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On the cost of misperceived travel time variability

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ABSTRACT

Because individuals may misperceive travel time distributions, using the implied reduced form of the scheduling model might fall short of capturing all costs of travel time variability. We reformulate a general scheduling model employing rank-dependent utility theory and derive two special cases as econometric specifications to study these uncaptured costs. It is found that reduced-form expected cost functions still have a mean–variance form when misperception is considered, but the value of travel time variability is higher. We estimate these two models with stated-preference data and calculate the empirical cost of misperception. We find that: (i) travelers are mostly pessimistic and thus tend to choose departure times too early to achieve a minimum cost, (ii) scheduling preferences elicited using a stated-choice method can be relatively biased if probability weighting is not considered, and (iii) the extra cost of misperceiving the travel time distribution might be nontrivial when time is valued differently over the time of day and is substantial for some people.

1. Introduction

The concept of the value of travel time has been well established in the long history of economics (Becker, 1965; DeSerpa, 1971). The value accounts for a significant share of the social benefit of infrastructure investments and the social cost of traffic congestion. However, travelers are confronting increasingly unreliable travel times because pervasive congestion makes the trip duration more sensitive to non-recurrent variations (e.g., traffic incidents). This unreliability leads to additional scheduling costs and psychological anxiety for users, making travel time variability an important part of the generalized travel cost. Thus, policy makers have been gradually shifting their focus to how travel time variability should be valued and how to provide a reliable level of service in road networks.

A behaviorally consistent and pragmatic approach for analyzing the value of travel time variability (VTTV) is a central question. In a substantial body of research, the mean–variance model (Brownstone and Small, 2005; Small et al., 2005) and the scheduling model (Small, 1982; Noland and Small, 1995) are two mainstream methods. The former is the only viable option for cost–benefit analysis relevant to travel time reliability (see Kouwenhoven et al., 2014) because its results are directly associated with statistical measures of variability (e.g., the standard deviation and inter-quantile range). However, it is a black box model, where the microeconomic foundation of how travel time variability incurs a scheduling cost is hidden. In contrast, the scheduling model is micro-founded, whereby the stochastic travel time unavoidably makes a traveler arrive early or late relative to his/her preferred arrival time and thus causes disutility. Nonetheless, its formulation stands on the individual's perspective, making it unsuitable for appraisal purposes. A desirable solution combining the advantages of both approaches is to first estimate an individual's scheduling preferences and then convert these estimates to the VTTV.

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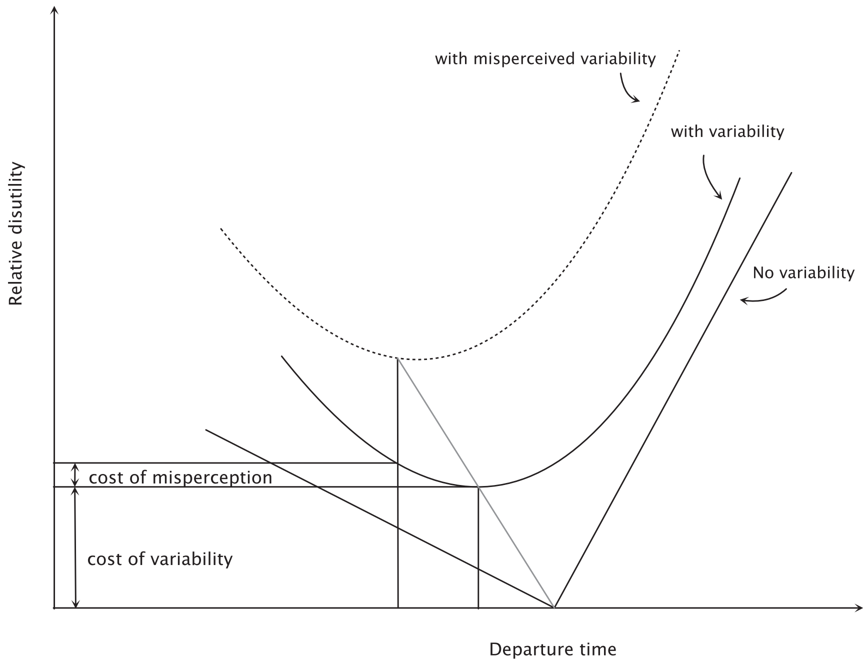

Fig. 1. Additional cost due to misperception of variability (Bates et al., 2001).

This solution requires the mean–variance model to be a reduced form of the scheduling model. Noland and Small (1995) and Bates et al. (2001) show that this condition holds when assuming (i) the travel time is exponentially or uniformly distributed, (ii) there is no change in recurrent delay, (iii) there is no discrete late-arrival penalty, and (iv) travelers maximize expected utility. Fosgerau and Karlström (2010) further generalizes this result to any distribution, so long as its standardized distribution is independent of the departure time. Studies (Fosgerau and Engelson, 2011; Engelson and Fosgerau, 2011) assume travelers derive utility from spending time at the origin and at the destination in the spirit of Vickrey (1973) with linear and exponential scheduling preferences and obtain reduced forms corresponding to variability measures that have better mathematical properties in practice. However, important discrepancies between the reduced-form scheduling model and its ad-hoc counterpart are found in some empirical studies (Börjesson et al., 2012), indicating that the former does not capture all disutility of the travel time variability.

We conjecture that the use of expected utility theory (EUT) contributes these discrepancies. In particular, the independence axiom in EUT is likely to fail when being applied to trip-timing decisions, as was the case in experiments of Allais (1953). For example, people may underweight the occurrence probability of an extremely long travel time if they believe it results from an accident and is less likely to be of concern on a daily basis. Thus, we argue that it is necessary to verify whether using EUT in a scheduling context is viable before taking advantage of its mathematical convenience. Otherwise, two types of errors are likely to occur.

The first type of error is *misspecification*. The estimation of the scheduling model relies mainly on data from stated-preference experiments, where risk is generally taken as one of the design attributes (e.g., occurrence frequency of a given travel time). If respondents do not act consistently with EUT, letting the expected value enter as a proxy for certainty equivalent is likely a misspecification (De Palma et al., 2008) and might bias the model estimates. The second type of error is *undervaluation*. Deriving a reduced-form model under EUT would ignore the cost of probability misperception; i.e., the additional cost relating to a traveler's subjectively optimized departure time cannot perfectly minimize the objective travel cost. Bates et al. (2001) mention the cost of misperception (see Fig. 1) but give no analytical result. Essentially, the cost of misperception depends on how much the perceived travel time distribution deviates from the objective distribution and the convexity of the scheduling disutility function. We refer to these two errors as type i and type ii errors, respectively. A mixed effect of these errors may exist in many relevant empirical studies conducted to date.

One generalization of EUT for accommodating the above behavioral anomalies and capturing the cost of probability misperception is using rank dependence[1]; i.e., an individual processes the objective probability to decision weight non-linearly according to his/her preference for the given outcome.[2] Koster and Verhoef (2012) formulate a rank-dependent scheduling model and show that the cost of probability weighting accounts for 0–24% of the total travel cost, using a series of values of weighting parameters. Hensher and Li (2012) estimate a rank-dependent model but implicitly assume that the marginal cost of time equals that of a scheduling delay. Wang et al. (2014) estimate weighting parameters in a scheduling context, but do

[1] Other sources of misperception are possible but are expected to be minor under well-organized experimental conditions.

[2] From a normative point of view, this approach is preferable than cumulative prospect theory because an individual's reference point is hardly measurable and is subject to change.