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The location selection problem for the household activity pattern problem

Jee Eun Kang, Will Recker *

Department of Civil and Environmental Engineering, Institute of Transportation Studies, University of California, Irvine, Irvine, CA 92697, USA

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ABSTRACT

In this paper, an integrated destination choice model based on routing and scheduling considerations of daily activities is proposed. Extending the Household Activity Pattern Problem (HAPP), the Location Selection Problem (LSP–HAPP) demonstrates how location choice is made as a simultaneous decision from interactions both with activities having predetermined locations and those with many candidate locations. A dynamic programming algorithm, developed for PDPTW, is adapted to handle a potentially sizable number of candidate locations. It is shown to be efficient for HAPP and LSP–HAPP applications. The algorithm is extended to keep arrival times as functions for mathematical programming formulations of activity-based travel models that often have time variables in the objective.

1. Introduction

Individual- or household-level destination choice is not an output of optimizing a single objective but rather is a complex decision-making process involving a multitude of issues related to such aspects as type of activity, personal preference, accessibility, time-of-day, trip chaining, and mode choice. For this reason, destination choice modeling has been studied within the context of associations with those influencing factors. Although there are other approaches to model destination choice (Gärling and Axhausen, 2003; Louviere and Timmermans, 1990), most of the work in this area has modeled destination choice using discrete choice analysis based on random utility theory.

Many trip-based single destination choice studies have focused on the influences of type of activity. A few of the papers in this category are Bhat et al. (1998) – work and shopping, Fotheringham (1988), Recker and Kostyniuk (1978) – grocery shopping, and Pozsgay and Bhat (2001) – recreational trip destination. In more fundamental approaches relative to how travel decisions are made, discrete choice models of destination choice have been integrated into tour-based approaches, involving such considerations as proximity to other activity locations, travel time and duration. Such considerations are particularly important in analyzing destination choice associated with non-primary activities that people tend to include in tours with other activities. Kitamura (1984) included a zone attraction component within trip chaining behavior that included considerations of locations of home and other activities within trip chains, but his approach was limited in that trip chaining sequence, time-of-day, and selection of activities in a tour are static. Bowman and Ben-Akiva (2000) proposed integrated activity-based demand modeling including destination choice as well as types of pattern, travel mode, time-of-day, etc.

* Corresponding author. Tel.: +1 949 824 5642; fax: +1 949 824 8385.
E-mail address: wwrecker@uci.edu (W. Recker).

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Here, we propose an integrated approach similar to Bowman and Ben-Akiva (2000), based on a scheduling and routing framework for daily activities that includes a capability of modeling the selection of activity locations, time-of-day, pattern types, and choice of personal travel modes (e.g., automobile, bicycle, walk).[1] In the formulation, destination choices for certain activities (i.e., those without fixed locations) are viewed not as a primary choice that travelers make, but rather as an auxiliary choice made within their daily schedule and routing. The scheduling and routing model we propose is based on the Household Activity Pattern Problem (HAPP) (Recker, 1995). HAPP is an interpretation of personal- or household-level daily activity scheduling based on an extension of the pickup and delivery problem with time windows (PDPTW). Distinct from the majority of activity-based travel demand modeling that has been based on either econometric or simulation approaches, HAPP is a network-based mathematical programming approach that can offer explanations to a variety of transportation behaviors not directly amenable to either econometric or simulation approaches (Chow and Recker, 2011; Recker et al., 2008; Gan and Recker, 2008; Recker, 2001; Recker et al., 2001; Recker and Parimi, 1999; Recker, 1995).

There are a number of potential practical advantages that the properties mathematical programming models, compared to discrete choice analysis, offer in application to activity-based travel demand. Principal among these is that such temporal constraints as the open hours of a particular shopping destination, or such spatial–temporal constraints as the space–time prism associated with an activity at particular location is insufficient to permit performance of a subsequent activity, that may be placed on travel/activity decisions can be incorporated explicitly, rather than be implied in the predefined specification of the set of discrete alternatives. For example, in the nested logit model example from Bowman and Ben-Akiva (2000), each decision nest needs pre-defined alternative choice sets, leading to 54 possible outcomes (discrete alternatives). Although infeasible decisions need to be addressed via constraints (which implicitly may nonetheless be enumerated as part of the solution algorithm), it is not required to pre-define all sets of actions—such as types of activity patterns, time-of-day, destination choice, and composition of activities in each tour—that are possible. Another (obvious) advantage of mathematical programming models is their ability to handle decisions involving both continuous (time) as well as discrete (location) variables. Additionally, because discrete choice model estimation allows for only a relatively small number of alternatives, with the alternative destination set universal for all individuals (although specific individuals typically may not include all alternatives in their respective choice sets), specification must be defined either to meet pre-specified requirements, or be randomly sampled. This aspect makes discrete choice analysis in application to destination choice particularly limiting in its ability to represent individual choices. For more discussion and literature review on choice-set generation sub-problem of destination choice modeling based on discrete choice analysis, refer to Thill (1992).

Of course, there are also significant disadvantages associated with the current state of mathematical programming approaches to activity-based travel/activity modeling, many of which are enumerated by Recker (2001) who showed that conventional discrete transportation choice models (e.g., destination, route, mode) can be represented as a special case of the HAPP family of mathematical programming models. In essence, both approaches are based on utility maximization principles applied at the individual (or disaggregate level), the principal differences being that the discrete choice case involves an *unconstrained* optimization of *discrete* choices based on specification of utility in terms of continuous and/or discrete variables with a *specified* error structure, while the mathematical programming case involves a *constrained* optimization of both *continuous and discrete* variables based on specification of utility in terms of continuous and/or discrete variables with *no* assumed error structure. The specification of the error structure in discrete choice models is conducive to estimation by standard maximum likelihood techniques, while the lack of such has presented a challenge to moving mathematical programming approaches toward being descriptive (and, ultimately, predictive) from being merely proscriptive; recent advances based on inverse optimization techniques (Chow and Recker, 2011) and genetic algorithms (Recker et al., 2008) have made progress toward estimation. And, as a constrained generalization of the discrete choice case, the mathematical programming modeling approach actually generally greatly increases the dimension of the choice set alternatives over that of discrete modeling approaches, but shifts the burden of the increased dimensionality to the solution algorithm rather than to the specification of the model choice alternatives; this can present a serious obstacle since mathematical programming models such as HAPP are known to be *np-hard*. Despite these disadvantages, the advantages that mathematical programming models offer in guaranteeing the internal consistency of the linkages dictated by time–space constraint considerations are deemed an avenue of research of potential benefit in modeling complex travel choices.

In this paper, we extend the basic HAPP formulation to the case involving a choice of selecting a location from many candidate locations for performance of a desired activity. As described above, a structural advantage that HAPP provides is a flexible form for incorporating new behavioral aspects while maintaining the consistency of inviolable rules governing construction of activity patterns that are ensured by the mathematical formulation of the basic HAPP model—extensions can be easily built from the basic formulation. Although the basic formulation for the Location Selection Problem (LSP) is easily obtained from the HAPP formulation by expanding the constraints that specify that only one location of each activity type is to be visited, the size and the complexity of the problem become an issue due to the various possible locations within the range of one's spatial and temporal accessibility—computational limitations have been an obstacle that makes it difficult for even the basic HAPP model to reflect realistic travel behaviors in the model. Fortunately, the PDPTW on which the model is based has been studied extensively, and numerous algorithms to handle large-scale problems have been offered. Here, we adopt

[1] Choice of such service-provider modes as public transit that have specific routes and schedules are not included in the proposed model, since the complications introduced by their discrete temporal availability and multiple routes greatly complicate the formulation.