Centre for Transport & Society

RESEARCH BRIEFING SHEET 019

Version: 12.08.05
Start: 01.01.05 End: 31.12.05

The Effect of Reference Point on Stochastic Network Equilibrium

Following studies of human decision-making under risk and uncertainty, extensive evidence of loss aversion and asymmetric risk-taking behaviour around a reference point was found. This work presents an investigation of the effect of the reference point value on the stochastic network equilibrium. Prospect Theory, based on empirical experiments, proposes an alternative to the traditional risk-taking modelling in travel behaviour, which might be too simplistic. The sensitivity of stochastic network equilibrium to the value of the reference point is presented here, and the potentiality of Prospect Theory is demonstrated.

This ongoing CTS research is currently being supported by modest 'seedcorn' funding from the Faculty of the Built Environment with a view to subsequently taking it forward more substantially with external funding.

Background

Many analyses of traffic-network systems are based on the assumed presence of network equilibrium. The most-widely used analytical tools based on equilibrium account for only a limited variety of cognitive processes which, in practice, underlie travellers' behaviour.

The assumptions about users' behaviour that many stochastic network models are based on are not well aligned to empirical results of behavioural sciences research. For example, such research found that people's rationality is restricted by their cognitive limitations; specifically, travellers are not necessarily utility maximizers, risk averse or rational learners. Violations of the assumptions of utility maximization have been reported in many studies. Following the works of behavioural scientists, the notion of travellers behaving rationally has been challenged by transport researchers.

Stochastic outcomes (such as variable travel times) may be framed as gains or losses relative to some reference point. Such a reference point may represent a status quo, but may be influenced by the presentation of the outcomes or expectations of the decision-maker. Kahneman and Tversky showed that changing the ways in which options are framed could generate predictable and dramatic shifts in preference. Their experiments capture a pattern of risk attitudes which differ from utility maximization: risk aversion when lotteries are framed as gains, and risk seeking when lotteries are framed as losses. Kahneman and Tversky also showed that the utility of risky lotteries is not linear in terms of outcome probabilities. Finally, they showed that losses loom much larger than gains. An asymmetry of such magnitude can not be explained by income effects or curvature in the classical utility function. Such anomalies led Kahneman and Tversky to abandon the utility maximization model in favour of what they considered to be a more behaviourally realistic alternative: Prospect Theory, and a later version of it, cumulative prospect theory.

Research Justification

Cumulative prospect theory (CPT) has already been applied fruitfully to some interesting settings in economics, such as explaining the behaviour of stocks and bonds traders, the behaviour of options traders and the low incidence of tax evasion. Recent route-choice experimental results provide evidences to violations of expected utility theory (EUT), that may be explained by prospect theory.

Despite the body of evidence of loss aversion and asymmetric risk-taking behaviour around a reference point value, the effect of reference point on the stochastic network equilibrium seemed not to have been studied before.

Within the context of travel behaviour modelling, a reference point may represent a threshold value that distinguishes between 'gain' and 'loss' of the journey, as perceived by

UWE BRISTOL Faculty of the Built Environment travellers. A better understanding of the effect of the reference point value on travel choice decision-making, and the mechanism influencing it, may contribute to determining the extent of success of transport policy schemes. For example, it may be worth investigating alternative ways to deal with the social dilemma in travel mode choice (car vs. public transport); a manipulation of the reference point (for example, by providing explicit information to the users) may lead to different choice propensities and therefore to a better social equilibrium.

Methodology

In this work, we demonstrate the possibility to develop a CPT-based user equilibrium model to simulate travellers' behaviour in a stochastic network. This model is studied and compared with the common model. Following the above works, a CPT-based traffic equilibrium is studied.

It is assumed that the traveller, faced with a stochastic network situation, behaves as if he/she is a prospect maximizer; thus, the traveller is assumed to know the *distribution* of travel times on each route, to compare prospect values of routes, and to choose the route which has a better prospect value. Wardrop's principle of user equilibrium is extended following the principles of risk-taking behaviour captured by prospect theory:

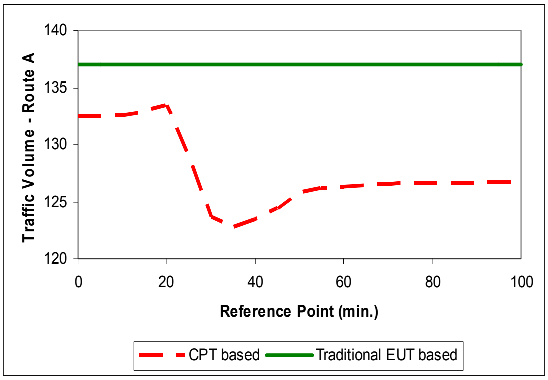
> *"Equilibrium under condition that no user can increase his/her route prospect value by unilaterally switching routes".*

In order to illustrate the CPT model, a simplified two-route choice decision problem is studied.

Outcomes and Benefits

The predictions of a CPT-based model were found to be very sensitive to the value of the reference point. The sensitivity of the CPT-equilibrium (Route's A Traffic Volumes) to the value of the reference point is presented in the following figure.

In a traditional EUT-based model, with a linear utility function and where no weighting of probabilities is assumed, the traffic volume on route A is 137. This result is unaffected by the reference point value, which has no meaning in this type of model. A different pattern results from a CPT-model; the traffic volumes resulting from assumed CPT-equilibrium are highly sensitive to reference point values between 20 and 40 minutes.



Although the concept of sensitivity to reference point value is not in conflict with the assumptions of utility maximization, the sensitivity to the value of the reference point is much increased where value and probability weighting functions are addressed, as described by prospect theory.

Regarding traffic equilibrium and travel choice, we do not propose any definite solution. We only intend to demonstrate the possibility to develop a CPT-based framework as an alternative to the maximum-utility-based approaches. Our aim is not to say which type of approach is the more convenient, nor to decide which the right one is. The nature of travellers' risk-taking behaviour is ultimately an empirical issue. In this respect, more empirical studies should be conducted in order to reach better descriptive models of travel choice behaviour.

For a full paper based on this research, please contact Dr. Erel Avineri.

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