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Indifference based value of time measures for Random Regret Minimisation models

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ABSTRACT

The notion of Value of Time (VoT) is a cornerstone of discrete choice based economic appraisal in transportation. Its derivation and interpretation in the context of Random Utility Maximisation (RUM) models with linear-additive utility functions is straightforward and well known. The choice set-composition effects and semi-compensatory behaviour emphasised in the Random Regret Minimisation (RRM) model induces deviations from this basic VoT specification. This paper reviews and provides new insights into the RRM based VoT measure developed by Chorus (2012a). It defines the theoretical properties of the measure using the micro-economic notion of indifference, and provides insights into the limitations of the measure with respect to deriving individual and aggregate welfare measures. Additionally, the representative consumer approach is adopted to derive an alternative VoT measure, which is behaviourally more complete than the Chorus (2012a) measure. Although alleviating some of the restrictions, the measure has its own theoretical disadvantage. The main contribution of the paper can therefore be summarised as the generation of the necessary insights into the extent to which RRM-based VoT measures can be applied for the purpose of economic appraisal.

1. Introduction

Gonzalez (1997) discussed the theoretical background of the value of travel time savings as developed within time allocation models. In contrast to the cost saving approach, which approximates the opportunity cost of travel time using the gross wage rate, time allocation models focus on an individual's *subjective value of time*. These models take specific interest in the extent to which individuals are willing to make trade-offs between travel time and travel costs and hence implicitly assign a value to travel time savings. Gonzalez (1997, p. 245) states the following: *"The generally accepted method for estimating a subjective value of time consists in finding the marginal rate of substitution between travel time and travel cost, typically from disaggregate models of discrete choice based on the random utility theory…"*.[1]

This paper concerns the Marginal Rate of Substitution (MRS) between travel time and travel cost embodied within the Random Regret Minimisation (RRM) model. The RRM model (Chorus 2010, 2012a) represents an alternative decision rule in the discrete choice modelling literature where individuals are minimising their regret instead of maximising their utility.

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[1] Train and McFadden (1978) are generally acknowledged for establishing the connection between time allocation models and the random utility maximisation theory.

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The extent to which individuals are willing to make trade-offs between travel time and travel costs are directly influenced by the modification of the decision rule and the specification of the regret function. The MRS and the implied subjective value of time are therefore not necessarily identical between the RUM and RRM model.

The difference between the Random Utility Maximisation (RUM) and RRM model arises in the way the attributes characterising the alternative, such as travel time and travel cost, translate into a measure of utility (regret). The utility of an alternative is defined as a function of the attribute levels of the considered alternative. In contrast, the regret of an alternative is defined by comparing the attribute levels of the considered alternative with those of all the other alternatives in the choice set. Regret only arises (in a non-linear fashion) when an alternative is outperformed by another alternative on a specific attribute. In short, the RRM model focuses solely on relative rather than on absolute attribute performance and thereby introduces a choice set dependency.[2]

Using the micro-economic notion of indifference, Chorus (2012a) derived the first RRM-based MRS (or value of time) measure. Since then limited attention has been paid to the properties, interpretation and usability of this particular measure. In this paper, I discuss how the measure differs from its RUM counterpart, relates to the behavioural intuition of the RRM model, derive its theoretical properties and show how the different parts of the measure should be interpreted. Specifically, I review the extent to which the measure can be used for welfare analysis of changes in the transport infrastructure. I will show that the measure has its merits, but is not (yet) a full-fledged alternative to its RUM counterpart for welfare analysis. As a first step, I develop an alternative RRM-based value of time measure based on the representative consumer approach (Anderson et al., 1988; Hau, 1985), which is central to the welfare economic framework for discrete choice models developed by Small and Rosen (1981). It turns out this measure alleviates some of the restrictions, but has its own theoretical concerns. Finally, based on the developed insights I discuss a road map for building a welfare framework around the RRM model.

The remainder of the paper is structured as follows: Section 2 briefly introduces the notion of Value of Time and how it can be derived within the RUM and RRM model. Section 3 provides a detailed account of the Chorus (2012a) VoT measure and its relation to economic welfare. Section 4 then adopts the perspective of the representative consumer and develops the associated VoT measure. Section 5 describes the challenges of conducting welfare analysis under context dependent preferences. Section 6 summarises the review and presents suggestions for further research.

2. Indifference, marginal rate of substitution and the subjective value of time

The Marginal Rate of Substitution is closely related to the microeconomic notion of indifference (e.g. Katz and Rosen, 1998). In the utility theory, an individual is assumed to be indifferent between two particular situations when they generate the same level of utility. The MRS emerges when studying the trade-off between two specific attributes characterising a particular alternative, in this case travel time T_i and travel costs C_i of alternative i. The increase in utility associated with a marginal decrease in travel time can be counteracted by a marginal increase in travel costs. The MRS measures the rate at which the individual is willing to trade one attribute for another in order to keep utility constant. Since travel cost are incorporated in the trade-off, the (negative of) the MRS can alternatively be interpreted as an individual's subjective *willingness to pay* for a reduction in travel time by one unit, or simply put the subjective Value of Time (VoT).

2.1. VoT in the linear-additive RUM model

In the linear-additive RUM model, the traveller is assumed to choose the alternative i which generates the highest level of utility U_i of all J alternatives in the choice set D. Utility in (1) is composed of a random part ε_i and a systematic part V_i. The assumed independence between ε_i and the attributes included in V_i, such as travel time and cost, implies that only changes in deterministic utility influence the MRS between travel time and travel cost.

$$U_i = V_i + \varepsilon_i \tag{1}$$

Eq. (2) derives the RUM-based Value of Time, i.e. the negative of the MRS between travel time and travel cost. The RUM-based VoT reduces to the ratio of marginal utilities of the considered alternative i as a result of imposing independence between ε_i and V_i. Moreover, Eq. (2) assumes changes in T_i and C_i only affect the utility of alternative i. The change in expected maximum utility is therefore solely determined by the changes in V_i. Accordingly, it makes no difference in the RUM model whether the 'unconditional indirect utility function', or the 'conditional indirect utility function' is considered as the basis for deriving the VoT measure. This distinction, however, becomes relevant for the RRM model and will be discussed in more detail in Section 2.2.

$$VoT_i^{RUM} = -MRS_i^{RUM} = \frac{\partial E\left(\max\{U_j, \forall j \in D\}\right)/\partial T_i}{\partial E\left(\max\{U_j, \forall j \in D\}\right)/\partial C_i} = \frac{\partial V_i/\partial T_i}{\partial V_i/\partial C_i} \tag{2}$$

In most empirical studies the ratio of marginal utilities reduces to the ratio of parameters β_T/β_C due to the adoption of a linear in the parameters and linear in the attributes utility function. This ratio is generic across alternatives when the same

[2] *Decisions* in both the RUM and RRM model are guided by utility (regret) differences across the alternatives. In linear RUM models choices are then determined by attribute level differences, but the experienced level of utility (up to a constant) of the chosen alternative still depends on absolute attribute levels. In RRM models attribute level differences across alternatives also determine the level of experienced regret.