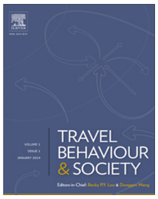
Travel Behaviour and Society 1 (2014) 31–35

Contents lists available at ScienceDirect

Travel Behaviour and Society

journal homepage: www.elsevier.com/locate/tbs



Effects of travel time delay on multi-faceted activity scheduling under space-time constraints: A simulation study

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ARTICLE INFO

Article history:
Available online 7 November 2013

Keywords:
Time geography
Space-time constraints
Uncertainty
Albatross

ABSTRACT

This paper presents the results of a study, which simulates the effects of travel time delay on adaptations of planned activity-travel schedules. The activity generation and scheduling engine of the Albatross model system is applied to a fraction of the synthetic population of the Rotterdam region, The Netherlands. Drawing from a truncated normal distribution of speed, the mean of which is equal to average speed, travel time delays for a set of links are simulated. Albatross is run using these travel times delays as input to simulate the effects on activity-travel schedule behavior. The paper reports differences in various aspects of activity-travel schedules. Results indicate that travel time delay affects activity participation the most.

Introduction

It is generally assumed in the time geography literature that individuals implement their activity agenda in time and space based on a set of stationary travel times, subject to space-time, institutional and several other constraints (e.g., Neutens et al., 2011). If these constraints become stricter and/or travel times increase, individuals may no longer be able to implement their intended schedule, which therefore may become (partly) infeasible. The impact of such changing constraints has been used in the time geography literature as measures of accessibility and social exclusion (e.g., Kwan, 1998, 1999, 2000; Weber, 2003; Miller, 1991, 1999, 2007; Neutens et al., 2010). The assumption of stationary travel times, however, does not seem valid as individuals may face delays when executing their activity agendas due to non-stationarity of travel times in the transport system. Of particular interest is the situation in which they face travel time delay of varying degrees due to congestion. Classical time geographic approaches would assume under these circumstances that travel time delay may lead to the deletion of activities in the agenda if the time to reach the location to conduct the planned activity would become insufficient. However, in addition to cancelling an activity, individuals may adapt to travel time delay in a variety of other ways. More specifically, they may adjust any combination of the multi-faceted profile characterizing their activity-travel pattern. A more valid model than the classical time-geography models would thus allow for such multi-faceted adaptation.

In the present study, the Albatross model system (Arentze and Timmermans, 2000, 2004, 2005) is used to simulate such effects. Although this model system does not explicitly address the problem of activity-travel rescheduling, it is based on a process model and therefore less sensitive to observed activity-travel patterns. This process model mimics the formation of activity-travel schedules under different conditions and various types of constraints. By assuming that this process model is stable and equally applies to scheduling and rescheduling decisions, the model can be used to simulate the effects of travel time delay on activity-travel scheduling. To that effect, we applied the activity generation and scheduling engine of the Albatross model system to a fraction of the synthetic population of the Rotterdam region, The Netherlands. A series of runs of the Albatross model system was conducted, each time using a different set of travel time delays on selected links of the network as input. The simulated schedules were then compared against the schedules that are generated under the assumption of no travel time delay on the various choice facets comprising the full schedule.

The paper reports the results of a series of descriptive analyses about differences in activity-travel schedules for average travel times and simulated travel time delay. The paper is organised as follows. First, to position this study, its theoretical background, based on time geographic approaches will be discussed. Next, we will summarize the Albatross model system that is used in this study. We will continue with an explanation of the design of this study and then report the main findings. The paper is completed

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http://dx.doi.org/10.1016/j.tbs.2013.10.002

with a discussion of some limitations of this study and potential avenues of future research.

Time geographic approaches

The classic view in economics and geography has been that observed (spatial) choices are manifestations of people's preferences. People choose what they prefer to do. However, Hägerstrand's (1970) seminal paper drew the attention to the fact that people's choices may be strongly affected by various types of constraints. In particular, he differentiated between capacity, coupling and authority constraints. Capacity constraints have a biological or instrumental origin. For example, sleeping, eating and drinking occur in regular rhythms and intervals. Bus schedules define limits to the possible execution of activities. Coupling constraints stem from the fact that activities often are conducted jointly with others. Consequently, the timing and the location where the activity takes places need to be synchronized. The activity schedules of two or more people need to coincide sometime, someplace, implying that scheduling options may become more limited. Finally, authority constraints such as driver's license and opening hours constrain the time and place when and where someone can conduct a particular activity.

The concept of space-time prism has received most continued attention in time geography. It has been instrumental in assessing the feasibility of planned activity-travel agendas. Let S be an activity-travel schedule. Assuming that the end time of activity i conducted at location j is $\hat{e}_i$ and the latest start of the next activity i+1 is conducted at located j+1 is $\hat{S}_{i+1}$, then the set of locations $\{K\}$ that can be reached between $\hat{e}_i$ and $\hat{S}_{i+1}$ is defined by the following relationship:

$$t_{k\in\{k\}} = \frac{d_{j,k} + d_{k,j+1}}{v} \leqslant s_{i+1} - \hat{e}_i \tag{1}$$

where t_k, is the travel time required to travel from j to j+1 via k; $d_{j,k}$ is the distance between activity location j and k; $d_{k,j+1}$ is the distance between k and the activity location j+1 and v is the travel speed (which is assumed constant here). Eq. (1) describes the set of locations or nodes that can be passed to reach the next activity location on time. If the problem is to examine whether an activity of duration δ_k can be conducted at location k, then Eq. (1) becomes:

$$t_{k\in\{k\}} = \frac{d_{j,k} + d_{k,j+1}}{v} + \delta_k \leqslant s_{i+1} - \hat{e}_i$$

Let h_{j+1} denote the closing hour of facilities at location j+1 with activity i+1. Then, an activity-travel schedule S is feasible if

$$t_{k\in\{k\}} = \frac{d_{j,k} + d_{k,j+1}}{v} \leqslant h_{j+1} - \hat{\delta}_{i+1} - \hat{e}_i \tag{2}$$

where $\hat{\delta}_{i+1}$ is the minimally required duration of activity j+1.

The space-time prism concept has been used in many studies to assess the impact of exogenous policies on the feasibility of current activity-travel schedules. For example, Weber and Kwan (2002) have shown that business hours affect individual accessibility. Schwanen and De Jong (2008) considered opening hours of nurseries in assessing dual-earner families' possibilities to combine employment and caring responsibilities.

Albatross

Albatross is a rule-based micro-simulation system, developed for the Dutch Ministry of Transportation that predicts which activities are conducted where, when, for how long, with whom and the transportation mode involved and their interdependencies (Arentze and Timmermans, 2000, 2004, 2005). The rule-based nature of the model implies that unlike most other activity-based models, which use algebraic expressions, Albatross is based on Boolean expressions. Each expression captures which kind of scheduling decision is made under a set of conditions. The model assumes that individuals exhibit context-dependent heuristic behaviour. This context-dependency is represented in terms of condition-action rules, which describe which action is taken under a particular set of conditions. This rule set is complete and consistent. Complete means that at least one rule is activated for any set of conditions. Consistent means that no more than one rule corresponds with every possible combination of values of condition variables.

Albatross uses probabilistic decision trees to represent these conditions-action rules. Decision trees are empirically derived from activity-travel diaries using a CHAID-based induction method. The aim of this method is to find the smallest decision tree that best explains the diary data by recursively splitting the sample on condition variables. A Chi-square based significance test is used to identify the best possible way of (further) splitting the condition variables. In case the condition variable is continuous variable, an F-statistic is used to evaluate possible ways of splitting.

Decision rules for each choice facet (activity participation, destination, timing and duration, transport mode, travel party) in the scheduling process are derived in successive steps according a priority-based process model in which mandatory activities are scheduled first and discretionary activities are scheduled next. Conditions reflect all choices and future possibilities. Consequently, activity-travel schedules are path-dependent. Activity-travel choices are simulated given a set of spatial-temporal, institutional and household constraints.

Given exogenous change in condition variables, activity-travel schedules are simulated by activating the decision trees, following the sequence implied by the assumed process model. Monte Carlo draws are used to simulate a realisation of the discrete probability distribution underlying the choice facet. The probability of choosing a particular option given the relevant set of condition states is proportional to the relative number of observations in the corresponding leaf node of the decision tree, corrected for any violations of imposed constraints. If the simulated choice violates any constraint, a new draw is made. In particular, predictions satisfy the following set of constraints: *situational constraints* which impose that a person, transport mode and other schedule resources cannot be at different locations at the same time; *institutional constraints*, such as opening hours, which influence the earliest and latest possible times to implement a particular activity; *household constraints*, such as bringing children to school, which dictate when particular activities need to be performed and others cannot be performed; *spatial constraints* which enforce that particular activities cannot be performed at particular locations, or individuals have incomplete or incorrect information about the opportunities that particular locations may offer; *time constraints* which limit the number of feasible activity patterns in the sense that activities do require some minimum duration and both the total amount of time and the amount of time for discretionary activities is limited, and *spatial-temporal constraints* which are critical in the sense that the specific interaction between an individual's activity program, the individual's cognitive space, the institutional context and the transportation environment may imply that an individual cannot be at a particular location at the right time to conduct a particular activity.

Albatross simulates daily activity-travel schedules for each household and its members. The model predicts which activities are conducted, where, when and for how long, the transport mode and travel party involved, subject to several types of constraints. The simulated output of the model thus consists of the individual space-time trajectories of activity-travel decisions with a temporal resolution of one minute and a spatial resolution of four-digit