Implementation of a Danish activity-based model

Mayara Moraes Monteiro, maymmo@dtu.dk, DTU Management
Ravi Seshadri, ravse@dtu.dk, DTU Management
Carlos M. Lima Azevedo, climaz@dtu.dk, DTU Management

1. Background and purpose

Accurately modeling individual travel demand and behavior is essential for forecasting the impact of alternative policies both at the disaggregated and aggregated levels. In the last decades, the state-of-the-art of travel demand models advanced from traditional four-step models, passing through tour-based models, to activity-based models. The latter models postulate that the demand for travel is derived from the demand for performing activities, i.e., travels are only undertaken when the utility of an activity and its associated travel exceeds the utility of activities involving no travel [1]. Furthermore, it considers that daily travels are temporally and spatially constrained, and individuals start their day at home and return to a home base at the end of the day [1].

In Denmark, different transport demand models are currently being used (OTM, COMPASS, and LTM) for mobility decision-making. The models differ in their modeling approach and coverage area. The Ørestad Traffic Model (OTM) is a tour-based model first developed in 1995 to forecast travel demand in the Greater Copenhagen Area (GCA). It is composed of tour frequency models and mode-destination models [2]. Also developed for the GCA, COMPASS (Copenhagen Greater Area Model for Passenger Transport) is a recently developed activity-based model that represents activities and travels conducted by a HH and its members over the course of an entire workday. It models in detail walk and bike trips, including trips when you take bicycles on the train or metro, as well as modeling new transport technologies, such as autonomous cars and car-sharing [3]. Finally, the Danish National Transport Model (Landstrafikmodellen or LTM) is a tour-based model which considers the entire Denmark as the region to be modeled and has an econometric approach to modeling individual travel behavior [4]. Its demand model follows a random utility framework of nested logit models representing choices of transport mode, destination, and frequency of trips [4].

This paper presents the estimation of an activity-based model for travel demand modeling in Denmark and its implementation within SimMobility [5]. SimMobility is an integrated agent- and activity-based simulation platform that allows for individual behavior simulation in different time scales (from seconds to years), simultaneously simulating demand and supply [5]. Similar to LTM (tour-based model), the activity-based framework we follow models individuals' travel behavior has a utility-maximizing approach and analyzes travels according to home-based tours. Yet, as the name suggests, our modeling framework is built under the premise that travel demand is derived from the need/desire to pursue activities and, thus, home-based tours are combined into a daily activity schedule for each individual [6]. By considering a daily activity schedule, it is possible to account for the limitations and opportunities of performing activities during the day, including at-home activities and multiple tours [1], as well as utilities and costs for individuals of both travel and activities [7]. The estimation builds on information about individuals' daily activity patterns from the Danish Travel Survey (TU) and the LTM to predict which activities are conducted in a day, as well as when, where and for how long they last, and the associated travel choices needed to complete these activities.

2. Methods

The activity-based modeling framework and discrete choice models that we implemented were based on the work developed by Siyu [8] for Singapore and Viegas et al.[9] for Boston, both of which follow the Day Activity Schedule approach proposed by Bowman and Ben-Akiva [10][1]. The framework consists of hierarchical discrete choice models that can be grouped into three levels: the day-pattern level, the tour level, and the intermediate stop level. The choice decisions in lower levels are conditional on upper-level decisions (solid lines), and the decisions in lower levels feed accessibility measures (or logsum) to upper-level models, as indicated by dashed lines in Figure 1.

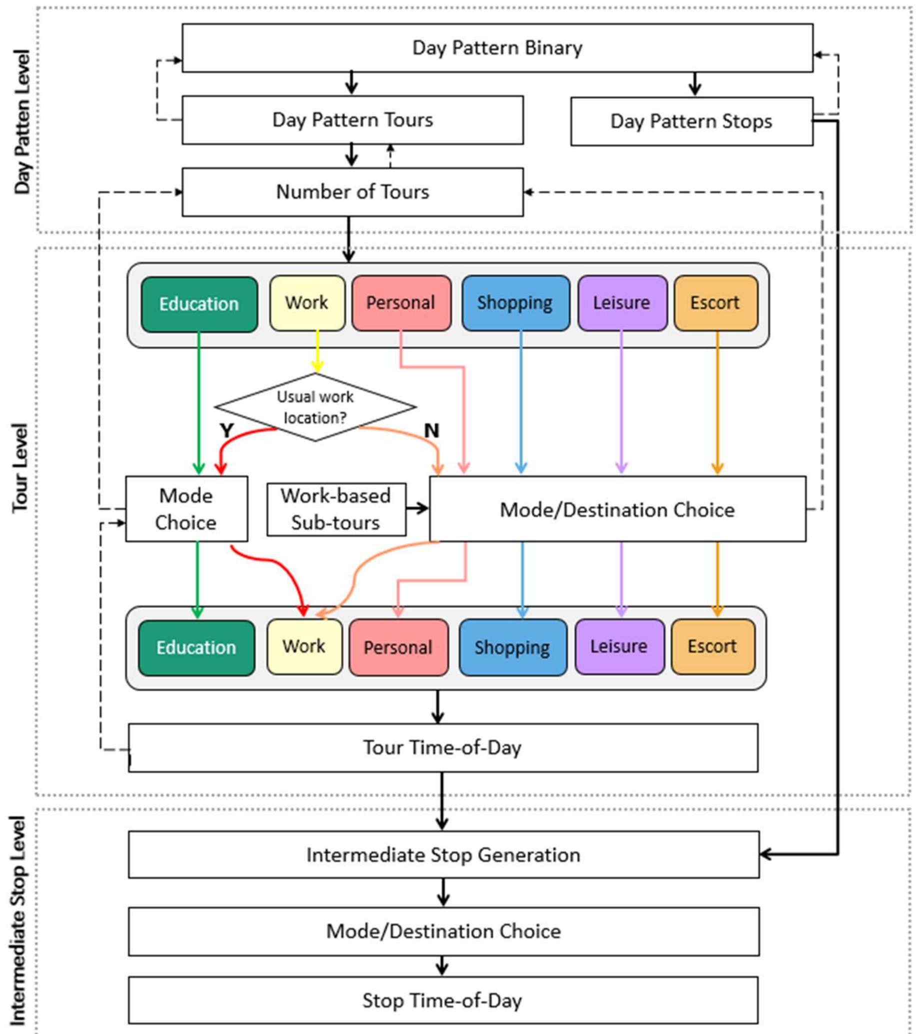

Figure 1. Activity-based model system

2.1 Model's structure

The Day Pattern Level is the level that distinguishes activity-based models from tour-based models since it arranges individuals' tours and their sequences according to day activity patterns [1]. To define a tour, we group together a sequence of trips where the origin of the first trip and the destination of the last trip is the home location. To define a Day Activity Schedule, we model the discrete choices related to whether the individual makes any tours on a given day or not (Day Pattern Binary), then, if traveling during the day, for what primary activity purposes or combination of primary activity purposes they are traveling for (Day Pattern Tours). Moreover, the choices about what types of secondary activities (or intermediate stops) the tours performed have (Day Pattern Stops) and how many tours of each primary activity tour purpose an individual will perform (Number of Tours) are also modeled at this level. The activity purposes modeled are: education, work, personal, shopping, leisure, and escort. The availability of tours for different purposes is defined according to individuals' socio-economic variables, for example, education tours are not available for non-students. The results of intermediate stops from the day pattern level will be used in the intermediate stop generation model (Intermediate Stop Level) to define the availability conditions of each activity purpose.

The Tour Level comprises the modeling of choices of mode, destination, and time of the day when each tour purpose happens. In the case of educational tours, the destination location is assumed to be fixed and known, so only the choice of mode needs to be modeled (Tour Mode Choice). As for work tours, we first model individuals' choice of going to the usual work location or other work-related locations (Tour Usual Work Choice). Conditional on the result of this model, if an individual has a work tour to the usual location, we only need to estimate the mode used to perform that tour (Tour Mode Choice), while if the individual performs a work tour to other work-related location, both mode, and destination choices are modeled jointly (Mode/Destination Choice). The destination is assumed not fixed for all other purposes, and thus, mode and destination choices are jointly modeled (Mode/Destination Choice). Finally, the time of day models estimate the departure and arrival times according to the primary activity's start time and end time (Tour Time of Day). The availability conditions of the mode choice model are defined based on distance thresholds for walking (7 km) and bicycle trips (22 km) and the availability of modes at the household level (for bicycle and car). Public transport is always available, and the availability of car trips performed alone (i.e., the person is the driver) depends on individuals characteristics, namely driver's license status. Still at the tour level, for every work tour, we estimate whether they have a work-based sub-tour associated (Work-based Sub-tour Generation). Like home-based tours, work-based sub-tours start and end at the work location. When a work-based sub-tour is performed, then the mode, destination (Work-based Sub-tour Mode Destination), and time of day models (Work-based Sub-tour Time of Day) are also estimated for this sub-tour.

The Intermediate Stop Level defines trips for secondary activities (called intermediate stops) within a tour through three discrete choice models. The first model estimates the intermediate stops of each tour (Intermediate Stop Generation) according to the availability conditions defined by the Day Pattern Stops. The second model estimate jointly the mode and destination decisions (Intermediate Stop Mode Destination), and the third model represents the time of day when the intermediate stop happens (Intermediate Stop Time of Day).

2.2 Data

The data used to estimate the Danish activity-based model comes from the years 2017-2019 (31,229 individuals) of the Danish National Travel Survey (TU survey) [11] and the level of service matrices for car and public transport travel times and costs for 2020 of the Landstrafikmodellen [12]. The TU survey is based on individual interviews with individuals that are five years old or above about their travels and activities during one day, which also collects individual and household characteristics [11]. Socio-economic characteristics included in the models are age, gender, occupational status, income, driver's license, public transport pass, work schedule flexibility, home-work distance, and car availability. As for the zoning system, we have used the National level (L2) of the Danish zone system, which divides Denmark into 907 homogeneous zones in terms of population and workplaces [4].

Before the estimation of the models, the data was cleaned and processed. In the data cleaning, interviews about weekends and special weekdays (e.g., Friday after Ascension Day, 1st of May, weekdays between Christmas and New Year) were removed. Moreover, individuals who performed trips longer than 6 hours and those who did not inform the purpose of their travels or the start and end time of travels, or the origin and destination zones where the travels occurred were removed from our dataset. As for the processing of data, it aimed to identify tours, sub-tours, and intermediate stops. After the data processing, we have also excluded individuals who performed incomplete home-based tours, i.e., those who do not start the day at home, do not finish the day at home, or only perform one one-way trip during the day. The dataset used for model estimation consisted of information from 19,588 individuals. The discrete choice models were estimated using Pandas Biogeme [13].

3. Implementation within SimMobility

The models estimated for Denmark will be integrated into SimMobility simulation platform [5]. SimMobility is an open-source integrated agent- and activity-based simulation platform that has been developed by the Massachusetts Institute of Technology (MIT) and the Singapore-MIT Alliance for Research and Technology (SMART) since 2012. It supports the activity-based modeling paradigm and allows for individual behavior simulation in different time scales (from seconds to years), simultaneously simulating demand and supply [5].

SimMobility has three primary modules, which consider different timeframes: long-term, mid-term and short-term. The Long-term module simulates year-to-year dynamics, capturing long-term land use and economic changes. The Mid-term module simulates day-to-day dynamics of travel demand, i.e., agents' daily travel and activity patterns. The Short-term module simulates what happens within a day, i.e., the movement of agents at a microscopic granularity [14].

The Mid-term module of SimMobility consists of three interacting simulators: Pre-day, Within-day, and Supply. The Pre-day simulator simulates individuals' daily activity and travel patterns according to the activity-based models estimated. The Within-day simulator simulates both departure times and route choice behavior, allowing for re-scheduling depending on real-time network conditions (provided by the supply simulator), and the Supply simulator simulates the transport network and its attributes, including both public and private transport [14].

SimMobility was entirely developed in C++ to favor efficiency and performance; the embeddable and lightweight scripting language LUA is used for implementing the models' specifications [9][14], due to its relatively simpler and more intuitive language syntax.

4. Expected results

We will run the Mid-term module of SimMobility to combine the results of the activity-based model estimated (model specifications implemented in LUA scripts) with the current Danish transport network and a synthetic population based on the Danish population (around 5.9 million agents will be created and simulated). The simulator will generate daily activity and travel plans for every individual in the synthetic population to simulate travel demand.

We will generate aggregate metrics of travel demand in Denmark, including the total number of tours by purposes, modal split, and spatial distribution of tour destinations. To validate the simulated results, we will compare them against aggregated measures of the same datasets used for estimation to verify how well the models can replicate individuals' behavior, as well as against other sensor data for traffic counts and travel times between zones data available. By doing so, we will be able to calibrate the models to match the mode shares and time-of-day choices based on overall aggregation and aggregating regarding the time of day.

5. References

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