The Journal of Choice Modelling 24 (2017) 51–62

Contents lists available at ScienceDirect

The Journal of Choice Modelling

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

A model of two-destination choice in trip chains with GPS data

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ARTICLE INFO

Article history:
Received 3 September 2015
Received in revised form
4 April 2016
Accepted 9 April 2016
Available online 26 April 2016

Keywords:
GPS data
Trip chaining
Axis of travel
Destination choice

ABSTRACT

Studying trip chaining behavior has been a challenging endeavor which requires the support of microscopic travel data. New insights into trip chaining can be gained from real-time GPS travel data. This research introduces a framework that considers two-destination choice in the context of home-based trip chains. We propose and empirically compare three alternatives of building choice sets where we consider various relationships of the two destinations (such as major–minor destinations, selecting one first, and selecting two concurrently). Our choice set formation alternatives use survival models to determine the selection probability of a destination. Our results reveal that trip chaining behavior is shaped by the features of retail clusters, spatial patterns of clusters, transportation networks, and the axis of travel. This research reveals that not only the spatial relationship but also the land use relationship of the destinations in a trip chain affect the decision making process.

1. Introduction

Based on the 2009 National Household Travel Survey, non-work trips account for approximately 90% of total trips in the US. The forces that shape non-work trip distribution are multifaceted and complex. Land use, transportation networks, geography, socio-economic factors, time constraints, and travel contexts all impact non-work destination choice. Compared with work destination choice, travelers tend to have greater flexibility in non-work destination choice, which renders the intricacies of decision making difficult to be sufficiently understood. Traditional paper-and-pencil surveys and interviews, while useful in capturing some of the shaping factors, cannot paint a full picture of urban life. Research on non-work destination choice needs to be pumped by travel data of fine granularity to answer more complex questions such as trip chaining. This research proposes a new framework which explicitly considers trip chaining behavior in non-work destination choice. This approach is data-driven. Given the real-time trip origin and destination information, we adopt mixed-effects logit models to model home-based trip chains with two destinations. We test several hypotheses on the relationship of the destinations in trip chains and investigate various forces that shape destination choice.

Our work is made possible by the collection of in-vehicle GPS travel data which recorded 141 participants' vehicle trips including origins, parking destinations, and travel routes during a study period of five months. To understand non-work destination choice behavior, we introduce a model for home-based trip chains with two destinations. The underlying hypothesis is that destination choice is not only influenced by the features of destinations but also by the connections between the destinations. We take a quantitative approach to evaluating this hypothesis. Our model considers both the spatial and

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http://dx.doi.org/10.1016/j.jocm.2016.04.002
1755-5345/

land use relationship of the destinations in trip chains. In building choice sets, we propose three context-sensitive alternatives and compare the goodness of fit of different results.

Our work provides three major contributions. First, we propose a framework that explicitly considers two destinations in non-work trip chains. Second, we introduce three alternatives of building choice sets for multi-destination trip chains. Our approach reflects the relationship of chained destinations based on multi-day GPS travel data. Third, we examine several hypotheses on the spatial and land use relationships of destinations in trip chains.

The rest of this paper is organized as follows: Section 2 describes the background and related literature. The data used in this research are introduced in refdata. Section 4 introduces the framework of the model. Section 5 overviews the key independent variables, following which is the choice set formation mechanism. Section 7 determines choice set size used in the models. Section 8 discusses the modeling results and Section 9 summarizes the key findings and concludes this paper.

2. Background and related work

The in-vehicle GPS data were collected in the Minneapolis-St. Paul Metropolitan Area from September to December of 2008 with 141 participants. The advantage of this data set is that in-vehicles GPS devices recorded geo-coded origins, parking destinations, and vehicles' other positions on travel routes. Further, as individuals' socio-demographics and home and work locations were reported, non-work destinations (parking destinations outside workplaces) were singled out for modeling. Note that specific buildings/stores one visited were unknown and detailed trip purposes for all trips were not totally amassed. The corresponding strategy is to measure cumulative walking opportunities (total number of existing services) around parking destinations. Consistent with Huang and Levinson (2015), this paper uses 15-min walking areas around destinations to measure walking accessibility and the diversity of services. Such land use features are measured using the business data set which records the number of establishments categorized by the North American Industry Classification System (NAICS) code at each Census block.

Our research on non-work destination choice is grounded in earlier works in discrete choice modeling. Exemplary models that have been used in modeling shopping destination choice include: Multi-nomial logit (MNL) (Timmermans, 1996; Pellegrini et al., 1997; Wang and Lo, 2007; Auld and Mohammadian, 2011), hazard model (Leszczyc et al., 2000), nested logit model (Newman and Bernardin, 2010), and decision tree model (De Palma et al., 2010). Such studies often use traffic analysis zones or major shopping malls as destinations. In deciding choice sets, there are two general approaches: (1) A consumer considers all possible alternatives in a region. (2) Individuals initially evaluate clusters of alternatives and then evaluate alternatives in a cluster (Fotheringham, 1988). As microscopic travel data become increasingly available, there have been a number of studies that investigated destination choice in the context of trip chains (Kitamura, 1984; Joh et al., 2002) and household travel activity patterns (Kwan, 2000; Srinivasan and Bhat, 2005; Charypar and Nagel, 2005; Ferdous et al., 2010). Nevertheless, not much such research is based on real-time GPS data. Given that the multi-day GPS travel data has become more and more available, there is a need for investigating chained destination choice using a data-driven approach. Huang and Levinson (2015) proposed a mixed-effects logit model to understand single-destination choice for non-work trips using the in-vehicle GPS travel data. Chen and Kwan (2012) proposed theoretical models to identify choice sets with multiple flexible activities under space–time constraints based on the concept of trip chaining. The activity-based travel demand model ACSIM considered purpose, time, and space to predict primary destination zones and parcels (Bradley et al., 2010). The CT-RAMP activity-based model further included individuals' occupation, work/school locations, and daily activity pattern in modeling destination choice (Vovsha et al., 2011). This research expands this effort by modeling two-destination choice in non-work trip chains validated by in-vehicle GPS data.

3. Data sets

The in-vehicle GPS data were collected in Minneapolis-St. Paul Metropolitan Area in 2008. The in-vehicle GPS data collection process lasted from September to December of 2008, during which 141 surveyed subjects made over 20,000 vehicular trips. The Minneapolis-St.Paul Metropolitan Planning road network is used to create vehicular trajectories based on the GIS points (the GPS frequency was one point per 25 meters). Detailed information about the in-vehicle GPS data can be found at Huang and Levinson (2015). To measure the land use characteristics of destinations, we use the business data categorized by the North American Industry Classification System (NAICS) code at the Census block level. The business data set was collected and published by the Minnesota Department of Employment and Economic Development in 2010. Out of 54,378 blocks from Census 2010 in the Minneapolis-St. Paul Metropolitan Area, there are 16,851 blocks with at least one service establishment.

4. Model formulation

The trip chains of interest are home-based, two-destination chains (i.e., home → destination 1 → destination 2 → home). Here we exclude trip chains involving work destinations where non-work destination choice is more likely to be influenced