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A generalized parallel constrained choice model for intra-household escort decision of high school students

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ABSTRACT

This paper presents an expanded and generalized formulation of discrete group decision-making model. The empirical model is developed for modelling high school student escort and travel mode choices. The development of the model uncovered issues with an existing group decision model, the multi-linear logit, that has recently been applied to similar decision contexts. The paper proposes an expanded formulation of parallel constrained choices logit model as an alternative to the multi-linear logit. The proposed model explicitly considers both the choice of mode of the students and commuting adults within the household and how those decisions change in response to household escort decisions. This structure is powerful as it allows both individual and group level decisions to be jointly modelled. The application of the model in this paper is generalized such that any number of adults can be accommodated within the modelling structure whereas previous studies have been limited to either two adults or two workers. The key findings of the analysis include a certain degree of altruism (or dedication) from adults to household children. This altruism which is captured indirectly within the modelling framework based on a lower utility weight for the adults in the household relative to the utility weight for household children.

1. Introduction

Within activity-based models of travel demand, there is often an underlying assumption regarding the structure of how an individual's daily schedule is developed. Specifically, an individual's work activity is viewed as the most important and all other activities are shaped by this activity (Bowman and Ben-Akiva, 2001). While there is merit to this concept and in many cases, it could be argued to be true, there are other considerations throughout the course of a day that may play an equal, if not greater, role in constraining the scheduling process. There is convincing evidence that interactions between household members play a pivotal role in shaping an individual's daily choices, which in turn create an individual's travel pattern (Golob and McNally, 1997; Gupta and Vovsha, 2013; Bhat and Pendyala, 2005; Zhang et al., 2009; Timmermans and Zhang, 2009). Moreover, Ho and Mulley (2015a,b) and Akbari and Habib (2015) suggest that decisions in both the short and long term that are conventionally viewed as being made by a household unit are instead composite decisions involving multiple household members making tradeoffs in response to achieving a reasonable household level utility. Ignoring these trends could lead to irrational and biased results which could then seriously compromise the validity of any forecasts based on the

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model results. As such, incorporating these issues into models of travel demand is of utmost importance within the field of transportation planning and demand forecasting as to avoid misspecified model forecasts (Gliebe and Koppelman, 2005).

To address potential household interactions, travel demand modellers have used two main techniques. First an implicit/endogenous approach, whereby household characteristics enter the utility function of an individual making their own independent decision. A common example of this is the inclusion of the number of household vehicles into the utility for automobile mode choice. While not explicitly capturing the allocation of the vehicle to an individual, individuals living in households with fewer vehicles will implicitly be less likely to be allocated the vehicle given that they may have to bargain for access to a vehicle with other household members. Alternatively, these bargaining trends and tradeoffs can be captured explicitly within the model formulation or structure. Such explicit models represent a broad array of research over the last 20 years. Of these approaches, models which explicitly consider group decision-making dynamics are particularly appealing as they allow for the consideration of trade-offs between individuals for a set of discrete choices. That said, there exists little to no consensus within the field of transportation or other fields regarding the appropriate approach to take to capture household interactions. Therefore, it is prudent to empirically investigate each relevant approach for a given empirical context or utilize a latent class approach (as done in Zhang et al., 2009).

Random utility maximization based discrete choice theory of decision making is particularly useful as it provides a theoretically robust way of evaluating empirical models. However, not all group decision-making models are appropriate in the context of random utility maximizing discrete choice models. The multi-linear logit (MLL) model as presented by Junyi Zhang and colleagues has some significant issues with respect to their applicability for discrete choice modelling (Zhang et al., 2009). These issues will be formally presented below and call into question the work done with the multi-linear model within a discrete choice context. These issues were encountered when attempting to extend the existing work of Ermagun and Levinson (2016), who examined escort and mode choice decisions for school aged children using an MLL structure. Given these considerations, this paper has two main objectives:

1. Capture decisions regarding the mode choice for high school students and commuting adults living in the same household. We will also consider the issue of the choice of escort decision (does and adult drive the student to school and if so, which adult) within the model structure. This is particularly relevant as most existing literature has limited their analysis to two parent households (with a few notable exceptions outlined below).
2. Identify the limitations of the work of Zhang et al. (2009) and Ermagun and Levinson (2016) and present an alternative which is consistent with random utility-maximizing theory.

Looking forward, the remainder of the paper will be organized in the following five sections. First, a literature review focusing on behavioural models of household decision making (with a small discussion of school escort decisions). Second, a formal presentation of the multi-linear utility structure, its limitations and then a presentation of the alternative theoretically consistent approach, the parallel constrained logit model. Fourth, an overview of the study area and dataset used for the analysis. Fifth, the presentation of the three modelling structures and a discussion on the implications of these result. Finally, a concluding section overviewing the contributions of this work and potential avenues for future research.

2. Literature review

Within the field of travel demand modelling there exist numerous forms of possible intra-household interactions. Vovsha et al. (2005) distinguished between three principal levels of intra-household interactions for integrated models of travel demand: coordinated principal daily pattern types, episodic joint activity and travel, and allocation of maintenance activities, in the context of regional travel demand models. More generally within travel demand as a broad field Zhang et al. (2005) identify joint activity participation (with potential coordination of arrival times), joint travel, household resource allocation, task and time distribution and role specification. That said, capturing intra-household interactions is still a relatively recent concept in travel demand modelling. In the last 15 years, some progress has been made, with two special issue journals (Bhat and Pendyala, 2005; Timmermans and Zhang, 2009) as well as two sets of comprehensive reviews of recent intra-household interaction models within the transportation literature (Ho and Mulley, 2015b; De Palma et al., 2014). These reviews and special issues acknowledge the importance of increasing the understanding of these models, while further highlighting methodological and data limitations that currently exist. These limitations include limited consensus on the appropriate modelling techniques and failure to identify these interactions in either individual or even household level surveys. The issues surrounding model selection are nuanced, with the selection of the appropriate modelling technique requiring a review of existing practices and then potentially empirical investigation to determine which approach best matches the needs of the modelling exercise in question. As this paper is examining school escort decision, a review of the prevalent approaches to modelling these choices is presented below. When dealing with data concerns, techniques such as those proposed by Kang and Scott (2011) can be employed to account for poorly identified or recorded data. These techniques involve matching departure time, destination location and relevant modal pairs (driver and passenger) to identify occurrences of joint travel.

As this paper examines the school escort choice context, it is pertinent to review the literature on this subject. Gupta et al. (2014), who notes the importance of considering household mode choice jointly with the decision to escort (a point addressed in this paper). Other works tend to greatly simplify or overlook these issues. Examples of these