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Investigating the nonlinear relationship between transportation system performance and daily activity–travel scheduling behaviour

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ABSTRACT

The paper presents an econometric investigation of the behavioural relationship between transportation system performance in terms of travel time changes and daily activity–travel scheduling processes. Innovative survey data on the complete daily activity-scheduling adaptation process is used jointly with revealed scheduling information. The survey, conducted in Zurich, Switzerland, collected daily scheduling information together with stated adaptation responses corresponding to four adaptation scenarios. The four scenarios are defined by applying hypothetical increases in travel time of 50%, 100%, and 200% and a 50% decrease in travel time. Stated adaptation responses are collected in the context of 24-h activity scheduling. Data are used to estimate RUM based daily travel activity scheduling models. Models are estimated for one revealed schedule and four stated scheduling datasets. In addition, a joint model is estimated for pooled revealed and stated scheduling data. In the joint model, separate scale/variance parameters are estimated for revealed and stated information. Results clearly identify the nonlinear responses of activity–travel scheduling to the changes in travel time. Asymmetric responses are shown for travel time increases and decreases. People become more conservative with time expenditures when scheduling activities subject to increased travel times. However, beyond a certain limit of travel time increase, scheduling behaviour becomes more unpredictable. The lessons learned from this investigation have implications in the application of activity-based models for forecasting and policy analyses. Models developed using only a revealed preference dataset should not be used to extrapolate to situations where travel times changes by large margins. The results also prove that significant improvements in capturing behavioural responses in the activity scheduling process are possible by pooling revealed preference and stated preference data sets and jointly modelling with an explicit representation of RP scale/variance differences.

1. Introduction

It is well known that travel conditions imposed by the performance of the transportation system influence travel demand. All growing cities have experienced periods of change in their transportation systems and the ways that people travel. Over time, development, technology and changing social and economic environments in urban areas have had major impacts on

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both travel patterns and development of the transportation system. In turn, the usage of transportation and the operational attributes of the system have a reciprocal effect on each other. For many transportation policy decisions, it is vital to have an understanding of the forces motivating travel demand patterns in a city. The effect of system performance attributes such as travel times, wait times and costs on travel demand is of specific interest to all those involved in the design of a sustainable transportation system. However, the nature and extent of the influence of transportation system performance on our travel behaviour is not yet fully understood (Weis et al., 2010). One of the main reasons is the traditional tendency to rely only on Revealed Preference (RP) travel survey data. Although RP data are less subject to error and bias than Stated Preference (SP) data, RP data may not always contain information on a wide range of scenarios.

Transportation system performance does not change drastically at the system scale level very frequently. Therefore, RP data often fail to present information on a wide variety of transportation system performance levels and the resulting influence on activity–travel demand. Travel demand models developed using RP data may fail to capture changes in travel demand trends due to variation in transportation systems over time (Roorda et al., 2008). However, such models are often used to forecast medium to long term forecasting and policy scenario analyses. RP data used in developing activity-based travel demand models often describe stable/equilibrium interactions between transportation demand and supply. Travel activity scheduling decisions are made on a daily or even weekly basis. Changing traffic congestion, economic and social conditions may lead to increasing complexities in our activity–travel behaviour. Many such changes are unprecedented and create significant challenges for modelling activity-based travel demand (Bifulco et al., 2010). Such challenges are mostly related to increasing the sensitivity of travel demand models to previously unobserved conditions. RP survey based activity–travel data often fail to provide sufficient information for modelling these. In such cases, SP data are valuable because they provide a unique way to evaluate the expected response to potential future system changes.

An RP activity–travel survey is very unlikely to contain observations from a wide variety of transportation system performance scenarios and the resulting activity–travel behaviour adaptations. Even a 6-week RP travel survey may not show significant variations in activity travel scheduling process behaviour if significant changes in transportation system performance do not happen during the survey time (Schlich and Axhausen, 2003). Failing to capture a variety of system states limits our ability to forecast demand patterns and/or predict reactions to new policies that may affect transportation system performance significantly by using activity-based travel demand models. One way to overcome this basic limitation in activity-based analysis is to use Stated Preference (SP) survey data. A properly designed SP survey (involving pivoting the SP scenarios to the RP responses) can present a rich set of information for developing comprehensive activity scheduling models. Such models would be capable of predicting a wide range of transportation demand–supply interaction scenarios. In this investigation, we use such a dataset that contains RP activity scheduling information together with four Stated Adaptation (SA) responses corresponding to four transportation system states. SA scenarios are created to collect SP responses in activity scheduling decisions by pivoting to the RP scheduling information to generate a complete 24-h response pattern. Both RP and SP data are used independently and jointly to develop dynamic RUM based daily activity scheduling models. Comparisons of the model parameters highlight the complexities of activity–travel scheduling behaviour and its relationship with transportation system performance.

The paper is arranged as follows: the next section presents a literature review followed by a description of the scheduling model based on random utility theory, a description of the Stated Adaptation survey and the datasets and discussions on empirical models. The paper concludes with recommendations for further investigations.

2. Literature review

The complexities of the relationship between daily activity–travel scheduling decisions and transportation system performance have long been of interest to researchers. Recker et al. (1986) summarize the efforts of various researchers in conceptualizing this issue in the early 1980s, when the concept of an activity-based approach was first recognized as a legitimate theory for modelling travel demand. Since then, the theoretical understandings on the dynamics and complexities of activity travel behaviour have been complemented by many researchers from various disciplines of science and engineering (Han et al., 2008, 2011). It is now well recognized that modelling activity-based travel demand requires consideration of the interactions among multidimensional activity planning horizons, psychological processes of planning and decision making, intra- and inter-household interactions, effects of social networks, as well as the dynamics of transportation system performances (Garling et al., 1994; Lin et al., 2008).

Various approaches of modelling such complex activity–travel behaviour are evident in literature. Some researchers consider hybrid mixing of behavioural rules and econometric choice models for capturing behavioural complexities (Arentze and Timmemans, 2000; Roorda et al., 2008; Auld and Mohammadian, 2008). Some researchers apply discrete choice models for modelling activity–travel patterns (Ben-Akiva and Bowman, 1998; Bowman et al., 1998; Shiftan, 2008). Hybrid approaches of activity-based travel demand models often try to capture activity–travel rescheduling and/or adjustments by directly addressing the rescheduling process in the modelling structure. On the other hand, discrete choice model based activity pattern choice modelling captures rescheduling behaviour indirectly through utility feedback from lower level decisions (such as activity start time and activity durations) to upper levels decisions (such as choice of specific tour pattern) in activity travel pattern choices. In any type of modelling approach, dynamics of transportation system performance needs to be accurately captured into the activity–travel pattern dynamics and vice versa. This is very important for maintaining the behavioural realism of activity-based travel demand modelling.