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Jointly modelling individual's daily activity-travel time use and mode share by a nested multivariate Tobit model system

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Abstract

Understanding mechanisms underlie the individual's daily time allocations is very important to understand the variability of individual's time-space constraints and to forecast his/her daily activity participation. At most of previous studies, activity time allocation was viewed as allocating a continuous quantity (daily time budget) into multiple discrete alternatives (i.e. various activities and trips to engage with). However, few researches considered the influence of travel time that needs to be spent on reaching the activity location. Moreover, travel time itself is influenced by individuals' mode choice. This can lead to an over- or under-estimation of particular activity time location. In order to explicitly include the individual's travel time and mode choice considerations in activity time allocation modelling, in this study, a nested multivariate Tobit model is proposed. This proposed model can handle: 1. Corner solution problem (i.e. the present of substantial amount of zero observations); 2. Time allocation trade-offs among different types of activities (which tends to be ignored in previous studies); 3. Travel is treated as a derived demand of activity participation (i.e. travel time and mode share are automatically censored, and are not estimated, if corresponding activity duration is censored). The model is applied on a combined dataset of Swedish national travel survey (NTS) and SMHI (Swedish Meteorological and Hydrological Institute) weather record. Individuals' work and non-work activity durations, travel time and mode shares are jointly modelled as dependent variables. The influences of time-location characteristics, individual and household socio demographics and weather characteristics on each dependent variable are examined. The estimation results show a strong work and non-work activity time trade-offs due to the individual's time-space constraints. Evidences on a potential positive utility of travel time added on non-work activity time allocation in the Swedish case, are also found. Meanwhile, the results also show a consistent mode choice preference for a given individual. The estimated nested multivariate Tobit model provides a superior prediction, in terms of the deviation of the predicted value against the actual value conditional on the correct prediction regarding censored and non-censored, compared to mutually independent Tobit models. However, the nested multivariate Tobit model does not necessarily have a better prediction for model components regarding non-work related activities.

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1. Introduction

Individuals every day make choices intentionally or unintentionally of investing what amount of time in which type of activity. On the one hand, such choices depend partially on the available resources they access to, such as car availability and other travel resources. On the other hand, it also depends partially on the constraints that the individuals have on the given day, such as available time in a day, compulsory and non-compulsory commitments, required time to commute and travel between locations, stores' opening hours, etc. Such constraints and resources affect our daily activity participations and travel related decisions (Hägerstrand, 1970). In general, activity time allocation problem is a subset problem of activity scheduling problem which includes activity time allocation and activity sequencing. Modelling activity time allocation can be viewed as allocating a continuous quantity (daily time budget) into multiple discrete choices (i.e. activity types to engage).

Whilst there have been a lot of studies modelling individuals' daily activity time allocation problem, most of these studies ignored the relationships between the individual's activity participation decisions and his/her activity duration and travel time, mode choice. Many researches pointed out the negative utility of travel time in the activity scheduling problem (Supernak, 1992 and Joh et al., 2001). Given that an individual's ability to travel and engage in the activity is highly influenced by the amount of the activity duration available and that, in many circumstances, an individual has to do trade-offs between his/her travel distances and activity durations in selecting his/her activity locations (Susilo and Dijst, 2010), it is therefore important to consider the influence of travel time on the activity time allocation problem in one integrated model structure. Assuming an individual would like to invest his/her time on a certain type of activity *i*, the corresponding travel time for this kind of activity is zero if this activity is not conducted, otherwise the corresponding travel time is non-zero and this amount of travel time would potentially affect individual's activity time allocation. If this activity is to be conducted, the individual would also need to decide which travel mode he/she wants to take, whilst considering the whole trip chaining pattern, which indeed affects the travel time of this particular trip. Besides, the interaction among activity time allocation, travel time and mode choice also varies between different activity types (work or non-work). The previous studies (e.g. Kang and Scott, 2010; Susilo and Kitamura, 2005; Susilo and Axhausen, 2014) have shown that the time allocation for work activities are more predictable and less dependent on an individual's daily space-time constraints than that for non-work activities.

In order to model the relationship among the individual's activity-travel indicators (i.e. his/her activity time allocation with his/her travel time spent and selected travel modes), for different types of activities on the given day, an integrated model framework should be able to address at least the following three methodological issues. First, there are activities which many individuals do not participate in the given day. For example, for an individual who is not working on the given day, his/her work activity duration is zero. Thus the proposed model structure should have zero as a boundary, and not allow negative values as a solution, which is called corner solution and censoring. Secondly, since an individual has a limited available time to allocate to different types of activities, more time allocated in one type of activity would conceptually lead to a fewer amount of time allocated in other types of activities. Such correlations among different activity types as well as the correlations among activity duration, travel time and mode choices, should be considered in the proposed model. Thirdly, travel indeed is a derived demand of activity participation, thus individuals make mode choice and have travel time only when this particular type of activity is conducted. Thus, the proposed model structure should model the corresponding travel time and mode choice conditional on observing a non-zero activity duration, which can be handled by the sample selection method.

Generally there are two basic categories of model systems that serve the purpose of modelling the activity time allocation. The first category is the utility maximization-based Kuhn–Tucker (KT) demand systems (Kim et al, 2002). This type of model formulates an individual's utility of activity time allocation as the sum of the utilities of