The final publication is available in: Safety Science
Volume 77, August 2015, Pages 1-9 https://doi.org/10.1016/j.ssci.2015.03.006

Car drivers' valuation of landslide risk reductions

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3 September 2014

Acknowledgement

The data collection for this study 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". Some additional funding for the design of the study was obtained under the strategic institute programme "Methodological challenges related to valuation of non-market goods" (155683), supported by the Research Council of Norway. Luis I. Rizzi and Juan de Dios Ortúzar also acknowledge financial support from the Millennium Institute in Complex Engineering Systems (ICM: P-05-004-F; CONICYT: FBO16) and the TEMPO Project funded by the Research Council of Norway. We are very grateful for the insightful comments from two referees to this journal. Finally, we thank Anna Alberini, Julian Arellana, Gunne Håland, Svenn Jensen, Anne Kjerkreit, Kristin Magnussen, Harald Minken, Ståle Navrud, Farideh Ramjerdi and Hanne Samstad for their contributions to various parts of the development of the study. All remaining errors and omissions are entirely our own.

Abstract

Approximately one car occupant per year is killed as a result of landslides or avalanches in Norway, compared to 150-200 fatalities due to accidents. Still, protection from landslides is a major transport safety issue, possibly due to the concern and dread felt by the car-driving population travelling through landslide-prone areas. A main challenge when valuing landslide risk economically lies in distinguishing it from the standard road accident risk of having a collision or running off the road.

In this paper we present an approach to the valuation of landslide risk, using a stated choice experiment where internet survey respondents were asked to choose between route alternatives that differed in terms of landslide risk, casualty risk, time use and cost. Thus, landslide risk was explicitly valued as an attribute, besides travel time and casualty risk, conveying a valuation of a feature different than the risk of fatality or injury caused by ordinary road accidents.

The stated route choice data were analysed using mixed logit models. We obtained point estimates for the value of landslide risk removal per kilometre driven ranging from about EUR 0.2 to EUR 0.3. These results indicate that landslide risk was perceived as something different from casualty risk related to collisions with other road users or driving off the road. More research is warranted for developing the procedures for valuation of landslide risk before such valuations can enter as input into cost-benefit analyses of landslide-reducing measures.

Keywords: fatality; injury; internet survey; stated choice; mixed logit

1. Introduction

Landslides are a natural disaster risk that can affect road users´ welfare and behaviour (Hervás et al., 2003; Elvik et al., 2009). In Norway, landslides occur in the form of debris flows or quick clay, snow avalanches and floods. Based inter alia on registered slides after 1850 and their consequences, comprising more than 2000 fatalities, Nadim et al. (2008, p. 176) expect about ten large slides over the next 50-100 years, with 200-1000 fatalities. Most fatalities due to slides are related to other activities than transport. The last major road accident caused by an avalanche was in 2000, when five bus passengers were killed (Sklet, 2006). In the first decade of this millennium, 13 people have been killed and 11 seriously injured in a road transport context, in eight different landslides (rock slides) and avalanches (Bjordal, 2009). Thus, for road traffic, the injury/fatality risk due to landslides/avalanches is relatively minor, as approximately only one car occupant, on average, is killed annually in landslides (Elvik et al., 2009, p. 362) in comparison with approximately 150-200 people that die in road accidents per year (Elvik, 2010). Yet, protecting from landslides has been a major transport issue in Norway. This was reflected, for example, by the former government's announced increase in spending on reducing the risk of ice and rockslides on the road and rail network (MTC, 2009, p. 10), budgeting NOK 1 billion (about EUR 130 millions) for landslide protection measures in the period 2010-2019 (MTC, 2008-2009, p.9).

Our study was based on a commissioning of landslide risk valuation by the transport sector (Flügel et al., 2010). Public road administrators seek valuations of landslide risk changes for the assessment of such impacts in cost-benefit analyses of road construction projects, together with collision risk changes, time-use changes and other project impacts. Thus, in this paper we estimate the value of landslide risk reductions based on stated choice (SC) experiments where respondents to a web survey had to choose between route alternatives that differed in terms of various features of the trip, including landslide risk and fatality/injury risk. The landslide risk attribute therefore conveys willingness to pay (WTP) on the part of drivers for some other welfare impact than injury due to ordinary road accidents. To our knowledge, such valuation of landslide risk in choice experiments has not been reported in the literature[1]. Our main aim was, therefore, to test a procedure for the valuation of landslide risk in road transport, applying choice experiments consistent with the approaches used for valuing other public good factors in Norway (Ramjerdi et al., 2010; Veisten et al., 2013). Our choice experiment and the assessment of the procedure also comprised, as a necessary first step, consideration of establishing value functions or unit values for landslide risk reduction in cost-benefit analysis in the road transport sector.

The remainder of the paper is arranged as follows. The next section presents psychological and economic approaches to hazards and insecurity in transport. The third section describes the methodology underlying choice experiments and the associated modelling issues. The fourth describes the internet-based web survey and the applied choice experimental design to landslide risk evaluation. The fifth section gives the resulting model estimates that are discussed in the last section.

[1] In parallel to our SC experimental study a contingent valuation of landslide risk reduction in Norway was also carried out by Midtbø and Røssland (2010).

2. Theoretical Underpinnings

2.1 Cognitive and emotional elements of landslide risk

The risk of landslides is of considerable concern to people living in or driving through landslide-prone areas in Norway (Elvik et al., 2006). This has been related to less control over the landslide risk compared to collision risk or risk of driving off the road (Elvik et al., 2009, p. 360). Landslide risk may be perceived as a “catastrophic risk”, with potentially many casualties in one but rare occurrence, rather than a “chronic risk”, with one or few casualties occurring more frequently (Rundmo et al., 2011, p. 226). If so, it may lead to a relatively higher demand for safety measures against this type of hazard (Elvik et al., 2009, p. 360) and to a greater willingness to pay for landslide risk reduction in road transport, compared to risks due to collisions or driving off the road (Carlsson et al., 2004; Chilton et al., 2006). If dread is an important feature, a main challenge when it comes to valuation of landslide risk would be to disentangle it from the valuation of standard road accident risk due to collisions or driving off-road (Elvik et al., 2006).

A standard definition of (objective) risk is probability multiplied by consequence (USNRC, 1975); subjective risk being the perceived (subjective) probability multiplied by the perceived consequence, the latter likely involving an emotional element (Sjöberg 1998, 1999). While a consequentialist model would bring the cognitive evaluation onto the decision-making, Loewenstein et al. (2001) present a hypothesis of judgment and decision-making under risk termed “risk as feelings”, where they depict a separate direct impact from emotions to the behavioural response. They stress that different things determine the cognitive and emotional reactions to risk. Economic theory and methods are closer to the consequentialist model, but the preferences and valuations related to risk change may well be driven by an emotional part, such that specific consequence, fatality or injury, may not be sufficient by itself to explain risk reduction valuation; the cause of premature deaths also have importance (Chilton et al., 2006, p. 165). Such a dread effect related to risk in transport can also partly be due to a perception of lack of control over adverse outcomes (Slovic et al., 1979; Slovic, 1987; 1999; Jones-Lee and Loomes, 1995). Subsequently, preventing a fatality due to a particular cause might be given a higher valuation than preventing one due to some other cause, e.g. in different transport modes (Carlsson et al., 2004). Rundmo and Nordfjærn (2013) found that both risk awareness and worry were significant predictors of demand for risk mitigation in Norwegian transport.

Although relatively few people are killed or injured in a transport context due to landslides in Norway, roads and railways can be blocked and sometimes entire communities isolated by landslides. Thus, the insecurity or dread attached to a low-probability event such as a landslide or an avalanche might have welfare effects beyond being a cause of transport casualties (Elvik et al., 2006; 2009). If landslides are a type of hazard that people dread (Slovic, 1999; Rundmo et al., 2011), individuals may demand relatively higher protection, a measurably higher WTP for fatality risk reductions compared to, for example, the WTP for fatality risk reductions related to collisions or driving off the road (Carlsson et al., 2004; Chilton et al., 2006; Elvik et al., 2009). However, Chilton et al. (2006) found that dread premiums were largely offset by (low) baseline risk.

In a SC experiment, the inclusion of landslide risk as a specific attribute, apart from fatality/injury risk, should potentially indicate the landslide risk premium beyond the general fatality/injury risk. However, since landslides encompass also other welfare elements (see next section) isolating the risk premium is hard to achieve.

2.2 Other welfare effects of landslide risk reduction

A common welfare impact of landslides and avalanches in Norway is temporary closures of road or rail sections (Håland, 2011; Vennemo and Rasmussen, 2010). Thus, beyond the dread as such, the reliability of getting from an origin to a destination will be reduced for road users, either implying a detour and increased time use and/or congestion or the possibility of being temporarily trapped in some area (Jeekel et al., 2010). Given several incidents of blocked roads every year in Norway (Bjordal, 2009; Håland, 2011), the objective probability of experiencing congestion due to landslides is considerably higher than the probability of being injured/killed by landslides. Therefore, one might argue that the main welfare effect of landslide risk reduction is actually connected to reduced congestion (risk) rather than fatality risk. However, this does not necessary imply that the utility connected to landslide risk reductions as perceived by car drivers follow this logic. Even though the objective probability of a fatal incident is very small, a major part of the disutility of landslide risk may be directly due to fear, discomfort and other emotional components related to driving on roads exposed to the risk. To some extent we control for the unreliability caused by landslides, incident-related delays/detours or blockages, as we include in our choice experiment a separate and deterministic travel time attribute. The procedure for valuing landslide risk changes in road transport should, therefore, be based on choice experiments including travel time and casualty risk, in addition to landslide risk and travel cost, consistent with the approaches used for valuing other factors in Norwegian road transport (Ramjerdi et al., 2010; Veisten et al., 2013). The hypotheses that we test comprise the sign and statistical significance of the landslide risk parameter and whether choice behaviour is explained by the choice attributes and the individual characteristics according to theoretical expectations.

2.3 Methodological approach – modelling the valuation of landslide risk reductions

We specified a random utility model (RUM) with the following indirect utility for each available alternative *j* and person *i*:

$$V_{ij} = \alpha \cdot \text{SLIDE - KM}_{ij} + \theta \cdot \text{CAS}_{ij} + \beta \cdot c_{ij} + \gamma \cdot t_{ij}$$

Feil! Fant ikke referansekilden.

where SLIDE-KM_{ij} refers to the landslide risk measured as kilometres driven in risk-prone areas (based on an approximate share of a route with a certain length prone to landslide risk); CAS_{ij} represents the risk of death or serious injury, measured as the expected number of casualties (annually) on a given route; the term t_{ij} refers to travel time and c_{ij} to the cost per trip on the route. All parameters in **Feil! Fant ikke referansekilden.** are expected to have negative signs, and the equation is a simplified specification where all attributes enter utility additively. V_{ij} represents the deterministic part of a random utility function, U_{ij}, which also includes an error term (ε_{ij}) which is typically assumed to distribute independent and identically extreme value type I in the simplest multinomial logit (MNL) model (McFadden, 1974; Ortúzar and Willumsen, 2011).

In this paper, we specify a type of RUM appropriate for mixed logit (ML) modelling of the choices, including an additional error term (τ_{ij}) to account for the correlation among choices/responses, *l*, from the same individual (Train, 2009), such that:

$$U_{ijl} = V_{ijl} + \tau_{ij} + \varepsilon_{ijl} \qquad (1)$$

Each alternative has a probability of being chosen which is given by the probability that U_{ijl} is the highest random utility for each individual *i*. The monetised marginal utility of an attribute in an alternative is given by the marginal rate of substitution between that attribute and the cost attribute. With a linear specification of V_{ijl}, the value of a kilometre reduction in the route length prone to landslide risk is simply given as the ratio of the landslide risk coefficient and the cost coefficient:

$$\mathrm{WTP}_{\text{SLIDE-KM}} = \frac{\partial V_i / \partial \text{SLIDE - KM}}{\partial V_i / \partial c}\Bigg|_{V=\bar{V}} = \frac{\alpha}{\beta} \quad (2)$$

Similarly, we can obtain the WTP for a casualty reduction, $\mathrm{WTP}_{\mathrm{CAS}}$, as:

$$\mathrm{WTP}_{\mathrm{CAS}} = \frac{\theta}{\beta} \quad (3)$$

This expression can be termed the subjective value of a casualty reduction (Hojman et al., 2005; Veisten et al., 2013), and the casualties will contain a share of serious injuries, p_{si}, and a share of fatalities, p_f =(1–p_{si}). Similarly, γ/β yields a subjective value of travel time savings (Gaudry et al., 1989; Hensher et al., 2009).

The composition of attributes in the utility function, stemming from the presented attributes in the choice experiments (described in section 3.1), has an effect on what elements of landslide risk will be contained in the landslide coefficient, SLIDE-KM$_{ij}$ (and consequently in the monetised WTP). As casualty risk is represented with an own attribute, the landslide coefficient will not encompass the particular (objective) fatality risk. This rests on the assumption that respondents actually perceive (and are able to process) the two attributes as separated from each other. Thus the SLIDE-KM$_{ij}$ is not expected to contain the cognitive element, but only the emotional component of risk. Furthermore travel time is a separate attribute presented as a deterministic characteristic of the alternatives. Therefore, one might argue that the landslide coefficient should not encompass travel time losses (travel time variability/unreliability) due to possible congestion caused by landslides. Hence, $\text{WTP}_{\text{SLIDE-KM}}$ will represent, to a large extent, the fear and discomfort of driving on roads prone to landslides independently from the WTP of fatality risk and time reductions. This is a desirable feature of the experimental design such that the problem of double counting in cost-benefit analysis (which normally includes own posts for travel time and fatality risk changes) can be reduced when putting the estimated parameters forward for policy analysis.

3. Survey Design

3.1 Including a landslide risk attribute and a casualty risk attribute in a route choice experiment pivoted to a recent trip

We applied a four attribute stated choice (SC) experiment, including cost (fuel and toll), travel time, casualties (fatalities and serious injuries) and landslides described as the share of the route (of a reported trip length) with landslide risk. We developed the landslide attribute in such a way that it could be pivoted to a recent trip by car reported by the respondents, either "during the last week" or, for longer trips (beyond 100 km), "during the last month". In addition to those reporting that their reference car trip was through an area prone to landslides, some respondents who did *not* drive in areas prone to landslides were also considered in this choice experiment. The latter group's reference level was then "no risk of landslide on route". The landslide attribute specification is displayed in Table 1.

Table 1 approximately here

The casualty attribute, presented as the annual expected number of fatalities and serious injuries over a given route of a certain length, was defined from travel time levels that were calculated from known distances at an average speed (45 km/h), and adjusted by the travel density estimated for that route. The basis for these calculations was the actual casualty numbers in Norway over the past decade (Elvik, 2008). We did not consider relevant to subtract the minuscule share (less than 1%) of road traffic casualties caused by landslides. The annual average daily traffic (AADT), in three levels, was used as an approximation of traffic density, while adjusting the casualty number in the reference level. Initial AADT levels were based on the urbanisation level at the respondents' place of residence, and were adjusted by the respondents' own assessments of traffic density. Table 2 gives the procedure used for estimating base levels of casualties on road sections of different length and with different traffic density levels.

Table 2 approximately here

Using the above four attributes, we followed the design for pair-wise choices applied by De Jong et al. (2007), with two lower and two higher levels than the base. For landslide risk, the difference between levels, stated as shares of the route prone to landslide risk, depends on the reference level (Table 1). For casualties, the two levels with higher values (worse levels) were set to, respectively, 15% and 30% above the base level (rounded to integer), while the two lower levels (better levels) were set to, respectively, 15% and 30% below the base levels (in Table 2). The exception was for base level 10-19 min, where the increases were set to 1 and 2 and reductions to –1 and –2 (from the base levels), since the low base level would not yield any differentiation when applying just 15% and 30% changes.

The full-factorial design for the SC experiment (four attributes with five levels) would yield $5^4 = 625$ choice pairs. This was reduced to 96 choice pairs by means of two adjustments: (*i*) the choice pairs with dominant alternatives were removed, and (*ii*) not all combinations of the time level increases/decreases were included with the cost and casualty variables. The 96 choice pairs were then blocked into six choices per respondent following de Jong et al. (2007). For about one fourth of the choice pairs, one of the alternatives would include only the reference trip attribute levels. The four attributes were related to trip alternatives in the pair-wise choice structure, plus an opt-out option, as depicted in Figure 1.

Figure 1 approximately here

3.2 Estimating values of landslide risk reductions from the choice data

We asked car drivers about changes relative to an actual car trip, where we altered the levels of costs, travel time, number of casualties and the share prone to landslide risk on the section driven by car. For the landslide risk reductions, we first re-calculated the attribute levels (i.e. stating the landslide risk shares of the routes to kilometre landslide risk), by multiplying the midpoints of the stated shares by the length of the reference trip. That is: for “more than half of the route is prone to landslides”, 0.75 was multiplied by the trip length; for “maximum 10% of the route is prone to landslides”, 0.05 was multiplied by trip length, and so on. For both “the whole route is prone to landslides” and “the risk of landslides on the whole route is doubled” we applied the entire length of the reference trip[2]; and for "one spot" we applied 100 m as the distance. This fits into our specified model in (2), and we estimated $WTP_{SLIDE\text{-}KM} = \alpha/\beta$ directly as the value of removing one km of landslide risk per trip. This is a unit value that will fit into cost-benefit analysis, as it can be annualised by the annual average daily traffic (AADT) on the section, as follows:

$$\text{Annual value of slide risk removal per km} = WTP_{SLIDE\text{-}KM} \cdot AADT \cdot 365 \quad (4)$$

It is also relevant to assess the VSC, which is given by:

$$VSC = \frac{\theta/\beta}{\Delta r_{CAS}} = \frac{WTP_{CAS}}{\Delta r_{CAS}} \quad (5)$$

where Δr_{CAS} is the casualty risk change valued in the SC experiment. The casualty risk depends on traffic density, measured by AADT, and we have Δr_{CAS} equalling 1/(AADT·365), as the change in risk if we reduce it by one casualty. If risk equals the number of casualties divided by total yearly flow, the change in risk brought about by one less casualty is the inverse of the total yearly flow, and this flow is simply the annual number of passing vehicles on the road section (AADT·365). Thus, the VSC is given by:

$$VSC = \frac{WTP_{CAS}}{\Delta r_{CAS}} = \frac{WTP_{CAS}}{\frac{1}{AADT \cdot 365}} = WTP_{CAS} \cdot (AADT \cdot 365) \quad (6)$$

[2] The attribute level "the risk of landslides on the whole route is doubled" is somewhat inconsistent with the other attribute levels, as it refers to the frequency (and consequence) of landslides instead of measuring the share of the route length that is prone to landslide risk. However, this attribute level applied to only 0.2% of the sample (see Tables 4 and 1), such that the effect of this inconsistency should be indiscernible on the valuation of the landslide risk.

As for the value of landslide risk, the calculation of VSC can be based on different levels of aggregation for WTP_{CAS} and Δr_{CAS}. We based our main calculations on the sample average of both WTP_{CAS} and AADT.

To derive the value of a statistical life (VSL) from the VSC, based on WTP_{CAS} for combined reductions of fatalities and serious injuries, we employed a so-called *death-risk equivalent* (DRE_{si}), i.e. 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). Thus, to estimate VSL from VSC, we applied the following formula:

$$\mathrm{VSL} = \frac{\mathrm{VSC}}{\mathrm{DRE}_{si} \cdot p_{si} + (1 - p_{si})} \qquad (7)$$

where p_{si} and $(1–p_{si}) = p_f$ represent the actual shares of, respectively, serious injuries and fatalities in car accidents (Hultkrantz et al., 2006, p. 163). Our default value of DRE_{si} was 0.2 (Svensson, 2009; Veisten et al., 2013), which is close to estimates from other Scandinavian and British studies (Jones-Lee et al., 1995; Hultkrantz et al., 2006; Svensson, 2009)[3].

3.3 The survey

Development of the survey material was initiated by focus group sessions in May 2008, including assessments of people's perception of fatality risk causes and risk communication. Based on this we opted for the approach of presenting and altering

[3] Hultkrantz et al. (2006) and Svensson (2009) wrote this formula with WTP_{CAS} instead of VSC. Then the denominator should include the relative risk changes for serious injuries and fatalities, and therefore each share was multiplied by the risk change, $\Delta r_{CAS} = 1/(\mathrm{AADT} \cdot 365)$.

fatality/injury numbers instead of fatality/injury risk figures (Rizzi and Ortúzar, 2003). A first pilot test of the internet-based survey instrument was carried out in February 2009, involving 156 car drivers, and a second pilot in July 2009, involving 2102 car drivers. The main survey was carried out in April/May 2010, where the choice experiment involving landslide risk was part of a second wave resurveying car drivers who had faced another choice experiment in a first wave (with a response rate of 21.87%); 3109 of the 9538 car drivers from the first wave were routed to the second wave survey and 75.33% responded, i.e. 2342 (Veisten et al., 2013)[4].

Some data were cleaned at the first wave stage of the survey. Respondents with reported trips of more than 13 hours and NOK 10,000 were removed (with remaining maximum cost equal to NOK 6242). With this, the effective sample in the second wave was 927 for those responding to the landslide risk choice experiment.

3.4 Descriptive statistics

Table 3 lists the means and distributions of the sample, focusing on the variables applied in the analysis of landslide risk valuation.

Table 3 approximately here

[4] According to Synovate Norway, our response rate was common for their internet panel, and they applied 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*, and now *IPSOS-MMI*, is part of the international opinion research company IPSOS (www.ipsos.com) since 1 January 2012.

If we compare our sample with the 2005 Norwegian Travel Survey (NTS), which contained a representative sample of the car-driving population, it seems fairly representative in terms of demographic characteristics. Notwithstanding, both the share of male car drivers (0.59) and the average age (46.7) are slightly higher in our sample (Denstadli et al., 2006)[5].

About 20% of respondents described a recent trip through landslide-prone areas, half of which had only one dangerous point on the route; most other respondents stated that less than 10% of their route was prone to landslides (Table 4). However, about one-third stated that sometimes their preoccupation with landslide risk had made them choose an alternative route or travel at another time. A quarter of the respondents never drove in landslide-prone areas, while half did, but only occasionally. Slightly fewer than 10% of the respondents claimed that nearly all of their trips by car took place in areas prone to landslide.

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[5] The 2005 Norwegian Travel Survey interviewed approximately 10,000 people constituting a representative sample of the population. They were asked about all types of travel, "including short trips taken on a daily basis and longer journeys undertaken less frequently, as well as by all modes of transport" (Denstadli et al., 2006, p. 1). The valuation of landslide risk in the choice experiment with four attributes was carried out after another choice experiment with only three attributes (lacking the landslide risk attribute). In the three-attribute choice experiment, the 2,290 respondents had fairly similar values on individual demographic and socioeconomic characteristics except for the share of them living in rural areas which was lower (22% vs. 29%). This is related to the fact that there is self-selection of those driving in landslide risk prone areas, as most of these are situated in rural areas.

Table 4 approximately here

Respondents were first allocated to one of three AADT levels on the basis of their municipality being: (i) a larger city (mean AADT set equal to 12,000); (ii) another densely populated area (mean AADT set equal to 6,000) or (iii) a rural area (mean AADT set equal to 2000). Second, they were asked about the traffic density on their reported route. Adjustments (to the mid-AADT level, that is, 6,000) were made if those in rural areas reported "very high density" or those in larger cities reported "very low density". Respondents were also asked to assess the allocated casualty number, based on AADT and trip length. One-third considered the level as correct, while half found the reference levels "too high". As indicated, and particularly for shorter trips, the reference values for casualties were rounded up to the nearest integer in the choice experiments.

4. Modelling Results

4.1 Level-of-service attributes only

In this section we present the results of modelling the choices between two hypothetical routes characterised by four attributes: the share of the route travelled that was prone to landslides (re-coded as kilometres prone to landslides), number of casualties, travel time and cost. The SC exercise allowed for the possibility of not choosing any of the two alternatives (opt-out) and for choosing "route A and B are almost alike". In the first case, the responses were excluded from the analysis (Veisten et al., 2013). Notwithstanding, in the second case, the observations were entered twice, once as choosing the safer route and once as choosing the more dangerous route. We included a personal specific error term (normally distributed) in the two utility functions such that the (pseudo) panel-data effect of our SC data was accounted for (Train, 2009).

We present three model versions: In the first, routes are labelled as “less casualty risk” and “more casualty risk”, but we do not include an alternative specific constant (ASC) measuring the general propensity towards either of the routes. In the second model, we include such a constant (“ASC_less_casualty”). Finally, in the third model, the two alternative routes are labelled “less landslide risk” and “more landslide risk”, and we include an ASC for the alternative with less landslide risk (measured in km). While in the first model only the marginal utilities of attributes are assumed to matter to decision-makers, the last two models also account for the potential preference for, respectively, landslide-risk and casualty-risk avoidance *per se* (Table 5). Thus, the last two models can be considered as a way of controlling for the possible influence of lexicographic choice of the least risky alternative (Veisten et al., 2013).

Table 5 approximately here

In all three model specifications, all coefficients have the expected signs. In models 1 and 2, the WTP for avoiding one km of landslide risk-prone area is estimated at NOK 2.31 and NOK 2.23, respectively. In the third model, where we control for preferences towards land landslide risk *per se*, the WTP is considerable lower, namely NOK 1.51 (or about two-thirds compared to the WTP derived in the first two models). The ratio of the constant term (“ASC_less_slide_risk”) and the cost coefficient is 66.4, and can be interpreted as the monetary equivalent of the utility difference between alternatives, independent of the size in landslide risk reduction provided by the alternative with lowest landslide risk.

The WTP for reducing one casualty (WTP_{CAS}) is estimated at NOK 18.19 in the first model and NOK 9.03 in the second, where we control for casualty risk *per se*[6]. The strong decrease in WTP_{CAS} after including an alternative-specific constant with respect to the casualty risk of the alternative is consistent with the findings of Veisten et al. (2013) and points to the strong propensity of respondents towards the alternative that offers less casualty risk.

We may also differentiate our estimates according to the extent to which individuals drive in landslide risk-prone areas. Table 6 gives WTP estimates for respondents who had reported that they normally do not drive in landslide risk-prone areas and for others who do it (seldom or regularly). Those who drove in landslide risk-prone areas were also subdivided into those who reported no landslide risk in their reference trip and those who also had their reference trip in a landslide risk-prone area.

Table 6 approximately here

The results indicate that respondents who do not drive in landslide risk-prone areas have a higher valuation of reduced landslide risk (both marginally and *per se*). They also indicate

[6] All respondents replying to the choice experiment described in this paper (with four attributes) had first responded to the three-attribute choice experiment reported by Veisten et al. (2013), with WTP estimates of NOK 21.3, in a model similar to Model 1, and NOK 9.7, in a model similar to Model 2. Our sample for the four-attribute choice experiment was smaller, since some of those responding to the first choice experiment faced a second one involving a different fourth attribute than slide risk. The differences between the WTP_{CAS} estimates in this paper and in Veisten et al. (2013), for similar model types, are not significantly different.

that people who drove in landslide risk-prone areas but not in their reference trip, had a higher WTP than people who drove in risk-prone areas both in the reference trip and in general. However, as suggested by the overlapping confidence intervals, there is no statistically significant difference between these three sub-samples.

4.2 Models including individual characteristics

We parameterised the constant term (ASC_less_slide_risk) in Model 3 (Table 5) with the covariates listed in Table 3. The results of this specification are displayed in Table 7.

Table 7 approximately here

As can be seen, parameterisation of the constant term hardly changes the marginal measures, such that the WTP values obtained are similar to those obtained in Model 3 (Table 4). Of the covariates included, only four are significant at the 10% significance level. Men appear to have a considerably lower propensity to choose the alternative with less landslide risk. Consistently with Table 5, respondents that did not report landslide risk on their reference trips assigned a higher utility to the less slide-risk alternative *per se*. Also, people with higher education tend to choose more often the alternative with lower landslide risk. Finally, and perhaps somewhat unexpectedly, respondents stating that a family member or close friend had been in a car accident had a lower propensity to choose the less slide-risk alternative, but this was not significant at the 5% level.

5. Discussion and Conclusions

To our knowledge, this study represents a first attempt to value landslide risk reductions on roads by means of a stated choice experiment. The valuation was carried out within a context involving road casualties and travel time attributes as well. The landslide risk attribute conveyed a WTP for a different welfare effect than the risk of injury/fatality as such. The valuation of landslide risk increased with the size of the risk reduction (a higher valuation of risk reductions was obtained for those reporting a higher share of the distance travelled prone to landslides), implying a sensitivity to scope that is fundamental for theoretical validity (Arrow et al., 1993). For the segment of respondents who travelled regularly through landslide risk-prone areas, or that reported having risked landslide on their particular trips, the valuation of landslide risk removal per kilometre driven was approximately NOK 1.77 (or EUR 0.22, using a conversion rate of EUR 1 = NOK 7.8972[7]). For the entire sample the estimate varied between EUR 0.19 and EUR 0.29, depending on the modelling approach.

We cannot determine from our data whether the stated WTP for landslide risk reductions conveys WTP solely for reducing some particular risk or if, in addition, it conveys WTP for transport accessibility, although we did control for part of the congestion/unreliability element by including a travel time attribute. In Norway, landslides might block up communities for some considerable time, thus occasioning discomfort other than fear and dread (Elvik et al., 2006). The possibility that the valuation of the landslide risk attribute comprises various types of welfare impacts goes some way to explaining the size of the

[7] The average conversion rate for May 2010, following the Central Bank of Norway (http://www.norges-bank.no/en/price-stability/exchange-rates/eur/mnd/, accessed 30 November 2013).

estimated WTP for landslide risk reductions. Moreover, a low baseline landslide risk could actually offset the dread effect (Chilton et al., 2006). The models including alternative-specific constants, either for the alternative(s) with lowest landslide risk or for the alternative(s) with lowest number of casualties, resulted in lower welfare estimates for, respectively, landslide risk reductions and casualty risk reductions. These constants account for potential preferences for, respectively, landslide risk removal and casualty risk removal *per se*, apparently removing large part of the influence of potentially lexicographic respondents (Veisten et al., 2013).

If an average individual of our sample drove 20 km in an area with about 1 km of the road section prone to landslide risk using a car consuming 0.05 litres of fuel/km (i.e. costing EUR 2 per litre), s/he would pay EUR 2.0 for the fuel and, according to our results, would be willing to pay an additional EUR 0.25 if the landslide risk was removed. Comparing the landslide risk valuation to the time valuation, an average speed of 45 km/h (Denstadli et al., 2006) would yield a value of landslide risk removal (per hour) that amounted to about 40% of the value of travel time savings, and about 50% if the average speed was 60 km/h. The value of reliability as a share of the value of travel time savings has been found to be context specific. For example, Jeekel et al. (2010) present intervals from 0 to 25%, while Ramjerdi et al. (2010) present estimates of about 35% for long trips and 45% for short trips.

Although not statistically significant, the estimated $WTP_{SLIDE\ RISK}$ (NOK/km) was higher for those *not driving* in landslide risk-prone areas than for those *driving* in these areas (moreover, for those driving in slide risk-prone areas, $WTP_{SLIDE\ RISK}$ was higher for the sub-group *not* reporting landslide risk in the reference trip). There are several possible elements that might have contributed to elevating the estimated (marginal) $WTP_{SLIDE\ RISK}$

from those not driving in landslide risk-prone areas. A major element is design-driven and related to the non-proportionality of WTP for risk reductions; stated preference-based WTP estimates do not increase linearly with risk change size (Hammitt, 2000). Those not driving in landslide risk-prone areas, plus those who did not report landslide risk in their reference trips were all allocated to the lowest reference level of “no risk of landslide on route”. This implied that they faced the lowest level of risk change, that is, between “only one spot prone to landslide on the route (max. length of 100 m)” and “maximum 10% of the route is prone to landslides” or down to “no risk of landslide on route”.

Those reporting (maximum) 10%, between 10 and 50% or between 50 and 100% of the reference trip prone to landslide risk (altogether barely 10% of the sample), would value (much) larger risk changes, thus yielding, *ceteris paribus*, somewhat lower estimated (marginal) $WTP_{SLIDE\ RISK}$. Other elements that might have contributed to higher estimated $WTP_{SLIDE\ RISK}$ for those *not driving* in landslide risk-prone areas are: (i) endogeneity, in the sense that respondents who fear landslides are less likely to drive on routes prone to landslide and have a stronger preference for landslide risk removal; (ii) possible protest behaviour from drivers in landslide risk-prone areas, although protesting in stated choice experiments is slightly more difficult as in contingent valuation experiments (Meyerhoff and Liebe, 2008); and (iii) some people living and travelling in areas prone to landslide risk might be of the opinion that the reduction/removal of landslide risk is something they are entitled to and should not pay for (Elvik, 2010). Finally, the estimated $WTP_{SLIDE\ RISK}$ might have been less stable if most respondents regarded the landslide risk attribute as relatively less important, all over, compared to fatality risk (and travel time and trip cost).

The respondents allocated themselves to the level of landslide risk extent on the route they had used (Table 4) before the choice experiments. The landslide risk attribute was not described in terms of the expected frequencies and possible consequences of landslides. We did not endeavour to demarcate the various types or levels of landslides. Thus, respondents had to imagine or define for themselves what they perceived as areas prone to landslide risk. This also applied to the temporal extension of landslide risk, in as much as different areas might be prone to landslide risk over different periods during a year or during a longer time period. Clearly, the frequency as well as the consequence, say the amount of snow/ice or rocks that fall onto the road, constitute major features of landslide risk. Presenting well-defined classes of landslide frequencies and sizes/consequences, in addition to their extension on the given route, would be quite a challenging task in a choice experiment pivoted on actual trips on actual routes for a countrywide sample of car drivers. This is a challenge left for future research.

Notwithstanding the limitations of our study, our results clearly indicate that landslide risk is perceived as something more than, or different from, casualty risk related to collisions with other road users or driving off the road. We believe that our study provides a novel approach to the valuation of landslide risk, and that pivoting the design of the landslide attribute to a recent car trip reported by the respondents themselves was a strong positive feature, as it helped in making the scenario more realistic. But more research is warranted for disentangling more precisely what the consequences of landslide risk are for welfare; more studies are needed before such value estimates can be considered as input into public cost-benefit analyses of landslide-reducing measures.

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Table 1. The landslide risk attribute in the four-attribute choice experiment

Reported reference level of landslide risk	**Changed levels of landslide risk relative to reference**				
	Level -2	Level -1	level 0	Level 1	level 2
Base = "no risk of landslide on route"	"no risk of landslide on route"	"no risk of landslide on route"	"only one spot prone to landslide on the route (max length of 100 m)"	"maximum 10% of the route is prone to landslides"	"between 10% and 50% of the route is prone to landslides"
Base = "only one spot prone to landslide on the route (maximum length of 100 m)"	"no risk of landslide on route"	"no risk of landslide on route"	0	"maximum 10% of the route is prone to landslides"	"between 10% and 50% of the route is prone to landslides"
Base = "maximum 10% of the route is prone to landslides"	"no risk of landslide on route"	"only one spot prone to landslide on the route (maximum length of 100 m)"	0	"between 10% and 50% of the route is prone to landslides"	"more than half of the route is prone to landslides"
Base = "between 10% and 50% of the route is prone to landslides"	"only one spot prone to landslide on the route (maximum length of 100 m)"	"maximum 10% of the route is prone to landslides"	0	"more than half of the route is prone to landslides"	"the whole route is prone to landslides"
Base = "more than half of the route is prone to landslides"	"maximum 10% of the route is prone to landslides"	"between 10% and 50% of the route is prone to landslides"	0	"the whole route is prone to landslides"	"the risk of landslides on the whole route is doubled"

Table 2. Reference levels of casualties in choice experiments, derived from car drivers' actual trip length (in time)

Base time (min)	Mean time (min)	Km [a]	Mean annual expected number of casualties					
			Official statistics			Adjustment for underreporting (×1/0.7) and rounding		
			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

[a] The conversion from reference trip time (midpoints) to trip length means that in 15 min a trip by car will cover 11.25 km [(15/60) × 45]; a trip lasting 32 minutes will cover 24 km, and so on (Elvik, 2008; Veisten et al., 2013).

Table 3. Descriptive statistics for main study variables in the car driver data (n = 927)

	Mean	SD	Min	Max
Age	49.42	13.85	18	84
Gender (male)	0.67	0.47	0	1
Children (below 18 years) in household	0.35	0.48	0	1
University degree	0.63	0.48	0	1
Income (personal monthly net income, NOK)	21930 [a]	10480	0	55000
Income missing	0.06	0.24	0	1
Live in semi-urban area	0.30	0.46	0	1
Live in city	0.41	0.49	0	1
Daily travel distance by car (km)	38.06	43.46	1	500
Drive regularly in areas prone to landslide risk	0.24	0.43	0	1
Drive seldom in areas prone to landslide risk	0.53	0.50	0	1
Never drive in areas prone to landslide risk	0.23	0.42	0	1
Reference trip not in area prone to landslide risk	0.49	0.50	0	1
Relative/friend seriously injured or killed in road accident	0.28	0.45	0	1

[a] The mean income is slightly downward biased since missing values are set to zero.

Table 4. Landslide risk on reference trip (n = 2,343)

Landslide risk on reference trip	n	Percent
No risk of landslide on the reference trip	1,863	79.5
Only one spot prone to landslide on the reference trip (maximum length of 100 m)	262	11.2
Maximum 10% of the route is prone to landslides	168	7.2
Between 10% and 50% of the route is prone to landslides	45	1.9
More than half of the route is prone to landslides	5	0.2

Table 5. Mixed logit models with level-of-service attributes [a]

ML models	Model 1: without constants		Model 2: constant for alternative with less casualty risk		Model 3: constant for alternative with less landslide risk	
	Estimate	Robust t-test	Estimate	Robust t-test	Estimate	Robust t-test
ASC_less_casuality			0.762	10.58		
ASC_less_slide_risk					0.511	10.74
B_cost	-0.00775	-6.67	-0.00753	-6.63	-0.0077	-5.83
B_time	-0.0208	-5.87	-0.0197	-5.62	-0.0265	-6.96
B_casualty	-0.141	-6.78	-0.068	-3.84	-0.166	-7.34
B_sliderisk-km	-0.0179	-6.67	-0.0168	-6.4	-0.0117	-5.23
Sigma	0.848	19.86	0.771	18.98	0.576	15.36
Number of observations	5419		5419		5419	
Number of individuals	927		927		927	
Null log-likelihood	-3,756.165		-3,756.165		-3,756.165	
Constant log-likelihood			-3,496.192		-3,629.078	
Final log-likelihood	-3,266.753		-3,190.345		-3,287.22**	
ρ^2(Null)	0.13		0.151		0.125	
ρ^2(Cte)			0.087		0.094	
$\bar{\rho}^2$ (Null)	0.129		0.149		0.123	

$WTP_{SLIDE\ RISK}$ (NOK/km)	2.31(1.21-3.41)	2.23 (1.15-2.98)	1.51 (0.93-2.11)
WTP_{CAS} (NOK/casualty)	18.19 (9.98-26.41)	9.03 (5.13-12.93)	21.56 (15.70-27.42)
VSL (NOK)	129 mil (71-187 mil)	64 mil (36-92 mil)	153 mil (111-195 mil)
VSSI (NOK)	26 mil (14 -37 mil)	13 mil (7-18 mil)	31 mil (22-39 mil)
VTTS (NOK/hour)	161 (79-244)	157 (104-210)	206 (140 -273)

[a] All models were estimated using BIOGEME (Bierlaire, 2003) applying 500 Halton draws. Robust t-tests were computed taking into account the repeated observations nature of the data. The delta method was applied for the estimation of 95% confidence intervals (Hole et al. 2007). All parameters are significant at the 1% level, except the alternative-specific constant of the leftmost model. Opt-out options were removed from the estimation.

Table 6. Valuations according to whether driving in landslide risk-prone areas or not (for Model 3) [a]

	Do not drive in landslide risk-prone areas (N=184) [b]		Drive in landslide risk-prone areas: No landslide risk in reference trip (N=273)		Drive in landslide risk-prone areas: Slide risk in reference trip (at least 100 m or 10% of trip) (N=440)	
	Value	95% conf.int.	Value	95% conf.int.	Value	95% conf.int.
$WTP_{SLIDE\ RISK}$ (NOK/km)	2.90	(0.12-5.69)	1.98	(1.00-2.95)	1.77	(0.86-2.67)
$MEQ_{constant}$ (NOK) [c]	61.54	(18.62-104.45)	57.89	(5.33-110.44)	47.50	(20.84-74.16)
WTP_{CAS} (NOK/casualty)	25.77	(11.42-40.12)	14.55	(5.62-23.49)	22.19	(14.40-29.97)

[a] The delta method was applied for estimation of the 95% confidence intervals (Hole et al., 2007).

[b] Thirty respondents stated that they never drive in areas prone to landslide risk, but they also stated that their reference trip had some landslide risk. These inconsistent answers were excluded. The remaining 184 respondents stated that their reference trip did not go through areas prone to landslide risk.

[c] The monetary equivalent of receiving the alternative with less land landslide risk was calculated as ($-\hat{\alpha}/\hat{\beta}$, that is, –ASC_less_slide_risk / B_cost).

Table 7. Mixed logit models including individual characteristics interacting with the alternative with least landslide risk

	Estimate	Robust std. error	Robust T statistic
B _cost	-0.00776	0.00132	-5.88***
B _risk	-0.165	0.0227	-7.27***
B _time	-0.0265	0.00383	-6.92***
B _slide risk (km)	-0.0131	0.00239	-5.48***
ASC_constant_term	-0.664	1.14	-0.58
B_logpnetincome	0.115	0.119	0.97
B_income_miss	1.09	1.20	0.90
B_age	0.000793	0.00349	0.23
B_men	-0.276	0.0990	-2.79***
B_high_education	0.150	0.0886	1.69*
B_child	-0.0619	0.0959	-0.65
B_semi_urban	-0.0216	0.114	-0.19
B_urban	-0.0241	0.107	-0.23
B_log_km_per_day	-0.0110	0.0336	-0.33
B_family_friend	-0.183	0.0941	-1.94*
B_no_slide_risk_ref	0.320	0.102	3.14***
B_never_slide_risk	-0.0183	0.152	-0.12
B_seldom_ slide_risk	0.0499	0.115	0.43
Sigma	0.561	0.0376	14.91***
No. of obs.	5419		
No. of respondents	927		
Null-LL	-3756.165		
Constant-LL	-3629.078		
Final-LL	-3269.890		
ρ^2(Null)	0.129		
ρ^2(Cte)	0.099		
$\bar{\rho}^2$ (Null)	0.124		
$WTP_{SLIDE\ RISK}$ (NOK/km)	1.69 (1.17-2.21)		

WTP_{CAS} (NOK/casualty)	21.26 (15.5-27.03)
VSL (NOK)	151 mil (110-192 mil)
VSSI (NOK)	30 mil (22 -38 mil)
VTTS (NOK/hour)	205 (139-271)

*p < 0.10; **p < 0.05; ***p < 0.01.

Everything else equal, would you choose travel alternative *k* or travel alternative *l*?

Alternative *k*	**Alternative *l***	
Average travel time per trip: X min (approximately X*K*52/60 hours per year)	Average travel time per trip: R min (approximately R*K*52/60 hours per year)	do not know
Cost per trip: Y NOK (approximately Y*K*52 NOK per year)	Cost per trip: S NOK (approximately S*K*52 NOK per year)	
Seriously/severely injured and fatalities per year: Z	Seriously/severely injured and fatalities per year: T	
No risk of landslide on route	Between a tenth (10%) and a half (50%) prone to landslides	

Figure 1. Illustration of the pair-wise choice format with four attributes (K is a constant based on the respondents' stated car trip frequency per week).