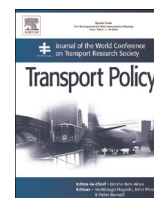




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## Intra-household Interactions in tour-based mode choice: The role of social, temporal, spatial and resource constraints



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### ABSTRACT

Under social, temporal, spatial and resource constraints, household members interact and search for ways to fulfil household and individual needs, one of which is travelling together. Understanding the motivation for joint household travel and its effect on an individual's mode choices is critical to the formulation of transport policies and planning practices for sustainable transport choices. This paper examines individuals' mode choices with joint household travel being explicitly incorporated within a nested logit model using the Sydney Household Travel Survey data and a typology of tours that captures various patterns of household interactions. The results indicate that joint travel is influenced by household resources, social and mobility constraints, activity types, and the land use patterns at both origin and destination. Also, mode choices differ significantly across joint tour patterns with public transport being less likely to be used for joint travel. Scenario analysis shows that individual tours contribute the most while complex joint tours contribute least to modal shifts from car to public transport which results from changes to transport policies and the level of services. Contrary to suggestions in the literature, a joint household (as compared to individual) travel analysis does not necessarily identify a lower modal shift for policy outcomes.

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### 1. Objectives

Everyday experience shows that the travel decisions of a household member are not necessarily independent of the travel behaviour of other members of their household. This suggests that an analysis of daily arrangements of activity and travel should take account of intra-household interactions. Whilst difficult to implement, it is important to recognise interpersonal interactions explicitly in travel demand models not only to achieve a better understanding of travel behaviour but also for more accurate travel demand forecasting. Research centred on intra-household interactions and group decisions has recently become a particularly active area of research, as seen by special issues of *Transportation* (Bhat and Pendyala, 2005) and *Transportation Research* (Timmermans and Zhang, 2009). Using an activity-based modelling framework, household interactions have extensively been modelled at three layers: interactions in the generation of household daily activity patterns (DAPs), the participation of household members in joint activities, and the allocation of maintenance activities among household members. However, much remains to be

explored and this study aims to inform specifically on household interactions in household activity arrangement and mode choice.

Understanding the motivation for joint household travel and the circumstances under which it occurs is important for developing policy and this can be illustrated by examples from the planning of public transport and the creation of high occupancy vehicle/toll (HOV/HOT) lanes. For instance, if the spatial separation between home and school is the main motivation for chauffeuring children to school, then improved school bus services may reduce traffic congestion and the environmental impacts of school travel. On the other hand, the introduction of HOT lanes or higher tolls may help in raising revenue, but not necessarily reduce congestion, if joint household travel arrangements are the result of time schedule synchronisation of household members' activities or limited household resources (Gupta and Vovsha, 2013). This is because the opportunity for travelling with other household members in order to avoid (higher) toll costs is not available to every driver of a single-occupancy-vehicle and travel demand is inelastic with respect to travel cost.

Thus, travel demand models without direct regard to intra-household interactions may mis-estimate the market response to transport policies. These include changes directly affecting travel segments that involve more than one person (i.e., joint travel such as the introduction of HOT lanes or discounted tickets for group travel) but also changes that impact all travel (such as public

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transport fares, in-vehicle travel time, parking policy and employer-based incentives). To understand and quantify how significant any difference in the market response to pricing policy, this paper contributes a parallel analysis comparing joint and individual household travel analysis. The parallel analysis results provide insight into the conditions under which a model ignoring joint household travel will over-estimate or under-estimate the market response to transport policy. More than simply addressing policy issues, the paper also has important implications for modelling practices as to whether mode choice should continue to model without taking joint travel into consideration.

This paper provides an analysis of individual's tour-based mode choice under social, temporal, spatial and resource constraints. Specifically, the study explores how intra-household interactions, household resources, social constraints, and the household's spatial setting influence the travel mode of each household member. The travel mode for each home-based tour of all household members is modelled conditioned on joint household decisions, which are identified as patterns of joint household travel, in arranging daily activities into home-based tours. The research objective of this paper is to contribute to the understanding of the role of interpersonal interactions in travel behaviour and thus to effective transport policy. Recognising the role of intra-household interactions in travel demand and quantifying the impact of these interactions is an important first step to their inclusion in travel demand models to provide a more credible analysis of travellers' response to policies and changes in land use.

The paper starts with a review of the literature on intra-household interactions focusing on modelling approaches, empirical findings, and limitations. This is followed by a description of data sources and a typology of joint household tours used in this paper. Descriptive and model estimation results are then presented, followed by the model application. The paper concludes with a summary of the main findings and a discussion of the implications for transport policy and planning practice.

## 2. Literature review

Research of interpersonal interactions can be broadly classified into four groups based on the modelling methodology and the choice variable type (Srinivasan and Bhat, 2005; Kang and Scott, 2011). The first approach involves joint estimation of multiple continuous choice variables using either Structural Equations Modelling (SEM) or Seemingly Unrelated Regression (SUR) such as described by Fujii et al. (1999) and Zhang et al. (2005). The second approach is based on discrete choice models and time shares models, such as Scott and Kanaroglou (2002) and Gliebe and Koppelman (2002). The third approach uses a discrete-continuous model system that jointly estimates both discrete and continuous aspects of the choice (e.g., Srinivasan and Bhat, 2006). The final approach is based on micro-simulation including the work of Meister et al. (2005) and Miller et al. (2005). This section provides an overview of these approaches as detailed descriptions and example applications of each technique are provided in the cited references above and elsewhere (Timmermans, 2009; Kang and Scott, 2011; Ho and Mulley, 2013a).

From the household decision-making perspective, in each of the methodologies discussed above, the intra-household interactions can be grouped into two major classes. The first class makes use of existing individual decision choice models such as Wen and Koppelman (2000), Scott and Kanaroglou (2002), Rose and Hensher (2004), Vovsha and Petersen (2005), Srinivasan and Bhat (2005; 2006), and Schwanen et al. (2007). The second class explicitly incorporates group decisions into household travel behaviour models using different types of group utility functions,

which include the work of Timmermans et al. (1992), Abraham and Hunt (1997), Gliebe and Koppelman (2002; 2005), Meister et al. (2005), Miller et al. (2005), Zhang et al. (2009), and Kato and Matsumoto (2009). The two classes share common features in terms of data requirements and their ability to incorporate and represent heterogeneous intra-household interactions. While the group-based modelling approach can identify the relative influence and hence the power of each household member in the household decision-making, the individual-based modelling approach facilitates model estimations and predictions. Both of these approaches have drawbacks discussed below. The main difference between the two modelling approaches is the incorporation of household interactions and group decision rules in the second class.

The individual-based approach, used in most practical activity-based travel demand modelling systems, classifies intra-household interactions into several components. Due to the complexity of travel behaviour with interpersonal interactions, it is inevitable that the decisions are broken down and modelled in a particular sequence. Typically, five important components of intra-household interactions are considered. These are the coordination of household members' daily activity-travel patterns (e.g., Vovsha et al., 2004; Bradley and Vovsha, 2005), serving household members with restricted mobility by providing drop-offs and pickups (e.g., Vovsha and Petersen, 2005; Davidson et al., 2011), engagement in joint household activities (e.g., Scott and Kanaroglou, 2002; Vovsha et al., 2003), sharing household maintenance responsibilities (e.g., Srinivasan and Athuru, 2005; Srinivasan and Bhat, 2005; Schwanen et al., 2007), and the allocation of household cars (e.g., Wen and Koppelman, 2000; Roorda et al., 2009). The main drawback to this approach is the lack of structural linkages between model components and the reliance upon simulation to ensure consistency between household members (Gliebe and Koppelman, 2005).

The group-based approach uses a group utility function to aggregate individual utilities into a household utility. Different group utility functions are used in the literature including multi-linear, iso-elastic, capitulation, autocracy, compromise, maximum, minimum, and Nash-type functions (Zhang et al., 2009). This approach defines alternative utilities with respect to the household as opposed to each individual, although probability expressions for each household member may be preserved (Gliebe and Koppelman, 2002; 2005). The group-based approach typically faces the challenge of representing choices of multiple-person households due to the combinatorial explosion of potential alternatives. Consequently, this approach is more applicable to one-off decisions (such as residential location, household vehicle ownership and daily time use) that have a manageable and tractable number of alternatives. When applied to repeated choices based on a discrete unit of travel, such as daily activity-travel patterns and travel mode, the choice set must be formed in such a way so one chosen alternative exists for each household member while joint household travel outcomes must be consistent among/between household members. This requires active agents to be limited to two household heads and constraints to be imposed on model specification (Gliebe and Koppelman, 2005).

Empirically, intra-household interactions appear to be a relevant factor to decision-making as reflected by the substantial proportion of regional travel which is made jointly (e.g., Vovsha et al., 2003; Kang and Scott, 2008) and the statistically significant influence of household members on household decisions in every empirical study that has identified explicitly a role for individual relative influences (e.g., Gliebe and Koppelman, 2005; Zhang et al., 2009). However, the empirical evidence to date has focused primarily on adult behaviour or a limited set of activities such as maintenance and discretionary journey purposes. In fact, most of

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