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Understanding seasonal variation in individual's activity participation and trip generation by using four consecutive two-week travel diary

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ABSTRACT

This paper explores the interactions between travel demand, time allocation and mode choice in different seasons by jointly modeling the work and/or study, routine and leisure activity-travel engagements of 67 individuals in Stockholm, Sweden. A longitudinal panel two-week travel diary data collected in four consecutive waves over a span of seven months period that covers all four different seasons; autumn, winter, spring and summer, were analysed by using simultaneous Tobit models. The model was applied to explore the interactions among each activity-travel indicator, and individuals' unique characteristics and endogeneity in activity-travel engagements between different seasons were also considered in the model system. The results of models reveal clear trade-offs between mandatory activities (work and/or study) and non-mandatory activities (routine and leisure), regardless of any seasons, although the magnitudes vary between seasons. There is also a positive mutual endogeneity relationship between number of trips and activity duration within the same activity type. The trade-offs between work and/or study trips towards routine and leisure trips are larger in winter and spring respectively, than in other seasons. It is also found that mode effects on travel time for conducting mandatory activity are much larger in spring than in other seasons. However, the effects of public transport and slow modes on travel time for leisure activities are much larger in summer than in other seasons.

1. Introduction

Individuals travel behaviour may vary across different seasons and in different regions due to the variations in weather conditions. People's movements on local, regional, national and global levels can be influenced by the changing of the seasons (Silm and Ahas, 2010). In tourism research, seasonal effects on tourists' locational choices have been examined extensively (e.g. Kozak and Rimmington, 2000, Lundtorp, 2001; Tkaczynski et al., 2015) since understanding of the seasonal effects are crucial for predicting tourism demand (Baum and Hagen, 1999; Lee and Jang, 2013). Meanwhile, in weather-related research, some studies have examined the impacts of weather in different seasons on transport mode choice (e.g. Liu et al., 2015a; Bergstrom and Magnusson, 2003). For example, Liu et al. (2015a) found that slow-mode shares (e.g. walk and cycling) are affected the most by the weather conditions.

In spatial behaviour research, the impacts of seasonal variations on human activity-travel behaviour have increased in recent years due to the development of information and communication technology (ICT), particularly mobile technologies. For example, Silm and Ahas (2010) examined the seasonal variability on mobility of the population's residence in Estonia by using mobile-positioning data. They found that at least 5% of the Estonian population migrates its place of residence seasonally with the majority migrating during summer (June-August). Järv et al. (2014) examined the individual monthly spatial travel behaviour by using mobile phone call detail records of one-year (1 January to 31 December 2009) collected in Estonia. They found that the seasonal effect explains 17% of the total variance for monthly activity space and 87% for daily activity space. Interestingly, they also found that the intra-personal (e.g. within-person variations) outlier months in spatial behaviour is concentrated in the summer months (June-August). An excellent literature about the concept of activity space can be found in Golledge and Stimson (1997). Schönfelder and Axhausen (2010) studied individuals' monthly activity space patterns and found that individual's trips are significantly more dispersed in space and the destinations are further from home during spring and summer (April-July) seasons compared with autumn and winter seasons.

In activity-travel behaviour research, some studies analysed the

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impacts of seasons on individual's travel pattern by using weekly data. For example, Kitamura and van der Hoorn (1987) have found that there was no seasonal variations effect on individuals' activity-participations in the Netherlands, but individuals maintained the same weekly activity participation in March and September. Bhat and Gossen (2004) analysed weekend activity participation behaviour which focused only on recreational activity episodes by using the San Francisco Bay Area Travel Survey (BATS) dataset collected in the year 2000. They found that less participation in out-of-home recreational activity participations during weekends in February and March, and also less in pure recreational activity participations in March and October compared to other months of the year. By using the same dataset, Bhat and Srinivasan (2005) examined the frequency of participation of individuals in out-of-home non-work and non-school episodes over the weekend. They found that in winter season, individuals tend to participate less in recreational and maintenance shopping during weekends. Meanwhile in autumn and spring, individuals, especially adults, tend to do pick-up/drop-off activities. At the aggregated level, Tang and Takhuriah (2012) analysed the impact of seasonality on human activity-travel behaviour in Chicago through the use of public transportation, in which they found that bus ridership was higher in autumn (September-November) and spring (March-May), and lower during summer and winter months (except for February).

The above literature has indicated that seasonal variations play an important role in human mobility on space. Järv et al. (2014) argued that seasonality does not only affect tourism-related activities, but also repetitious activities in our daily lives. However, most of the above studies, if not all, did not take into account the seasonal effects on both mandatory (e.g. work and school) and non-mandatory (e.g. routine and leisure) activity-travel patterns simultaneously. Based on the space-time constraints (Hägerstrand, 1970), the mandatory activities will shape the participation in non-mandatory activities. Moreover, Susilo and Axhausen (2014) argued that routine obligations, different needs and desires on different days, commitments between household members and changes in the travel environment transform individuals' daily activity-travel patterns into a dynamic process with learning and changing on the one hand, and rhythms and routines on the other.

Thus, in order to better understand the effects of seasonal variations on individuals' travel behaviour, both mandatory and non-mandatory activities should be considered and analysed simultaneously. This can only be realised by using multi-day multi-period data at an individual level which provide a wealth of information on short- and/or long-term dynamics in travellers' behaviour that would not be available in conventional single-day or single-period cross-sectional surveys that are dominating in travel behaviour research (Pendyala and Pas, 2000). This conventional approach has been criticized for neglecting the mid- and long-term effects on variability in individuals' activity-travel patterns (Pas and Koppelman, 1987; Kitamura et al., 2006). Therefore, to fill in the research gaps, this study aims to investigate the seasonal variation by incorporating the interactions between activity demands, the number of trips derived from the demand for activities, travel time generated from the trip and activity demand and also mode share which generates the travel time across different seasons at individual level. Individuals' socio-demographic characteristics, land use and built environment characteristics and also weather characteristics were treated as external or exogenous factors. Mandatory activities refer to the daily out-of-home work and school or study activities. Meanwhile, non-mandatory activities consist of routine and leisure activities in which routine activities refer the daily out-of-home maintenance activities such as pick-up/drop-of children, shopping groceries, health care, visiting close family such as parents and siblings, religious (e.g. visiting church) and walking the dog. Leisure activities refer to the discretionary activities such as visiting friends/distant relatives, sports and eating out.

A total of eight-week travel diary (with two-week travel diary collected in each wave for four different seasons in the given year) of 67 individuals in Stockholm, Sweden was used in this study. Although the sample size used in this study was low, the eight-week (56 days) travel diary collected for each individual may provide rich information about how people travel on space and time. The output of this paper will provide a more comprehensive understanding on how individuals adapt and arrange their activity-travel participations across different seasons. This knowledge will help transport planners to design transport policies that are suitable for different socio-demographic groups in different season conditions.

The remainder of the paper is organized as follows. Section 2 explains the panel data used, Section 3 describes the model formulation and specifications, Section 4 discusses estimation results from the models and Section 5 contains the conclusion and suggestions for future research.

2. Travel diary survey and data

A longitudinal panel data of 67 individuals who live in sub-urban areas of Stockholm, namely Solna and Sundbyberg municipalities, was collected in four consecutive waves of a seven-month period that covers all four different seasons (autumn to summer). A two-week travel diary collected in each wave or season, which means that a total of eight weeks (56 days) of individuals travel diaries were collected within the study period. Chikaraishi et al. (2013) argued that it is hard to obtain an optimal travel survey design for multi-day and multi-period panels because of relatively little data on changes in travel behaviour to date. However, based on the existing literature, it is preferable to have more than two waves of data with the first wave being treated as a base condition (Kitamura, 1990; Bradley, 1997; Schönfelder and Axhausen, 2001). Furthermore, many evidences have supported the notion that there is considerable day-to-day variability in travel behaviour (e.g. Hanson and Huff, 1986; Huff and Hanson, 1986; Pas, 1987, 1988). It is preferable to have at least two weeks of observations in each wave (Schlich and Axhausen, 2003) in order to capture the day-to-day variability and even the similarity in travel behaviour including the repeated behaviour (e.g. routines). For example, Kitamura and van der Hoorn (1987) found that shopping participation of 70% male and 59% female workers in the Dutch panel dataset had identical daily patterns on five or more days of each two weeks (six months interval). Meanwhile, it is difficult to say the best interval between waves in transportation research. Chikaraishi et al. (2013) concluded that the behaviour of interest variations and changes might be more important for the survey design so that the statistical power can be maximized. Note that this study aims to analyse the impacts of seasonal variations on individual activity-travel patterns, thus the data should be collected in all different seasons. Therefore the first wave was collected during autumn season in between 14th to 27th October 2013 and the second wave was collected in winter season in between 2nd to 15th December 2013. The third and the fourth or final waves were collected during spring (17th to 30th March 2014) and summer (26th May to 8th June 2014) seasons respectively. It is acknowledged that cautions should be made in deriving the conclusion from this study because the analysis was done on only on one observation per season. However, it is assumed that 14 days of observation per season may be enough to capture the effects of seasonal variations on individuals' activity-travel patterns as discussed above. Moreover, based on the preliminary analysis done by [omitted for review] on the same panel dataset, the travel characteristics in this panel data are similar to the Swedish National Transport Survey (NTS) dataset for Solna and Sundbyberg municipalities in the year 2011, with the exceptions for travel distance, trip purpose and user type (e.g. public transport user, private vehicle user, slow-mode user, mixed user). The authors speculated that the differences between the data in this study and the NTS dataset may contributed by the difference in survey approach used in this panel survey (e.g. pen and pencil approach) and in the NTS survey (telephone interview approach). Table 1 shows the socio-demographic profile of the