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Valuing casualty risk reductions from estimated baseline risk

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Abstract

Stated choice studies have been applied regularly to the valuation of time savings and other attributes of travelling as perceived by individuals. In such experiments, respondents often provide reference levels for the attributes and the hypothetical choices presented to them are pivoted around actual behaviour. However, most individuals are not able to provide reference levels for the number of casualties on the road they travel. Thus, if valuation of this important element is attempted, it is the researcher who must provide casualty risk reference levels to the respondents. Some studies have applied route choice experiments including a safety attribute but the majority have been limited to only one particular road section with a common baseline risk for all respondents.

This study discusses the setting up and results of a more generalized route choice experiment including a safety attribute. Respondents provided, at an initial stage, their travel times and costs related to a recent trip by car. Then, expected numbers of casualties for different trip lengths were calculated based on travel distances and traffic densities. So, the calculated number of severe injuries and fatalities (casualties) per year, on the road section the respondent had travelled, entered as a third attribute in the choices, together with the reported travel times and costs. Route choice was analysed using multinomial logit and mixed logit models. From the latter models we obtained point estimates for the value of the statistical life ranging from € 7.3 million to € 19.1 million.

Keywords: fatalities; injuries; mixed logit; stated choice; value of statistical life; willingness to pay
JEL: C25, C83, C93, R41

1. Introduction

The worst possible outcomes of a road accident are dying or becoming severely injured. Casualty risks are, to some extent, influenced by road users' own protective behaviour, but are also determined, to a large extent, by road design and the quality of enforcement of traffic rules (Elvik et al., 2009). Public road administrators seek valuations of casualty risk changes for the assessment of road safety impacts in cost-benefit analyses, together with time-use changes and other project impacts (see for example Gaudry et al., 1989; Hensher, 1994; McFadden, 1974; Sillano and Ortúzar, 2005; Small and Verhoef, 2007). Casualty risk changes have been valued using various methodologies based on revealed preferences (RP) from market data or on stated preferences from specially designed surveys. Among stated preference techniques, the contingent valuation method dominated in the last century (De Blaeij et al., 2003), but stated choice (SC) has emerged as the preferred alternative during the last decade (Hensher et al., 2009; Hojman et al., 2005; Rizzi and Ortúzar, 2003; 2006a).

Most SC studies have been cast as route choices, that is, hypothetical choices between two routes with different travel times, costs, number of fatalities and number of severely injured victims. If the hypothetical choices are pivoted on actual travel behaviour, this provides a realistic context for the trade-off between casualties and other trip attributes (Hojman et al., 2005). In preliminary RP surveys, individuals can provide reference levels for attributes like travel times and costs, thus helping the analyst to pivoting the choice experiment on actual behaviour (Bradley and Daly, 1994; Caussade et al., 2005; Hensher, 2004; Louviere, 2006). Although road safety is also perceived by individuals, as revealed for example by speed adaptations to different traffic conditions and by the level of care in private transport (car driving, cycling, and walking), respondents are usually not able to provide reference levels for casualties (fatalities/injuries) on the roads they travel. For this reason, if this important element is to be valued, the survey designer must provide reference levels to the respondents.

In the still relatively small number of route choice experiments for valuing risk reported in the literature, pivoting from actual behaviour has been enabled mostly by limiting the study to one particular road section. For example, Rizzi and Ortúzar (2003) and Hojman et al. (2005) sampled groups of drivers that travelled regularly between two specified cities, and the hypothetical travel times, costs (tolls), and casualty numbers varied around the real figures for that particular intercity route. Studies who have presented more generalized settings for the hypothetical choices have not pivoted the experiment to an actually driven section by the respondents (De Blaeij et al. 2002; Iragüen and Ortúzar, 2004; Brabander 2006; Hensher et al., 2009).

In this study we build further on the internet approach introduced by Iragüen and Ortúzar (2004) and also used by Hojman et al. (2005), by designing a choice experiment for the valuation of risk reductions that can be pivoted to the actual travel behaviour of a Norwegian sample of car drivers, encompassing both urban and inter-urban settings. We combine fatalities and injuries, as done by Hojman et al. (2005), but our study takes a step further in generalization, compared to Hensher et al. (2009), by customizing/pivoting to any type of reference trip of more than 10 min duration.

Respondents provided, at an initial stage, their travel times and costs related to a recent trip by car yielding reference levels for these attributes. A combined annual number of fatalities and serious injuries on the reported road section was calculated by estimating the distance travelled using average speeds and adjusting by the annual average daily traffic estimates for the corresponding road section. The SC experiment was carried out as a self-administered internet survey among a fairly large sample of Norwegian drivers. To our knowledge, this is the first study for a countrywide sample of car drivers that pivots hypothetical choices involving risk reductions from actual travel behaviour.

The remainder of the paper is organised as follows. The next section describes the theory and methodologies underlying choice experiments and the associated modelling issues in road safety. The third section describes the internet-based survey and the applied choice experiment design. The fourth section provides the resulting model estimates that are discussed in the last section.

2. The value of fatal and serious injury risks reductions

In this section we describe the microeconomic foundations of risk reduction valuations in a road safety context and show how this theory may be operationalized using discrete choice models. We also show how to deal with risks when they are tiny, as in our context of road safety in Norway. Instead of valuing separately fatal risk reductions and serious injury risk reductions, we value reductions in casualty risks (that encompasses both fatalities and serious injuries) and from this value we derive the values of fatal risk and serious injury risk reductions. We then proceed to briefly describe alternative questionnaire methods designed to elicit people's valuation of risk reductions, giving special emphasis to stated choice experiments.

2.1 Modelling the valuation of risk reduction

Assume that a trip, on a given route, provides traveller j a level of dissatisfaction given by a deterministic indirect utility function $V_j = V(r, c, t)$, where r stands for the risk of becoming a fatal (or seriously injured) victim, c is the cost of travelling and t is the travel time on the route (there could be more attributes, of course). Jones-Lee (1974) formally defined the value of a statistical life (*VSL*) as the value of avoiding one expected death per unit of time. This corresponds to the population (or sample) average of the marginal rate of substitution between income and risk of death for *j* (MRS_j), plus a covariance term that accounts for possible correlation between the MRS_j and the reduced risk (δr_j):

$$MRS_j = \frac{\partial V_j / \partial r}{\partial V_j / \partial c} \tag{1}$$

$$VSL = \frac{1}{N}\sum_{j=1}^{N} MRS_j + N\operatorname{cov}\left(MRS_j, \left|\delta r_j\right|\right) \tag{2}$$

The value of a statistical serious injury (*VSSI*) may be defined analogously. In empirical work it is typically assumed that the second term in equation (2) is zero; this assumption would be correct if, for example, δr were the same for every individual. Then, equation (2) would simplify to equation (3) , and to estimate the *VSL* it would be sufficient to have a good estimate of the *MRS* (equation (1)).

$$VSL = \frac{1}{N}\sum_{j=1}^{N} MRS_j \tag{3}$$

The *MRS* can be interpreted as an implicit value for the own life, and we can see from equation (3) that averaging it over all individuals travelling on the route yields the *VSL*. The *MRS* clearly depends on personal risk perceptions according to the functional form of V_j. The same analysis can be carried out in terms of fatalities *f* (or serious injuries) instead of risk *r* (where $r = f/N$). However, in this case the *VSL* should be derived differently (but obviously yielding the same value):

$$VSL = \sum_{j=1}^{N} \frac{\partial V_j / \partial f}{\partial V_j / \partial c}\bigg|_{V=\bar{V}} = \sum_{j=1}^{N} SVF_j \tag{4}$$

where *SVF* stands for the subjective value of fatalities (or serious injury) reductions and can be interpreted as a Lindahl price or Lindahl tax (Varian, 1992, Ch 23).

Equation (4) embodies the definition of community willingness-to-pay (*WTP*) for a public good (i.e. road safety in this case), as the sum of individual marginal rates of substitution between income and number of fatalities (or serious injuries) and we avoid making any assumption about δr. If we think in terms of a hypothetical tolled route the operators of which were able to extract the full consumer's (compensatory) surplus, the *SVFj* would be the maximum amount of money that can be extracted from person *j* following the safety improvement, such that s/he is as well-off as before the improvement.

2.2 Making the model operational

The above model can be made operational within a discrete choice framework where the indirect deterministic utility of each available alternative *i* for person *j* is given by:

$$V_{ij} = \alpha \cdot f_{ij} + \eta \cdot SI_{ij} + \beta \cdot c_{ij} + \gamma \cdot t_{ij}$$

where the letter *f*, stands for number of fatal crashes and *SI* for serious injuries; as can be seen, all attributes enter utility in an additive way. As the modeller does not possess (or is incapable of observing) all the relevant information, he must assume randomness in the utility function. Random utility, U_{ij}, is simply expressed as the sum of two terms: the deterministic utility, V_{ij}, and a random component, ε_{ij}:

$$U_{ij} = V_{ij} + \varepsilon_{ij}$$

and it is assumed that each alternative has a probability of being chosen given by the probability that U_{ij} is the highest random utility for each individual *j*. The *SVF* is equal to α/β for fatalities and η/β for serious injuries (Hojman et al., 2005). Also, γ/β gives the subjective value of travel time savings (Gaudry et al., 1989; Hensher et al., 2005).

If the random terms distribute identically and independently Gumbel (i.e. Extreme Value Type I) among alternatives and across individuals, the popular multinomial logit (MNL) model is obtained and the probability that individual *j* chooses option *i* is given by:

$$P_{ij} = \frac{\exp\left(\lambda \cdot V_{ij}\right)}{\sum_{k=1,2} \exp\left(\lambda \cdot V_{kj}\right)} \qquad (5)$$

where λ is a scale factor inversely related to the unknown standard deviation of ε; in practice λ has to be normalised as it is not identifiable (Ortúzar and Willumsen, 2011, Ch 8). This model is not strictly appropriate when we have repeated observations per respondent, as in our case, as it assumes these to be independent. In such cases, the recommended approach is to estimate a mixed logit (ML) model, which is the current state-of-practice (Train, 2009). We will provide more details about this in section 2.4.

2.3 Estimating values of statistical lives and serious injuries from combined numbers

Equation (4), in section 2.1, provides the formulae for the valuation of a statistical life or a statistical serious injury, when measuring fatalities (*f*) or serious injuries (*SI*) instead of risks (*r*). In the case of working with combined numbers of fatalities and serious injuries, defined as "casualties", we have to rewrite the indirect deterministic utility as follows:

$$V_{ij} = \theta \cdot \mathrm{CAS}_{ij} + \beta \cdot c_{ij} + \gamma \cdot t_{ij}$$

where CAS = $f + SI$, is the sum of fatalities (*f*) and serious injuries (*SI*). Assuming a linear-in-parameters utility function, the subjective value of a casualty reduction (WTP_{CAS}) is given by ϑ/β, the marginal rate of substitution between casualties and cost. Dividing this *WTP* measure by the (individual) risk change (δr_{CAS}) yields an estimate of the value of a statistical casualty (*VSC*) as $WTP_{CAS}/\delta r_{\mathrm{CAS}}$. As indicated above, the *VSC* can also be calculated as the sum of individual valuations for an aggregate risk change equal to one casualty reduction per year.

An individual driver's casualty risk per trip on a route of a given length is given by the number of casualties on that route per reference period (say a year), divided by the average annual daily traffic (*AADT*) times 365; where *AADT* is equal to the average number of daily vehicle km (on the route) divided by the length of the route (trip km), that is: r_{CAS} = $\mathrm{casualties}_{\mathrm{yr}}/(AADT \cdot 365)$. The risk change equivalent to *one* casualty reduction is then:

$$\delta r_{\mathrm{CAS}} = \frac{\mathrm{casualties}_{\mathrm{yr}}^{\mathrm{before}} - \mathrm{casualties}_{\mathrm{yr}}^{\mathrm{after}}}{AADT \cdot 365} = \frac{1}{AADT \cdot 365}$$

With this, the *VSC* is given as[1]:

$$VSC = \frac{WTP_{CAS}}{\delta r_{\mathrm{CAS}}} = \frac{WTP_{CAS}}{\dfrac{1}{AADT \cdot 365}} = WTP_{CAS} \cdot \left(AADT \cdot 365 \right) \qquad (6)$$

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[1] Note that compared to equations (11) and (12) in Hensher *et al*. (2009, p. 696), we do not divide by the number of casualties over the trip length since the valuation from the choice experiment is given for *one* casualty change. Our notation is slightly different from that applied by Hensher *et al*. (2009).

The calculation of VSC can be based on different levels of aggregation for WTP_{CAS} and δr_{CAS}. Hensher et al. (2009) present values of statistical lives and injuries for rural and urban communities in Australia, while Tofte (2006) gave separate VSL estimates according to trip purpose (i.e. commuting vs. leisure). We base our main calculations on sample average WTP_{CAS}, sample average risk change and sample average $AADT$.

To derive VSL from the VSC, based on WTP_{CAS} for combined reductions of fatalities and serious injuries, we employ a so-called *death-risk equivalent* (DRE_{SI}), which equals the relative value of preventing a serious injury with respect to preventing a fatality: $DRE_{SI} = VSSI/VSL$ (Jones-Lee et al., 1995; Viscusi et al., 1991). Clearly, the DRE_{SI} will depend on the specification of 'serious' or 'severe' injuries, a term which has been applied interchangeably in the transport literature (Hultkrantz et al., 2006; Svensson, 2009).

The Oxford dictionary (http://oxforddictionaries.com/definition/serious) defines 'severe' as something "very great or intense of something bad or undesirable"; this is stronger than 'serious', which is defined as "something not slight or negligible". In the health sector and literature, the *abbreviated injury scale* (AIS) has been applied, which indicates the severity of the most life threatening injuries in one or several body parts; this scale goes from level 1 'minor injury' to level 6 'un-survivable'/'fatality' (Miller, 1993); in particular, level 3 is 'serious injury' and level 4 is 'severe injury' (while 2 is 'moderate injury' and 5 is 'critical injury'). So, injury severities potentially classified as either levels 4 and 5, have probably been included in the specified serious (or severe) injuries applied in accident valuation in transport. Beattie et al. (1998) differentiated between 'serious' with temporary disability and 'serious' with permanent disability, a differentiation that potentially could be related to AIS = 4 vs. 5, but, as indicated, the AIS focuses on the immediate impact rather than the long term effect.

We could expect the following order $DRE_{AIS=4} \geq DRE_{SI} \geq DRE_{AIS=3}$ in terms of valuations. Miller (1993, Table 5, p. 602) presents AIS-based statistical injury valuations that would yield the following estimates: $DRE_{AIS=3} \approx 0.15$ and $DRE_{AIS=4} \approx 0.38$, whereby the first is equal to or below the Swedish estimate for 'serious injuries' and the latter unequivocally higher (Svensson, 2009), but slightly below the Chilean estimate for 'severe injuries' (Hojman et al., 2005). In our application, when we apply the term 'serious injury', we cover both 'serious' and 'severe' cases if nothing else is specified. Jones-Lee et al. (1995) estimated values of DRE_{SI} between 0.1 and 0.15, while Swedish studies from the last decade have estimated DRE_{SI} between 0.15 and 0.2, the former being the official Swedish value (Svensson, 2009). Hojman et al. (2005) propose a DRE_{SI} as high as 0.47, but in their case SI referred to *severe* injuries. Based on this we will apply *DRE* equal to 0.2 in our main calculations, but then show the impact on VSL when *DRE* is increased or decreased.

Thus to estimate *VSL* from *VSC* we need to apply the following formula:

$$VSL = \frac{VSC}{DRE_{SI} \cdot delta\,si + delta\ f} \qquad (7)$$

where *delta si* and *delta f* represent, respectively, the actual shares of serious injuries and fatalities in car accidents involving fatalities and/or serious injuries (Hultkrantz et al., 2006, p. 163). Relative shares of 0.8 serious injuries and 0.2 fatalities follow from the official figures from 1998 to 2005, when serious injuries are upward adjusted for underreporting (Elvik 2008). Actually, Hultkrantz et al. (2006) and Svensson (2009) write this formula with WTP_{CAS} instead of *VSC*. Then for *delta si* we would multiply 0.8 by the risk change representing one less casualty, 1/(AADT·365), and for *delta f* we would multiply 0.2 by 1/(AADT·365). This yields the same *VSL* estimate as we get in our alternative formula with *VSC*.

2.4 Stated preference method approaches to the valuation of risk reduction

Stated preference (SP) approaches are based on the idea that values for goods/attributes without (specific) market prices can be elicited from specialised surveys (Bateman et al., 2002; Bateman and Willis, 1999). In particular, contingent valuation (CV) has been a very popular method for the valuation of risk changes (Jones-Lee et al., 1985; Krupnick et al., 2002). In these original studies, people were confronted with situations expressing risks as tiny probabilities and needing a trade-off between risk and money to arrive at a monetary value. For a typical presentation of a CV survey of a road safety measure, we take an example from Hultkrantz et al. (2006):

"[consider] a road traffic safety programme that will reduce the number of fatal and severe injuries within the urban area of Örebro with 16 persons killed or severely injured within this urban area during one year. The reduction applies to pedestrians, bicyclists and car users. Outside the urban area the number of road accidents will be unaffected[2]*."*

Then respondents were asked whether they would be willing to pay an annual fee at a predetermined bid level. This kind of simulated context may not bear upon actual choices on route selection where individuals have to consider a bundle of attributes describing each alternative (i.e. travel time, toll and safety in a route choice context). Other techniques that have been used, similar

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[2] The population of Örebro at the time of the survey was approximately 97,000 inhabitants.

in spirit, are *standard gamble* or the *chain method* (Beattie et al., 1998; Carthy et al., 1998; Jones Lee et al., 1993; Viscusi et al., 1991). The latter method poses a risk - risk trade - off (e.g. trading off the risk of dying on the road with the risk of having a chronic bronchitis) and a risk - money trade - off. The standard gamble approach asks respondents to assume that they suffered a road accident and became seriously injured. Then they are offered a medical treatment that, if successful, will permit the patient to recover her health status previous to the accident, but if it is not successful, death will follow. The standard gamble method also needs to be supplemented with a risk - money trade-off to produce a monetary value.

The CV approach, however, has been heavily criticized by specialists in human behaviour (Fischhoff, 1991; 1997) and by economists (Diamond and Haussman, 1994; Hausman, 1993). Rizzi and Ortúzar (2003) proposed a different approach based on stated choice (SC) techniques. A SC survey asks individuals to choose among different alternatives, the attribute levels of which vary according to a statistical design aimed at maximizing the precision of the estimates; as such, SC allows the analyst to mimic actual choices with a high degree of realism and for this reason many experts believe that it is an appropriate elicitation method for the valuation of intangibles (McFadden, 1998; Louviere et al., 2000). The approach was also applied later by de Blaeij et al. (2002), Iragüen and Ortúzar (2004), Hensher et al. (2009) and Hojman et al. (2005).

A fundamental challenge in SP (both CV and SC) surveys is the communication and comprehension of the risk change (Jones-Lee et al., 1985; Hammitt, 2000; Hojman et al., 2005). Rizzi and Ortúzar (2003) proposed the use of fatality numbers in a designated area (e.g. annually on a road section) instead of presenting fatality risk measures, like 5/100,000. By using fatalities, the probability of risk from the respondents' standpoint is subjective. Valuing changes in fatality or injury numbers, instead of risk changes, is of course also possible in CV[3].

In a SC survey, each respondent has to make choices in several choice scenarios, providing multiple responses. This is an advantage in the sense of yielding more information, but it comes at the price of increasing the complexity of modelling as there are repeated

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[3] The implicit estimation of fatality risk change valuations from the valuation of changes in fatality numbers, is somewhat related to the issue of behavioural assumptions in RP methods, like hedonic pricing (Viscusi and Aldy, 2003), where it is normally assumed that people perceive the risk correctly when deciding on more or less risky employment or purchase of safety equipment to cars (Andersson, 2005; Blomquist *et al*., 1996; Riera *et al*., 2006). In CV studies, visual aids have been applied in an attempt to facilitate the comprehension of the risk change, including risk ladder scales showing various activity/health related risks, grids with squares, and arrays of dots (Corso *et al*., 2001; Krupnick *et al*., 2002; Ortúzar *et al.,* 2000). For a discussion of pros and cons of SC versus CV in risk valuation, see e.g. Bhattacharya (2006) and Rizzi and Ortúzar (2003; 2006a).

responses from the same individual. To address this issue, we perform two types of simple analyses as suggested by Daly and Hess (2010) in our current study. First, we will consider MNL models based on equation (5), but robust t-test will be computed that take into account the fact that each respondent provides several responses. Second, we will estimate mixed logit (ML) models (Hensher and Greene, 2003; Train, 2009) that incorporate a simple error structure to account for the correlation among choices from the same individuals; for each individual, an independent and identically distributed (iid) Normal error term is added to the utility of each alternative, across all her choices. This error term generates correlation among the utilities (and probabilities) of each alternative across all choices. If *j* indexes individuals; *i*, alternatives and *l*, responses from the individual, the indirect stochastic utility for alternative *i*, individual *j*, and choice *l* may be written as:

$$U_{jil} = \theta \cdot CAS_{jil} + \beta \cdot c_{jil} + \gamma \cdot t_{jil} + \tau_{ji} + \varepsilon_{jil} \tag{8}$$

where τ is an iid Normal error term and ε is the traditional iid Gumbel error term. The first error component carries only two indices (*j* and *i*), thus correlating the utility of alternative *i* for individual *j* across all her choices. The likelihood of the observed sequence of choices for individual *j* is given by the following equation (where the subscript *j* is eliminated for notational convenience):

$$\int \prod_{l} \prod_{i} \left(\frac{\exp\left(\theta \cdot CAS_{il} + \beta \cdot c_{il} + \gamma \cdot t_{il} + \tau_i\right)}{\sum_{i'} \exp\left(\theta \cdot CAS_{i'l} + \beta \cdot c_{i'l} + \gamma \cdot t_{i'l} + \tau_{i'}\right)} \right)^{g_{il}} \prod_{i} f\left(\tau_i\right) d\left(\tau_i\right)$$

where $f\left(\tau_i\right)$ is a Normal density function with zero mean and variance to be estimated, and g_{il} is a dummy variable that takes the value of one if alternative *i* is chosen in choice scenario *l*; otherwise it is zero.

3. Survey Design

In our survey, the safety attribute is the number of casualties due to car accidents. It was presented as the annual expected number of fatalities and serious injuries in a road trip of a certain length with a certain travel density. This produced the same attributes used by Hojman et al. (2005) in their internet survey, but our study differs in the use of individually differentiated reference levels of casualties for the particular recent car trip.

From the reported travel times, using the known average speed, which is 45 km/hour on Norwegian roads (Denstadli et al., 2006), we were able to estimate the distances travelled by respondents. The casualty number was given in three classes per distance level, based on the assumed travel density estimated for the route. The reference values were thus determined from the base travel time, assuming a relationship between travel time and trip length, and applying an annual average daily traffic (*AADT*) approximation for travel density. The basis for these calculations was the actual casualty numbers in Norway over the last decade (Elvik, 2008). Thus, respondents did not need to provide a reference value for casualties. Generating a correct *AADT* value for the specific road used by each respondent would have implied a rather tedious programming (e.g. linking a road data base with *AADT* to the internet-based questionnaire). We opted for a simpler approach, where initial *AADT* levels were based on the urbanization level at the respondents' place of residence, and adjusted by the respondents' own assessment of traffic density.

One particular issue of our route choice experiment is that we did not know which roads the car occupants had actually used. We therefore chose to customize the risk level information by assigning respondents to three different types of traffic density environments (Elvik, 2008). These three *AADT* classes were pre-assigned to respondents based on information about their municipality: *i*) Respondents living in cities with more than 20,000 inhabitants (19 cities with a total population of 2.15 million) were pre-assigned to trips on roads with an *AADT* of approximately 12,000; *ii*) Respondents living in built-up areas with a population of 200-20,000 (898 communities with a total population of 1.5 million) were pre-assigned to trips on roads with an *AADT* of approximately 6,000; *iii*) Respondents living in rural areas (a total of 1.1 million people) were pre-assigned to trips on roads with an *AADT* of approximately 2,000 (Elvik, 2008). *AADT* and trip length are important covariates for casualty risk, but several other route characteristics also may have an impact on risk (Elvik et al., 2009). In Hensher et al. (2009), for example, the variation in casualty risk between routes was represented at either an urban or a non-urban setting, and risk was calculated from regional accident data over a five year period. In our case, casualty risk was already calculated into the reference levels, differentiated with respect to the trip length estimate and the *AADT* estimate of the actual route.

Table 1 shows the procedure for estimating base levels of casualties (serious injuries and fatalities) on road sections of different length and traffic density levels. The conversion from reference trip time (mid points) to trip length means that in 7 min a trip by car will cover 5.25 km [(7/60)·45]; a trip lasting 60 min will cover 45 km, and so on.

For the estimation of fatality/injury risk per trip length it was implicitly assumed that the roads used would have an injury/fatality risk close to the mean value for all public roads;

we also assumed that the shortest trips were mostly made in urban areas and the longest trips mostly made on rural roads with 0.4 and 0.3 injured road users/million vehicle km of travel respectively. The proportion of all injuries that are serious or fatal is higher in rural areas (0.17) than in urban areas (0.11).

Table 1. Base levels of safety attribute (fatalities and serious injuries) in choice experiments, derived from car drivers' actual trip lengths (in time)

Base time (min)	Mean time (min)	Km	Mean annual expected number of casualties*					
			Official statistics			Adjustment for underreporting		
			AADT 12,000	AADT 6,000	AADT 2,000	AADT 12,000	AADT 6,000	AADT 2,000
10 – 19	15	11.25	2.46	1.85	0.99	4	3	2
20 – 44	32	24	5.26	3.94	2.10	8	6	5
45 – 74	60	45	9.86	7.39	3.94	14	11	6
75 – 119	90	67.5	14.78	11.09	5.91	21	16	8
120 – 179	150	112.5	24.64	18.48	9.86	35	26	14
180 – 239	210	157.5	34.49	25.87	13.80	49	37	20
240 – 359	300	225	49.28	36.96	19.71	70	53	28
360 – 539	450	337.5	73.91	55.43	29.57	106	79	42
540 – 1439	990	742.5	162.61	121.96	65.04	232	174	93
1440 +	1500	1125	246.38	184.78	98.55	352	264	141

* Casualties refer to fatalities and serious injuries. The adjustment for underreporting consisted of dividing the official statistics by 70% and rounding.

Compared to national statistics the base values for fatalities and serious injuries in Table 1 are on the high side, in particular for respondents living in remote rural areas. This was considered a necessary adjustment to ensure that large enough values, to allow variation, would be obtained for the number of injured road users, while at the same time ensuring that casualty numbers were not entirely outside the range of credibility.

Based on national data between 1993 and 2000 it was found that roads with an *AADT* of approximately 12,000 had an injury rate per million vehicle km of 0.40, with a proportion of fatal or severe/serious injuries of 0.10, with car occupants comprising 60% of these casualties. Roads with an *AADT* of approximately 6,000 were assigned an injury rate per million vehicle km of 0.50, with a proportion of fatal or severe/serious injuries of 0.15, with car occupants comprising 70% of the casualties. Roads with an *AADT* of approximately 2,000 had an injury rate per million vehicle km of 0.60, with a proportion of fatal or severe/serious injuries of 0.20, and car occupants comprising 80% of the casualties. Finally, taking into account the well-known underreporting of serious injuries in official accident statistics (Elvik et al., 2009), an upward adjustment was made and the resulting estimated numbers were finally rounded to the nearest integer (Elvik, 2008).

The safety attribute range and levels followed the three-attribute design for pair-wise choices from De Jong et al. (2007), with two lower levels than the base and two higher levels than the base. The two levels with higher values (worse cases) were set to 15% and 30% above the base level (rounded to integer), while the two lower levels (better cases) were set to 15% and 30% below the base levels in Table 1. The exception was for the 10-19 min base level, where absolute rather than relative changes were applied (i.e. increases were set as one and two casualties over the base, and reductions to one and two casualties less than the base levels), as otherwise level differences would be too low. The different routes that respondents reported to have driven by car, all around Norway, were then grouped into 10 × 3 route classes, applying trip length (min) and *AADT* (see Table 1 and Appendix).

The full-factorial design for a choice experiment using three attributes with five attribute levels would yield 5^3 = 125 choice pairs. This was reduced to 96 choice pairs by means of two adjustments:

- choice pairs with dominant alternatives were removed, and
- not all combinations of time level increases/decreases were included with the cost and casualty variables.

The 96 choice pairs were then blocked into blocks of six choices per respondent as shown in the Appendix (de Jong et al., 2007). The three attributes were related to trip alternatives in the pair-wise choice structure, plus an opt-out option, as depicted in Figure 1; K is a constant based on the respondents' stated car trip frequency per week.

*** FIGURE 1 APPROXIMATELY HERE ***

The attribute levels in the SC experiment were set relative to an actual car trip (i.e. the reference levels were given directly by the respondents). Then, the reference levels for fatal and serious injuries (casualties) on the road section were determined on the basis of the reported trip length and assumed *AADT*.

Before answering, respondents were informed about the implications of serious and severe injuries (that were lumped together as 'hard injuries'), with descriptions of pain and duration in hospital and pain/discomfort after leaving hospital based on Beattie et al. (1998). The data from our SC survey allows estimating WTP per trip for a casualty reduction over one year, WTP_{CAS}.

3.1 Survey development

The survey design was initiated in 2008 and in May that year draft scenarios were presented at focus group sessions with eight participants. An important issue in the focus groups was the communication of risk and the reasons for different fatality risks. Although participants tend to understand risk communication devices like grids with black squares representing fatalities (Alberini and Chiabai, 2007), for this particular route choice study we opted for the approach suggested by Rizzi and Ortúzar (2003), presenting and altering fatality/injury numbers instead of fatality/injury risk figures. Another element worth mentioning was that knowledge about fatality risks in road traffic was far better than knowledge about fatality risks due to less direct transport-related issues, such as health effects from air pollution.

In February 2009, the two-wave internet-based survey was piloted by e-mail recruiting from the national internet panel of *Synovate Norway*[4]. In a first wave respondents answered a questionnaire related to the valuation of travel time, reliability, and comfort, either related to a car trip or another transport mode (Ramjerdi et al., 2010). About a week or two later, the same respondents received the link to a second wave questionnaire about the valuation of safety. The pilot sample contained 156 respondents (car drivers) and 936 choices of the three-attribute pair-wise choice format (Figure 1). The questionnaire was structured as follows:

i) Introduction to the issue of fatality/injury risk and casualty numbers.
ii) Scenarios for change in casualty numbers and choices/valuations.
iii) Questions on reasoning for choices/valuations.
iv) Respondent's income.
v) Questions on fatality/injury risk beliefs, accident experience.

In this pilot the safety (casualty) attribute levels with respect to the base levels (Table 1) were: –50%, –25%, 0, 25%, 50%. The utility balance was relatively good for both time and cost but regarding the safety attribute almost 80% of the chosen trip alternatives were those with the lowest casualty number, suggesting that the levels of cost or time increase provided could not balance the gain in safety. For this reason, we decided to reduce the range of the safety attribute to: –30%, –15%, 0, 15%, 30%. Regarding other elements of the questionnaire,

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[4] Synovate Norway has joined the IPSOS group since 1 January 2012.

the assessment of the pilot survey was that it worked fairly well, and only relatively minor changes were made in the wording and illustrations.

3.2 The main two-wave internet-based survey

Our main survey was applied to a fairly large sample (9,489 individuals) drawn from the national internet panel of *Synovate Norway* during late April and the beginning of May, 2010. The overall response rate was 21.87%[5]. From this sample 3,109 car drivers were asked to participate in a second survey, on safety valuation in route choice, and 75.33% completed it (i.e. 2,342 individuals).

3.3 Descriptive statistics

In the road safety sample the average age was 50 years (from 17 to 84), and the median was 51 years; 65.1% of respondents were men, 23.5% had a university degree at master level, while another 38% had lower university degrees. On the other hand, 19.3% of the sample came from single households, and 40.2% from households with two persons. The average monthly personal income was approximately NOK 24,000 (n = 2,205); this calculation was based on taking midpoints from income intervals and setting the maximum to NOK 55,000. Tables 2 and 3 list the respondents' assessment of traffic density on the road section they had driven, and their base values for "fatalities and serious injuries".

Table 2: Assessment of travel density on the road section of their reported trip

Question	Response	Percent
Consider the road section you described in detail some days ago; would you describe this as (approximately) a road ...	with very low density (less than 1,000 vehicles per day)	7.4
	with low density (between 1,000 and 5,000 vehicles per day)	18.7
	with fairly high density (between 5,000 and 10,000 vehicles per day)	36.0
	with very high density (more than 10,000 vehicles per day)	35.2
	don't know	2.8

If respondents had been pre-registered with, for example, low (or very low) traffic density on their reported trip (*AADT* = 2,000), based on the urbanised degree of their municipality, but answered

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[5] According to Synovate Norway, this response rate is common for their internet panel, and they apply techniques to adjust the sample to population figures (i.e., distributions of gender, age, and regional appurtenance). Synovate Norway, formerly *MMI (Markeds- og Mediainstituttet) AS*, is part of the international opinion research company Synovate. Synovate Norway has joined Ipsos Group since 1 January 2012 (http://ipsos-mmi.no).

"very high density" in Table 2, their *AADT* was adjusted to 6,000. Conversely, people pre-registered as high density (*AADT* = 12,000) who answered "low density" or "very low density" in Table 2, had their *AADT* adjusted to 6,000.

Table 3: Assessment of base level of dead/seriously injured on road section of reported trip

Response	Percent
The number of seriously injured and dead seems to be too high	52.2
The number of seriously injured and dead seems to be correct	34.9
The number of seriously injured and dead seems to be too low	4.2
Don't know	8.7

From Table 3 it is clear that many respondents considered that the number of annual fatalities and seriously injured presented on the road section they had used was "too high". As indicated in 3.1, the base values for fatalities and serious injuries were on the high side compared to official accident statistics.

Regarding potential lexicographic (i.e. non-compensatory) answering, 37% of respondents always chose the alternative with the lowest number of casualties, 4.9% always chose the alternative with the lowest cost, and 1,8% always chose the alternative with the lowest travel time. This relatively high share of potentially lexicographic answers for the safety attribute is not uncommon in choice experiments of this type (Hojman et al., 2003; Iragüen and Ortúzar, 2004).

4. Modelling results

Routes were labelled for modelling purposes. Route one corresponds to the safer route (i.e. with the lower value of casualties); route two is obviously the 'dangerous' route. The survey included a follow-up question if an opt-out alternative was chosen. When respondents replied that both routes were too similar to decide (indicating indifference), we considered it as two different choices: in the first, the safe route was chosen and in the second choice, the dangerous route was chosen. This happened in 134 choices. When respondents replied that neither route was relevant or 'other reason', we excluded these 272 observations from analysis. In addition, 52 respondents (2.2 percent of respondents) always chose the opt-out option and all their six choices were excluded from the modeling. Models that included responses where the opt-out option was chosen produced inconsistent results, so we carried out the analysis removing (272 + 52 * 6) 584 choices.

We estimated many models but will show the results for only eight of these in this section. First, we show four binary logit models incorporating robust t-test[6] (Table 4). The first two include potentially lexicographic individuals and the difference between them is that in the second an alternative specific constant (ASC) was added to the safer route to account for a potential preference for safety *per se*. The second two models exclude potentially lexicographic individuals and, once again, the second of these include an ASC added to the safest route.

Table 4: Binary Models with level-of-service attributes

	All respondents		Excluding potentially lexicographic respondents	
	BL_1_1	BL_1_2	BL_2_1	BL_2_2
ASC_safer_route	-	1.01	-	0.46
	-	(23.68)	-	(11.34)
Cost	-0.0149	-0.0106	-0.0201	-0.0188
	(-8.87)	(-7.78)	(-9.6)	(-9.11)
Casualty	-0.363	-0.110	-0.248	-0.152
	(-15.33)	(-7.17)	(-13.07)	(-8.74)
Time	-0.0451	-0.0328	-0.0661	-0.0618
	(-11.95)	(-10.56)	(-13.01)	(-12.49)
Number of observation	13,602	13,602	7,452	7,452
Number of respondents	2,290	2,290	1,265	1,265
Null log-likelihood	-9428.19	-9428.19	-5165.33	-5165.33
Constant log-likelihood	-	-7651.63	-	-4917.81
Final log-likelihood	-8050.93	-7363.55	-4598.48	-4507.68
ρ^2	0.146	0.219	0.110	0.127
$\bar{\rho}^2$	-	0.037	-	0.083
WTP_{CAS}(NOK/casualty)	24.4	10.4	12.3	8.1
VTTS(NOK/hour)	181.6	185.7	197.3	197.2

All models were estimated using BIOGEME (Bierlaire, 2003). Robust t-tests were computed taking into account the repeated observations nature of the data. Opt-out options were removed from estimation.

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[6] In these logit models, the robust t-tests take into account the panel data structure (via the PANEL section in BIOGEME).

Table 5 shows the mixed logit (ML) version of the previous four models. The ML models add an extra coefficient (SIGMA) for the value of the standard deviation of an iid Normal error with mean zero added to every alternative across all choices from the same individual as described by equation (8). The SIGMA variable is significant and the goodness-of-fit of the models improves substantially indicating that the error correction term provides a superior way to consider the panel nature of the data.

Table 5: Mixed Logit Models with level-of-service attributes

	All respondents		Excluding potentially lexicographic respondents	
	ML_1_1	ML_1_2	ML_2_1	ML_2_2
ASC_safer_route	-	1.65	-	0.477
	-	(21.51)	-	(11.29)
Cost	-0.0181	-0.0162	-0.0208	-0.0194
	(-8.39)	(-7.73)	(-9.46)	(-8.93)
Casualty	-0.385	-0.157	-0.253	-0.158
	(-11.86)	(-6.57)	(-12.76)	(-8.48)
Time	-0.0554	-0.0493	-0.0684	-0.0639
	(-11.14)	(-10.08)	(-12.87)	(-12.33)
SIGMA	1.24	1.23	0.347	(0.284)
	(34.56)	(28.88)	(9.92)	(7.04)
Halton draws	500	500	500	500
Number of observations	13,602	13,602	7,452	7,452
Number of respondents	2,290	2,290	1,265	1,265
Null log-likelihood	-9428.19	-9428.19	-5165.33	-5165.33
Constant log-likelihood	-	-7651.63	-	-4917.81
Final log-likelihood	-7090.72	-6644.36	-4580.12	-4498.70
ρ^2	0.248	0.295	0.113	0.129
$\bar{\rho}^2$	-	0.132	-	0.085
WTP_{CAS}(NOK/casualty)	21.3	9.7	12.2	8.1
VTTS(NOK/hour)	183.6	182.6	197.3	197.6

All models were estimated using BIOGEME (Bierlaire, 2003). Robust t-tests were computed taking into account the repeated observations nature of the data. Opt-out options were removed from estimation.

The coefficients of casualties, time and cost have all the expected negative sign, in all models and are always highly significant. Removing the potentially lexicographic respondents does have an impact in terms of willingness-to-pay to reduce one casualty (WTP_{CAS}). For example, in model BL_1_1, the WTP_{CAS} (NOK 24.4) is almost twice the value derived for model BL_2_1 (NOK 12.3).

On the other hand, in Model BL_1_2 where an ASC was added to the utility of the safest route, WTP_{CAS} turns out to be NOK10.4; thus, the ASC appears to remove the influence of potentially lexicographic respondents from the willingness-to-pay values. This ASC may be interpreted as a preference for safety that goes beyond how much safer route 1 is compared to route 2; that is, as long as route 1 is safer, many people just choose it (given the levels provided for the remaining attributes). Hence, the inclusion of the constant terms may balance off the undesirable effects of potentially lexicographic choice behaviour. In model BL_2_2, the inclusion of the ASC also lowers down WTP_{CAS} to NOK 8.1. Although in this model all potentially lexicographic respondents were removed, we infer that even those respondents who were compensatory tended to choose the safest route more often than what can be explained from differences in the actual safety of each route.

With respect to the valuation of travel time savings, they are quite similar among the four models and in line with other Norwegian estimates. As a reference, these values are somewhat higher than values derived from a choice experiments with just two attributes, cost and time (Ramjerdi et al., 2010), where the value of travel time savings (VTTS) was estimated at NOK 150/hour for long distance trips and NOK 80/hour for short distance trips.

4.1 Introducing demographic variables

We next show the results of models that include socio-demographic variables interacting with level of service (LOS) variables in an effort to estimate models with "systematic taste variations", that allow customising the marginal utilities (with respect to cost, casualties and time) according to the demographic profile of each respondent. Schematically, the indirect utility is now written as (Ortúzar and Willumsen, 2011, p 279):

$$V_i = \left(\theta + \sum_d \theta_d X_{dj}\right) CAS_i + \left(\beta + \sum_d \beta_d X_{dj}\right) c_i + \left(\gamma + \sum_d \gamma_d X_{dj}\right) t_i$$

There are new coefficients to be estimated θ_d, β_d, γ_d where d indexes covariates X. These demographic variables could be either binary or continuous and are multiplied by the LOS variables. The subscript j accompanying each covariate means that the values of these variables depend only on the respondents characteristics and as such they are the same across all alternatives and across choice scenarios for every respondent. With this formulation, the marginal utility for casualties (MU_{cas}) is given now by:

$$MU_{CAS} = \theta + \sum_d \theta_d X_{dj}$$

This marginal utility depends on the demographics of the individual and as such it may differ across respondents. Obviously, this also affects the willingness-to-pay:

$$WTP_{CAS} = \frac{\theta + \sum_{d} \theta_d X_{dj}}{\beta + \sum_{d} \beta_d X_{dj}}$$

The interpretation of results is now more complex and interesting, as we need to verify that the marginal utilities are negative for every respondent. Also, WPT_{cas} has to be estimated as an average or median value across respondents. Table 6 lists the means and ranges of the demographic variables that were considered in the models.

Table 6: Descriptive statistics for demographic variables (*n* = 2,290)

	Mean	Minimum	Maximum
Age	49.89	17	84
Children (below 18 years) in household	0.36	0	1
University degree	0.62	0	1
Income (personal monthly net income, NOK)*	12,860	0	55,000
Income missing	0.05	0	1
Gender (1 for males)	0.65	0	1
Live in semi-urban area	0.33	0	1
Live in urban area	0.45	0	1
Live in rural area	0.22	0	1
Daily travel distance by car (km)	19.78	1	600
Relative/friend seriously injured/killed in road accident	0.25	0	1

* Income is slightly downward biased since missing values are set to zero.

All models from Table 5 were re-estimated and results showing the most relevant interactions are displayed in Table 7. As can be seen, the interaction between cost and distance travelled is negative and the interaction between cost and income is positive. The first results implies that as distance travelled increases, the marginal disutility of travel expenses increases; the second result implies that high-income people has a lower marginal utility of income. For all respondents, the marginal utility of travel costs is always negative across all four models.

Table 7: Mixed Logit Models with covariates

	All respondents		Excluding lexicographic respondents	
	MLC_1_1	MLC_1_2	MLC_2_1	MLC_2_2
ASC_less_risk	-	1.62	-	0.471
	-	(20.39)	-	(10.53)
Cost	-0.0879	-0.077	-0.105	-0.1
	(-1.82)	(-1.95)	(-2.81)	(-2.61)
Cost - income missing	0.076	0.0673	0.0947	0.091
	(1.59)	(1.72)	(2.48)	(2.34)
Cost - log (daily travel distance by car)	-0.00266	-0.00332	-0.00284	-0.00321
	(-2.99)	(-3.79)	(-3.14)	(-3.45)
Cost - log (Income)	0.0076	0.00688	0.00903	0.00875
	(1.62)	(1.8)	(2.44)	(2.32)
Casualty	-0.289	-0.0853	-0.275	-0.182
	(-3.15)	(-1.65)	(-4.06)	(-3.10)
Casualty - age	-0.00455	-0.00286	-0.00128	-0.000854
	(-2.74)	(-2.81)	(-1.10)	(-0.92)
Casualty-children in h-hold	-0.0862	-0.0403	0.00371	0.0195
	(-1.76)	(-1.21)	(0.12)	(0.78)
Casualty - male	0.178	0.086	0.0954	0.0645
	(2.98)	(2.53)	(2.93)	(2.27)
Time	-0.0619	-0.0542	-0.0546	-0.0501
	(-3.01)	(-2.76)	(-2.60)	(-2.36)
Time - age	0.00102	0.000932	0.000689	0.000654
	(3.15)	(3.05)	(1.95)	(1.86)
Time - children in household	-0.0176	-0.00947	-0.0174	-0.0153
	(-1.82)	(-1.05)	(-1.88)	(-1.70)
Time - high education	-0.0159	-0.0104	-0.0113	-0.00865
	(-1.83)	(-1.29)	(-1.32)	(-1.05)
Time – log (daily travel distance by car)	-0.00567	-0.00681	-0.00763	-0.00813
	(-2.07)	(-2.62)	(-3.19)	(-3.40)
Time -living in suburban area	-0.0163	-0.0191	-0.0186	-0.0184
	(-1.42)	(-1.71)	(-1.74)	(-1.73)
Time - living in urban area	-0.0209	-0.0215	-0.0204	-0.02
	(-2.22)	(-2.31)	(-2.04)	(-2.18)
SIGMA	1.21	1.22	0.33	0.269
	(32.69)	(27.36)	(8.71)	(6.22)
Number of observations	13,602	13,602	7,452	7,452
Number of respondents	2,290	2,290	1,265	1,265
Null log-likelihood	-9428.19	-9428.19	-5165.33	-5165.33

Constant log-likelihood	-	-7651.63	-	-4917.81
Final log-likelihood	-6975.37	-6558.37	-4505.77	-4428.17
ρ^2	0.260	0.304	0.128	0.143
$\bar{\rho}^2$	0.088	0.143	0.084	0.100

For the demographic variables Children in household, University degree, Income missing, Male, Live in semi-urban area, Live in urban area and Relative/friend seriously injured/killed in road accident, the interaction is the product of a level-of-service variable times a dummy taking the value of one if the individual possesses the demographic characteristic. For Age, Income and daily travel distance by car, the interaction multiplies the LOS variable by the demographic variable as a continuous variable.

When looking at monetary values, these models provide more valuable information as respondents' willingness-to-pay depend on their demographic attributes. Table 8 shows the median willingness-to-pay for casualty reductions and the 25th and 75th percentiles to account for the interquartile range as a measure of spread. Median WTP_{CAS} are very close to the values shown in Table 5. Table 8 also shows that the values of travel time savings are also quite similar to those from Table 5.

Table 8: Willingness-to-pay values from ML models with covariates

	MLC_1_1	MLC_1_2	MLC_2_1	MLC_2_2
Median WTP_{CAS} (NOK / casualty)	21.7	10.3	11.6	7.8
25th percentile	18.0	8.1	9.8	6.4
75th percentile	26.6	13.3	13.9	9.7
Mean *VTTS* (NOK / hour)	179.4	179.1	187.4	189.1
25th percentile	127.1	132.2	149.7	153.0
75th percentile	234.7	229.1	230.4	229.8

4.2 Estimating values of statistical lives and limbs

To estimate the values of statistical casualties according to equation (6), we need the average calculated *AADT*; this value is taken to be 7,000 (from the adjusted distribution between 2,000, 6,000 and 12,000). Then to estimate the values of statistical lives and statistical severe injuries according to equation (7), we need the values of DRE_{SI}, *delta si* and *delta f* which are respectively 0.2, 0.8 and 0.2. Table 9 shows the VSC, VSL and VSSI estimated from the models shown in Table 5.

The estimates shown in Table 9 are sensitive to the assumed *AADT* and DRE_{SI} values. Table 10 shows how the point estimates values of *VSC*, *VSL* and *VSSI* –corresponding to Model ML_1_2– would change if different values for these parameters were assumed; we consider $AADT$ values of 4,000, 7,000 and 10,000 and DRE_{SI} values of 0.1, 0.2 and 0.3.

Table 9: The values of statistical life and limb (NOK million)

	ML_1_1	ML_1_2	ML_2_1	ML_2_2
Value of Statistical Casualty	54.3	24.8	31.1	20.8
Confidence interval[a]	(43.3; 67.0)	(18.8; 31.8)	(26.4; 37.4)	(16.8; 25.6)
Value of Statistical Life	151.0	68.8	86.3	57.8
Confidence interval[a]	(125.9; 186.2)	(52.1; 88.4)	(73.3; 103.8)	(46.7; 71.1)
Values of Statistical Severe Injury	30.2	13.8	17.3	11.6
Confidence interval[a]	(25.2; 37.2)	(10.4; 17.7)	(14.7; 20.8)	(9.3; 14.22)

[a] 95 % confidence intervals according to Armstrong et al. (2001).

Table 10: Sensitivity analysis to assumed values of AADT and DRE_{SI} (NOK million)

	$AADT = 4000$	$AADT = 7000$	$AADT = 10000$
$DRE_{SI} = 0.1$	$VSC = 14.1$	$VSC = 24.8$	$VSC = 35.4$
	$VSL = 50.5$	$VSL = 88.4$	$VSL = 126.3$
	$VSSI = 5.1$	$VSSI = 8.8$	$VSSI =12.6$
$DRE_{SI} = 0.2$	$VSC = 14.1$	$VSC = 24.8$	$VSC = 35.4$
	$VSL = 39.3$	$VSL = 68.8$	$VSL = 98.3$
	$VSSI = 7.9$	$VSSI = 13.8$	$VSSI = 19.7$
$DRE_{SI} = 0.3$	$VSC = 14.1$	$VSC = 24.8$	$VSC = 35.4$
	$VSL = 32.2$	$VSL = 56.3$	$VSL = 80.4$
	$VSSI = 9.6$	$VSSI = 16.9$	$VSSI = 24.1$

All values assume a point estimate WTP_{cas} = NOK 9.7, from model ML_1_2 in Table 5.

5. Discussion and Conclusions

We now compare our results with other results reported in the literature on valuation of road safety. First we will convert our estimates to € using a conversion rate of € 1 = NOK 7.8972[7]. Considering the

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[7] This value is an average of the conversion rate for the month of May 2010 and was taken from the Central Bank of Norway's web site (http://www.norges-bank.no/en/price-stability/exchange-rates/eur/, accessed 25 November 2011).

results from the ML_1_2 model in Table 5, the point estimate *VSL* is € 8.71 million, with a 95% confidence interval of [€ 6.6 million; € 11.2 million]. The respective *VSSI* values can be obtained simply dividing by five. If we considered the *VSL* point estimates from the four ML models from Table 5, those values range from € 7.3 million to € 19.1.

De Blaeij et al. (2003) reported estimates of the *VSL* for road safety from 29 studies conducted in the US, Europe and New Zealand[8]. Most of these studies were based on hypothetical surveys and the values spanned a wide range of figures, being the lowest around a few hundred thousand € and the highest between € 20 and € 30 million[9]. Further, 11 of those 29 studies only reported a single point estimates; 17 reported a lower and a higher estimate and only one study reported a point estimate from a RP survey and lower and higher estimates from a SP survey. The three highest values are in the range € 20-€ 30 million and the next three highest values in the range € 10-€ 20 million; 34 reported values are in the range €1 - €10 million and the rest of the values are below € 1 million.

Thus, the *VSL* point estimate from model ML_1_2 would come in eight place among the values reported by de Blaeij et al. (2003). If, instead, we considered the point estimate from the model ML_1_1, the corresponding *VSL* would rank in fourth place. Our highest estimate from the ML models (i.e. the upper limit of the 95 % confidence interval from model ML_1_1) would rank in third place; our lowest estimate –the lower bound for the 95 % confidence interval from model ML_2_2– would rank in tenth place.

We can also compare our values to those reported, more recently, for studies conducted in both Norway and Sweden. Strand (2004), using SC surveys among different governmental projects aimed at reducing the number of annual premature deaths, estimated a *VSL* for road safety projects between € 6.6 and 7.6 million[10]. These values are close to our point estimates. Although he uses a SC approach, the choice situations faced by respondents were among different public health projects, that is, without taking into account the fact that when driving travel time is a most relevant factor.

Hultkrantz et al. (2006), by means of a contingent valuation (CV) survey, estimated the value of a life saved in a road safety public scheme at € 2.3 million in Sweden. They called this value a lower

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[8] Actually, there are 30 studies reported in de Blaeij *et al*. (2003). The remaining one was conducted in Chile and was removed from the comparison because per capita income in Chile is considerable lower than per capita income in the other countries where those studies were undertaken.

[9] The values reported in de Blaeij *et al*. (2003) are in 1997 USD. These values were updated by the US inflation between 1997 and 2010 (36%, see inflation calculator at http://www.minneapolisfed.org/, accessed 25 November 2011) and converted to € using an exchange rate of 1 € = 1.3138 USD (http://www.federalreserve.gov/releases/h10/Hist/dat00_eu.htm, accessed 25 November 2011).

[10] These values are reported in in NOK from 1995. We updated them using an inflation calculator http://www.norges-bank.no/en/price-stability/inflation/price-calculator/ (accessed 25 November 2011) and then converted them to €.

bound since it was based on models estimated for those respondents who said, that on a scale from 1 to 10, they were confident at a level equal or greater than eight about their responses to the CV questionnaire[11].

Svensson (2009), using the data from Hultkrantz et al. (2006) plus another data set, arrived at *VSL* in the range € 1.2-€ 3.4 million. He estimated the *VSL* based on responses from people who were, on a scale from 1 to 10, at a confidence level of 10 about how certain their response was. All these values are below € 3.6 million, which is the lower bound of our confidence interval. However, the data sets used in these Swedish studies are representative of two small towns in Sweden, so a comparison between these and our values is not immediate at all.

Tofte (2006) presented a weighted *VSL* from two sub-samples, those facing a leisure trip scenario and those facing a commuting scenario. For the commuting scenario, she obtained a WTP for one fatality reduction equal to NOK 20.84 (her scope risk change was equal to four fatalities) and NOK 26.79 for the leisure trip scenario (with a scope risk change of six fatalities). This yielded *VSL* estimates of approximately NOK 80 million for commuting and NOK 317 million for leisure trips; however, these estimates are based on a high *AADT* value (equal to 16,889 for both scenarios, which seems unreasonably high in the Norwegian context). Applying the 7.9125 NOK/€ exchange rate of April/May 2010, these values turn out to be € 9.3 million and € 40 million respectively; and the weighted average from her data is NOK 247 million, or € 31 million. Thus, the *VSL* for commuting is a bit higher than our upper limit; the other two figures are way beyond our values, and are indeed among the highest values reported in the literature.

From the previous review, our *VSL* are above the median value of those reported in the literature on road safety valuation and most of our values tend to be among the higher-end values. However, most studies that have reported a *VSL* from a road context are based on CV surveys or risk-risk trade-offs that ignore the fact that, when driving, people are not only trading off money versus risk; travel time also enters the ‘equation’. In this regard, our survey place respondents in a more realistic context since they have to consider risk as one of the attributes of a trip, and not as the only relevant one. Even more, we strongly believe that choice scenarios based on hypothetical route choices pivoted around a real car trip, including safety risks presented as numbers of “fatalities and serious injuries” rather than tiny probabilities, have enhanced both the credibility and comprehensibility of studies in this area (Rizzi and Ortúzar, 2003; 2006a; 2006b).

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[11] All values reported are expressed at values from May 2010. The rate of inflation and the exchange rate between € and SEK were taken from the Swedish Central Bank: http://www.scb.se/Pages/TableAndChart____272152.aspx and http://www.riksbank.com/templates/stat.aspx?id=17212 (accessed 25 november 2011).

As a caveat, our approach implied less adapted and specified scenarios than the studies by, inter alia, Hojman et al. (2005) and Rizzi and Ortúzar (2003; 2006b). Although pivoted around an actual trip, here we were forced to apply a fairly schematic procedure for setting up the reference levels for "fatalities and serious injuries", based on respondents' reported trip distances and estimated *AADT*. In fact, half of our respondents indicated that they considered the reference levels as "too high". Notwithstanding, we were able to consider many types of trips and also incorporate many covariates to yield extremely rich indications about the heterogeneity of these valuations in the Norwegian context.

Finally, for the valuation of risk reductions, travel time savings, and other transport features more route choice experiments pivoted in existing travel behaviour are warranted, with more diversification in experimental design.

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Appendix

Tables A1 and A2 show the base levels for the travel time and cost attributes, given from respondents' reported trips, and alteration levels.

Table A1: The time attribute in the stated choice (SC) experiments, with base levels from car drivers' reported trip length in time

Base time of a trip (min)	Change in base time of the trip (min)				
	level -2	level -1	level 0	level 1	level 2
10 – 19	-4	-1	0	3	6
20 – 44	-5	-2	0	3	8
45 – 74	-10	-5	0	5	18
75 – 119	-12	-5	0	8	20
120 – 179	-15	-10	0	11	30
180 – 239	-20	-10	0	15	40
240 – 359	-40	-20	0	20	60
360 – 539	-60	-30	0	30	90
540 – 1439	-120	-60	0	60	180
1440+	-240	-120	0	120	360

Table A2: The cost attribute in the stated choice (SC) experiments, with base levels from car drivers' reported trip costs

Base cost of a trip (NOK)	Change in base cost of the trip				
	level -2	level -1	level 0	level 1	level 2
5 – 9	-50%	-30%	0	26%	80%
10 – 30	-50%	-25%	0	10%	20%
30 – 60	-40%	-12%	0	10%	20%
60 – 100	-40%	-11%	0	8%	25%
100 – 150	-35%	-9%	0	8%	22%
150 – 250	-30%	-8%	0	6%	30%
250 – 500	-23%	-7%	0	6%	16%
500 – 750	-20%	-7%	0	6%	21%

750 – 1000	-22%	-7%	0	6%	24%
1000 – 1500	-33%	-8%	0	6%	32%
1500+	-30%	-8%	0	6%	42%

Note: All NOK values, under levels -2, -1, 1, and 2 were rounded to integer values.

The following figure shows the distribution of travel time vs. travel cost (fuel consumption and possible toll payments) on the road section the respondents had driven, after removal of one extreme observation with reported travel cost of NOK 50,000 (Figure A1).

*** FIGURE A1 APPROXIMATELY HERE ***

The correlation between the out-of-pocket cost of car driving and travel time is obvious. The variance in cost increases in travel time. Maximum base time was 900 min (15 hours).