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An innovative approach to activity based travel demand modelling

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Abstrakt

The Danish Strategic Research Council for Transport funded the ACTUM project, *Analysis of activity based travel chains and sustainable mobility*, in November 2010 with million DKK 21,5. The project assembles a large number of research centres across different fields of transport-related research, both national and international. One of the major tasks in this 5-year project is to develop the European fist operational activity based traffic model. The model is called COMPAS – COpenhagen Model for Person Activity Scheduling, and it is aimed that this model will succeed the OTM model, which is a tour based model for the Greater Copenhagen Area.

The purpose of the article is to describe the basic ideas behind the COMPAS model. We start with some theory in chapter 1. Chapter 2 describes data to be completed within the ACTUM project, while chapter 3 describes a proposed structure of the COMPAS model. Conclusions and further work are presented in the final chapter.

1. Project hypotheses and some theory

The last decade or so in the US, activity based traffic models have been seen to be superior to tour/trip based models when modelling personal travel demand. Some of the recently developed activity based models are model for Sacramento, Portland, San Francisco, New York, Dallas-Fort Worth, Florida; two models have also been developed in Israel. The majority of those models are large-scale models, which in respect to population size can be compared to the existing National and major conurbation traffic models across Europe. However, the large-scale European models contain significantly fewer modelling aspects of the activity based approach than the US and Israeli models mentioned.

A motivation behind the ACTUM project is to develop an innovative activity based approach to travel demand modelling, which hopefully can bridge the existing US travel demand modelling practice to Europe, i.e. intention is to build an operational activity based traffic model for the Greater Copenhagen Area (GCA), the COMPAS 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 motorways - some solutions include differentiated road pricing[1], environmental city zones and restricted parking policy, ii) increase in slow mode traffic,

[1] The Danish Ministry of Transport is proposing to apply a differential road price according to i) vehicle type, ii) time of day travel and iii) road type.

especially bicycling, and iii) optimal strategy for infrastructure development in the region, e.g. Copenhagen Metro, Ring Road 5, the Harbour Tunnel project.

We propose an entirely disaggregated approach to modelling of travel demand in the COMPAS model. 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. A novelty here is 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. This is done by modelling periods of day where family members spend time together at home - we call that for *Primary Family Priority Time*, and periods of the day where family members are together on tour, e.g. escorting a child to school - we call that for *Secondary Family Priority Time*. Consequently, the family members fill up the rest of the day with activities in such a way that both personal and family obligations are fulfilled in the way that best meets their personal objectives.

In the situation of dramatically increasing road congestion in the GCA in the past ten years we believe that modelling of time constraints among family members is an important element of the improved modelling of travel demand. However, this improvement cannot be achieved in isolation, which is the reason for further suggestions of modelling improvements to be described in the article:

- Activity based travel demand models recognise that an individual is motivated to work[2] and not to make home-work trips. Therefore, activity based models need to be capable of modelling the trade-off between participating in, for instance, a shopping activity as a stop on the work tour versus making an additional tour for the sole purpose of shopping. That trade-off can be a function of the desirability of shopping locations near the home zone - data usually show that individuals living in cities are more likely to make additional home-based tours, whereas persons in inaccessible locations will seek trip chains into more complex tours.
- A strong feature of the activity based demand models is a connection between population modelling (usually a population synthesiser) and micro simulation of modelling outcomes, i.e. to simulate the choice made by each trip using a Monte Carlo approach. The simulation approach to modelling of travel demand gives a more detailed analysis of outputs, as the results of the demand models are a list of individual households, persons, tours, and trips that look like an ordinary household travel survey.
- These models give an improved ability to model pricing compared to the same VOT across the sample – it is to say that even individuals within the same income group can have different VOT and travel behaviour, e.g. a rich person bicycling to work.
- Importantly, activity based models give a more detailed representation of time where one activity in time gives constraints to the activities to follow.
- Finally, activity based models give a greater ease of extensibility. Because of the disaggregate nature of these models, it is actually quite easy to add a new descriptive variable to the model system. In an activity based model it is as simple as adding a column to a table, whereas in a trip/tour based model it involves further segmentation of trip matrices, which can quickly become unwieldy. Furthermore, the ability to simulate individual travellers greatly enhances the types of policies that can be tested.

1.1 Synthetic population

We want a model that mirrors travel demand being based on socio-demographic background of individuals, e.g. activity patterns of a parent differ from activity patterns of an adult living alone. We therefore base our modelling approach in COMPAS on population groups to be defined in a *population synthesizer*. Groups of the GCA population we wish to include are concentrated around the household size and structure: i) one adult household, ii) two adults household, iii) one adult with child/children in the household, and iv) two adults with child/children in the household. These four groups need to cover the city centre (two central

[2] "Motivation to work" is coincidentally another demand that can be at least partially considered to be derived, associated with the desire to get paid.

municipalities), cities in the GCA with a good access to the public transport system, and finally, cities in the GCA with a poor access to the public transport system.

The Danish Statistical Bureau is responsible for the population forecasts in the country. Until this year the Bureau have produced aggregated population statistics on the level of municipalities, cities and regions. However, from 2011 the Bureau will also make statistics on an individual level, which effectively can be combined with the population synthesizer in our model. Some basic ideas behind the population model from the Bureau is that age, sex, education, income and ethnic background impact the population size, family cycle (family structure), and the geographic placement (cities vs. rural areas).

1.2 Family vs. an individual

An innovative side of the COPMAS model is an attempt to model time constraints posed by the family and its impact on personal activity scheduling and execution. That is to say that the family does not plan nor execute activities – family's primary concern is definition of family day activities (say having a dinner together), which in return puts time constraints on the household members' daily activity scheduling and execution. 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.

At the family level the primary concern is how much time some, or all, family members spend together and where these time periods are placed along the day. The time spend at the home address is denoted as the *Primary Family Priority Time* (PFPT) while the time spend on-tour is denoted as the *Secondary Family Priority Time* (SFPT). A typical PFPT would be if a family decides on having dinner together in the period between 6pm and 7pm while atypical SFPT would be escorting a child to school. PFPT and SFPT put naturally constraints to the personal activities of the family members. Note that notation "Primary" and "Secondary" is related to home vs. on-tour activities and not a certain importance of the activities, as it is assumed that all activities of these two kinds are indeed important.

Family members fill up the daytime by maximising the family's and their own need for activities, both home activities and out-of-home activities. Again, these activities are constraint to PFPT and SFPT. An adult's day activities are dependent on position in the family, age/sex, e.g. important in relation to kids – mothers tend to have more childcare in a day, car availability, personal income, job type (e.g. self-employed), and lifestyle, e.g. playing tennis. A child's day activities are defined by age and interests.

For the sake of discussion along the article we consider a case-study family defined by two adults - both working, and one child of school age. The family members' day activities, together with the accompanied tours and trips, for a random workday are shown in figure 1. Figure 1 depicts activities and tours/trips undertaken for an average workday by the case study family members in the GCA. The figure can be split in three levels, which are also our three main modelling levels:

- Level 1, family based: PFPT and SFPT - Definition of type and time periods where family members spent time together. The blue area defines the PFPT while the green area defines the SFPT.
- Level 2, person based: Activity schedules for family members – they are constraint to PFPT and SFPT at level 1.
- Level 3, person based: Tours/trips for out-of-home activities for family members – they are constraint to the activity schedules at level 2.
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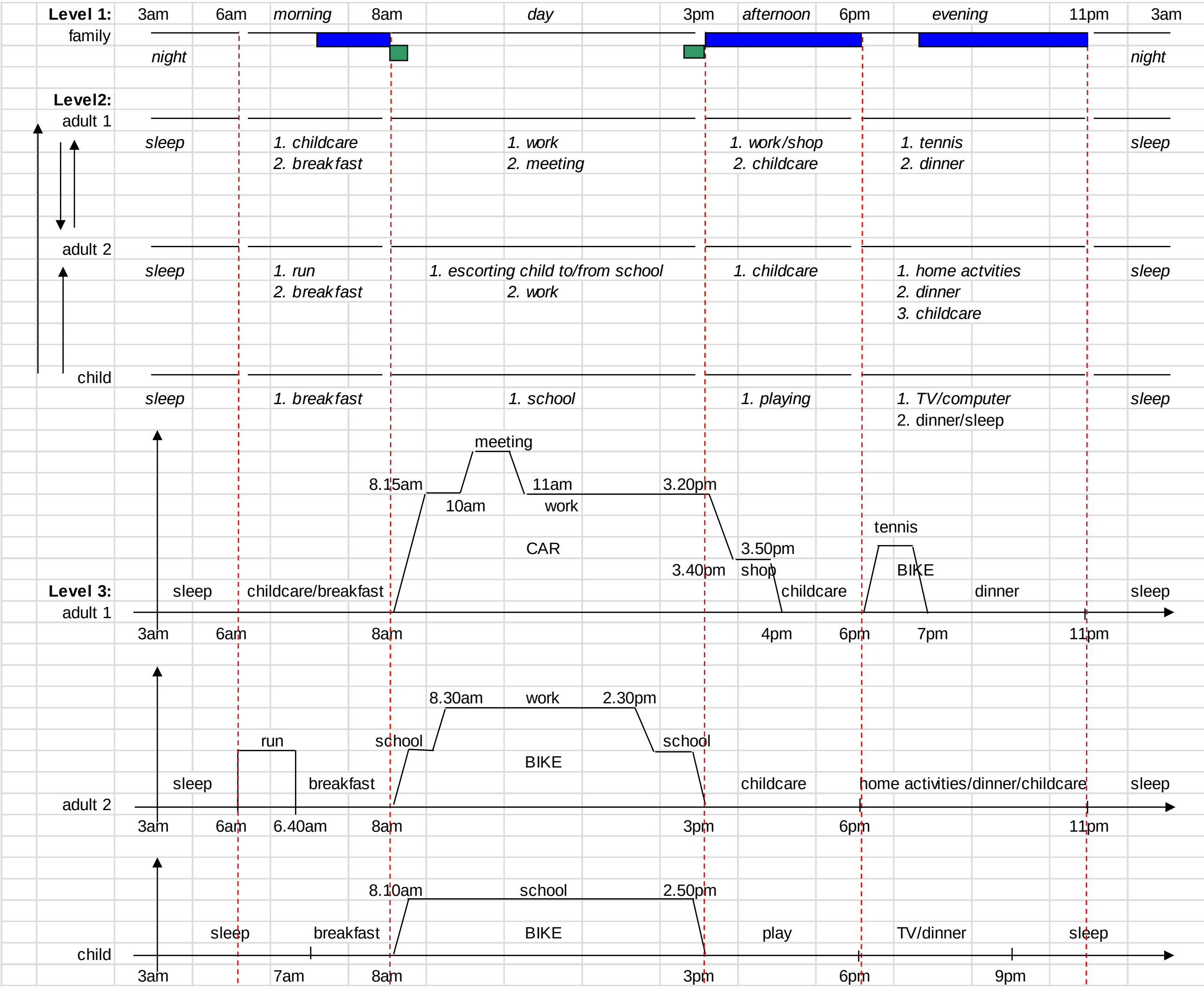
The three levels are interdependent in the same way as the models in a typical 4-stage tour/trip model, and they are modelled by different set of explanatory variables, e.g. car ownership impacts modelling of family priority at level 1 while car availability impacts models at level 2.

We postulate here that unless we investigate travel behaviour for all family members interactively and at all three levels, as defined above, then there will be some policy measures for witch the corresponding travel demand will be modelled incorrectly.
Arrows to the left in figure 1 show that the two adults interactively define the personal activity schedules for the day while the only family child can put time constraints on both parents.

Figure 1 – Activity schedules, tours and trips for the members of the case study family type



Legend: the blue area at the top of the figure denotes the family's PFPT while the green area denotes the family's SFPT

2. Data

With respect to geography, the following is requested from sampling:

- We need to over-sample the city of Copenhagen because of presence of congestion, presence of well-developed public transport infrastructure, and lots of bicycling.
- We also need respondents in those cities in the GCA which have a good access to the public transport infrastructure (e.g. Roskilde, Helsingør and Lyngby) because activity chaining is related to the degree of urbanisation.
- Finally, we need respondents who live in smaller cities with poor, or no, access to the public transport infrastructure, e.g. all smaller cities in the GCA not covered by the Re-tog and S-tog network.

COMPAS must mirror travel demand that is based on socio-demographic background of individuals, e.g. activity patterns of a parent differ from activity patterns of an adult living alone. We therefore base our modelling approach on population groups to be defined in a population synthesizer. Groups of the Greater

Copenhagen Area population we wish to include are concentrated around the household size and structure:

- one adult in the household – subgroups: age and job/student status,
- two adults without children in the household – subgroups: job status and income,
- one adult with child/children in the household – subgroups: job status, and
- two adults with child/children in the household – subgroups: children's age, job status and income.
-

There will be completed 2.000 person interviews in the period August-October 2011 with the sample defined by the above described structure. The core of the cross sectional data in the ACTUM project will be the existing TU data. Given the shortcomings of the current TU survey in capturing the daily activity patterns, the proposed survey, namely ACTUM TU survey, aims at gathering information regarding the following aspects:

- ***Mobility resources at the household level -*** including resources for both virtual and physical mobility, namely the household's motorized vehicle fleet and its characteristics, company car availability, bicycle availability, parking place availability at home, internet connection availability and connection type, shared household income.
- ***Socio-economic characteristics of household members*** – role as a household member, age, gender, income, education, employment status, current employment, and number of jobs.
- ***Mobility resources of household members*** - driver's license, possession of transit pass, mobility-related disabilities, availability of parking space at the workplace, travel expenses reimbursement, and availability of employer provided transport.
- ***Spatiotemporal mobility constraints*** - residential location, workplace or place of study location, availability of personal and household's fixed commitments (mandatory or routine activities conducted at least once a week) and their location.
- ***Daily activity and travel patterns of household members*** – in-home and out-of-home activities, virtual and physical travel. Activities are described in terms of purpose, duration and location, joint activity participation with other household members, means of travel (virtual, physical) and intermediate stops for short activities. For physical travel, trip characteristics include travel modes, travel time and travel cost.
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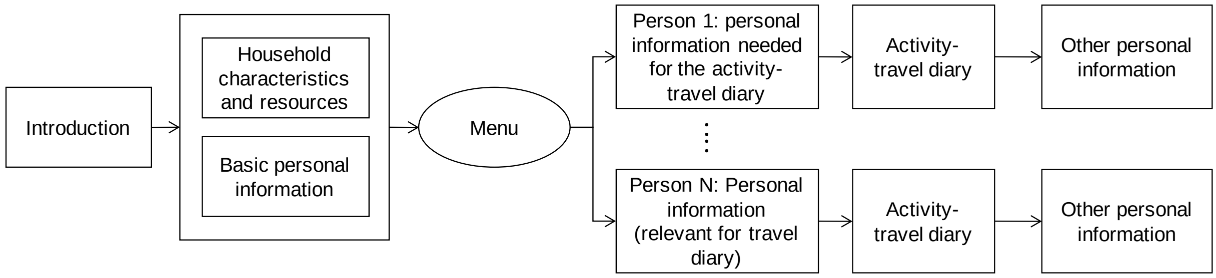
The proposed two-level survey structure derives from the current TU survey structure (*Christiansen, 2006*), and is depicted in figure 2. At level 1, an HH-adult completes a survey on basic HH-information as well as the basic information on HH-members. At level 2, each HH-member older than 10 completes a person-based survey; HH-adults complete this survey for those younger than 10 years of age.

The questionnaire note has been improved a number of times by getting comments from the ACTUM researchers, each time working on i) efficiency, e.g. shortening the questionnaire's length, and ii) detailed definitions, so that we obtain the expected data to be used in the model estimations. The ACTUM TU survey is a one day survey, for days between Monday and Friday, because the COMPAS model will be a working day model. Inspiration for the ACTUM TU questionnaire was found in a number of international activity-based surveys (Cambridge Systematics, 2007, Chalasani and Axhausen, 2004,Chicago Metropolitan Agency for Planning, 2010, Ditzian, 2009, New York Metropolitan Transportation Council, 2010, PTV NuStats, 2010).

Figure 2 – Proposed survey structure



3. COMPAS model structure

The main assumptions behind the proposed structure of the COMPAS model are the following:

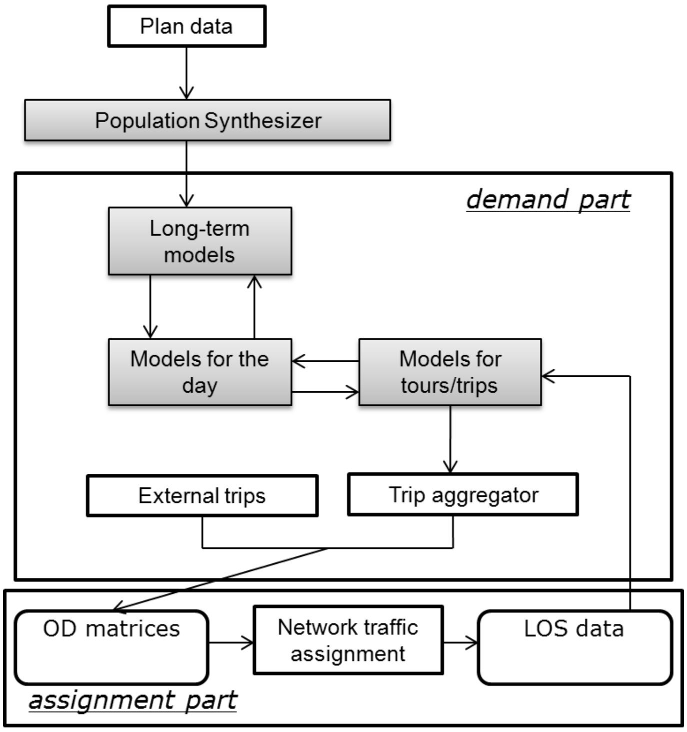
- COMPAS will be a successor of the OTM 5 model (Jovicic and Hansen, 2003, Vuk and Hansen, 2006, Vuk, Hansen and Fox, 2009). This is to say that (a) the OTM zonal system, the base year matrices, LOS and LogSums will be reused within the COMPAS, and (b) the OTM mode-destination choice models will be reused as far as possible on the tour level of COMPAS.
- COMPAS will be estimated in the DaySIM software (Bowman and Bradley, 2006, Bowman, Bradley and Gibb, 2006). The following reasons lie behind the decision of the DaySIM application:
  - DaySIM has a well organised structure of a large scale activity based model, including sub-models for (a) long-term decisions, (b) person day activity scheduling modelling, (c) tour and trip modelling.
  - DaySIM has been successfully applied in a number of US activity based models proving its operational value.
  - Parts of the OTM model can be inserted in the COMPAS models via DaySIM application. The OTM's mode-destination choice models should be considered here because it will allow us to (a) spend more time on estimations of new models, e.g. activity scheduling, (b) reuse the good parts of the OTM.
  - The parts of the DaySIM that we have no time, or budget, to fully estimate can be applied either as they are presently or with minor changes, e.g. a new calibration.
  - DaySIM automatically takes into consideration the time-space constraints. As DaySIM's choice models simulate activity and travel outcomes for a person, the required times in the person's schedule are blocked out. Subsequently, models lower in the DaySIM model hierarchy are prevented from double-booking time slots, and also take into consideration the fullness of the schedule in simulating additional activities and travel.
  - DaySIM can be used for model estimation and application. Once the models have been developed and estimated, the software can be used to apply the models with little extra programming effort.

3.1 COMPAS model components

Figure 3 shows the proposed structure of the COMPAS model. COMPAS will include two main groups of sub-models; the demand and assignment parts. Outside them the OTM's plan data (description of zones) will enter the Population Synthesizer model – a model that predicts the future population in the GCA. The idea here is to apply an official model from the Danish Statistical Bureau. The demand ends up with a table of trips split by mode, travel purpose and time-of-day for every person in the GCA. It is first at this point where the OD-matrices are built for the purpose of assignment. One of the assignment outputs is level-of-service data (LOS) to be returned to the demand sub-model for mode choice on the trip level. Finally, the log-sums go all the way from trip models to the long-term models.

The demand part of the COMPAS model will accompany a number of sub-models, which can be grouped at four levels, according to the proposed theory in chapter 1: long-term models, 2. models for the day, 3. tour models, and 4. trip models. For the matter of simplicity we joined the tour and trip modes into one box in figure 3.

Figure 3 – Proposed model structure



In the rest of this section we describe the proposed sub-models into more details.

Level 1: Long-term models; These models are characterised by long-term decisions, usually made by the HH-members together, e.g. car ownership. Therefore, the explanatory variables are not person-based but HH-based, such as family income and presence of children in the HH. An innovative part is modelling of fixed commitments among the HH-members; the activities that are performed at home.
Five models are supposed to be estimated at this level:

a) Usual work location for each HH-worker
b) Usual school location for students in the HH
c) Transit pass for each HH-member
d) Household car availability (car ownership)
e) Home-based PFPT – Predicts the start and end time of the home fixed (pre-agreed) activities where some, or all, household members are involved.
f)

Level 2: Models for the day; These models are the core of the COMPAS models. They predict the day activity (tour) pattern for each individual and joint trips (half tours), such as escorting kids to school on the way to work; modelling of Secondary Family Priority Time. An innovation part is modelling of working at home as substitution for working on destination (involving traveling).
a) Person day pattern model; Predicts for each HH-member the day travel pattern by:
- whether or not the person works at home that day,
- number of work-based sub-tours tours, main purpose of each sub-tour,
- number of individual non-mandatory HB tours, main purpose of each tour, and
- 0/1+ additional stops in a day, by stop purpose.

b) Partially joint half tour generation and participation (i.e. modelling of SFPT); Predicts number of partially joint tours for each HH-member, and for each one predicts:
- half tour direction (to or from home),
- who is driver and tour main destination (usual work or school location), and
- who are passengers, and work/school stop locations.

Level 3: Models for the tour; For each person tour from the activity (tour) pattern model we need to estimate travel purpose, travel mode and time of traveling. The intention here is to reuse the OTM mode-destination choice model, which is possibly the strongest part of the present OTM model.
a) Tour primary destination, main mode and time periods for tour to known work/school location.

Level 4: Models for the intermediate stops/trips on the half-tour; Each tour consists of, at least two trips. For each trip we must estimate stop generation, location, mode of travel and time of travelling. Therefore, even though that the tour main mode was car, the trip mode can be e.g. bike, and that must be modelled separately. The following sub-models are estimated at this level:

a) Stop generation – Predicts whether or not an(other) intermediate stop is made, purpose of stop.
b) Stop location.
c) Trip time of day/mode choice – Predicts the trip mode/sub-mode (detailed, including toll, non-toll in application), small period and exact minute departing from (arriving at on first half tour) next location.

Traffic modelling issues we want to address in the forthcoming model estimations are:

- Planning and execution of the day activities across HH-members.
- Time constraints posed by the HH to its members.
- Personal demand modelling for bicyclers.
- Impact of parking availability at home address and work address on mode choice.
- Impact of low-level models on models placed higher in the hierarchy of COMPAS models, i.e. application of different types of logsums.

4. Conclusions

The COMPAS model is an operational outcome of the ACTUM research project. In its demand part the COMPAS produces an activity schedule and trips for the GCA population, grouped by different types of household. Person day activities/trips will be modelled in function of time constraints posed by the family they belong to. COMPAS is a working day model, just as the OTM model.

All models in COMPAS will be estimated in the DaySIM software, which has been successfully applied in a number of similar US-based projects. The demand sub-models are grouped on four levels: i) long-term decision models, ii) day activity patter models, iii) tour models, and iv) trip modelling. COMPAS is a disaggregate model, meaning that traffic forecasts are obtained by combining the GCA population synthesizer and micro-simulations; i.e. for each person in the GCA population an outcome is produced (i.e. a trip by mode, destination, purpose and time-of-day) rather than probabilities.

The core data in the model estimation arrives from the family-survey to be completed in the ACTUM project. The survey questionnaire takes origin from the present TU questionnaire giving therefore a possibility of applying older TU data in this project –an activity that will though require lots of programming work. The new survey is fairly more complicated than the present TU survey because all HH-members are interviewed (in order to catch the activities executed among the HH-members) and in-home activities are included. In total 2.000 person interviews are planned in the project across the geography and socio-economic background of the respondents.

Even though that we are only at the beginning of a five-year project we can already now pinpoint some issues that cannot be properly addressed in the current project but which are potentially rather important. Two most important issues are i) impact of budget (money) constraints on person day activities, and ii) impact of travel reliability on person travel demand.

References:

Bowman, J. and Bradley, M., 2006. SACSIM/05 Activity-Based Travel Forecasting Model for SACOG. Technical Memo Number 1 – Model System Design.

Bowman, J., Bradley, M. and Gibb, J. 2006. The Sacramento Activity-based Travel demand Model: Estimation and Validation results. European transport Conference, Strasbourg, France.

Cambridge Systematics, 2007. PSRC 2006 Household Activity Survey Analysis final report.

Chalasani, V.S. and K.W. Axhausen (2004) Mobidrive: A six week travel diary, Travel Survey Metadata Series, 2, Institute for Transport Planning and Systems (IVT); ETH Zürich, Zürich. http://www.ivt.ethz.ch/vpl/publications/tsms/tsms2.pdf

Chicago Metropolitan Agency for Planning, 2010. Travel Tracker Survey Data dictionary. http://www.cmap.illinois.gov/travel-tracker-survey.

Christiansen, H., 2006. Documentation for The TU survey: variable definition for the Danish traffic survey (Variabeldeklaration for Transportvaneundersøgelsen), DTU-Transport, Model Center (in Danish).

Ditzian, Y., 2009. Israel national travel survey – survey design. Report number A-2 (in Hebrew).

Jovicic (Vuk), G. and Hansen, C.O., 2003. A passenger travel demand model for Copenhagen. Transportation research Part A. Volume 37. Issue 4. Page 333-349.

New York Metropolitan Transportation Council (2010) The Regional Travel Survey for New York, New Jersey and Connecticut: sample diary with completed travel information. http://www.regionaltravelsurvey.org/Materials.aspx?lang=en

PTV NuStats, 2010. Jerusalem Travel Habits Survey appendix C: retrieval script.

Vuk, G. and Hansen, C.O., 2006. Validating the passenger traffic model for Copenhagen. Transportation. Volume 33. Issue 4. Page 371-392.

Vuk, G., Hansen, C.O. and Fox, J. 2009. The Copenhagen Traffic model and its Application in the Metro City Ring project. Transportation Reviews. Volume 29. Issue 2. Page 145-162.