Prospect Theory and Travel Behaviour: a Personal Reflection Based on a Seminar

Bert van Wee[1]

Faculty of Technology, Policy and Management, Delft University of Technology, NL

This paper is the final paper of a special issue on Prospect Theory (PT) and its applications in travel behaviour research. It is largely (but not exclusively) based on discussions held during a seminar that took place on the 8th of October 2009. The paper presents some personal reflections based on the discussion subjects on the use of PT in the area of travel behaviour research, clustered by the position of PT as a theory, applications of PT, future research, and relevance for policy making. The most important conclusion of the papers are firstly that PT, in addition to other theories like Utility Theory (UT), can help to improve our understanding of choices in the area of travel behaviour. The concepts of loss aversion and reference points are especially useful. A second important conclusion is that PT is not the only theory challenging UT. For example Regret Theory and the concept of Bounded Rationality also challenge PT. In addition, some of the premises of PT, at least the importance of some reference points, are not exclusively the domain of PT, but also that of other theories, including UT. Thirdly, it is important to realize that critics of Utility Theory (UT) as it is used in specific studies related to travel behaviour are not necessarily critics of UT in general. Fourth, it seems better to focus on the distinguishing premises of PT than on the theory as a fully fledged alternative to UT. A fifth outcome is that PT can be used both to increase our understanding of travel behaviour, as well as for the evaluation of the outcomes of models. A final outcome is that there is no need to choose a theory before collecting the data.

Key words: Travel Behaviour, Prospect Theory, Utility Theory

1. Introduction

In recent years Prospect Theory (PT) has become increasingly popular in travel behaviour research. In October 2009 a seminar on PT and travel behaviour was organized by the Dutch research school TRAIL (www.rstrail.nl) in Delft, the Netherlands, aiming to discuss the state of the art in the area, as well as considering future directions. Leading researchers in this area were invited to present and discuss their work. In addition, Prof Timmermans (Eindhoven University of Technology, the Netherlands) was invited to discuss the added value of PT for travel behaviour related research. Table 1 gives an overview of the seminar speakers and the titles of their presentations.

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[1] Jaffalaan 5, 2628BX, Delft, NL, T: +31152781144, F: +31152782719, E: g.p.vanwee@tudelft.nl

Table 1: an overview of speakers and presentation titles

	Title presentation
Evert Jan van de Kaa	Prospect Theory and choice behaviour strategies. Review and synthesis of findings from social sciences
John Polak	Rank and reference dependent choice: two examples
John Rose	Comparison of Prospect Theory in WTP and preference space
Erel Avineri	Applying Prospect Theory in the design of information-based behavioural change interventions
Caspar Chorus	Loss aversion with respect to foregone alternatives. A tale of regret and compromises
Tim Schwanen	Specifying cumulative prospect theory's utility and weighting functions
Hani Mahmassani	Risk perception in highway driving: from Prospect Theory to operational driver behavior models
Harry Timmermans	On the (ir)relevance of Prospect Theory in modelling. Uncertainty in travel decisions

This special issue presents a selection of the research papers as well as the discussion paper (versions after review). This paper is the final paper in the special issue. Its aim is to synthesize ideas on the added value of PT, and to discuss options for further research and the policy relevance of applications in the area of PT and travel behaviour. The paper is partly based on the discussions during the seminar, and reflects on the ways forward, written down by the chairman of the conference. The paper is to a great extent inspired by the discussions that took place during the day. However, the author is fully responsible for the contents. Part of the paper is based on the seminar (presentations and discussion), and another part is based on the ideas and opinions of the author. It is therefore made explicit when the text is based on the seminar, or relate to the author's ideas. In the latter case the formulation 'in my opinion' or the word 'I' is used. To further clarify the origin of contributions of this paper, Table 2 in the conclusions section makes this explicit. In the case of the 'ideas of the author' I do not necessarily claim originality of the ideas, as they may have been expressed by others before. Note that because the paper is based on the seminar, presentations of papers which are not included in this special issue (and related discussions) are also used. In addition the version of the presented papers at the seminar is used, not the revised versions of the paper used in this special issue. The focus of this paper is on themes that were discussed at the seminar, not on discussions of the individual papers. In addition, the focus of this paper is mainly on two premises of PT that dominated the discussions: loss aversion and the existence of reference points.

The ideas below relate to the use of PT in the research area of travel behaviour, it is not the aim to discuss the wider use of PT for choices in general. To avoid overlap with the other papers in this special issue, this paper does not elaborate on PT and its premises, nor give an overview of literature in this area. For a description of PT: see the paper by Van de Kaa (2010, this issue), or Van de Kaa (2010, forthcoming).

Section 2 discusses the theoretical position of PT. Section 3 reflects on the application issues. Section 4 translates the issues of sections 2 and 3 into future research. Section 5 elaborates on the relevance of PT for policy making. Section 6 summarizes the main conclusions.

2. The position of PT

PT adds to UT

Most researchers emphasized that PT could add value to understanding choice-making in the area of travel behaviour, at least with respect to some choices, such as departure time. Methodologically speaking, this conclusion could be biased because of self-selection: only leading

travel behaviour researchers known for their expertise in the area of PT and travel behaviour were invited. Therefore the conclusion might not be valid for all researchers in the area of travel behaviour.

In addition, there was a high level of consensus about PT not being a fully fledged theory that could replace Utility Theory (UT), which for decades has been the most widely used theory in the area of travel behaviour – see also Avineri and Bovy (2008). The mainstream opinion among participants was that it should be the distinguishing premises, rather than the 'complete' theory that should be centrally placed, the most important of those being the existence of reference points and loss aversion.

Thirdly, it is important to realize that a lot of dissatisfaction with UT is related to the way UT is generally used, but not necessarily to UT *per definition*. Some of the premises of PT could theoretically also be included in UT, such as diminishing returns (see Kahneman and Tversky (1979), for example in the context of time gains and losses). At the seminar both Rose (2010, this issue) and Avineri (2010, this issue) explained that diminishing sensitivity does not only occur when there are gains but also when there are losses. Schwanen demonstrated the importance of multiple functions that exist for the form and parameterisation of both the utility value function as well as the weighting functions.

PT versus other theories

The general opinion during the seminar was that the premises of PT, in particular loss aversion and the existence of reference points, are not exclusively the domain of PT, but could also be included in UT. For example, people value arriving late as negative. Each minute of arriving late is valued relatively strong. In other words, the desired arrival time (whatever it may be exactly – see section 3) is a reference point. Utility theory can easily not only include the high negative value people put on each minute of arriving after the desired arrival time, but also the negative value of arriving late anyway (see Lam and Small, 2001; see also section 3). Other theories that can deal with (some of) the premises of PT include Regret Theory (Chorus, 2010, this issue), the concept of Bounded Rationality (see Timmermans, 2010, this issue), and economic psychology and experimental economics (as explained by Polak at the seminar). For example, Random Regret Minimization explicitly compares competing alternatives; such alternatives could serve as reference points (though to the author's knowledge no application of PT explicitly assumes so). An example of a choice that can be explained using PT or other theories could be the characteristics of a car. The current car people have may be a reference. Let us assume a person wants to buy another car (new or second hand). According to both PT as well as Regret Theory people might want to avoid their new car performing worse in some respects than their current car – see also section 3 that further discusses this example. In my opinion, the fact that other theories can deal with the premises of PT is not a reason to reject PT, but a reason to not exclusively claim them as premises of PT.

A second conclusion with respect to the comparison of PT with other theories, is that the same data and choice outcomes can be interpreted by a variety of 'stories', of which PT based stories are one of several – see also Timmermans (2010, this issue). An example could be that losses are valued more negatively than equal gains. In addition to the explanation provided by PT the same finding can be explained by economics, in particular the phenomenon of 'diminishing returns'. Let us take income as an example. It could very well be that *additional* income adds less to the wellbeing of a person compared to the effect of an equal volume of an income decrease.

Thirdly, not all people deal with reference points and loss aversion in the same way (see, for example, Van de Kaa, 2010, this issue): the added value of these premises is not only context specific, but also person specific.

EJTIR 10(4), December 2010, pp. 385-394
Van Wee
Prospect Theory and Travel Behaviour: a Personal Reflection Based on a Seminar

388

I think that PT should not primarily be seen as a competitor theory for UT. Instead, insights based on PT, but also on other non-UT theories, could be integrated into a UT-based framework. Note that PT also assumes utility based decision making. I think it is not very important to discuss 'claims' about the origins of the ideas, nor to discuss a 'winner theory'. In my opinion the 'stories to be told' explaining the results as found in the data (revealed preference or stated preference/stated choice/experiments) should be theory based as much as possible: which could be potentially sound explanations for the data as found? For example, simply claiming people are loss averse and therefore prefer to arrive on time, might not be very useful. The same applies to an earlier research step: data collection. Ignoring insights from PT and other non-UT theories could lead to missing chances to increase our insights into travel behaviour. In terms of considering research in the area of decision making with respect to travel behaviour, systematic thinking about UT as well as the theories which challenge UT is necessary, as well as paying attention to the data collection and questions in order to test the hypotheses or explore people's choices.

3. Applications

What is the reference point?

The researchers at the seminar recognized the importance of being precise about the reference point. This subject had been addressed in recent literature, see for example Van de Kaa (2008), Avineri (2009). Polak, Chorus (2010, this issue), and Avineri (2010, this issue) explicitly discussed this in their presentations. What the reference point is exactly, is not always completely clear. Let us take the 'late arrival' as an example, and in particular the hypothetical case of a guest speaker giving a lecture for students. I assume the lecture is scheduled for 10.30 am. But what then is being late? Maybe lectures generally start later than officially scheduled (as is the case in Dutch universities), implying that the lecture actually starts fifteen minutes after the stated time, in this case at 10.45 am. On the other hand, maybe the guest speaker wants to put slides on the PC, needs to find the specific room in the building, or wants to briefly discuss a few subjects with the course manager. So, there may not be a clear reference point. One can argue that the researcher can ask for it. But even then heterogeneity between persons in (seemingly) the same situation might occur. And even one person might have a range for the reference point. In our example, the person might prefer to be in the room at 10.15, to have some time to put the file with slides on the laptop, and discuss briefly with the course manager. But the ultimate arrival time might be 10.45, and the little time needed to put the slides on the computer could be simultaneously used for the introduction of the guest speaker and the subject.

In addition I think a second notion on reference points to be made is that not only the point itself, but the importance of not passing it can be very context specific. Let us again take the example of the guest speaker. Suppose she expects an audience of 200 persons. Then she might want to be definitely on time. But suppose at the time of invitation for the presentation she expected 200 persons, but two days before the event she received a message that an audience of 6 persons will attend the presentation. Then she might not care too much about being a little late.

Setting the reference point can get even more complicated if a choice is based on multiple attributes. Let us again (as in section 2) take the example of a car owner and her choice for a new (or second hand) car. Cars differ in many respects, such as power, top speed, acceleration, size (length, width), luggage space, luxury level, and the like. Maybe the current car a person has is the reference state. But does this apply to all attributes? Or maybe the new version of the current car of the person is her reference state, not the version she owns? Or maybe the reference state is not based on the comparison of one or more dominant attributes of the vehicle, but more on the

general impression or position in the car market of the vehicle ('I want at least a VW Golf or comparable class of car').

Note that it is highly questionable if car type choice is a choice under uncertainty anyway (the 'domain' of PT). But even if it is not, reference points are relevant even in this case: people might also have reference points in the presence of certainty - see below.

At the seminar both Avineri (2010, this issue) and Van de Kaa (2010, this issue) showed the importance of the formulation of questions: identical situations could be formulated in questionnaires suggesting different reference points. Avineri (2010, this issue) gave the example of a commuting trip by car of 20 minutes, and by bike of 15 minutes. The researcher can firstly present the commuting trip by car, and then commuting by bicycle as a gain of 5 minutes. Alternatively the trip by bicycle could be presented first, followed by the car commuting trip being a loss of 5 minutes.

Application areas: which behaviour?

Travel behaviour includes many categories of behaviour, including the decision to travel anyway, mode choice, route choice, and time of day/departure time. Relevant for travel behaviour, but not included in most definitions, are choices like residential choice, destination choice, activity type choice, and vehicle type choice. An important question is: which behaviour is to be covered by PT or another theory?

First of all, PT is a theory for decision making under uncertainty. An important question which then follows is: how do you define uncertainty? In the context of PT making a choice under uncertainty is defined as making any choice where the outcomes are not certain beforehand, where the distribution of probabilities of possible outcomes at the time of decision making can both be known and unknown. Note that this is a broader definition than the one often used in the context of decision making. Based on Knight's (1921) work, a distinction is often made between risk (known distributions of probabilities of possible outcomes, such as in the case of flipping a coin or rolling dice) and uncertainty (unknown distributions). The fact that PT is a theory for decision making under uncertainty could certainly limit the area of applications. Let us take the example of car type choice: one can argue that buying a car includes no or little uncertainty. Most of the attributes including price, size, power, speed, acceleration characteristics etc, are known. However, some level of uncertainty could exist with respect to maintenance costs. For those costs several sources with statistical information on the performance of brands and car types are available. The same applies to the value of a car after a certain period of use. So, for most attributes there is no uncertainty. For a few attributes there is uncertainty and the related distributions are known ('risk'), so these can be labelled as 'uncertainty' in the context of PT as described above. In addition to uncertainty with respect to attributes, uncertainty could exist at the level of the person: will she still feel happy about her choice after the decision has been made? I would argue that uncertainty in the case of car type choice is at least of another order than, for example, uncertainty with respect to arrival time, given a certain departure time. Uncertainty with respect to car type choice is to a large extent risk and person related. Car type choice probably includes a high level of emotions or affection, and a person choosing a car may not be able to fully evaluate her emotions and feelings of affection for a car beforehand. But what if there was no uncertainty? For example, the value of the car after a number of years is guaranteed by the seller? Strictly speaking PT would then be irrelevant. However, one of the premises, loss aversion, could still be relevant: people can be loss averse even when there is no uncertainty.

A second observation is that most (but not all – see Van de Kaa, 2008) research using PT in the area of travel behaviour, is related to travel time and arrival time. This also applies to the papers in this special issue. This is easy to understand, because travel and arrival time are often uncertain, and it is well known from the literature that in several cases people dislike being late,

EJTIR 10(4), December 2010, pp. 385-394
Van Wee
Prospect Theory and Travel Behaviour: a Personal Reflection Based on a Seminar

390

whereas arriving early is generally valued lower than arriving on time (Lam and Small, 2001). As discussed by Mahmassani at the seminar, PT can also be used to model and understand driving behaviour, in particular risk-perception and risk-taking behavior under uncertainty, not only under 'regular' conditions but also in complex environments such as those associated with congested conditions, accident-prone situations and extreme regimes.

In my opinion, the usefulness of PT in the case of mode choice is less clear because differences occur in many respects, not only time and costs, but also factors such as safety, effort, options to combine travel and other activities such as working, perceived health (especially for walking and cycling), fun of travel, and emotional aspects mainly related to the car. Some of them, including the expected travel time are subject to uncertainty and therefore potentially to some of the premises of PT. Because route choice is primarily related to uncertainty in travel time, it could be studied based on the premises of PT.

Application area: understanding and modelling choice versus evaluation of given choices

Most research in the area of PT and travel behaviour relates to the choices people make as travellers. The premises of PT can certainly contribute to the insights into these choices. In addition to choice making, PT could be useful for the evaluation of the outcomes of transport and land use policies. Examples could include the Marginal Value of Travel Time Savings (MVOTTS). Note that for changes in infrastructure (e.g. new roads or adding lanes to existing roads; new rail lines) most benefits result from travel time decreases. Therefore the value of MVOTTS could potentially have a great impact on the outcomes of related Cost-Benefit Analyses (e.g. Button, 2010). The value given to (increases in) congestion could also depend on the MVOTTS. The MVOTTSs could be related to reference points – see Van de Kaa (2008) for an analysis of the case of Singapore. Another example is that increases in noise levels, e.g. due to upgrading a regional or national road, could be valued more negatively than equal decreases in noise levels. The evaluation strongly related to differences related to Willingness to Pay (WTP) versus Willingness to accept (WTA), as also discussed by Rose (2010, this issue) at the seminar. Note that differences between WTP and WTA include phenomena other than those related to the occurrence of reference points, strategic behaviour being one of them.

A second note on the application area is that the premises of PT could also be useful in understanding the behaviour of actors other than travellers, at least for policy makers developing policy in the area of travel behaviour. They may also have reference points. For example, they might consider current levels of congestion, road safety, emissions or concentrations of pollutants as reference points. An extreme example of having a reference point is the idea of setting norms, e.g. for concentration levels such as the EU regulations for concentrations of PM10, and has a huge impact on the valuation of concentration levels. Loss aversion could relate to elections: politicians might be loss averse with respect to political power (related to the number or share of votes). This would link PT to Public Choice Theory (Buchanan and Tullock, 1962), a positive economic theory describing the behaviour of politicians (and employers of governments), which assumes that they act in their own interest.

PT could contribute to understanding the choices that people have made: data analyses can tell if people seem to have reference points, or if they are loss averse. A major challenge could be to find out if PT could also be used for forecasting, both with respect to travel behaviour as well as to the evaluation of specific outcomes (see above). For forecasting, *future* reference points are crucial but might be more difficult to set than reference points for current decisions.

Translation to modelling and policy making

Assuming it is desirable to translate the insights of theories which challenge UT into modelling, the seminar discussion recognized that it would take many years to develop trip or activity based models based on the premises of PT or of other theories which challenge mainstream UT. It could

be better to start with *quick wins*. For example, the outcomes of current models (related to travel times, and perhaps also to impacts like noise or road safety levels that are based on current models) could be explicitly interpreted (and valuated) based on the premises of PT. A likely candidate outcome indicator subject to interpretation in terms of the value of MVOTTS could be congestion levels: MVOTTS related to recurrent congestion could be valued lower than MVOTTS related to non-recurrent congestion, such as in the case of accidents. A second step could be to revise sub-models for specific choices like departure times.

A major challenge is to make choice and evaluation models consistent. This is also true for current UT models and the evaluation of results: the MVOTTS as related to UT based choice models in trip based models generally are not fully consistent with the MVOTTS as used in the *ex ante* evaluation of MVOTTS as used in Cost-Benefit Analysis (CBA). When changing (sub) models for travel behaviour choices based on theories, such as PT, which challenge UT, and when adapting the evaluations of the outcomes of current models based on these theories, the challenge of consistency increases. Note that UT has the advantage over PT when it comes to making theory, models and evaluation consistent.

4. Future research

Research challenges

Both the papers in this special issue and the presentations at the seminar presented both implicit and explicit challenges for further research. It is not the aim of this paper either to repeat them or develop a comprehensive research agenda. Nevertheless I want to briefly discuss one potentially challenging research area: the inclusion of self-selection and heterogeneity. It is generally recognized that travel behaviour is related to socio-economic and demographic variables like income, gender, age, household structure etc.

For the last 10 – 15 years attention has increasingly been paid to self-selection based on attitude related variables, the dominant form of self-selection being residential self-selection. See for example the recent issue of *Transport Reviews* (2009-3) that includes papers written by Van Wee (2009), Bohte *et al.* (2009), Cao *et al.* (2009) and Naess (2009). Van Wee's paper discusses the occurrence of self-selection with respect to many choices people make (e.g. residential choice, work location choice, mode choice, car type choice, exposure to safety levels), the three other papers focus on residential self-selection alone. It is very possible that heterogeneity between persons exists that is not related to traditional socio-economic and demographic variables, but to attitudes, and that this heterogeneity is related to premises of PT and other theories which challenge UT. In particular, people vary in terms of their reference points and their importance. For example, people can vary with respect to how much they dislike being late for meetings. In addition, some people might be much more sensitive to reference points than others, for example related to commuting times and decisions with respect to residential choice or job location choice and related travel times. One could argue that this is not relevant, because this kind of taste variation can easily be included in the error terms of choice models. However, insights into such attitudes might at least be helpful to increase our understanding of choice making. And it is possible that trends in society occur with respect to, for example, being late. Such trends could affect the choice making of some people more than others.

Advice for researchers

Probably the most important advice for researchers that was derived from the seminar is that at the outset there is no need to choose a specific theory, including PT. The best way to do research in the area of travel behaviour is to be fully aware of UT and theories which challenge UT (including PT), in order to be able to make choices with respect to hypothesis to be tested and

data to be collected. In the analysis phase the data indicates which choices people make. And the interpretation of the data (stories to be told) can be based on several theories.

I think that in-depth interviews may enable us to better understand which of the several possible stories is 'the best' story: we should interview travellers to find out more about the motivations behind their choices.

5. Relevance for policy making

The seminar was sponsored by the Dutch Ministry of Transport and Public Works, as was the PhD research of Evert Jan van de Kaa whose PhD thesis on Prospect Theory and travel behaviour was the trigger for the conference. An important related question therefore is: what is the relevance of PT in the area of travel behaviour research for policy making? In my opinion this is firstly that PT, or at least the concept of reference points and loss aversion, can shed a new light on the pros and cons of several policies that include travel time. Example policies can be the construction of new infrastructure or improving current infrastructure, and road pricing policies and their travel time gains. Secondly, for road pricing, the idea of reference points and loss aversion could not only relate to time but also to money. Maybe the policy-induced increase in monetary costs of travel due to the introduction of road pricing is interpreted by travellers as 'a loss' that is negatively valued relatively strongly. Thirdly, the concepts can help to better understand the importance of travel information. Such information may be helpful to reduce the 'losses' of unexpected interruptions of travel while travelling, or to provide the traveller with up-to-date information shortly before the start of a trip, for changes with respect to the regular situation such as accidents and related congestion, and disruptions in train timetables. Losses due to such disruptions could be decreased, and the concept of loss aversion may increase our understanding of the importance and valuation of such information.

6. Conclusions

The most important conclusions of this paper are summarized in Table 2.

Table 2: a summary of conclusions of this paper

Positive conclusions of the seminar	Prospect theory can add to the understanding of choice in travel behaviour.
	The concepts of reference points and loss aversion are probably the most useful.
Critics of the seminar	PT is not a fully fledged theory that can replace UT.
	Loss aversion and reference points can also be included in UT and other theories.
	It would take many years to develop trip or activity based models based on the premises of PT (or of other theories which challenge mainstream UT). It might be better to start with *quick wins*.
Other conclusions of the seminar (that can partly also be found in the literature on PT)	The same data can be interpreted by a variety of stories.
	The reference point is sometimes hard to define.
	There is no need to choose a specific theory, including PT, at the outset.
	PT is applicable for choices under uncertainty (unknown probabilities) and that includes risk (known probabilities).
	PT is in particular (but not exclusively) useful for time-related choices such as arrival time, travel time.

Continued Table 2: a summary of conclusions of this paper

Ideas of the author	Reference points can be very context specific.
	Setting the reference point can be problematic if it includes multiple variables of one alternative, such as all the characteristics of a car.
	PT could be useful to understand the choices of not only travellers, but also, for example, policy makers and politicians.
	A challenge for the future is to find out if PT could be used for forecasting and evaluation
	It is a major challenge to make choice and evaluation models consistent. This applies to PT but also to UT and other models.
	Self-selection and related heterogeneity can be linked to the premises of PT.
	PT is useful for policy making because it can help to better understand the valuation of policies, at least those related to travel time changes, road pricing, and travel information.

Table 2 leads to the overall conclusion that PT, or at least the concepts of reference points and loss aversion, could add to our understanding of travel behaviour, and to the valuations of several transport policy options. However exclusive claims of PT in these areas cannot be made, and there is still a long way to go to fully include PT and its premises in these areas – if that is at all possible.

Acknowledgement

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EJTIR 10(4), December 2010, pp. 385-394
Van Wee
Prospect Theory and Travel Behaviour: a Personal Reflection Based on a Seminar

394

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