A revealed preference method for modelling passengers' risky choice behaviours

Guotao Hu, John W. Polak, Aruna Sivakumar

In recent years conventional models of travel choice behaviour have increasingly recognised the importance of accommodating risky choice situations, i.e., decision making among alternatives which are described by a series of probabilistic outcomes. The prevailing approach for modelling travellers' risky choice behaviour is Expected Utility Theory (EUT) which is based on the assumption of utility maximization and instrumental rationality. EUT has been incorporated into discrete choice models of travel behaviour to address travellers' risky choice behaviour, for example in the context of uncertain travel times affecting route and departure time alternatives. With the development of experimental economics and behavioural economics, the validity of EUT has been increasingly challenged; the main argument is that decision makers are not as instrumentally rational as EUT assumes. A number of non-expected utility theories (non-EUT) have been proposed that attempt to address the perceived shortcomings of EUT. However, to date little attention has been given to the empirical evaluation of these non-EUT approaches – the case for their use has been largely rhetorical rather than empirical. Despite their current popularity in some academic circles, we have very little evidence regarding whether they actually produce materially different and better results and such evidence as we have is almost exclusively based on stated rather than revealed preference (RP) data.

Against this background, this paper presents a novel RP method for modelling risky choice behaviour including EUT and non-EUT approaches. It proposes a risky choice framework that incorporates risky choice theories into a Random Utility Maximization (RUM) structure, allowing model calibration and validation. The general functional form is expressed as follows:

$$u^n = f\left(u^n_{risky}, v^n_{riskless}, \alpha, \beta\right) + \varepsilon^n$$

where u^n_{risky} and $v^n_{riskless}$ measures the utility of risky attributes and riskless attributes respectively, and α and β correspond to individual's attitude parameter and taste parameter that are to be estimated. The RUM decision rule *f(.)* and an unobserved error term ε^n convert deterministic choice into probabilistic choice formulation. A set of popular non-EUT approaches are applied to characterize u^n_{risky} , and their model specifications are also explained in details. These candidate models consist of Subjective Expected Value Theory (SEV) model, Subjective Expected Utility Theory (SEU) model, Rank Dependent Expected Value (RDEV) model, Rank Dependent Expected Utility (RDEU) model, Prospect Theory (PT) model, and Cumulative Prospect Theory (CPT) model.

Almost all the empirical evidence for non-EUT models in transport is based on stated choice data. These hypothetical data collection strategies are flexible and economical, but have significant weaknesses in terms of the external validity and generalisability of their results. To address these shortcomings, in this research we have adopted a RP data strategy. The RP dataset used in this research consists of traveller route choice data and network travel time data from the London Underground system. In particular, we model choice between a number of pairs of station for which there exist topologically simple alternative routes (see in Figure 1) and relate these route choices to the distributional characteristics of travel time on the different routes. The traveller choice data is derived from the Rolling Origin Destination Survey (RODS) and the level-of-service (travel time) data are derived from the Network Management Information System (NetMIS) dataset, which records the running time of each underground train between each pair of stations on the London Underground system. Both the RODS and NetMIS data are provided by Transport for London.

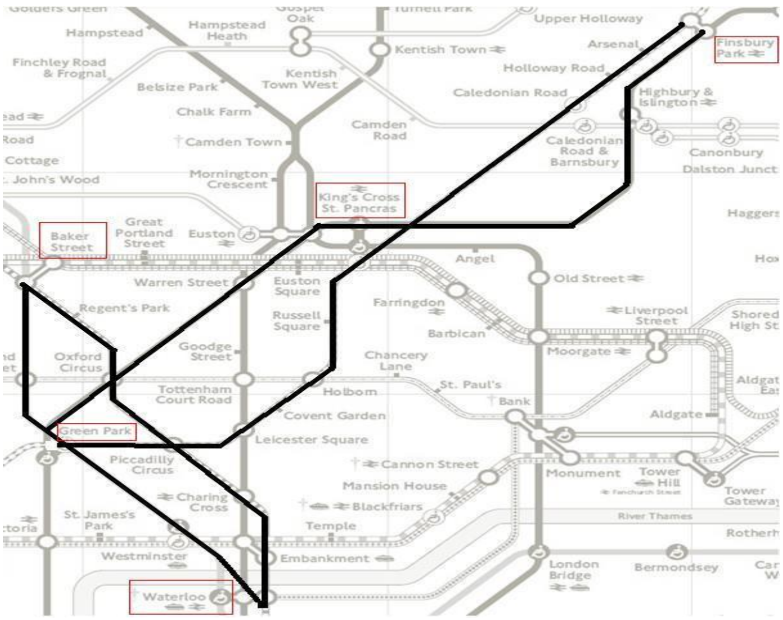

Figure 1: Illustration of choice scenarios on the LU map

Four key elements of the of non-EUT literature are investigated in this paper, namely nonlinear decision weight, rank dependence, reference dependence and diminishing sensitivity. The concept of decision weight corresponds to the nonlinear transformation of outcome probability, and it is applied to the SEV and SEU model. The central element of the RDEV and RDEU model introduced by Quiggin (1981) is the idea that individuals evaluate risky alternatives not on the basis of probabilities but rather using (nonlinear) decision weights that reflect inter alia the preference ordering of potential outcomes. The central feature of the PT and CPT model, proposed by Kahneman and Tversky (1979) is the idea of reference dependence – the idea that individuals evaluate potential alternatives in terms of the gains or losses relative to some specific reference point. Another important component of PT is diminishing sensitivity which leads to nonlinear outcome utility function. That is outcome utility turns out to be concave for gain and convex for loss, if diminishing sensitivity holds in travel behaviour. In this paper we apply these non-EUT models and compare their performance to the expected value and expected utility models.

The empirical results show that all non-EUT models lead to modest gains in model fit. The nested test of fit shows the superiority of SEV model over the other alternative model specifications. PT and CPT also show improvement of model fit over the other models except SEV and SEU according to the non-nested test result. In addition to the statistical test in estimation sample, the predictive test using aggregate and disaggregate methods also reveals that non-EUT models actually provide better predictive performances. The results from calibration and validation jointly reinforces the importance of adopting a critical and empirically driven approach to evaluating the merits of non-EUT models, especially taking into account the much greater complexity involved in the estimation and application of these models. The empirical evidence also encourages future research to account for non-EUT approaches which offer better calibration and prediction power in this paper.