The Journal of Choice Modelling 6 (2013) 17–33

Contents lists available at SciVerse ScienceDirect

The Journal of Choice Modelling

journal homepage: www.elsevier.com/locate/jocm

Modelling travellers' heterogeneous route choice behaviour as prospect maximizers

Giselle de Moraes Ramos*, Winnie Daamen [1], Serge Hoogendoorn [2]

Department of Transport & Planning, Faculty of Civil Engineering and Geosciences, Delft University of Technology, P.O. Box 5048, 2600 GA Delft, The Netherlands

ARTICLE INFO

Available online 28 May 2013

Keywords:
Prospect Theory
Reference point
Travel behaviour and heterogeneity

ABSTRACT

The use of Prospect Theory to model route choice has increased in the past decades. The main application issue is how to define the reference point, i.e., the value that travellers use as a reference to distinguish gains and losses in the experienced travel times. Moreover, the question can be asked whether all travellers have the same reference point or whether heterogeneity in their behaviour plays an important role.

This paper aims to (i) provide a behavioural interpretation of the reference point, (ii) investigate the role of heterogeneity in the reference point and (iii) discuss how to take heterogeneity into account. These aspects are discussed with the aid of an empirical route choice experiment and a model specification in which travel time is the main variable. Two model frameworks are proposed, one accounting for heterogeneity and another considering *no* heterogeneity in travellers' behaviour, and their outcomes are compared.

Results show improvements in the ability of Prospect Theory to predict route choice behaviour by accounting for heterogeneity in the reference point. This is particularly the case when the reference point reflects travelers' route preferences. Statistical analyses show the significance of accounting for heterogeneity in travellers' behaviour. Thus, we cannot reject the hypothesis that heterogeneity leads to improvements in the prediction ability of Prospect Theory.

1. Introduction

Travel is the result of individual choice behaviour regarding (i) whether to leave home to engage in an activity, i.e., activity choice, (ii) where to perform the activity, i.e., destination choice, (iii) how to reach the destination, i.e., mode choice, (iv) when to depart, i.e., departure time choice and (v) which route to take, i.e., route choice (Bovy et al., 2006). Altogether these travel related decisions directly affect the performance of the transportation network, especially in the scenario of increased mobility observed in most major city centres. As a result, travel characteristics such as travel times and congestion patterns are even more severely impacted leading to more travel time uncertainty, which is one of the main impacting factors on travellers' behaviour (Noland and Small, 1995; Avineri and Prashker, 2003; De Palma and Picard, 2005; Henn and Ottomanelli, 2006). A proper understanding of travellers' behaviour, therefore, is of fundamental importance to predict travellers' decisions and to forecast future traffic conditions on the network.

The literature on behavioural theories shows that travellers employ different criteria in the process of evaluating what the best choice is. The majority of existing route choice models, however, is based on the utility maximization assumption which assumes that people act rationally in order to get the maximum utility (benefit) from the decision made. In the field

* Corresponding author. Tel.: +31 15 278 49 14; fax: +31 15 278 31 79.
E-mail addresses: g.m.ramos@tudelft.nl (G. de Moraes Ramos), w.daamen@tudelft.nl (W. Daamen), s.p.hoogendoorn@tudelft.nl (S. Hoogendoorn).
[1] Tel.: +31 15 278 59 27; fax: +31 15 278 31 79.
[2] Tel.: +31 15 278 54 75; fax: +31 15 278 31 79.

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http://dx.doi.org/10.1016/j.jocm.2013.04.002

of route choice under uncertainty *Expected Utility Theory* (Von Neumann and Morgenstern, 1947), in particular, is the most widely used theory (De Palma and Picard, 2005). Situations dealing with routes' travel times definitely involve uncertainty. For instance, irrespective of the experience someone has gathered due to frequently driving a specific route, the travel times may reasonably vary depending on the traffic conditions.

Despite the widespread use of Expected Utility Theory, experiments in behavioural studies have found deviations from its axioms leading to the development of *Non-Expected Utility Theories* of which *Prospect Theory* (Kahneman and Tversky, 1979) is the most discussed (Starmer, 2000). Prospect Theory argues that choices are based on gains and losses measured against a reference point, i.e., values above it are perceived as gains and values below it as losses. What matters, therefore, is the relative gain and not the final state of wealth or welfare as argued by Expected Utility Theory.

Prospect Theory has been widely used in the field of economics, but applications in the field of transport are relatively recent (Sumalee et al., 2005; Avineri, 2006; Connors and Sumalee, 2009; Gao et al., 2010). Its application has been facing two main issues: (i) definition of meaningful reference points within the travel behaviour context and (ii) estimation of appropriate parameters for the value and weighting functions.

The lack of consensus about the meaning of the reference point in a route choice context has often surfaced in the literature. For instance, De Palma et al. (2008) suggest that the determination of reference points is one of the major obstacles for the application of Prospect Theory and that it is likely that the reference point varies depending on individuals and choice contexts. While for situations dealing with monetary outcomes, zero is the usual reference point (meaning neither gains nor losses), for situations dealing with travel times this value may vary, for instance, with respect to the decision maker, to the distances travelled, to the level of stress and to constraints regarding arrival time (Schwanen and Ettema, 2009; Senbil and Kitamura, 2004). Therefore, questions concerning the meaning of the reference point in situations involving route choice as well as its pattern over time are raised. In other words, it still has to be made clear what values travellers use as a reference to distinguish experienced travel times into gains and losses. Do all travellers have the same reference point or does heterogeneity in their behaviour play an important role? How do repetitive route choices influence the reference point over time?

As both intuition and literature suggest, attitudes towards risk vary across the population. As a result, travellers may have different perceptions on how to characterise outcomes into gains or losses and thus different reference points. In order to capture travellers' perceptions of travel time variability and how this influences their route choices over time, we propose to investigate travellers' heterogeneity in relation to their reference point. We hypothesise the following:

(i) The reference point varies among travellers *and* over time, i.e., in case travellers' route preferences change over time, such as switching to a more reliable route instead of a fast but unpredictable route, the reference point will follow travellers' new behaviour.
(ii) The reference point reflects travellers' (risk) preferences when making route choice decisions, i.e., the reference point is aligned with the travel time distribution of the preferred route.
(iii) In case pre-route information is provided, such as travel time, travellers might use that value as a reference point.

Different from what has been observed in the literature, the contributions of this paper lie on the investigation of the reference point in light of its behavioural appeal and the on the role of heterogeneity in the reference point. As a result, we try to grasp the rationale behind risky and risk-averse choices throughout the reference point and the relationship between travellers' heterogeneous preferences and the reference point. This is done by directly applying Prospect Theory in two model specifications, one accounting for heterogeneity and another considering *no* heterogeneity. Afterwards, their results are compared.

The model comparison is based on data from an empirical route choice experiment (Bogers, 2009) in which travellers were asked to make choices among three possible routes: route 1 consisting mainly of highways, route 2 consisting mainly of rural roads and route 3 consisting partly of highway and partly of urban roads. Two conditions of information provision and two travel purposes were investigated which resulted in four scenarios.

Rather than claiming a higher importance of heterogeneity in the reference point to other types of heterogeneity related to risk, we intend to demonstrate, based on empirical data, the benefits of taking the heterogeneity in the reference point into account. Despite the existence of a great variety of models, (mostly) based on the utility maximization assumption, that are able to describe route choice behaviour quite well, we propose to investigate the suitability of Prospect Theory due to its potential to better capture travellers' behaviour. Results from previous research conducted by the authors suggest the suitability of Prospect Theory to model route choice behaviour and that depending on the reference point Prospect Theory can perform better than Utility Theory (Ramos et al., 2011). This motivated further investigation into the role of heterogeneity in the reference point, which is presented here.

Another well-known factor to be observed is that provision of travel information is likely to change the level of uncertainty of travel related decisions. Modelling its impact is hardly a simple task. Additional information together with advanced technologies, such as GPS-based path-finders, are likely to contribute to reduce travel time uncertainty, to enable travellers to choose efficiently among available routes, to save travel time and to reduce congestion (European Commission, 2008). The impact of information, however, is likely to be sensitive to travellers' behavioural and cognitive response to information that is much less understood. In addition, effects such as experience and learning also seem to play an important role in the decision making process (Ben-Elia and Shiftan, 2010).