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# TOWARDS A BETTER UNDERSTANDING OF THE REFERENCE POINT IN A TRAVEL BEHAVIOUR CONTEXT

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## ABSTRACT

The use of Prospect Theory (PT) to model travelers' behavior has increased in the past decade due to its potential to capture a more realistic behavior. Its use has one main difficulty: the establishment of meaningful reference points (RPs) for a travel behavior context. This paper presents developments towards the definition of meaningful RPs. The ability of PT to predict route choice behavior in response to different RPs is shown in a case study. Results show that PT's highest prediction ability occurs when the RP is aligned with the observed behavior, thus reinforcing the necessity of establishing appropriate and meaningful values.

## KEYWORDS

Prospect theory, reference point, travel behavior, route choice

## INTRODUCTION

The majority of existing route choice models is based on the utility maximization assumption which proposes that people act rationally in order to get the maximum utility (benefit) from the decision made. The use of utility theory to assess travellers' behavior has been widespread over the past decades and, especially in the field of route choice under uncertainty, Expected Utility Theory (EUT) is the most widely used theory [1-4].
Despite the large use of EUT, experiments in behavioral studies have found inconsistencies with its axioms [5], leading to the development of non-expected utility theories of which Prospect Theory (PT) is the most discussed. The basic assumption of PT is that choices are based on gains and losses measured against a RP, where the choices are defined in terms of a prospect, i.e. outcomes associated to probabilities of occurrence. What matters, therefore, is the relative gain and not the final state of wealth or welfare. PT has been widely used in the field of economics, but applications in the field of transport, and in particular on route choice behavior, are relatively recent. The main issue addressed throughout the literature is the lack of consensus with respect to the so-called reference point in a travel behavior context as its

values plays an important role in the choices made [6-8]. For situations involving monetary outcomes, based on which PT was developed, zero is the usual RP and it can be interpreted as the status quo of wealth. But the question is: what is the meaning of the RP in a context involving route choice and travel times? In other words, what is the value that travelers use as a reference to distinguish the experienced travel times into gains and losses? The contribution of this paper is to propose developments towards a better understanding of its meaning in a travel behavior context based on a case study focusing on the ability of PT to predict route choice behavior in relation to different RPs.

# PROSPECT THEORY

PT, a descriptive theory of decision making under risk, was developed in 1979 as a critique to the EUT. The point is that changing the ways in which options are presented has the potential of generating predictable shifts in preferences and systematically violates the axioms of EUT [5]. PT explains choice behavior as a two-step process: an initial phase of editing and a subsequent phase of evaluation. In the editing phase the options are organized and reformulated by the application of heuristics to simplify the evaluation and in the evaluation phase the prospect is subjectively valued. The evaluation phase is divided into two scales: a weighting function, $\omega(p)$, and value function, $v(x)$. The probability-weighting function, $\omega(p)$, associates to each probability, $p$, a decision weight, $\omega$, that reflects the impact of $p$ on the overall value of the prospect, ($V$). The value function, $v(x)$, reflects the subjective value of the outcome, thus measuring the deviations from the RP. Thus, neither $v(x)$ is perceived as valuing $x$ nor $\omega(p)$ as valuing $p$.

In 1992, advances were made to extend PT to uncertain outcomes [9], which lead to the so-called Cumulative Prospect Theory (CPT). This extension was necessary to allow evaluation of situations involving uncertainty in which some of the outcomes or probabilities are unknown. This is clearly the case for situations involving travel times. CPT employs cumulative rather than separable decision weights, it is applicable to uncertain and risky prospects and it allows different weighting and value functions for gains and losses due to people's different perception of gains and losses. Thus, there are functions respectively associated to positive and negative outcomes, $V^+$ and $V^-$. The overall value of a prospect is given by $V= V^+ + V^-$, where $V^+ = \sum_{i=0}^{n} w_i^+(p).v(x_i)$ and $V^- = \sum_{i=-m}^{0} w_i^-(p).v(x_i)$ given $-m \le i \le n$. The value and weighting functions are defined by:

*Value function*

$$v(x) = \begin{cases} (x)^\alpha & \textit{If } x \ge 0 \\ -\lambda(-(x))^\beta & \textit{if } x < 0 \end{cases}$$

*Weighting function*

$$w^+(p) = \frac{p^\gamma}{(p^\gamma + (1-p)^\gamma)^{\frac{1}{\gamma}}} \quad \text{and} \quad w^-(p) = \frac{p^\delta}{(p^\delta + (1-p)^\delta)^{\frac{1}{\delta}}}$$

where $x$ is the attribute to be measured against the RP, $\lambda$ reflects the degree of loss aversion, i.e. the aggravation one experiences when incurring in losses, $\alpha$ and $\beta$ measure the degree of diminishing sensitivity, i.e. the decrease on the marginal value of gains and losses with their magnitude and $\gamma$ and $\delta$ define the curvature of the weighting function. The values of these parameters as estimated in [9] for situations involving monetary outcomes are $\alpha= \beta= 0.88$, $\lambda= 2.25$, $\gamma= 0.61$ and $\delta= 0.69$. For a comprehensive review about PT we refer to [5, 9].

# CASE STUDY

The case study was based on part of the data from the stated preference survey performed in [10], in which a travel simulator was used to investigate travelers' route preferences. The

situations involved daily departures at 8:00 a.m. and arrivals within 1 hour at the destination for either a meeting with colleagues (scenario 1) or a job interview (scenario 2). No specific aim, such as minimizing travel time, was proposed. 20 respondents participated in scenario 1 and 25 in scenario 2. Each of them made 40 consecutive choices among 3 routes with an approximate length of 30 km and the following characteristics: (i) route 1, the fastest route, consisted mainly of highways, (ii) route 2, the most reliable route, consisted mainly of rural roads and (iii) route 3, the intermediate route regarding performance, consisted partly of highway and partly of urban roads (going through the city centre). Thus, in total, 800 route choices were made in scenario 1 and 1000 in scenario 2. For detailed information about the case study, we refer to [10].
In addition, it was assumed that during the first 10 route choices people were gaining experience with the routes' travel times and as of the 11$^{th}$ the prediction ability of each theory was investigated. In addition, the travel time distributions were updated and as a result, choices made on the 11$^{th}$ day were based on data from the first 10 days, choices made on the 12$^{th}$ day, were based on data from the first 11 days and so on.
The determination of the predicted route was based on the maximum prospect theoretic value of travel times. In the value function, $x=RP-TT$, where $TT$ are the real travel times of each route and in the weighting function, $p$ is the probability of occurrence of travel times. Four RPs were proposed: (i) the mode of the fastest route, (ii) the mode of the most reliable route, (iii) the average travel time of all routes and (iv) the minimum travel time of the fastest route. The first RP implies that people derive satisfaction from getting the best probable result, while the second RP assumes that people are more conservative in their choices and tend to avoid losses, thus risk averse. The third RP, however, does not have a clear behavioral meaning and is aimed to explore the type of choice predicted under this circumstance. The fourth RP is a specific group within the first RP and in behavioral terms this means that people are aggressive in their choices and want only the best possible route.
The parameters of the value function and the weighting function are set equal to the originally estimated values. For detailed information about the calculation procedure, we refer to [6].

# Results and discussion

The results show that route 2 is the route chosen most often (Table 1). This implies that after getting experience people tend to be more conservative in their choices, thus preferring the most reliable route. Moreover, the more serious the travel purpose is, the more conservative people tend to be in their choices.

**Table 1: Travelers' route choice pattern for different travel purposes**

| *travel purpose* | *route 1* | *route 2* | *route 3* |
|---|---|---|---|
| Meeting with colleagues | 40.5% | 48.8% | 10.7% |
| Job interview | 34.5% | 52.0% | 13.5% |

In line with the literature review, the RP substantially influences the prediction ability of PT. The highest prediction ability is observed when the RP is equal to the mode of the most reliable route, and the lowest prediction ability is observed when the RP is equal to the average travel time of all routes (Figure 1). These results allow inferring that when the RP is aligned to the observed behavior, the prediction ability of PT increases. Therefore, when the RP is equal to the mode of the most reliable route, thus aligned with the conservative way people behave, the prediction ability of PT is the highest. On the other hand, when the RP is set equal to a less meaningful value such as the average of travel times, thus not really capturing travellers' behavior, the route predicted the most is route 3. Therefore, it is possible to infer that when the RP is not based on a specific type of behavior, but on average values, routes of intermediate performance benefit from this. These results reinforce the necessity of establishing appropriate and meaningful RPs.

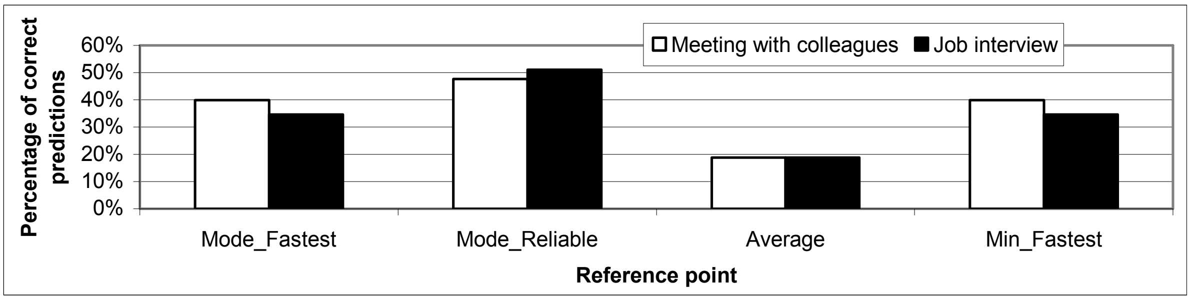


**Figure 1: Prediction ability of PT in relation to the reference point**

# CONCLUSIONS

The use of PT for modeling travelers' behavior is relatively new and the literature has made clear the lack of empirical experiments to validate its use on route choice behavior. This case study is one of the first attempts to validate its use based on data from a stated preference experiment. In line with the literature, the RP considerably influences the prediction ability of PT, thus reinforcing the need of establishing meaningful values. Natural extension of this research, already in progress, is to further extend this analysis for situations involving different types of information and to compare results obtained making use of EUT and PT.

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