Journal of Choice Modelling 28 (2018) 56–70

Contents lists available at ScienceDirect

Journal of Choice Modelling

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

Understanding activity engagement across weekdays and weekend days: A multivariate multiple discrete-continuous modeling approach

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ARTICLE INFO

Keywords:
Activity-travel demand
Modeling weekly activity schedules
Time allocation
Multiple discrete-continuous probit model
Weekday and weekend travel

ABSTRACT

This paper is motivated by the increasing recognition that modeling activity-travel demand for a single day of the week, as is done in virtually all travel forecasting models, may be inadequate in capturing underlying processes that govern activity-travel scheduling behavior. The considerable variability in daily travel suggests that there are important complementary relationships and competing tradeoffs involved in scheduling and allocating time to various activities across days of the week. Both limited survey data availability and methodological challenges in modeling week-long activity-travel schedules have precluded the development of multi-day activity-travel demand models. With passive and technology-based data collection methods increasingly in vogue, the collection of multi-day travel data may become increasingly commonplace in the years ahead. This paper addresses the methodological challenge associated with modeling multi-day activity-travel demand by formulating a multivariate multiple discrete-continuous probit (MDCP) model system. The comprehensive framework ties together two MDCP model components, one corresponding to weekday time allocation and the other to weekend activity-time allocation. By tying the two MDCP components together, the model system also captures relationships in activity-time allocation between weekdays on the one hand and weekend days on the other. Model estimation on a week-long travel diary data set from the United Kingdom shows that there are significant inter-relationships between weekdays and weekend days in activity-travel scheduling behavior. The model system presented in this paper may serve as a higher-level multi-day activity scheduler in conjunction with existing daily activity-based travel models.

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https://doi.org/10.1016/j.jocm.2018.05.004
Received 8 September 2017; Received in revised form 11 May 2018; Accepted 13 May 2018

1. Introduction

Activity-travel demand model systems in use around the world simulate or predict activity-travel patterns and choices for a single day, typically a "representative" weekday (e.g., Bradley et al., 2010; Yagi and Mohammadian, 2010), although the notion of what constitutes a "representative" weekday may be debated. One-day travel diary data is typically used to estimate and calibrate model systems (Frazis and Stewart, 2012). More recently, there has been a growing interest in understanding broader, longer-term time use and activity patterns that span multiple days or weeks (see Jara-Díaz and Rosales-Salas, 2015). Activity and time use patterns not only vary among persons, but they also vary within persons between different days (Pas and Sundar, 1995; Zhou and Golledge, 2003), with estimates of within-person variability as high as 60 percent of the total variability in travel. A number of studies have made a case for why one-day data is insufficient to model activity travel patterns, and why variability analysis that examines activity time allocation and travel over a multi-day period is more appropriate to explain and forecast travel demand (Bhat and Koppelman, 1993; Liu et al., 2015; Jara-Díaz and Rosales-Salas, 2015). The use of one-day data to understand and model activity-travel patterns implicitly assumes that each day is independent of the other, and that people's activity-travel scheduling process is generally based on a one-day horizon. However, it is not possible to fully capture weekly cycles in activity-travel engagement by looking at single day activity-travel data. For example, a worker may focus on pursuing work activities during the weekdays and leave shopping/leisure pursuits for the weekend days.

From a system performance standpoint, the variation in individual activity-travel rhythms between weekdays and weekend days manifests itself in network traffic congestion patterns which, in turn, affect activity-travel rhythms in a cyclical fashion. For example, peak traffic congestion on weekdays often corresponds to morning and evening commute periods, while peak traffic on weekend days corresponds to the mid-day periods (Agarwal, 2004; Bhat and Gossen, 2004). Consistent with these variations across days of the week, weekend and weekday public transport options and services often differ. This further deepens the distinction between the weekday and weekend travel options, modal accessibility, and constraints. The differences in activity-travel patterns between different days of the week (especially weekdays and weekend days), coupled with rhythms of behavior depicting a multi-day periodicity, implies an inter-dependency in activity-travel patterns across days of the week that is likely engendered by activity-travel scheduling horizons that exceed a 24 h period. The possible existence of a longer planning horizon for personal and household activity schedules has been recognized in the literature (Doherty, 2005), leading to notable data collection activities aimed at gathering information about people's activity-travel schedules over a period of a week or longer (Muthyalagari et al., 2001; Axhausen et al., 2002).

One of the challenges associated with developing and deploying multi-day activity-travel models is that there is very limited data on multi-day activity-travel behavior. While there are small scale data sets (Zhou and Golledge, 2003) that include information on activity-travel schedules over multiple days, the vast majority of regular household travel surveys (upon which activity-travel models are estimated) are limited to one-day activity-travel diary data. In an era of limited attention spans and declining survey participation and response rates, it has proven to be an immense challenge to collect information for multiple days due to respondent burden and reluctance (Singer and Presser, 2008). Even with new travel survey data collection methods that employ smart phones, GPS technologies, or passive tracking mechanisms, the collection of large sample data for multiple travel days remains a challenge due to cost considerations, technology limitations, or privacy concerns (National Research Council, 2007; Nitsche et al., 2014).

Even if the data collection challenges can be overcome, methodological challenges remain. In the activity-travel literature, a few studies have examined time use patterns over the course of an entire week to reflect longer term needs and rhythms (e.g., Lee and McNally, 2003). However, these studies do not explicitly capture weekday-weekend interactions in their modeling framework. The complementary relationships and competing trade-offs in activity scheduling and time use across days of the week are poorly understood, and methods to effectively model activity-travel scheduling processes over multiple days have proven to be elusive. This paper aims to address this gap by presenting a holistic and comprehensive model capable of modeling activity scheduling and time allocation behavior across days of the week, explicitly accounting for inherent complementary relationships and competing trade-offs. The model takes the form of a multivariate multiple-discrete continuous probit (MDCP) model system, in which two distinct MDCP components – corresponding to weekday and weekend activity-time allocation respectively – are stitched together in a multivariate framework. By tying the two MDCP components together in a joint modeling framework, the model is able to explicitly account for relationships in activity engagement between weekdays on the one hand and weekend days on the other. The model system presents a methodological basis for modeling week-long activity-travel schedules at a macro-level, but does not operate at a day-level to explicitly model activity-time allocation for each day of the week (this remains a future effort). Rather, the model in this paper is capable of depicting how the entire time budget encompassing all weekdays may be allocated for various activity pursuits; and similarly for the entire weekend time budget. The model system is estimated and its efficacy demonstrated through an application to a week-long travel diary data set collected in the United Kingdom in 2015. The data set is a typical large sample travel survey data set and ideally suited to study and model multi-day activity-travel engagement and time allocation behavior.

The remainder of this paper is organized as follows. The next section presents a brief discussion of considerations in modeling activity-travel behavior over a week-long time horizon. The third section presents an overview of the data and survey sample, the fourth section presents the modeling methodology, and fifth section offers details of the model estimation results. The sixth section compares and contrasts the prediction results of the joint model system with that of independent model systems (in which relationships in activity engagement between weekdays and weekend days are note accounted for). Discussion and concluding thoughts are offered in the seventh and final section.