The final publication is available in: Transportation Research Part F: Traffic Psychology and Behaviour, Volume 31, May 2015, Pages 112-123 10.1016/j.trf.2015.04.001

Asymmetric preferences for road safety: Evidence from a stated choice experiment among car drivers

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Abstract

Recent research has proposed fitting responses from discrete choice experiments to asymmetric value functions consistent with prospect theory, taking into account respondents' reference points in their valuation of choice attributes. Previous studies have mainly concentrated on travel time and cost attributes, while evidence regarding road safety attributes is very limited.

This paper investigates the implicit utility of a road safety attribute, defined as the number of casualties per year in alternative car trip choices, when safety improves or deteriorates. Using appropriate statistical tests we are able to reject symmetric preferences for losses and gains in the level of safety and estimate a sigmoid value function that exhibits loss aversion and diminishing sensitivity. This adds an interesting psychological dimension to the preference of road safety. Possible implications of this finding for policy making are discussed.

Keywords: road safety, prospect theory, stated preference, asymmetric preferences

JEL: D03, D11, D61, H41, H51, I18, R41

1. Introduction

The economic valuation of changes in road safety, or fatality and injury risk in road transport, constitutes a key input to policymaking on how much to spend on road safety. The monetary valuation of road safety is often referred to as the value of preventing a statistical fatality or the value of a statistical life (VSL). VSL is the population mean of the marginal rate of substitution (MRS) between wealth and mortality risk; that is, the monetary value of a “small” mortality risk change that aggregated over the population would amount to the prevention (or the increase) of one statistical death (Schelling 1968, Mishan 1971). Similarly, values of preventing injuries of different severity, can also be established (Jones-Lee 1974, Jones-Lee *et al.* 1995; Hojman *et al.* 2005).

An extensive literature exists regarding the economic valuation of preventing fatalities and injuries (Viscusi and Aldy 2003, Rizzi and Ortuzar 2006; Lindhjem *et al.* 2011). Most studies have applied stated preference (SP) methods (Carson and Louviere 2011) that have their theoretical underpinning in standard neo-classical economic theory. However, recent research has proposed fitting responses from discrete stated choice (SC) experiments to a value function proposed by prospect theory (Kahneman and Tversky 1979, Thaler 1980, see also Malul *et al.* 2013), taking into account respondents’ reference points in their valuation of choice attributes and allowing for asymmetric preferences. De Borger and Fosgerau (2008) applied SC data but only with trade-offs between travel time and money and tested for reference-dependent preferences. They found that “loss aversion plays an important role in explaining responses; moreover, participants were found to be more loss averse in the time dimension than in the cost dimension”; they also found “evidence of asymmetrically diminishing sensitivity” (p 101). Hjorth and Fosgerau (2012) present a similar SC study, also finding that the value function was consistent with prospect theory, exhibiting loss aversion for both travel time and cost. Ramjerdi *et al.* (2010) found the same evidence in the Norwegian Value of Time Study. Masiero and Hensher (2010) found that their Swiss SC data on freight transport were much better explained when allowing for asymmetric preferences, a steeper utility function for losses than for gains; and found that loss aversion was significant for all three attributes (punctuality, time and cost). Many of these empirical studies seem to give support for an asymmetric value function (and loss aversion) as proposed by prospect theory regarding travel time and travel cost. Evidence regarding road safety attributes is very limited.

To our knowledge, only Rizzi and Ortúzar (2003) presented a test for reference dependency and loss aversion involving road safety. They found only weak indication of differences between valuations of safety gains and safety losses. De Blaeij and van Vuuren (2003) presented a prospect theory approach to road safety valuation, analysing the form of the utility function for safety losses based on a very small pilot sample, but did not assess loss aversion.

This paper contributes to the limited literature on reference dependency and loss aversion in discrete choice experiments involving road safety (or casualty risk) by utilizing a large dataset (Veisten *et al.* 2013). The dataset is also rich in the sense that the reference levels are person specific, pivoted to an actual trip described by the respondent (while Rizzi and Ortúzar 2003 used a common “pseudo-reference point”, ibid, p. 17).

The remainder of the paper is arranged as follows: The next section presents some relevant theory regarding value functions. The third section describes the survey, the design of the choice experiments (CE), and the loss aversion hypothesis applicable to our data. The fourth section provides the results of our analysis. These results are discussed and conclusions drawn in the last section.

2. Theoretical background

Kahneman and Tversky (1979) proposed an alternative value function to the one assumed in expected utility theory, the prospect theory-based value function which models the changes in utility level (i.e. marginal utility) associated with equal-sized losses and gains as asymmetric. More precisely, their value function was (1) defined in terms of changes from a reference point, (2) it was concave for gains and convex for losses (decreasing marginal values for gains and for losses), and (3) it was steeper for losses than for gains (loss aversion). Figure 1 displays this *S* shaped asymmetric value function.

Figure 1 about here *(Caption:* "Figure 1: The value function in prospect theory (Kahneman and Tversky 1979")

The functional form of such a value function can be rather simple. Departing from a linear and symmetric value function, $V = \beta_0 + \beta * X$, a modification to: $V = \beta_0 + \beta_{loss} * Loss^{\lambda} + \beta_{gain} * Gain^{\lambda}$, allows for more flexibility and would be consistent with prospect theory if:

(1) $Loss = \begin{cases} X_{ref} - X & if\ X_{ref} > X \\ 0 & else \end{cases}$, $Gain = \begin{cases} X_{ref} - X & if\ X_{ref} < X \\ 0 & else \end{cases}$,

(2) $\lambda < 1$

and

(3) $|\beta_{loss}| > |\beta_{gain}|$,

These three conditions correspond to the three characteristics described above (reference point (X_{ref}) dependent utility, diminishing sensitivity and loss aversion). Hence, prospect theory implies that answers to valuation questions in SP surveys will depend on the reference point, which, in the case of safety would be the current level of safety. When asked about the compensation needed to offset a reduction in safety, the valuation function would be in the domain of losses and display loss aversion, which is akin to the so called *endowment effect* (Thaler 1980, Bateman *et al.* 1997). Prospect theory, proposing asymptotic preferences for road safety, adds an interesting psychological dimension to modelling human travel behaviour, compared to traditional neo-classical economic assumptions of preferences that are the same, in absolute terms, for gains and losses. Prospect theory expands neo-classical theory by arguing for different preferences and mind-sets depending on the endowment, that is, the current level of road safety that the individual holds when facing a safety change

In psychology and marketing literature loss aversion is explained by at least four components (Paraschiv and L'Haridon 2008): (1) the neural component, that losses and gains are processed in different primary areas of the brain; (2) the affective component, that persons are (emotionally) attached to what they possess; (3) the cognitive component, acknowledging that the cognitive progress prior to transactions differs between cession/selling and receiving/buying; and (4) the conative component, explaining loss aversion by negative feelings connected to giving up a possession (independent of the degree of emotional attachment). The literature underlines that the conative ("possession") component does not have to be strictly related to "real endowment" but can also apply to "mental endowment" (Ariely and Simonson 2003). This latter aspect is important in our context as road users do not literally own/possess the existing level of road safety (see also the discussion in section 5).

3. Stated choice experiment design

3.1 Choices pivoted around reported reference trips

Preferences for road safety can be elicited by means of choice experiments. In our case, car drivers were asked to choose one of two route alternatives characterised by three different attributes: cost per trip, travel time per trip and casualties per year (for time and cost, the aggregate value per year was also given in parenthesis). Figure 2 presents an example of a choice experiment situation used in this survey. The travel alternatives were pivoted around a reported reference trip in order to make them as realistic and meaningful as possible. The respondents reported the reference values for time and cost. The reference value for the number of casualties in car accidents, however, was calculated on the basis of the reported reference time and the value of annual average daily traffic (AADT), representing traffic density in the route actually chosen by each respondent.

Figure 2 about here *(Caption:* "Figure 2: Illustration of the pair-wise choice format of CE, with three attributes. The example is based on a reference trip of 15 minutes (#base_time#), costing 30 Norwegian crowns (#base_cost#), and a stated trip frequency per week equal to 10 (simply multiplying by 52 for annual estimates). The casualty reference level is calculated as 3 (#base_casualty#) based on an assumed annual average daily traffic of about 6,000, as given from Table 2. This is an example of "Choice 1" (of the 96 choice types specified in Table A1, in the Appendix), whereby Alternative A has the reference level for all three attributes, while Alternative B has "slightly worse" levels for time and cost and "much better" level for casualties."*)*

The safety attribute was presented as the annual expected number of casualties on a road trip of a certain length on a road with a stated traffic volume (AADT). The number of casualties was estimated by converting the reported trip time on the reference trip to kilometres driven, by applying average speeds for car driving on Norwegian roads (i.e. 45 km/hour, Denstadli *et al.* 2006), and then adjusted by the AADT estimated for the reference trip. Three AADT classes were pre-assigned to respondents based on their residence (see Veisten *et al.* 2013 for details). The estimates were based on representative accident rates (accidents per million kilometres of driving) for public roads in Norway in the previous decade (Elvik 2008).

From the reference levels of casualties, five attribute levels were defined (including the reference level), for every trip length / AADT class, according to Table 1 (Veisten *et al.* 2013).

Table 1 about here

The other two attributes in the SC experiment were travel time and (out-of-pocket) trip cost, including fuel and possible toll costs (Ramjerdi *et al.* 2010). A full-factorial design for a SC experiment with three attributes having five levels each would yield 5^3=125 choice pairs; this was reduced to 96 choice pairs by removing cases with dominant alternatives and with the additional removal of some of the time level changes, following De Jong *et al.* (2007). These 96 choice pairs were blocked into six choices per respondent, where the three attributes were related to trip alternatives in the pair-wise choice structure, plus an opt-out option. Doing so, one can identify 24 different choice tasks in terms of losses and gains relative to the references values (see Table A1 in the Appendix).

The reference values for the casualty attribute varied from two to 232 casualties, and about two thirds of the sample faced choices where the casualty reference value was in the range of two to eight; 40% of the reference levels were five or lower, 81% were lower or equal to 20, and only 4% of the observations had a reference value of more than 50 casualties.

3.2 Utility specification and hypothesis testing

In the following, only reference dependency for the casualty attribute is tested. In more complex models (not reported here), we simultaneously tested reference dependency for the cost and time attributes as well,[1] but as the general implication regarding the casualty attribute did not change we preferred more straightforward models assuming symmetric preferences for the time and cost attributes.

In the most general specification considered for this paper, the utility functions for the left hand-side alternative (LS) and the right hand-side (RS) alternative were specified as follows:

$$(1) \qquad V_{LS} = \beta_{0,LS} + \beta_{TIME} * TIME_{LS} + \beta_{COST} * COST_{LS}$$

$$+\beta_{CAS\_GAIN} * CAS\_GAIN_{LS}{}^{\lambda_{CAS\_GAIN}} + \beta_{CAS\_LOSS} * CAS\_LOSS_{LS}{}^{\lambda_{CAS\_LOSS}}$$

$$V_{RS} = \qquad \beta_{TIME} * TIME_{RS} + \beta_{COST} * COST_{RS}$$

$$+ \beta_{CAS\_GAIN} * CAS\_GAIN_{RS}{}^{\lambda_{CAS\_GAIN}} + \beta_{CAS\_LOSS} * CAS\_LOSS_{RS}{}^{\lambda_{CAS\_LOSS}}$$

The parameter $\beta_{0,LS}$ is a constant term intended to capture a possible propensity towards the left side alternative. β_{CAS_LOSS} represents the weight put on losses, which is expected to

[1] For the time attribute we found substantial reference dependency (loss aversion) while for the cost attribute no significant differences could be detected.

be negative. β_{CAS_GAIN}, on the other hand, is the weight put on gains (meaning fewer fatalities) and is therefore expected to be positive. For linear models (i.e. when λ_{CAS_GAIN} and λ_{CAS_LOSS} are fixed to unity), the two weights correspond to the marginal utility of losses and gains. In the non-linear models (where the lambda terms are estimated) the marginal utility also depends on the exponents.

In this paper we are particularly interested in comparing the absolute values of the coefficients ($|\beta_{CAS\_LOSS}|, |\beta_{CAS\_GAIN}|$). Five model versions with different value functions are specified, where model (1), stated above, is the fifth (M5); the others are as follows:

M1: As (1) but assuming $|\beta_{CAS\_LOSS}| = |\beta_{CAS\_GAIN}|$ and $\lambda_{CAS\_GAIN} = \lambda_{CAS\_Loss} = 1$

M2: As (1) but assuming $\lambda_{CAS\_GAIN} = \lambda_{CAS\_Loss} = 1$

M3: As (1) but assuming $|\beta_{CAS\_LOSS}| = |\beta_{CAS\_GAIN}|$ and $\lambda_{CAS\_GAIN} = \lambda_{CAS\_Loss}$

M4: As (1) but assuming $\lambda_{CAS\_GAIN} = \lambda_{CAS\_Loss}$

The null hypothesis underlying the test of loss aversion is:

$H1_0$: $|\beta_{CAS\_LOSS}| = |\beta_{CAS\_GAIN}|$

We test therefore if the impact on utility (negative for losses, positive for gains) is sensitive to whether road safety deteriorates or increases compared to the *status quo*. We expect $|\beta_{CAS\_LOSS}| > |\beta_{CAS\_GAIN}|$ implying that losses should result in higher disutility than corresponding (i.e. equally high) gains in utility.

With a second hypothesis, we test whether the lambda terms ($\lambda_{\text{CAS\_GAIN}}, \lambda_{\text{CAS\_LOSS}}$) are equal to one:

$H2_0$: $\lambda_{CAS\_GAIN} = \lambda_{CAS\_LOSS} = 1$

We expect decreasing marginal returns (diminishing sensitivity for losses and gains), e.g. values lower than 1, as implied by the sigmoid form (S-shaped form) proposed by prospect theory as illustrated in Figure 1.

For hypothesis testing, we used the Likelihood ratio (LR) tests, i.e. statistical tests that compare the relative performance (in terms of goodness-of-fit as measured by the final log-likelihood statistic) of a model that is a restricted version of a more general model (Ortúzar and Willumsen, 2011, page 279).

In the case of models M2 and M1 we test for asymmetric preferences given linear value functions. If $H1_0$ is rejected at the 95% confidence level and if $|\beta_{CAS\_LOSS}| > |\beta_{CAS\_GAIN}|$, we would conclude that loss aversion (given linear value functions) is present in our data. Testing M5 against M3 is the main test for asymmetric preferences in non-linear value functions. As the marginal effect of losses and gains depends on both the beta and lambda terms in the nonlinear models, one cannot infer loss aversion from asymmetry based on the beta parameters only. Therefore, the test for loss aversion will be a LR test between M4 and M3 (i.e. assuming generic exponents for losses and gains). Then the conclusion about loss aversion will again be based on the LR test and the absolute size of the weights between losses and gains. Attempting to be on the safe side, we performed an additional LR-test between M5 and M4 to check if indeed generic exponents for losses and gains could be assumed.

On the other hand, a LR test between M3 and M1 tests $H2_0$. If $H2_0$ is rejected and if lambda is found to be lower than unity we can conclude that also diminishing sensitivity is present in our data set.

3.3 The survey

The survey, carried out during late April and the beginning of May, 2010, was administered by e-mail to an Internet panel of respondents maintained by a major polling firm in Norway. It was sent out in two waves and the survey item dealing with the valuation of changes in the number of seriously/severely injured and killed people (henceforth termed "casualties") going by car was part of the second wave. In this second wave 3,109 car drivers participating in the first wave were asked to participate in a safety valuation survey in a hypothetical route choice context; 75.33% completed this second wave of the survey, that is, 2,342 individuals (as the response rate to the first wave was about 22%, the effective response rate for the second wave of the survey can then be calculated as 75.33% of 22%, yielding about 16.5% of those invited to the first wave of the survey).

The respondents were invited to the second wave (just a week or so after responding to the first wave part) by an e-mail from the polling firm referring to their participation in the first wave. It was stated that the topic of the second wave was health, safety and security, and that it was not quite as comprehensive as the first wave survey part. The invited persons were also informed that their answers would contribute to transport policy and by their participation taking part in a draw for a prize (four travel gift tokens worth 10,000 Norwegian kroner each, or about 1250 Euro, applying the average exchange rate of 2010). The first two questions of the survey referred to the reference journey that they stated in relation to the first wave survey, asking if they remembered being asked about this journey and if it was correct that it was a journey by car on a date X with travel purpose Y, with travel time equal to #base_time# minutes and travel cost equal to #base_cost# Norwegian kroner. These questions were intended to assure a correct linkage from the first to the second wave, as well as reminding the respondents about their reported reference journey. The next questions before the CE introduced the issue of casualty risk, asking the respondents if they knew the number of fatalities in road accidents per year, describing different levels of injury severity and asking if they themselves had been injured in road accidents. The respondents were then asked about the traffic density on their reported itinerary, for the possibility of adjusting the annual average daily traffic, and then presenting the estimated annual casualty base level (#base_cost#) for their reference trip (see Table 2), asking if they thought it was about right, too high or too low. After being asked about how many trips the respondents carried out on the itinerary of their reference trip, they were presented an introduction to the CE (shown in Figure 2) as described in Textbox 1.

Textbox 1 about here *(Caption:* “Textbox 1: Introduction to the choice experiment*)*

3.4 A measure of the credibility of the specified casualty risk reference level

Prospect theory implies that respondents are aware of their reference values and consider them in their decision-making. As the reference values for the casualty attribute were assigned to respondents, we cannot be certain that they internalized these values. Presumably, a critical question relates to whether or not respondents regarded the assigned casualty reference levels as realistic. In Veisten *et al.* (2013, Table 3) the following figures were presented: 52% of the respondents perceived the assigned reference levels as “too high”, while only 4% regarded them as “too low”, and 35% stated that the assigned reference level seemed correct for the route they had driven. Investigating this a bit further, we found that the share considering the (calculated) reference as “too high” was highest for the shorter trip lengths with lower reference values (six casualties and below). Thus, e.g., five or six casualties annually on a short route were perceived as more unrealistic than 30-40 casualties on a longer route.

4. Results

4.1 Descriptive statistics

The final sample consisted of 2,290 respondents (52 respondents always choosing the "opt out" / "do not know" option, see Figure 2, were deleted from analysis) and, with six choices per respondents this implies 13,740 choice observations. These include the cases where the "do-not-know" alternatives were chosen. Deleting the choice observations with "do-not-know" (which will be left out from statistical analysis in correspondence with Veisten *et al.* 2013), yields 13,334 observations. Table 2 presents the characteristics of the chosen alternative with respect to casualties, time and cost.

Table 2 about here

Table 2 shows that for casualties and time, the alternatives with the reference values were chosen only slightly more often than the non-reference values (51.1% (38.2%+12.9%) versus 48.9% (11.6%+37.7%) for casualties, and 53.4% versus 46.6% for the time attribute), while for cost, the alternatives with reference values were chosen slightly less often (48.4% versus 51.6%). Not surprisingly, the reference value for casualties was chosen more often when the rejected alternative implied a loss, i.e. it was the more dangerous alternative (N=5088), compared to choice situations where the rejected alternative implied a gain (N=1728). Similarly, 4,977 of the chosen alternatives implied a gain with respect to safety (casualty reduction), while only 1,551 chosen alternatives implied a loss with respect to safety. Hence, 75% (i.e. (5,088 + 4,977)/13,334) of the chosen alternatives were associated with the lower number of casualties The propensity towards choosing the least-casualty alternatives was apparently so strong that it drove respondents to select more losses than gains with respect to the travel time attribute. There were barely any differences between the shares of alternatives implying losses and gains in terms of costs As apparent from these descriptive statistics, it seems that the absolute number of casualties is the main driver in the observed choose behaviour, while the choice between reference value and non-reference value in itself seems to play only a minor role.

4.2 Estimation Results

We estimated both Multinomial logit (MNL) and error components mixed logit (ML) models (Ortúzar and Willumsen, 2011, Chapter 7) following the error specification chosen in Veisten *et al.* (2013). As both models gave the same indications for the LR tests described above, we only present the MNL model results here as they are easier to interpret.

4.2.1. All respondents

In this section we estimate the model versions M1-M5 on the whole sample, i.e. regardless of whether the respondents perceived the casualty reference level as realistic or not (this is altered in the consecutive subsection). Table 3 displays the MNL model results for the five different model specifications (i.e. value function for the casualty attribute) described in section 3.2[2].

Table 3 about here

All parameters have the expected signs and are significantly different from zero (except the left-side alternative specific constant that was expected to be zero). The lambda values are statistically different from unity whenever they are estimated. The goodness-of-fit, as indicated by the final log-likelihood (LL) statistic, increases, as expected, with the inclusion of more parameters. The largest jump is from model 2 to model 3, i.e., when moving from a linear to a non-linear value function.

An indication of loss aversion can be seen from the fact that the coefficient for losses is greater (in absolute terms) than the coefficient for gains. In model 2 the estimated values are 0.399 versus 0.350 implying that losses are valued 14% higher than corresponding gains, while in model 4, the difference is 1.09 versus 0.989 implying that the losses are valued 10.2% higher than gains. In model 5 the difference is 1.08 versus 1.00, however here the relative impact of losses depends on the size of the losses/gains as the lambda values differ.

As indicated above, LR tests were performed to get formal statements about loss aversion. Interpreting M1 as a restricted version of M2, we calculated the LR-test statistic

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[2] The robust t-test statistics adjust partly for the repeated choices structure of the data by means of the 'Panel Data' section in BIOGEME (Bierlaire 2003). Note that the robust-t-test statistics are not used for hypothesis test. As mentioned above the seldom selected "opt out" ("do not know") choices were discarded in all models.

to be 12.8. This is greater than 3.84 (the critical value for one degree of freedom - one restriction - at the 95% confidence level). Hence, we reject H1$_0$: $|\beta_{CAS\_LOSS}| = |\beta_{CAS\_GAIN}|$ and conclude that there exists loss aversion (given constant rate of returns). As stated above, losses are weighted 14% higher than the corresponding gains. Interpreting M3 as a restricted version of M4, the LR-test statistic is 10.3; hence we also find evidence for asymmetric preferences under diminishing sensitivity. As the very low LR-test statistic between M5 and M4 indicates that the lambda values for losses and gains are statistically equal we also conclude that we have found loss aversion with the LR-ratio test between M4 and M3. Thus, loss aversion - despite relative small in size (10-14%) - is a significant feature of the estimated value function.

Notwithstanding, the hypothesis of constant rate of returns, H2$_0$: $\lambda_{CAS\_GAIN} = \lambda_{CAS\_LOSS} = 1$, is clearly rejected (M3 versus M1), thus providing a clear indication of diminishing sensitivity. Figure 3 depicts the implied value function of models versions 1-5.

Figure 3 about here *(Captions:* “Figure 3: The value functions, models M1 – M5”)

4.2.2. Segmentation of respondents according to whether or not the assigned reference value is perceived as realistic

As mentioned above only 35% of the respondents regarded the assigned casualty reference number as correct. An interesting analysis is whether the relative gap between the beta-coefficients for losses and gains differs between the subgroup finding the casualty reference correct (realistic) and the sub-group finding it unrealistic (mostly too high; and we also include the 9% answering “do not know” in this subgroup). One would presume that reference dependency (and loss aversion) is greater for those that perceive the reference value as realistic.

We therefore estimated model versions M1-M5 for both subgroups. Detailed results (for the MNL model) are presented in Tables A2 and A3 in the Appendix. As seen from those tables we obtained a result showing significant loss aversion for both subgroups, but still with some differences. Table 4 below summaries the %-gap between the weights for losses and gains (i.e. "the degree of loss aversion") for the two subgroups.

Table 4 about here

Clearly, the relative gap between the weights on losses and gains is higher for the subgroup that regards the reference value as realistic. For the linear model, the relative gap is almost double the size, while the difference between subgroups is somewhat less for the non-linear model.

5. Discussion and conclusions

In this paper we tested reference dependency, loss aversion and diminishing sensitivity in a discrete choice experiment involving a road safety attribute. The results indicate that the respondents' valuation of changes in road safety fits well to the value-function proposed by prospect theory. Based on the data, we can depict a value function that has an *S* shape around the reference point, implying that respondents value losses in safety (i.e. an increased number of casualties) higher than gains (i.e. a reduced number of casualties), in absolute terms. This finding represents an important behavioural aspect of decision making and adds a psychological component to the utility maximization framework that is not represented in classical models with symmetric preferences.

Loss aversion regarding road safety can be motivated by conative costs of drivers related to giving up the level of road safety they are currently endowed with. Even though the road safety level does not constitute a real endowment one physically possess, our empirical evidence suggest that loss aversion is a significant factor in choice behaviour (at least in stated choice experiments). Thus, we believe that the concept of mental endowment (Ariely and Simonson 2003) is relevant in our application.

While loss aversion is found statistically significant, the degree of losses aversion is estimated to be relatively small, within the range of 8-19%. Descriptive statistics of choice behaviour (Table 2) indicate that reference dependency and loss aversion were only a secondary feature of the way respondents made their choices the stated choice experiments. Clearly, whether or not an alternative was the safest (regardless of the reference values) was the most crucial determinant of the choices made. This is especially true for respondents choosing lexicographically with respect to the safety attribute (about 37%). In spite of this, our LR test indicated that loss aversion is a significant feature of the value function for casualties in our data set. The LR test also indicated a strong case for diminishing sensitivity with rather low estimated exponents, yielding a strong convexity (concavity) for losses (gains).

The exact reference point for road safety is hard to obtain because respondents are - in general - not aware about road safety statistics (annual number of casualties) for the road they are driving on (and thus are not able to report a "correct" reference point). Our approach was to inform every respondent about their (presumed) current reference level (derived from aggregated statistics) before the start of the choice experiment. Of course, this level may be inaccurate and (even if accurate) differ from the respondent's perceived level; and indeed only 35% of respondents accepted the assigned reference level as being "correct". The degree of loss aversion for this subgroup was higher, with losses being valued around 19% higher than the corresponding gains for the linear model version (compared to 14% for the whole sample). This finding is expected under the hypothesis that there is indeed reference dependency in respondents' choice behaviour. Notably, we found also significant loss aversion for the subsample that did not perceive the reference value as realistic. It might be the case that respondents adapted to the assigned reference value even though it was (initially) perceived as too high or too low. The finding might however also indicate that some sort of mental accounting was done by some respondents, in a sense that they had a slight propensity to choose the alternative with the more familiar (more frequently appearing) attribute value (the reference value appeared in all six choice tasks while the two levels for losses and for gains appeared generally not more often than twice). Notwithstanding, the degree of loss aversion (estimated at 10%) was considerably lower for this subgroup. Psychologically this might be explained as follows: the negative feeling connected to giving up the "possession" (conative component) was not active for these respondents; they might not have felt (mentally) endowed with the assigned reference level of road safety.

The alternatives in our choice experiment involved deterministic attribute values and are, therefore, not applicable to estimate probability weighting functions as in the "cumulative prospect theory" approach (Tversky and Kahneman 1992). A possible direction of future research could be to design the road safety attribute in such a way that a probability distribution about possible outcomes (annual number of casualties) would be given in the choice experiments. Then, one could assign probabilities to losses and gains and could test (besides loss aversion) whether different weights would be given to small versus large probabilities.

Our discrete choice experimental data were analysed in parameter space, which has been the standard approach for stated choices, but they could alternatively have been analysed in willingness-to-pay (WTP) space, by modelling directly the ratio of the casualty parameter and the cost parameter (Train and Weeks 2005). A difference between willingness to accept (WTA) compensation for road safety deterioration and WTP for safety improvement also follows from prospect theory. Thus, although analysing reference dependence and loss aversion in parameter space, we might assert that our results are consistent with findings from Guria *et al.* (1999) that found considerably higher values of a statistical life when risk was increased than when it was reduced. A meta-analysis of SP studies on the valuation of transport safety by de Blaeij *et al.* (2003), confirmed the WTA-WTP disparity, yielding a 20% higher WTA than WTP for a given risk change. Horowitz and McConnell (2002), assessing WTA/WTP ratios from 45 studies involving a wide range of goods, found highest ratios for health/safety goods, together with (other) public/non-market goods.

Standard economic theory relates SP and WTP/WTA to Hicks compensating and equivalent variations/surpluses for use in cost-benefit analysis, resting on the axioms and assumptions of consumer behaviour. With prospect theory, we are not aware of similar measures that can be derived in a consistent fashion. Thus, we might face two non-optimal alternatives: *i*) sticking to the nice microeconomic theory of consumer behaviour that is consistent with cost-benefit analysis, but seemingly fails in terms of describing people's actual behaviour; and *ii*) selecting another behavioural theory, like prospect theory, that apparently describes behaviour better but lacks the microeconomic foundation linking the analysis of values to cost-benefit analysis. However, if we take a pragmatic approach to this dilemma, what would be the implications from reference-dependent valuation of road safety? If a prospect-theory based modelling of preferences could yield acceptable inputs to cost-benefit analysis, a main policy indication would be to apply separate values for policy that (implicitly) deteriorate road safety versus policy that improves safety. For example, if we can assume that the existing official valuation of a statistical life, that is symmetric for gains and losses (about 30 mill Norwegian kroner, NOU (2012), or about 4 mill Euro), yields an approximately correct average of the values for safety improvements (gains) and deteriorations (losses), it will represent an overestimation of the value of a gain (WTP) and an underestimation of the value of (avoiding) a loss (WTA compensation).

The diminishing sensitivity, a decreasing marginal value for both gains and losses, can be considered, to some extent, as expected from standard economic theory (Rollins and Lyke 1998); but might be exaggerated in SP surveys, the so-called "insensitivity to scope" phenomena (Carson and Mitchell 1993, Hammitt and Graham 1999). The value function of prospect theory implies that the WTP for many small improvements in safety is larger than the WTP for an equivalent single large improvement. This follows from the concavity of the value function in the domain of gains. The implication from this non-linearity of the value function is that estimated unit values, e.g., related to the value of a statistical life, will depend on the size (scope) of the changes presented in SP studies. Thus, the size of the impact of a policy measure, in addition to the direction of the safety change, should be taken into account.

Acknowledgements

The data collection was funded by the Norwegian Public Roads Administration, the Norwegian National Rail Administration, Avinor, the Norwegian Coastal Administration, and the Norwegian Ministry of Transport and Communications, through the project "Valuation study". The main funding of the study was obtained through the strategic research initiative “Road safety”, project 208437/F40, funded by the Research Council of Norway. The Chilean members of the team also gratefully acknowledge the support of the Millennium Institute in Complex Engineering Systems (ICM: P05-004F; FONDECYT: FB016), the Alexander von Humboldt Foundation and the Centre for Sustainable Urban Development, CEDEUS (Conicyt/Fondap/15110020). We also thank Mogens Fosgerau and Katrine Hjorth, for their contributions and comments to various parts of this research. All remaining errors and omissions are entirely our own responsibility.

References

Ariely, D., Simonson, I., 2003. Buying, bidding, playing, or competing? Value assessment and decision dynamics in online auctions, Journal of Consumer Psychology, 13, 113-123.

Bateman, I.J., Munro, A., Rhodes, B., Starmer, C., Sugden, R., 1997. A test of the theory of reference-dependent preferences. Quarterly Journal of Economics 112, 479-505.

Bierlaire, M., 2003. BIOGEME: A free package for the estimation of discrete choice models. Proceedings of the 3rd Swiss Transportation Research Conference, Ascona (http://biogeme.epfl.ch).

Carson, R.T., Louviere, J.L., 2011. A common nomenclature for stated preference elicitation approaches. Environmental and Resource Economics 49, 539-559.

Carson, R.T., Mitchell, R.C., 1993. The issue of scope in contingent valuation studies. American Journal of Agriculture Economics 75, 1263-1267.

Coursey, D.L., Hovis, J.L., Schulze, W.D., 1987. The disparity between willingness to accept and willingness to pay measures of value. Quarterly Journal of Economics 102, 679-690.

De Blaeij, A.T., van Vuuren, D.J., 2003. Risk perception of traffic participants. Accident Analysis and Prevention 35, 167-175.

De Blaeij, A., Florax, R.J.G.M., Rietveld, P., Verhoef, E., 2003. The value of statistical life in road safety: a meta-analysis. Accident Analysis and Prevention 35, 973-986.

De Borger, B., Fosgerau, M., 2008. The trade-off between money and travel time: a test of the theory of reference-dependent preferences. Journal of Urban Economics 64, 101-115.

De Jong, G., Tseng, Y., Kouwenhoven, M., Verhoef, E., Bates, J.J., 2007. The value of travel time and travel time reliability, survey design. Final Report, Significance, Leiden.

Elvik, R., 2008. Risk information in value of safety study. Working paper SM/1962/2008, Institute of Transport Economics (TØI), Oslo.

Graves, P.E., 2009. The simple analytics of the WTA-WTP disparity for public goods. Department of Economics, University of Colorado at Boulder, Boulder, CO.

Guria, J., Jones, W., Jones-Lee, M., Keall, M., Leung, J., Loomes, G., 1999. The values of statistical life and prevention of injuries in New Zealand. Draft report November 1999. Wellington, Land Transport Safety Authority.

Hammitt, J.K., Graham, J.D., 1999. Willingness to pay for health protection: inadequate sensitivity to probability. Journal of Risk and Uncertainty 18, 33-62.

Hjorth, K., Fosgerau, M., 2012. Using prospect theory to investigate the low value of travel time for small time changes. MPRA Paper No. 42246, Munich Personal RePEc Archive (MPRA), Universitätsbibliothek, Ludwig-Maximilians-Universität (LMU) München, Munich.

Hojman, P., Ortúzar, J. de D., Rizzi, L.I., 2005. On the joint valuation of averting fatal and serious injuries in highway accidents. Journal of Safety Research 36, 377-386.

Horowitz, J., McConnell, K., 2002. A review of WTA/WTP studies. Journal of Environmental Economic Management 44, 426-447.

Jones-Lee, M.W., 1974. The value of changes in the probability of death or injury. Journal of Political Economy 82, 835-849.

Jones-Lee, M.W., Loomes, G., Philips, P.R., 1995. Valuing the prevention of non-fatal road injuries: contingent valuation vs. standard gamble. Oxford Economics Papers 47, 676-695.

Kahneman, D., Tversky, A., 1979. Prospect theory: an analysis of decision under risk. Econometrica 47, 263-292.

Lindhjem, H., Navrud, S., Braathen, N.A., Biausque, V., 2011. Valuing mortality risk reductions from environment, transport and health policies: a global meta-analysis of stated preference studies. Risk Analysis 31, 1381-1407.

Masiero, L., Hensher, D. A. 2010. Analyzing loss aversion and diminishing sensitivity in a freight transport stated choice experiment. Ch. 2 in: Masiero, L. Modelling freight transport demand and reference dependent choice behaviour. Ph.D. Thesis, Faculty of Economics, University of Lugano, Switzerland.

Mishan, E.J., 1971. Evaluation of life and limb: a theoretical approach. Journal of Political Economy 79, 687-705.

Morrison, G., 1997. Willingness to pay and willingness to accept: some evidence of an endowment effect. Applied Economics 29, 411-417.

Malul, M., Rosenboim, M., Shavit, T., 2013. So when are you loss averse? Testing the S-shaped function in pricing and allocation tasks. Journal of Economic Psychology, 39, 101-112.

NOU 2012. Cost-benefit analysis. NOU 2012:16, Official Norwegian Reports (NOU), Ministry of Finance, Oslo.

Ortúzar, J. de D., Willumsen, L.G., 2011. Modelling Transport. 4th Edition, John Wiley and Sons, Chichester.

Paraschiv, C., L'Haridon O., 2008. Recherche et Applications en Marketing (English Edition), 23, 67-82.

Ramjerdi, F., Flügel, S., Samstad, H., Killi, M., 2010. Den norske verdsettingsstudien. Tid. Rapport 1053B. Oslo, Transportøkonomisk institutt.

Rizzi, L.I., Ortúzar, J. de D., 2003. Stated preference in the valuation of interurban road safety. Accident Analysis and Prevention 35, 9-22.

Rizzi, L.I., Ortúzar, J. de D., 2006. Estimating the willingness-to-pay for road safety improvements. Transport Reviews 26, 471-485.

Rollins, K., Lyke, A., 1998. The case for diminishing marginal existence values. Journal of Environmental Economics and Management 36, 324-344.

Schelling, T.C., 1968. The life you save may be your own. In: Chase, S. B. (Ed.), Problems in Public Expenditure Analysis, The Brookings Institution, Washington, D. C., 127-176.

Thaler, R.H., 1980. Toward a positive theory of consumer choice. Journal of Economic Behavior and Organization 1, 39-60.

Train, K., Weeks, M., 2005. Discrete choice models in preference space and willingness-to-pay space. In: Alberini, A., Scarpa, R. (Eds.), Applications of Simulation Methods in Environmental and Resource Economics, Kluwer Academic Publishers, Boston/Dordrecht/London (Ch.1, p. 1-16).

Tversky, A., Kahneman. D., 1992. Advances in prospect theory: cumulative representation of uncertainty. Journal of Risk and Uncertainty 5, 297-323.

Veisten, K., Flügel, S., Rizzi, L., Ortúzar, J. de D., Elvik, R., 2013. Valuing casualty risk reductions from estimated baseline risk. Research in Transport Economics 43, 50-61.

Viscusi, W.K., Aldy, J.E., 2003. The value of a statistical life: a critical review of market estimates throughout the world. Journal of Risk and Uncertainty 27, 5-75.

Appendix

Table A1 about here

Table A2 about here

Table A3 about here

Table 1. The casualty attribute; the levels of severe/serious injuries and fatalities, in the stated choice experiment (CE)

Reference trip time interval (min)	Casualty attribute level (relative to base, fatalities and severe/serious injuries) level -2	level -1	level 0	level 1	level 2	Base, fatalities and severe/serious injuries AADT 12000 Car-12	AADT 6000 Car-6	AADT 2000 Car-2
10 - 19	-2	-1	0	1	2	4	3	2
20 - 44	-30%	-15%	0	15%	30%	8	6	5
45 - 74	-30%	-15%	0	15%	30%	14	11	6
75 - 119	-30%	-15%	0	15%	30%	21	16	8
120 - 179	-30%	-15%	0	15%	30%	35	26	14
180 - 239	-30%	-15%	0	15%	30%	49	37	20
240 - 359	-30%	-15%	0	15%	30%	70	53	28
360 - 539	-30%	-15%	0	15%	30%	106	79	42
540 - 1439	-30%	-15%	0	15%	30%	232	174	93
1440 +	-30%	-15%	0	15%	30%	352	264	141

Source: Veisten *et al.* (2013).

Figure 1

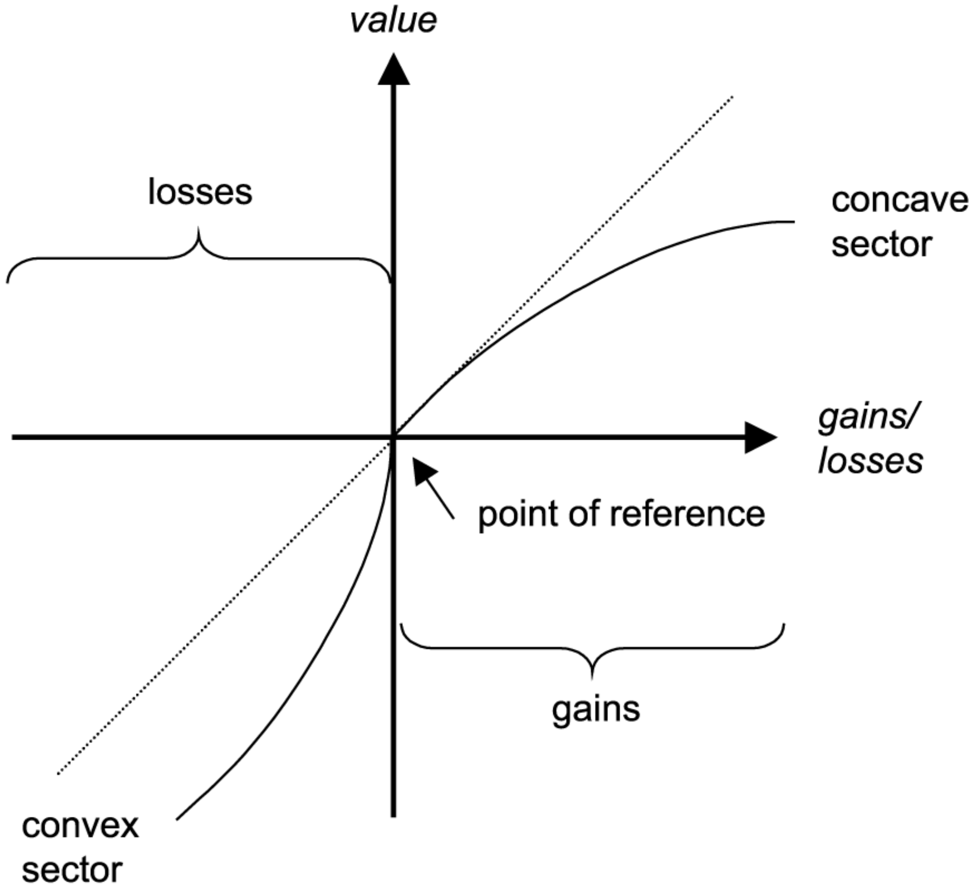

Figure 2

Everything else equal, would you choose travel alternative A or travel alternative B?		
Alternative A	**Alternative B**	
Average travel time per trip: *15* min (approximately *130* hours per year) Cost per trip: *30* NOK (approximately *15,600* NOK per year) Seriously/severely injured and fatalities per year: *3*	Average travel time per trip: *17* min (approximately 147 hours per year) Cost per trip: *34,50* NOK (approximately *17,940* NOK per year) Seriously/severely injured and fatalities per year: *1*	do not know

Figure 3

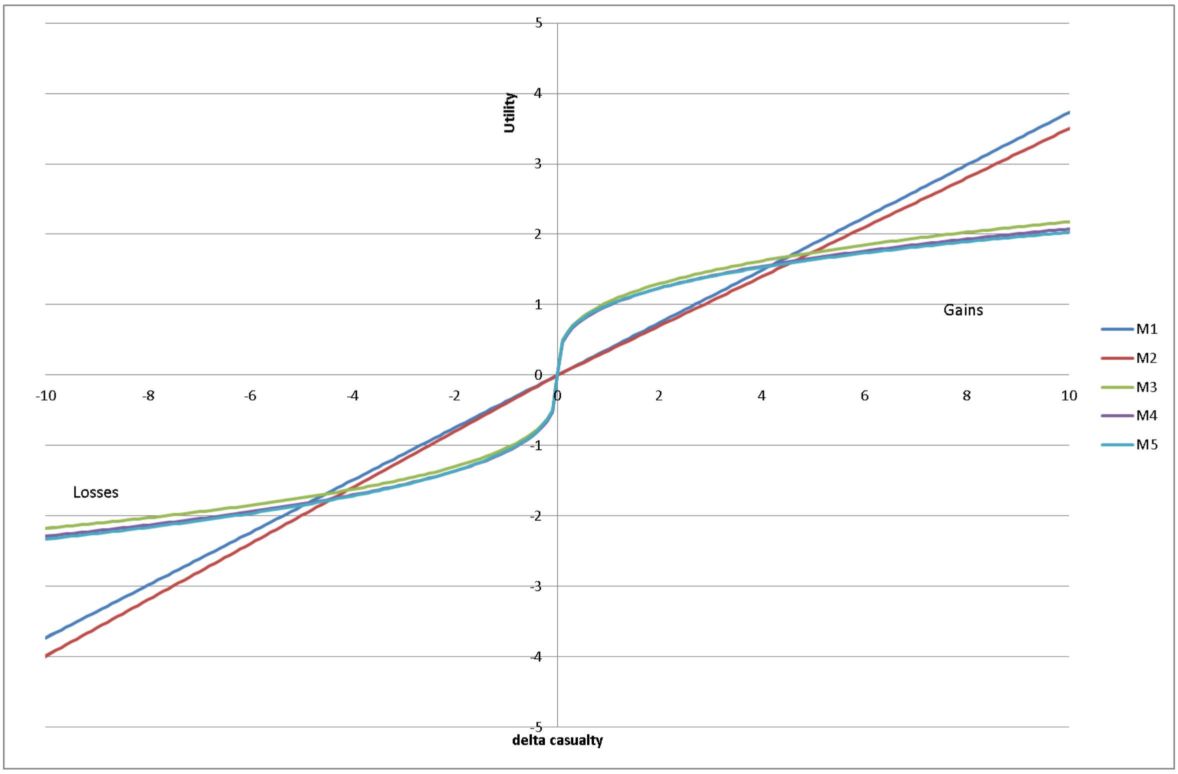

Table 2. Characteristics of chosen alternatives

Attributes	Attribute levels	Frequency	Percent
Casualty	Reference casualty (versus a more dangerous route)	5088	38.2
	Reference casualty (versus a safer route)	1718	12.9
	Loss casualty	1551	11.6
	Gain casualty	4977	37.3
	Total	13334	100
Time	Reference time (versus a slower route)	3139	23.5
	Reference time (versus a faster route)	3986	29.9
	Loss time	3513	26.3
	Gain time	2696	20.2
	Total	13334	100
Cost	Reference cost (versus a more expensive route)	3230	24.2
	Reference cost (versus a cheaper route)	3220	24.1
	Loss cost	3411	25.6
	Gain cost	3473	26.0
	Total	13334	100

Table 3. Multinomial logit modelling results, M1-M5

All choice types; all respondents	M1 (linear, symmetric)		M2 (linear, asymmetric)		M3 (non-linear, symmetric)		M4 (non-linear, asymmetric)		M5 (non-linear, asymmetric)	
Parameter Name	Value	robust t-test	value	robust t-test	value	robust t-test	value	robust t-test	value	robust t-test
ASC_left	-0.0064	0.73	-0.0066	0.73	-0.0061	-0.28	-0.00634	0.30	-0.0064	0.77
B_cost	-0.0151	-8.58	-0.0152	-8.66	-0.0105	-7.41	-0.0105	-7.42	-0.0105	-7.42
B_time	-0.0466	-11.76	-0.0469	-11.79	-0.0320	-9.82	-0.0321	-9.84	-0.0322	-9.84
B_cas_loss	-0.373	-15.15	-0.399	-14.52	-1.04	-28.14	-1.09	-26.41	-1.08	-24.36
B_cas_gain	0.373	15.15	0.350	13.40	1.04	-28.14	0.989	25.59	1.00	22.69
Lambda_cas_loss	1	--fixed--	1	--fixed--	0.321	10.37	0.322	10.44	0.334	9.86
Lambda_cas_gain	1	--fixed--	1	--fixed--	0.321	10.37	0.322	10.44	0.307	7.91
No of parameters [a]		4		5		5		6		7
No of observation		13334		13334		13334		13334		13334
No of respondents		2290		2290		2290		2290		2290
Null LL		-9242.425		-9242.425		-9242.425		-9242.425		-9242.425
Final LL		-7841.208		-7834.813		-7137.915		-7132.773		-7132.469
rho-sq		0.152		0.152		0.228		0.228		0.228
Adjusted rho-sq		0.151		0.152		0.227		0.228		0.228
LR Test against M1				12.8		1406.6				
LR Test against M3								10.3		10.9
LR Test against M4										0.6

[a] Note the restriction B_cas_loss = -B_cas_gain in model M1 and M3, and the restriction Lambda_cas_loss=Lambda_cas_gain in model M3 and M4.

Table 4. Degree of loss aversion for subgroups with different perception of the realism of the assigned casualty risk on their reference trip

%-increase of weights for losses (compared to gains)	All respondents (N=2290)	Those who perceive reference value as realistic (N=810)	Those who perceive reference value as unrealistic (N=1480)
Linear model (M2)	14.0%	19.2%	10.4%
Non-linear model (M4)	10.2%	13.7%	8.4%

Table A1. The 24 choice types (for choices between A and B)[a]

Attributes	Route A	Route B	Route A	Route B	Route A	Route B	Route A	Route B
	Choices 1-6		Choices 7-12		Choices 13-18		Choices 19-24	
Time	Ref	Loss	Loss	Ref	Ref	Loss	Ref	Gain
Cost	Ref	Loss	Ref	Loss	Loss	Ref	Ref	Gain
Casualty	Ref	Gain	Ref	Gain	Ref	Gain	Gain	Ref
Time	Ref	Loss	Loss	Ref	Ref	Loss	Ref	Loss
Cost	Ref	Gain	Ref	Gain	Loss	Ref	Ref	Gain
Casualty	Ref	Loss	Ref	Loss	Ref	Loss	Loss	Ref
Time	Ref	Gain	Loss	Ref	Ref	Gain	Ref	Gain
Cost	Ref	Loss	Ref	Loss	Loss	Ref	Ref	Loss
Casualty	Ref	Loss	Ref	Loss	Ref	Loss	Loss	Ref
Time	Ref	Loss	Gain	Ref	Ref	Loss	Ref	Loss
Cost	Ref	Gain	Ref	Gain	Gain	Ref	Ref	Gain
Casualty	Ref	Gain	Ref	Gain	Ref	Gain	Gain	Ref
Time	Ref	Gain	Gain	Ref	Ref	Gain	Ref	Gain
Cost	Ref	Loss	Ref	Loss	Gain	Ref	Ref	Loss
Casualty	Ref	Gain	Ref	Gain	Ref	Gain	Gain	Loss
Time	Ref	Gain	Gain	Ref	Ref	Gain	Ref	Loss
Cost	Ref	Gain	Ref	Gain	Gain	Ref	Ref	Loss
Casualty	Ref	Loss	Ref	Loss	Ref	Loss	Loss	Ref

[a] "Ref" means "reference level" (i.e. the attribute value is as reported or inferred from the reference trip)

Table A2. Multinomial Logit modelling results, only respondents that perceive the derived reference levels for causalities as realistic

	M1 (linear, symmetric)		M2 (linear, asymmetric)		M3 (non-linear, symmetric)		M4 (non-linear, asymmetric)		M5 (non-linear, asymmetric)	
Parameter Name	Value	robust t-test	value	robust t-test	value	robust t-test	value	robust t-test	value	robust t-test
ASC_left	-0.0150	-0.46	-0.0146	-0.45	-0.0106	-0.29	-0.0103	-0.28	-0.0103	-0.28
B_cost	-0.0106	-3.67	-0.0106	-3.67	-0.0070	-3.65	-0.00691	-3.66	-0.00689	-3.63
B_time	-0.0371	-6.40	-0.0372	-6.45	-0.0262	-5.28	-0.0264	-5.32	-0.0265	-5.34
B_cas_loss	-0.340	-8.97	-0.372	-8.74	-1.09	-16.91	-1.16	-16.07	-1.14	-14.30
B_cas_gain	0.340	-8.97	0.312	8.14	1.09	16.91	1.02	15.15	1.04	13.81
Lambda_cas_loss	1	-fixed-	1	--fixed--	0.279	5.71	0.281	5.76	0.293	5.41
Lambda_cas_gain	1	-fixed-	1	--fixed--	0.279	5.71	0.281	5.76	0.266	4.42
No of parameters [a]		4		5		5		6		7
No of observation		4745		4745		4745		4745		4745

No of respondents	810	810	810	810	810
Null LL	-3288.983	-3288.983	-3288.983	-3288.983	-3288.983
Final LL	-2764.727	-2760.863	-2479.801	2476.531	2476.413
rho-sq	0.159	0.161	0.246	0.247	0.247
Adjusted rho-sq	0.158	0.159	0.245	0.245	0.245
LR Test against M1		7.7	562.1		
LR Test against M3				6.5	6.8
LR Test against M4					0.2

[a] Note the restriction B_cas_loss = -B_cas_gain in model M1 and M3, and the restriction Lambda_cas_loss=Lambda_cas_gain in model M3 and M4.

Table A3. Multinomial Logit modelling results, only respondents that perceive the derived reference levels for causalities as unrealistic

	M1 (linear, symmetric)		M2 (linear, asymmetric)		M3 (non-linear, symmetric)		M4 (non-linear, asymmetric)		M5 (non-linear, asymmetric)	
Parameter Name	Value	robust t-test	value	robust t-test	value	robust t-test	value	robust t-test	value	robust t-test
ASC_left	-0.00182	-0.08	-0.0021	-0.09	-0.0041	-0.16	-0.0046	-0.17	-0.0046	-0.17
B_cost	-0.0189	-9.41	-0.0189	-9.43	-0.0138	-8.46	-0.0138	-8.50	-0.0138	-8.53
B_time	-0.0537	-10.07	-0.0539	-10.08	-0.0367	-8.50	-0.0368	-8.50	-0.0368	-8.49
B_cas_loss	-0.400	-12.64	-0.421	-11.78	-1.02	-22.57	-1.06	-20.98	-1.04	-19.75
B_cas_gain	0.400	12.64	0.381	11.06	1.02	22.57	0.977	20.62	0.996	17.96
Lambda_cas_loss	1	-fixed-	1	--fixed--	0.353	9.32	0.353	9.40	0.370	8.80
Lambda_cas_gain	1	-fixed-	1	--fixed--	0.353	9.32	0.353	9.40	0.334	8.80
No of parameters [a]		4		5		5		6		7
No of observation		8589		8589		8589		8589		8589
No of respondents		1480		1480		1480		1480		1480
Null LL		-5953.441		-5953.441		-5953.441		-5953.441		-5953.441
Final LL		-5056.286		-5053.677		-4636.711		-4634.264		-4633.919
rho-sq		0.151		0.151		0.221		0.222		0.222
Adjusted rho-sq		0.150		0.150		0.220		0.221		0.220
LR Test against M1				5.2		839.2				
LR Test against M3								4.9		5.6
LR Test against M4										0.7

[a] Note the restriction B_cas_loss = -B_cas_gain in model M1 and M3, and the restriction Lambda_cas_loss=Lambda_cas_gain in model M3 and M4.