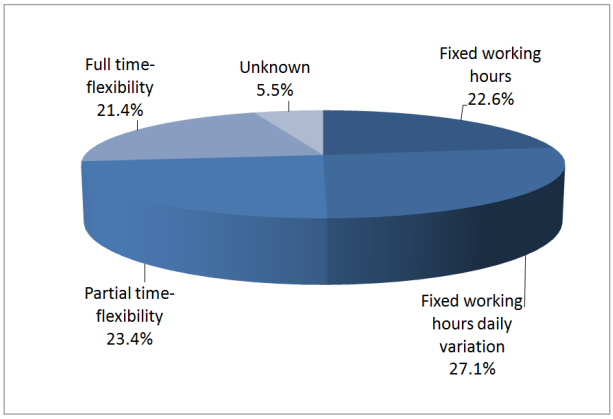
a. Employment status



b. Personal income in thousand DKK



c. Number of weekly working hours



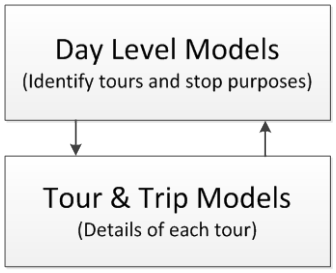
d. Work-hour flexibility

4. Model estimations

The household travel demand portion of the COMPAS model system consists of an integrated set of discrete choice models implemented on the DaySim software platform, an evolving and adaptable platform used for the development and application of practical AB microsimulation models. The COMPAS models implemented in DaySim simulate a one day itinerary of activity and travel for the members of each household in a synthetic population of Copenhagen. This microsimulation is designed to work in conjunction with models of longer term choices, such as work location and car ownership, freight demand, and network assignment to model the traffic in the Copenhagen region.

As depicted in Figure 3, the COMPAS household day models consist of models at the day level that identify the tours and stop purposes for the day, as well as tour and trip models that model the details of each tour. The day level models constrain and condition the tour models, and are also impacted by accessibility arising from those models. Also, in the course of the simulation, when a model at the day or tour and trip level determines that an activity or travel spans a particular period of time, that period becomes unavailable for other activities and travel.

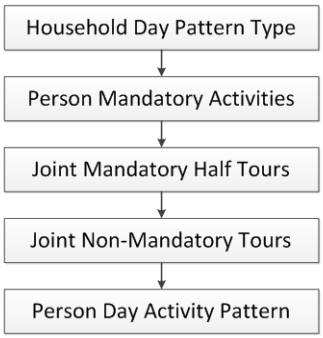
Figure 3: COMPAS household day models



The day level models, which are the broad focus of this paper, consist of numerous models in five main groups that operate in conditional sequence, according to an assumed priority hierarchy, as shown in Figure 4. The household day pattern type models determine the highest priority aspects of the day from the perspective of the household, including the PFPT, and also the pattern type for each member of the

household. PFPT models include the model of participation and a model of PFPT schedule. Because of small sample size the second model is modelled very simply by randomly drawing a schedule from among the schedules observed in the survey data, depending on whether the household has children or not. Each person's pattern type is either mandatory (work, business or school) on tour, non-mandatory on tour, or home all day.

Figure 4: COMPAS day level models



Given the household's day pattern type, the next group of models determine the mandatory activities for each person in the household, including the participation in at-home work activity for each worker, the number of work, business and/or school tours for each person with a mandatory pattern type, and whether they have any intermediate stops for work or school in their day.

Given the needs within the household for travel to work and school, the next set of models determines joint travel to and/or from those mandatory activities. Joint travel for work and school can take the form of half tours, either to or from work and/or school. These half tours can be either paired or unpaired, where paired half tours go both directions. They can also be either partially joint, in which one person drops off one or more others on their way to work or school, or fully joint, in which the destination for all participants is the same place. In fully joint half tours it is possible that one participant serves as a chauffeur and returns home after dropping off the other(s). To model joint half tours, a generation model determines for the household whether, and what type of joint half tour occurs. This is followed by a participation model that determines which eligible members of the household participate. This pair of models is repeated until the generation model determines that no more joint half tours occur.

Once the joint travel for mandatory activities has been determined, the next set of models determines the number of joint tours for non-mandatory purposes conducted by members of the household, and the purpose of each one. A joint tour is one in which two or more members of the household conduct a complete tour together, sharing purpose(s), destination(s), and all travel. It can involve situations where one person escorts another to an activity, stays while that person carries out the activity, and then returns home together with them. This is modelled via a tour generation model followed by a participation model, repeating until the generation model determines that there are no more joint tours to be conducted.

The last of the day level models is the person day activity pattern. Constrained by all the prior model outcomes, this pair of models determines, for each person, the number of tours in the day, the purpose of each tour, and the purposes for which intermediate stops are to be made, if any. First, the pattern model determines the presence of tour and stop purposes. Second, the generation model determines the number of tours for each purpose determined to be present by the pattern model. The number of intermediate stops for each purpose is left to be determined subsequently as the tours determined here are being simulated.

The sequence of the day level models is based on reasoned a priori assumptions about the priorities that households usually adhere to in making their choices. The household choices of Primary Family Priority Time and household pattern type are considered to be highest priority. These are followed by the participation in and joint travel arrangements for mandatory activities. Decisions about joint non-mandatory tours are considered to be lower priority than mandatory activities, but higher priority than the remaining choices about non-mandatory activity participation by individuals in the household. It is left to further research to test empirically the validity of these priority assumptions.

Table 2 shows the number of the sample households where all members were at home together, for different start and end periods across the day. This is the case for 331 households in total, where only households with 2+ members are included, just as in the model. The table shows therefore a potential for occurrence of PFPT.

Table 2: Number of ACTUM 2+ households where all household members were at home

Hours	Start period	End period
Before 3 p.m.	51	15
3 p.m. – 4 p.m.	48	4
4 p.m. – 5 p.m.	112	15
5 p.m. – 6 p.m.	60	31
6 p.m. – 7 p.m.	32	45
7 p.m. – 8 p.m.	27	58
8 p.m. – 9 p.m.	1	79
9 p.m. – 10 p.m.	0	29
10 p.m. – 11 p.m.	0	38
11 p.m. – 12 p.m.	0	17

The “Start period” column shows that for the majority of the sample households, all family members are assembled at home before 6 p.m.. This is almost certain for the households with young children. On the other side, family activities in which all members participate usually end before 9 p.m.. Therefore, the chance for occurrence of PFPT is largest in the period between 6 p.m. and 9 p.m. in a workday.

The PFPT model is a binary logit model, identifying whether or not the household participated in PFPT. The exact definition used for PFPT depends on analyst judgment and on the details of how the survey was administered. In the model reported here, a household was deemed to have participated in PFPT if it satisfied the following conditions:

- At least one person age 13 or older journeyed away from home during the day, returned home by 8 p.m., and reported shared at-home activities after returning home. This requirement is imposed because information about shared at-home activities was only collected from survey participants in these cases.
- The respondent explicitly reported participation in shared at-home activity for purposes other than work, school or commerce.
- The shared activity involved all members of the household and lasted at least 20 minutes.

With this definition, 206 of the 644 households with two or more members (32%) were deemed to have participated in PFPT. Table 3 shows the estimation results. All coefficients are associated with the PFPT participation alternative, where the utility for no participation was fixed to zero.

Table 3: Estimation results of the PFPT model

File	PFPT8.F12	
Title	Actum PFPT Model	
Converged	True	
No. of iterations	5	
Observations	644	
Final log (L)	-224,4	
D.O.F.	13	
Rho²(c)	0.444	
ASC	-2.37	(-2.1)
HH size 3	-1.19	(-3.4)
HH size 4+	-1.39	(-3.6)
Pre-school children	1.15	(3.6)
One adult + school children	1.14	(2.9)
Two adults, both working	1.77	(4.2)
One adult has high education	3.51	(10.7)
HH with one car	-0.465	(-1.5)
HH with 2+ cars	-0.896	(-2.0)
HH income 3-600.000	0.619	(1.6)
HH income 6-900.000	0.324	(0.8)
HH income over 900.000	-0.168	(-0.4)
LogSum	0.054	(0.5)

The household size dummies are both significant and negative relative to the base household size of two, i.e. it is more difficult for larger households to complete a PFPT. The following household characteristics significantly enhance a chance for the existence of PFPT: the presence of small (pre-school) children, a single parent with school child/children (e.g. typically, a single mother with children), a household with at least two working adults, and a household with at least two adults in which at least one has high academic education. On the other hand, households with car(s) are less likely than those without a car to participate in PFPT activities, and this negative tendency increases with the number of cars. It is unlikely that simply

having cars causes a drop in PFPT participation, but apparently the factors that cause households to own cars are also causing them to participate less in PFPT, e.g. work constraints. With respect to income, we estimated values for three household income classes, all relative to a base value of up to DKK 300,000 (year 2010 gross household income). The obtained estimates are not statistically significant, but suggest that PFPT might be somewhat more important for middle income households (those between DKK 300,000 and 900,000). Finally, the logsum variable, which represents accessibility to personal business activity opportunities from the household's residence, has a positive estimate but is not statistically significant. The interpretation is that better accessibility for necessary out-of-home personal business helps a household to plan for and achieve their goal of spending time together at home. However, the real value for the logsum variable will be tested extensively first when the tour and trip models have been estimated based on the sample data.

The impact of Primary Family Priority Time was tested in other day-level models of COMPAS, as summarised in this section, in which the tables appear in the hierarchical order of the pattern modes, as described in chapter 4.1.

Table 4 shows the effect of PFPT participation in the Household Day Pattern Type (HDAP) model. The HDAP model aims in determining the main activity of the day (i.e. mandatory, non-mandatory, home) across household members – i.e. the number of observations in the model equals the number of available households in the sample. In this way different degrees of interactions across household members (e.g. 2 way-, 3 way- and 4 way-interactions) could be taken into account when determining the person main activity of the day. As shown in the table, the positive coefficients for mandatory and non-mandatory pattern type indicate that in a household with PFPT, persons are more likely to have mandatory or non-mandatory on-tour patterns than to stay at home all day. The degree of this effect differs between non-mandatory and mandatory pattern types, and it also differs by person type. The positive effect of PFPT on the tendency to have on-tour pattern types is partly an artefact of the definition of PFPT in the survey data: only households in which at least one person aged 13 or greater journeyed away from home during the day were deemed eligible for PFPT participation. Viewed in this way, the results in this model assure consistency of the pattern types with the PFPT definition. However, the results here are probably also caused in part by the fact that active households are those with less free time and therefore greater need for spending quality time together in a busy workday.

Table 4: Coefficients of the PFPT participation variable for different person types in the HDAP model

Variable	Estimate	t-value
Mandatory; Full time worker	+0.684	+2.1
Mandatory; gymnasium or university student	+1.67	+2.2
Mandatory; School child	+1.84	+2.7
Non-Mandatory; Full time worker	+0.795	+2.2
Non-Mandatory; Retired	+2.88	+3.4
Non-Mandatory; Non-working adult	+2.79	+2.5
Non-Mandatory; gymnasium or university student	+2.41	+2.8
Non-Mandatory; School child	+1.38	+2.0
Non-Mandatory Pre-school child	+0.934	+1.4

Table 5 shows the values of the PFPT in the Work at Home model. This is a binary logit model where the work at home alternative represents spending at least two hours at home working. Work at home, as defined here, can occur instead of going to work, or in addition to going to work, such as in the evening, after the PFPT. The coefficient for PFPT attached to the work-utility is positive but not highly significant. For workers, the participation in PFPT increases somewhat the likelihood of working at least two hours at home.

Table 5: Coefficient of the PFPT participation variable in the Work at Home model

Variable	Estimate	t-value
Work at Home	+0.249	+0.6

The following two models, presented in Tables 6 and 7, deal with the occurrence of joint travel and out-of-home activity among household members. We define the time spent in those activities as Secondary Family Priority Time (SFPT). Table 6 shows the values of PFPT in the Joint Half Tour Generation model, which deals with joint travel to and/or from work or school. There are utilities in the model for full half tour generation, partial half tour generation and for not generating joint half tours, as described above in Section 3.1. As shown in the table, PFPT substantially increases the likelihood of generating partially joint half tours, relative to fully joint half tours or not generating joint half tours. This effect is large and significant for paired partially joint half tours (i.e. dropping others off on the way to work or school and then picking them up later on the way home) and for half tour 1 (dropping off, but not picking up on the return), but is also positive for half tour 2. Clearly, households that are committed to spending time together at home after their daily work and school are more likely to coordinate their schedules so they can travel together to and from their different work and school locations.

Table 6: Coefficients of the PFPT participation variable for tour types in the Joint Half Tour Generation model

Variable	Estimate	t-value
Partially Joint Paired Half Tours	+1.67	+3.1
Partial Joint Half Tour 1	+1.83	+2.9
Partial Joint Half Tour 2	+0.565	+1.3

Table 7 shows the impact of PFPT in the Joint Tour Generation model, which generates joint tours for non-mandatory purposes including personal business, shopping and social, as described above in chapter 3.1. The results show that participation in PFPT increases the likelihood that households will engage in joint tours for shopping and social purposes, but not for personal business. Together, tables 6 and 7 show that households that participate in activities together at home (PFPT) are more likely to coordinate travel for mandatory activity and to join together in non-mandatory tours as well (SFPT).

Table 7: Coefficients of the PFPT participation variable for different activity purposes in the Joint Tour Generation model

Variable	Estimate	t-value
Shopping	+0.908	+2.1
Social activity	+0.660	+1.8

Table 8 shows the values of the PFPT in the Work-based Sub-tour Generation model. A positive estimate in this model (a binary logit model for having or not having a work-based sub-tour) is most likely related to the social profile of the respondents with such activities, e.g. having an office job with high education (resulting in e.g. meetings along the workday) also has a high priority in spending time together with the rest of the family after the work. However, the coefficient is not significant.

Table 8: Coefficient of the PFPT participation variable in the Work-based Sub-tour Generation model

Variable	Estimate	t-value
Work-based sub-tour	+0.724	+1.1

5. Conclusions

Purpose of the paper has been to show that planning and execution of the person day activities is constraint by the household. The notion of the Primary Family Priority Time (PFPT) is innovative and it has been introduced in the COPMAS model across a number of demand sub-models.

The work on the COMPAS model is still to be finalised that including possibilities for further changes within the PFPT model.

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