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The role of source preference and subjective probability in valuing expected travel time savings

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ABSTRACT

This paper proposes a fully subjective approach to capture the impact of travel time variability on travel decision making that accommodates subjective probabilities and source preference, the latter construct referring to respondent preferences to make judgments on matters that they have reasonable if only vague beliefs about than on matched chance events. The methods of eliciting subjective probabilities and source preference are discussed together with a suggested way forward to introduce, and hence capture parametrically, attitudes towards uncertainty. Using a 2014 survey of commuters in Sydney, we provide examples of modelling source preference and the implications for valuing expected travel time savings. The paper highlights the limitations of stated choice experiments when subjective attribute levels and their occurrence are relevant, suggesting a return to a revised focus on revealed preference data.

1. Introduction

Travel time variability, a feature of transport systems, is gaining interest as congestion and system unreliability (both on the road and in public transport) become daily occurrences and a major concern for service providers and politicians. Gaver (1968) is one of the earliest studies that investigated individuals' behavioural responses to travel time variability, including it within a framework based on utility maximisation, and found that a traveller would plan an earlier departure time when facing travel time variability, compared with the circumstance with certain travel times. This typical behaviour is explained by the notion of a "safety margin" proposed by Knight (1974). Since the early 1990s, the focus of research has been on empirically estimating the value of willingness to pay (WTP) for improved travel time reliability (see e.g., Small et al., 1999; Bates et al., 2001; Bhat and Sardesai, 2006; Hensher et al., 2011) assuming degrees of risk aversion; however the majority of the studies have assumed risk neutrality.

In recognising that travel times vary for a repeated trip activity (such as the commuting trip), Expected Utility Theory (EUT) has been drawn on as the representation of travel time variability, known as Maximum Expected Utility (MEU) (Noland and Small, 1995), which involves a choice process in which the alternative with the highest value of expected utility is preferred. Since Noland and Small's seminal paper in 1995, this has become the standard approach in travel time reliability studies (see e.g., Small et al., 1999; Bates et al., 2001; Hollander, 2006; Asensio and Matas, 2008). The research focus is to estimate the value of reliability (VOR) or variability, along with the value of travel time savings (VTTS); while some recent studies (see e.g., Hensher et al., 2011, 2013a,b) have focused on the valuation of expected travel time (probability weighted time), arguing that the distinction between VTTS and VOR is not necessary when the full travel time distribution for a given trip on repeated occasions is recognised.

The most common approach to accommodating trip time variability in the valuation of travel time reliability is a stated choice experiment. This paper highlights a potential limitation of the traditional stated choice (SC) experiment which predefines the attribute levels (including attribute occurrence probabilities) under a specific statistical design rule such as D-optimality, in contrast to behavioural relevance. We question the merits of the traditional SC experiment in circumstances where statistical precision could be a high price for behavioural relevance. This means that an individual is advised of the variations in travel time for a repeated trip (such as the regular commute) and is told of the occurrence (or likelihood) of a specified travel time occurring. In reality, it is common to recognise that individuals form beliefs and opinions about the likely travel time, and this is known as the subjective probability associated with the occurrence of the perceived level of a specific attribute.

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The challenge is to find a way to recognise and accommodate this feature of choice making in choice studies, be they linked to a stated choice experiment or some modification of the standard information sought under a revealed preference regime. There appears to be (at least) two ways to resolve this. One approach is to stay with the traditional stated choice experiment design pedagogy and to find a way of conditioning the objective probabilities associated with specific attribute outcomes so that a subjective assessment is invoked. A promising way is through an additional belief-based weighting which imposes some subjective perceptual conditioning on the role of the offered objective probability. The second approach involves abandoning some of the strict design features, that are essentially statistical and not necessarily behavioural, and adopting a method such as the one used in this paper which is a modified revealed preference approach.[2] The latter approach introduces an additional behavioural perspective to the concept of travel time variability, by embedding subjective probabilities and sources of influence on uncertainty of occurrences (referred to as source preference) into the behavioural specification.

This paper is organised as follows. The next section provides a review of existing travel time variability studies using stated choice methods, and identifies a potential limitation associated with using an objective approach to represent travel time variability. We then discuss the differences between *risk* and *uncertainty*, and introduce the concept of subjective probability for decision making under uncertainty. This is followed by a comparison of different approaches to eliciting subjective probabilities using evidence from the psychological literature. A new revealed preference data set of commuter mode choice, collected in 2014, is used to demonstrate the role of source preference and its implications for valuation of expected travel time savings. The concluding section highlights avenues for future travel time variability research.

2. Existing travel time variability research: an overview

The MEU framework is the generally accepted state-of-practice method to measuring and valuing travel time variability (see Li et al., 2010 for a review). The progression from traditional Random Utility Maximisation (RUM) to MEU not only changes the specification of a utility function that incorporates travel time reliability, it also leads to significant innovation in the way that stated choice experiments have to be designed to capture travel time variability. In recognition that travel time does vary, a series of arrival times (or travel times), rather than the extent and frequency of delay, have been considered in recent stated choice (SC) experiments (see, e.g., Small et al., 1999; Hollander, 2006; Asensio and Matas, 2008; Batley and Ibáñez, 2009; Li et al., 2010). However, in SC studies that do not incorporate a EUT probability weighting function, travel time variability is typically presented by the extent and frequency of delay relative to 'normal' travel time (see e.g., Jackson and Jucker, 1982).

In terms of a modelling framework, the mean-variance model and the scheduling model are the two dominant approaches in the transport literature. While most stated preference experiments are similar to the approach developed by Small et al. (1999) (see Fig. 1) with some slight changes (e.g., some used vertical bars to represent travel times (e.g., Batley and Ibáñez, 2009), some provided 10 travel times instead of five (see e.g., Bates et al., 2001, and some show the departure time explicitly to the respondents

PLEASE CIRCLE EITHER CHOICE A OR CHOICE B	
Average Travel Time **9 minutes** You have an equal chance of arriving at any of the following times:	Average Travel Time **9 minutes** You have an equal chance of arriving at any of the following times:
7 minutes early **4 minutes early** **1 minute early** **5 minutes late** **9 minutes late**	**3 minutes early** **3 minutes early** **2 minute early** **2 minutes early** **On time**
Your cost: **$0.25**	Your cost: **$1.50**
Choice A	**Choice B**

Fig. 1. A choice example from Small et al. (1999).

(e.g., Hollander, 2006)). The behavioural paradigm widely used in the MEU model is a mix of RUM and EUT (i.e., a linear utility specification with linear probability weighting).

In addition to RUM and MEU, a relatively small number of transportation studies have adopted alternative behavioural theories to analyse travellers' choices given the presence of travel time variability. For example, Prospect Theory (see Kahneman and Tversky, 1979 for its original version and Tversky and Kahneman, 1992 for its cumulative version) has become increasingly popular in traveller behaviour studies (see Li and Hensher, 2011 for a review of Prospect Theoretic contributions in traveller behaviour research). In addition to Prospect Theory (PT), other alternative theories have been adopted by transport researchers, such as Expected Utility Theory (see e.g., Senna, 1994; Polak et al., 2008; Li et al., 2010), Extended EUT (see Hensher et al., 2013), and Rank-Dependent Utility Theory (RDUT) (see e.g., Michea and Polak, 2006; Hensher and Li, 2012), mainly using stated choice methods.

Michea and Polak (2006) and Polak et al. (2008) used SC data collected by Bates et al. (2001) shown in Fig. 2, in which respondents were presented two train operators with different fares, timetables, and combinations of 10 equally possible arrivals (early or late) at the destination in terms of the clockface of cards for each alternative. Senna (1994) used an SC experiment, shown in Table 1, where one route has no travel time variability on five occasions, and the alternative route has different levels of mean travel times and variability, along with cost. The choice response is sought from a five-point semantic scale. Both designs are similar to the one shown in Fig. 1 by Small et al. (1999).

A series of studies by Hensher, Rose and Li used an alternative design, given available data, (see Fig. 3), which assumes a fixed level for arriving earlier or later (e.g., arriving 6 min earlier and

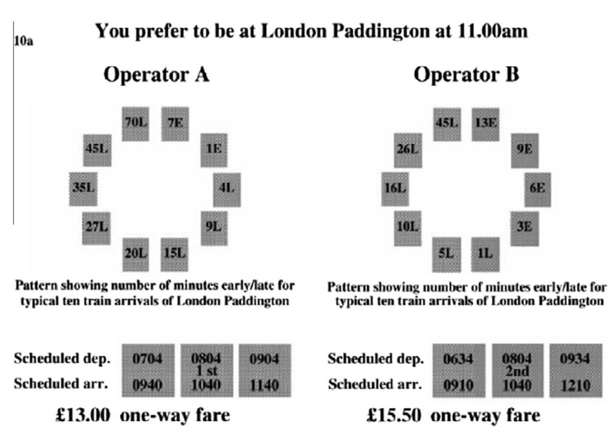

Fig. 2. A choice example from Bates et al. (2001).

[2] This may also be a way to use the idea of a reference (or status quo) alternative to define the attribute levels in a choice experiment; however the probabilities associated with the incidence of specific attribute levels such as travel time will no longer be the subjective levels, although now we have a bounding guide based on the subjective levels.