THE SENSITIVITY OF ACTIVITY-BASED MODELS OF TRAVEL DEMAND: RESULTS IN THE CASE OF ALBATROSS

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Abstract. The concept of activity-based models was introduced as an alternative to existing trip-based and tour-based models a few decades ago. Potentially, activity-based models are able to predict individuals' secondary responses, i.e. re-scheduling of activities, as well as primary responses to changes in transport and land-use systems. In addition, the models are sensitive to changes affecting the time budgets of people. Little is known about the extent to which activity-based models come up to this promise. In this paper, we report the results of scenario analyses conducted to test the sensitivity analysis of the activity-based model Albatross.

1. Introduction

Currently, the first operational activity-based models of travel demand start to appear and are making the transition to practice (e.g., [4], [6], [5], [1]). The concept of activity-based models was introduced as an alternative to existing trip-based and tour-based models a few decades ago. Subsequent development have focused on developing conceptual frameworks and developing methods to specify, estimate and test models. One of the major promises of the activity-based approach is an increased sensitivity for scenarios that are generally important in transport planning and policy making. In contrast to trip-based and tour-based models, activity-based models should be sensitive to institutional changes in society in addition to land-use and transportation-system related factors. Such changes may be related, for example, to work times and work durations of individuals and opening hours of stores or other facilities for out-of-home activities. Furthermore, the models should be sensitive to secondary responses to land-use and transportation-related changes that in the past have been responsible for unforeseen and unintended effects of transport demand measures by policy makers. Typical examples of such possible effects are an increase of out-of-home social activities in response to measures stimulating tele-working or increased use of car for

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shorter trips as a secondary effect of stimulating car-pooling for trips to work (car stays at home and can then be used by other members of the household).

The first models are now making the transition to practice. One of the models of this group is Albatross, which was developed for the ministry of transportation ([3], [2], [1]). Albatross is a computational process model using a set of linked decision trees in a sequential process of activity scheduling. The last version of the model is applicable on a National scale (the Netherlands) and generates schedules from scratch for each individual and day simulated. A micro-simulation approach is followed meaning that a sufficiently large sample of the national population is synthesized and represented in the system.

The purpose of this study is to explore the sensitivity of activity-based models using the Albatross model as a representative exponent of the activity-based (and computational-process-modeling) approach. We describe the results of scenario analyses that were conducted to test the sensitivity of the Albatross model. Potentially, Albatross is sensitive to several groups of variables including: Population; Schedule skeletons; Opening hours; Land-use; Travel costs and Travel times. The scenarios considered are not necessarily realistic. Rather the purpose here is to test the sensitivity of the model for one independent or group of independent variables at a time.

The paper is structured as follows. First, we describe the specification of the scenarios considered related to the different groups of variables. Next, we discuss the results obtained and how the results compare to common expectations, empirical evidence or expert opinions. Albatross is a micro-simulation model meaning that every household and individual is individually represented in the system. All scenarios were based on a synthetic population representing 2% of the Dutch population in 1995. This (sample of the) population is synthesized using an iterative proportional fitting procedure. The effects of each scenario are analyzed by comparing the results of predictions between the base line and scenario.

2. Design of the scenarios considered

1.1. Population scenarios

In terms of population developments, there are several trends going on in the Dutch society and other western countries. In 2000 compared to 1995, for example, a number of changes related to attributes on household and person level took place and is still ongoing. These include:

1. Increasing participation of women in the labor force
2. Increasing number of 1-adult households resulting in a decreasing average number of persons per household.
3. Increasing household incomes as a consequence of general economic growth.
4. Aging of the population in terms of graying and 'de-greening'.
5. Related to 4: a decreasing share of households with children
6. Increasing average number of cars per household.

The scenarios were implemented by changing the demographic data that provide the marginal distributions or the sample data providing the initial cell proportions for the fitting procedure in the population synthesis model. In Albatross, the fitting procedure is constrained only by work status and age group of individuals meaning that car possession, household income and children scenarios were implemented at the level of the sample (cell proportions) and the other scenarios at the level of the marginal distriubutions.

1.2. Schedule-skeleton scenarios

Institutional changes in societies may pertain to the fixed activities and in particular work times. In Albatross, such scenarios can be modeled by implementing changes in the skeletons before flexible activities are scheduled (by interrupting the scheduling process and implementing changes before continuing). The following two scenarios of this type were considered.

Workweek. In this scenario, we consider the case where 80% of the full time workers switches from a workweek of 5 days of 8 hours to a workweek of 4 days of 10 hours. The change is implemented in schedules after the work activity and mode has been scheduled.

Work start time. In this scenario, 80% of the schedules including a work activity starting between 7 AM and 9.30 AM undergoes a change. The change consists of changing the start time of the work episode under concern in such a way that the new start time falls outside this range and deviates as little as possible from the original start time. This means that after 8.15 AM the work episode is delayed and before this time the work episode is reset to start earlier. All other existing sleep and work episodes in the schedule are shifted on the time axes such that all interval times remain constant.

1.3. Opening hours

In 1996, the Shopping Hours Act introduced a liberalization of shopping hours in the Netherlands. From that time, shops may open between 6 AM and 10 PM from Mondays to Saturdays, without any restriction on the total number of opening hours per week. In Albatross, opening hours are defined for each day of the week and for daily and non-daily shopping activities separately. The daily shopping activity includes service related activities such as going to a post office or a bank. Two scenarios are considered here a widening and a shortening of opening hours.

1.4. Spatial scenarios

With respect to the spatial distribution of facilities, the Netherlands has witnessed two major trends over the last decade. First, there is a trend of increasing spatial separation of locations for residence, work and facilities as a consequence of sub-urbanization. Second, the size and degree of clustering of facilities have increased in the same period. In this section we consider the following scenarios to investigate the sensitivity of the model for such trends: Spatial separation Work and Home (SeparW); Spatial separation Work & Facilities and Home (SeparWF); Concentration of facilities (Concen); De-urbanization (Urban).

The spatial-separation scenarios, *SeparW* and *SeparWF*, are implemented by operations of swapping employment between PCAs (post code areas) within municipalities. A swap of employment between any two locations *i* and *j* is implemented if employment in *i* is larger than in *j* and the population in *i* is larger than in *j*. In this way employment moves from PCAs with larger populations to PCAs with smaller populations, while the total employment in the municipality stays the same. Cycles of swapping are repeated until no more swaps are possible. In *SeparW* only employment in industrial/business is exchanged, whereas in *SeparWF* also employment related to facilities are substituted. As a result, the spatial correlations between work, home and facilities have changed. The first scenario effectively reduces the correlation between employment and population from 0.49 to approximately zero. The second scenario in addition leads to a decrease of the correlation between daily shopping facilities and population from 0.62 to approximately zero.

1.5. Travel-time and travel-costs scenarios

The predictions considered in this section are based on Albatross version 3 which is an extension of Albatross version 2 in which price and cost parameters are incorporated in the decision trees that are concerned with activity selection, timing, trip-chaining, location and mode choices. The decision trees extended in this way are called parametric action decision trees or in short PADTs. To test the sensitivity of the extended model, a car costs, car travel time and train travel time scenario was considered. All scenarios involved a 20% increase of variable travel costs or times for all times of the day and all pairs of postcode areas (in case of car) or subzones (in case of train). Variable car travel costs is a parameter in the Albatross model, whereas the travel time increases were implemented by editing the travel time matrices concerned. The scale of the travel costs and time parameters (which were estimated based on the SA data) was set to 0.6 and the VoTs were assumed to be equal to 13 Euro/hr (work) and 9 Euro/hr (non-work).

3. Results

The *work status variable* has several effects. An increase or decrease of engagement in work activities is compensated by a change in frequency of non-work activities with as a result that the number of trips tends to stay the same. Total travel demand does change because the average trip length changes. Work trips are long trips on average so that an increase in number of work activities leads to an increase in total distance traveled and vice versa. Related to this change in average trip length is a modal shift towards long-distance or short-distance modes depending on the direction of the change. In particular, the share of public transport and car passenger on total distance traveled is sensitive to this kind of scenario. In terms of the spread of activities across the day, a substitution between work and non-work activities leads to an increase or decrease of travel during peak hours.

Car-possession has an impact on mode choice, hardly any effect on activity choice and a moderate effect on location choice. An increase in car possession leads to an increase in distance traveled by car and an (smaller) increase in average trip length, whereas the number of trips does not change significantly. As a consequence, the total travel distance and the distance traveled by car increase.

The *presence of (young) children* in households has an impact on activity patterns. The variable is positively correlated with the number of bring/get activities. However, if the frequency of bring/get activities increases, the frequency of activities of other categories (in particular, social and leisure) tends to decrease with as a net effect that the total number of out-of-home activities and trips stays approximately the same. Although the shift in activity pattern has no significant impact on total travel demand, the distribution of activities and travel across the day does change somewhat.

The *age of (oldest person in) households* has only limited impacts when corrected for work status and presence of children. The variable has an effect on the choice of activity, but the total number of activities stays approximately the same. Whereas the number of bring/get activities and non-daily shopping decrease, social and leisure activities increase a little. Associated with this change is a small shift in timing of activities resulting in a small increase of activities in the early morning and evening. All effects are relatively small.

Socio-economic class has a limited impact in scenarios where car possession remains constant. An increase in income leads to a slight increase in mean trip length and a small increase in activities in evening hours. Probably, these shifts are caused by a change in choice of activity type within the activity categories considered.

Opening hours of daily and non-daily shopping facilities have impacts on activity patterns as expected. The widening of opening hours leads to an increase in frequency particularly of non-daily shopping and an increase of activities in early (small) and evening hours (larger) of the day.

The *timing of the work activity* variable does not have an important impact on activity generation, at least not within the small range of changes considered in the scenarios considered. Depending on the size of the change, the variable has a slight impact on the timing of other, non-work activities due to re-scheduling processes. An interesting result is that, at least in the scenario considered, the use of car for the non-work activities decreased somewhat. This may be the consequence of a decrease of car availability during the times of day when other than work activities tend to be conducted.

Spatial distances between work-facilities-homes have an impact on average trip length and, hence, total distance traveled, as one would expect. However, in the scenarios considered the model did not predict any activity generation effects which may be attributed to an insensitivity of the model. Changes of trip lengths incur a change in mode choice, as we have seen in other scenarios as well. *Spatial concentration* of facilities, on the other hand, has unanticipated impacts in predictions. An increase of spatial concentration, of the size considered in the scenario, did not have an impact on average distance traveled per trip, as one would expect, but did change the distribution of trips across length categories with associated changes in mode choice. A possible explanation for this is that a decrease of accessibility of low-order locations is compensated by an increase of accessibility of high-order locations for certain activities. Given a preference of people to visit high-order locations for certain activities, long trips are replaced by shorter trips. Since short trips are replaced by longer trips at the same time, the outcome may be sensitive to the specifics of the scenario.

4. Conclusion

This paper considered the results of a series of scenario analyses conducted to test the sensitivity of Albatross. The scenarios covered all categories of variables that can be manipulated by the user and that are generally relevant for policy making including variables of population, schedule skeletons, opening hours, the land-use system and the transport system (travel times and costs). As it turns out, the results are well interpretable and largely in line with experts' expectations and sometimes reveal unanticipated effects.

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