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Estimating the willingness-to-pay and value of risk reduction for car occupants in the road environment

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ABSTRACT:

In recent years there has been a re-focus on the valuation of a statistical life (VSL) from the ex post or human capital method to an ex ante willingness to pay approach. This is in part a recognition that we may have been undervaluing the cost of fatalities and injuries to society associated with crashes, but also a strong belief in the need to focus on establishing the amount, ex ante, that individuals are willing to pay to reduce the risk of exposure to circumstances that might lead to death or degree of injury on the road network. This study has developed a framework in which to identify the heterogeneity in willingness to pay (WTP) by individuals who are drivers or passengers in cars to avoid being killed or injured. A stated choice experiment approach is developed. The empirical setting is a choice of route for a particular trip that a sample of individuals periodically undertakes in Australia. The particular trip is described in enough detail to provide the respondent with a familiar market environment, providing all the relevant background information required for making a decision. Mixed logit models are estimated to obtain the marginal (dis)utilities associated with each influence on the choice amongst the attribute packages offered in the stated choice scenarios. These estimates are used to obtain the WTP distributions for fatality and injury avoidance, which are then aggregated to obtain estimates of the value of risk reduction (VRR), often referred to generically as the value of a statistical life.

KEY WORDS: ***Safety, value of life, willingness to pay, car travel, value of risk reduction, stated choice experiment***

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1. Introduction

An important conceptual advance in the state of practice of road safety valuation was achieved in the 80s by valuing road safety according to subjective preferences rather than by using the heavily criticised *human capital* (*HC*) approach (see Jones-Lee and Loomes, 2003 for a review). The *HC* approach rests on accounting principles: the benefit of avoiding a premature death is given by the present value of the income flow the economy could lose in that case (Ashenfelter 2006). More appropriately, the *value of risk reductions* (*VRR*) – initially known as the *value of a statistical life* (VSL)[1] – is based on subjective preferences, and defined as the amount of money that individuals are willing to pay for reducing the risk of their premature death (or of injury) while performing a certain risky activity. The focus on the VRR in contrast to the *HC* value yields higher benefits for risk avoidance, and hence the social net benefit of safety policy measures has increased in recent years, prompting many road safety interventions, otherwise not socially profitable, in the developed world.

The *VRR* for road contexts was estimated originally using contingent valuation (CV), standard gamble or the chain method (Viscusi *et al.*, 1991; Jones Lee *et al.,* 1993; Beattie *et al.,* 1998; Carthy *et al.,* 1998), but the approach, in general, was criticised by specialists in human behaviour (Fischoff, 1991; 1997) and economics (Hausman, 1993; Diamond and Haussman, 1994). In those original studies people were confronted with situations expressing risk as tiny probabilities, and needing a trade-off between risk and money to arrive at a monetary value[2]. This kind of simulated context may not bear upon actual choices of trip route selection where individuals have to consider a bundle of attributes describing each alternative (i.e., travel time, toll, and safety associated with each route alternative).

Rizzi and Ortúzar (2003) proposed a different approach based on Stated Choice (SC) technique. In a SC survey, individuals are asked to choose among different alternatives, the attribute levels of which vary according to a statistical design aimed at maximising 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 most experts believe that it is an appropriate elicitation method for the valuation of intangibles (McFadden, 1998; Louviere *et al.*, 2000). The approach has also been applied by de Blaeij *et al.* (2002), Iragüen and Ortúzar (2004) and Hojman *et al.* (2005) and is the starting position for the current study.

This paper develops an ex ante willingness to pay (WTP) model as input into the calculation of the value of a statistical life in the context of a fatality and three classes of injury (defined below) in the road environment for occupants of cars. New surveys have been undertaken in late 2007 in New South Wales to obtain WTP distributions which are then combined with secondary data on the recent history of fatalities and injuries as well as exposure (measured in kilometres), to obtain estimates of VRR.

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[1] Given the continued common use of the phrase VSL, we will also use it herein to be equivalent to VRR.

[2] Some of these studies posed a risk – risk trade-off. However, in order to arrive to a monetary value a risk – money trade off is necessary, sooner or later.

2. The value of fatal and injury risk reductions

Assume a route is used by *N* users. If person *n* travels more than once in a reference period, say m_n times, this gives rise to m_n pseudo-members with a total population of $N = \sum_{n=1}^{N} m_n$, observations, i.e., the individuals of a population. This population exactly amounts to the flow on a route in a given period (say a year)[3]. We define a route as a path connecting one origin-destination pair. A trip on a route provides a level of dissatisfaction given by a deterministic indirect utility function $V = V(r, c, t)$, where *r* stands for risk of a fatal accident or class of injury, *c* for the cost of travel and *t* for the travel time on a route; there could be more attributes, of course. The injury classes studied are:

- *Severe permanent injury* (or serious) (*SI*), defined as an injury that requires hospitalisation for a long period and results in some permanent disability;
- *Injuries requiring hospitalisation* (*HI*) defined as an injury that requires hospitalisation but there is a full recovery; and
- *Minor injury* (*MI*) defined as an injury that requires some medical treatment but no hospitalisation.

Jones Lee (1994), focussing only on fatality, formally defined the *VRR* as the value of avoiding one expected death, and this corresponds to the population (or sample) average of the marginal rate of substitution between income and risk of death for person *n* (MRS_n) plus a covariance term that accounts for possible correlation between WTP and reduced risk (δr_n)[4]:

$$MRS_n = \frac{\partial V_n / \partial r}{\partial V_n / \partial c\,\big|_{V=\bar{V}}} \quad , \tag{1}$$

$$VRR = \frac{1}{N}\sum_{n=1}^{N} MRS_n + N \operatorname{cov}\left(MRS_n, \left|\delta r_n\right|\right). \tag{2}$$

In empirical work, it is typically assumed that there is no correlation between WTP and δr in the population. Then, Equation (2) simplifies to Equation (3), below, and to estimate the *VRR* it is sufficient to have a good estimate of the *MRS*. This assumption would be correct, for example, if δr were the same for every individual.

$$VRR = \frac{1}{N}\sum_{n=1}^{N} MRS_n \,. \tag{3}$$

The MRS can be interpreted as an implicit value for the own life, and averaging it over all individuals travelling on the route yields the VRR. The MRS clearly depends on

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[3] Bear in mind though that a population is a stock variable whereas a flow is not.

[4] $\operatorname{cov}\left(MRS_n, \delta r_n\right) = \sum_n MRS_n \delta r_n - \frac{1}{N}\sum_n MRS_n \frac{1}{N}\sum_n \delta r_n$

personal risk perceptions according to the functional form of Vn. The same analysis can be carried out in terms of fatal crashes, f, (or injuries), instead of risks, r. However, in this case the VRR is derived differently (but yields the same value):

$$VRR = \frac{1}{e}\sum_{n=1}^{N}\frac{\partial V_n \big/ \partial f}{\partial V_n \big/ \partial c\,\big|_{V=\bar{V}}} = \frac{1}{e}\sum_{n=1}^{N} SVCR_n\,, \tag{4}$$

where e represents the number of fatalities or injuries (by class) per crash and $SVCR$ stands for the subjective value of fatal crash injury (by class) reductions, and is a Lindahl price (Varian, 1992, chapter 23). Equation (4) embodies the definition of community WTP for a public good, road safety in this case, as the sum of individual marginal rates of substitution between income and number of fatalities and injuries (by class). If we think in terms of a hypothetical tolled route whose operators were able to extract the full consumer's (compensatory) surplus, the $SVCR$ would be the maximum toll increase due to a safety improvement for individual n, such that he is as well-off as before the improvement. If the VRR is higher than the cost of reducing one fatality or one injury (by class), the safety project should be desirable from the community standpoint; in what follows we will assume that e is equal to one.

We will now show one advantage of dealing with the variable number of fatal or injury crashes, rather than risk, in empirical work. From Equations (2) and (4), it follows that

$$VRR = \sum_{n=1}^{N} SVCR_n = \frac{1}{N}\sum_{n=1}^{N} MRS_n + N\,\mathrm{cov}\left(MRS_n, \left|\delta r_n\right|\right). \tag{5}$$

In other words, estimating the $SVCR$ and aggregating across individuals will yield the correct VRR irrespective of the value of $\mathrm{cov}(\bullet,\bullet)$, and this follows from the very definition of our public good; one statistical death (or injury class reduction) reduction[5] (per unit of time) on a particular route. This suggests that to elicit the VRR, rather than asking people to place a value on risk reductions, they should be asked to value a reduction in fatal or injury class crashes; we believe this task is far easier from the respondents' standpoint as we will see below[6].

2.1 Making the model operational

The model can be made operational within a (binary) choice framework (and generalised to multiple choice settings) where the indirect deterministic utility of each available alternative j is

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[5] A statistical death reduction means saving one life, on average, per unit of time (obviously whose life is saved is unknown).

[6] The two approaches are mutually consistent only when respondents have the correct aggregate flow in mind (i.e., they would value an extra fatal or serious injury crash per year different if they were to make the only trip on that road that year, than when millions of trips would be made on that road). In this sense although a formulation in terms of number of crashes may sound more natural and easy-to-understand than a formulation in terms of probabilities to most respondents, the cognitive burden may not become any lighter.

$$V_j = \alpha f_j + \eta SI_j + \theta HI_j + \varphi MI_j + \beta c_j + \gamma t_j, \qquad (i = 1, 2) \tag{6}$$

where *f* is the number of *fatalities*, *SI* is the number of *severe permanent* (or serious) *injuries*, *HI* is number of *injuries requiring hospitalisation*, *MI* is the number of *minor injuries* not requiring hospitalisation, *t* is trip time and c is trip cost. The *SVCR* is equal to α/β for fatalities for every individual, η/β for serious injuries (Hojman *et al.*, 2005), θ/β for hospitalised injuries, and φ/β for minor injuries for every individual. Also note that by computing $\gamma/\beta,$ the behavioural value of travel time savings (VTTS) is obtained (see e.g., Gaudry *et al.*, 1989, Hensher *et al.,* 2005).

Let U_{nsj} denote the utility of alternative *j* in choice set *s* perceived by respondent *n*. U_{nsj} may be partitioned into two components, an observed (by the analyst) component of utility, V_{nsj}, and an unobserved (and un-modeled) component, ε_{nsj}, such that

$$U_{nsj} = V_{nsj} + \varepsilon_{nsj}. \tag{7}$$

The observed component of utility is typically assumed to be a linear relationship of observed attribute levels of each alternative, *x*, and their corresponding weights (parameters), β (as per Equation 6). It is possible for some or all of the parameter weights to vary with density $f(\beta \mid \Omega)$ over the sampled population. By allowing the parameter weights to vary between and not within respondents, the model accounts for the pseudo panel nature of SC type data (Ortúzar and Willumsen, 2001; Revelt and Train, 1998; Train, 2003). Under such an assumption, the observed components of utility may be represented as Equation (8).

$$V_{nsj} = \sum_{k=1}^{K} \beta_{nk} x_{nsjk}. \tag{8}$$

Assuming that (some of) the parameters are randomly distributed over the population, the choice probabilities of the model therefore depend on the random parameters. In estimating the model, rather than calculate a single probability for each alternative, the choice probabilities for each random draw are taken from the assumed probability distribution(s). In this way, multiple choice probabilities are obtained for each alternative, as opposed to a single set of probabilities as obtained from the typical multinomial logit (MNL) model. It is the expectation of these probabilities over the random draws which are calculated and used in the model estimation process. The expected choice probabilities for the model are given in Equation (9).

$$E\left[P_{nsj}\right] = \int_{\beta} \frac{\exp\left(V_{nsj}\right)}{\sum_{i \in J_{ns}} \exp\left(V_{nsi}\right)} f\left(\beta \mid \theta\right) d\beta. \tag{9}$$

Equation (9) represents the choice probability at the level of the alternatives. In the version of the model accounting for the panel format of SC data, the choice probability given in Equation (9), whilst calculated, is not of direct interest. Rather, what is of interest are the probabilities of observing the sequence of choices made by each respondent, not the probabilities that specific alternatives will be observed to be chosen. To this end, we define the probability P_n^* that a certain respondent *n* has made a certain sequence of choices $\{j \mid y_{nsj} = 1\}_{s \in S_n}$ with respect to the set of choice situations, S_n, by

$$P_n^* = \int_\beta \prod_{s \in S_n} \prod_{j \in J_{ns}} \left(P_{nsj}\right)^{y_{nsj}} f\left(\beta \mid \theta\right) d\beta, \tag{10}$$

which is what is used in model estimation (see e.g., Hensher and Greene, 2003; Sillano and Ortúzar, 2005; Train 2003).

2.2 Aggregating individual WTP to the population

The community demand for a public good is given by the summation of the WTP for the good by each individual (WTP_n). The public good is the avoidance of a fatality (or class of injury) known as the *value of risk reduction* (*VRR*) in the road vehicle environment. It can be shown (Jones Lee, 1994; Rizzi and Ortúzar, 2003) that the value of avoiding one event equals the population average of *MRS* (see Section 2 above).

In this paper we focus on car drivers[7] - excluding other contexts such as non users of roads, motorcyclists, pedestrians, etc. We focus on the WTP for car drivers in terms of fatalities and three classes of injury of road users. Importantly, the aggregate VRR (Equation 5) represents the valuation for one of the full set of impacted stakeholder classes; and hence is not the maximum VRR for society as a whole for fatalities and injury classes. However; the segment studied is arguably a substantial contribution to the community VRR[8].

For car drivers, the *WTP* is the vehicle driver's marginal rate of substitution between income and number of annual road fatalities; and *VRR* is the summation of *WTP (separately for fatalities and classes of injury on a specific route)* over all drivers that traverse a specific road in a given year. Summing *WTP* values over all drivers (annual flow) on each route, we obtain four values - the value of fatality risk reductions (*VF*), the value of serious (permanent) injury risk reductions (*VSI*), the value of hospitalised (non-permanent) injury risk reductions (*VHI*), and the value of minor injury risk reductions (*VMI*). The survey does not consider the driver's WTP for not harming pedestrians or other motorised or non-motorised users, at least explicitly, since the fatalities and injuries refer to individuals travelling in road vehicles.

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[7] In another paper we discuss pedestrians.

[8] The sources of community aggregate WTP are many and varied. These include users' WTP (including altruism if it exists) and non-users WTP; with respect to the latter we would only count altruism (in the sense of taking care of others' road safety). The WTP of non-users is unlikely to be the same as users' WTP (which includes the self-interest value). You cannot scale to the whole population from a sub-population. To capture WTP of non-road users one should consider a survey on non-users to infer their WTP. Thus multiplying drivers' WTP by the total population instead of by the drivers' population will over-estimate the WTP for his segment.

With a focus on specific car trips, we have to convert the individual WTP to a *driver population exposure risk measure*. The traditional method, based on the human capital approach, simply took the aggregate cost associated with all fatalities and injuries and paid no attention to the risk spectrum in which the cost of human capital was linked. This link is critical to the validity of the community WTP and cannot be disassociated from the specific level of risk associated with each trip.

The *exposure* of interest is reflected in the number of trips and associated kilometres undertaken by each driver in the population. The trip kilometres associated with driving has to be expanded up to the relevant population, based on the number of times an individual in a sub-population is exposed to risk. Identifying the actual amount of trip activity is crucial in aggregating up the average WTP per trip. The formulae for inputting the calculations for each risk class are

Community $\text{VRR}_{l,vf}$ (= $\text{VSL}_{l,vf}$) = Community VF_l ; l = region location 1,2,…,L,

Community $\text{VRR}_{l,vsi}$ (= $\text{VSL}_{l,vsi}$) = Community VSI_l ; l = region location 1,2,…,L,

Community $\text{VRR}_{l,vhi}$ (= $\text{VSL}_{l,vhi}$) = Community VSI_l ; l = region location 1,2,…,L,

Community $\text{VRR}_{l,vmi}$ (= $\text{VSL}_{l,vmi}$) = Community VSI_l ; l = region location 1,2,…,L.

The components of the calculation of the Community VRR can be defined simply as WTP/*chance*, where *chance* is defined by the relationship between the *risk* as measured by the number of fatalities or injuries in a class per annum, and *exposure* defined by the annual number of vehicle kilometres (AAVKM) (Equations 11 and 12).

$$\text{Community VF} = \frac{WTP\ per\ trip_l}{Trip\ Kms} \times \frac{AAVKM_l \times 365}{\#\ fatalities_l}, \quad \text{and} \tag{11}$$

$$\text{Community VI} = \frac{WTP\ per\ trip_l}{Trip\ Kms} \times \frac{AAVKM_l \times 365}{\#JI_l}, \tag{12}$$

where $I = S$ (serious), H (hospitalised) or M (minor injury) depending on what is being examined.

The WTP is an average or median WTP per person per trip; the average number of fatalities or injuries in a class is an average over the last five years; and the average annual daily vehicle kilometres is also over the last five years. The reason for five years is because accidents are very random in nature, so it is good to have averages over such a period of years.

To illustrate how this formula will work, let us assume a representative driver WTP (averaged over all drivers in the sample in the l^{th} region) of \$0.20 per vehicle kilometre. Let us assume from our population data in the l^{th} region that the chance of death per annum associated with driving a car is three fatalities ÷ 6,000,000 vehicle kilometres per annum. The VSL is the WTP of the representative car driving trip divided by the chance of death. This is \$2 ÷ [3/6,000,000] = \$400,000. This is the sum that society would be willing to pay to reduce the risk by one statistical death.

To be able to translate the WTP estimates (converted from per trip to per km) from the sampled population used in model estimation, we need data on (i) the number of fatalities and injuries by class on typical roads in each region, and (ii) the aggregate annual car kilometres for these roads. One major challenge is in how to work with a road network where the risks vary quite substantially across the network, within each region. That is, where the ratio of crashes to flow or exposure per route differs. There are two main options: (i) to work with each route safety record, or (ii) to group routes according to some characteristic, and work with their aggregated road safety record (for example, route A: 1 death per year; flow, 2,000,000; route B: 2 deaths per year; flow 3,500,000; aggregated: 3 deaths per 5,500,000 flow). In the latter situation, if routes are of different lengths it may be necessary to standardise in terms of deaths (and injuries in a class) per million vehicle-kilometres.

We suggest that a way forward for car drivers is to sample representative routes and obtain data on annual trip kilometres (based on number of trips and average distance if trip kilometres are not readily available) and crash record (road vehicle fatalities and injuries by class). As long as we have information on the amount of traffic that uses these roads, compared to the entire eligible regional network, we can use this data on exposure (annual vehicle kilometres) and risk (aggregated fatalities and respective injury classes) to obtain the chance indicator for Equations (11) and (12).[9]

3. Designing the stated choice experiment

The method implemented in the present study to obtain estimates of WTP and hence VRR involves the use of SC experiments in which we systematically vary combinations of levels of each attribute to reveal new opportunities relative to the existing circumstance of time-cost on offer (see Hensher, 1994; Louviere *et al.,* 2000; and Hensher *et al*., 2005). Through the SC experiment we are able to observe a sample of travellers making choices between the current trip attribute level bundle (or a package of service levels) and other attribute level bundles. This approach is a powerful method capable of separating out the independent contributions of each time and cost component, and quality differences, between links and routes.

For this study, a SC experiment is used to capture the preferences of road users (i.e., car drivers) for road safety, travel costs and travel times. Underlying SC experiments are what are known as experimental designs. An experimental design is used to systematically determine the attribute levels shown as part of the SC experiment.

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[9] Where we have different routes for given Origin-Destination (O-D) trips, everything will work fine as per the text. But if you have a link as part of a route for different O-D trips, you will also have to know the proportion of trips for each O-D, because vehicle kilometres will differ. For example you have Route 5 joining Taree - Sydney – Wollongong. Someone going from Taree to Wollongong will traverse the link Taree - Sydney, so on that stretch of the road all drivers (whether they go to Sydney, Wollongong or further south) will be exposed to the same travel time and road safety conditions, but the individual when choosing her preferred route will see what each alternative route offers to accomplish the trip. So to expand, one needs to know the proportion of trips corresponding to each O-D, to be able to establish a WTP measure per kilometre. As long as that proportion is known, the methodology will work fine. An O-D matrix with its corresponding traffic assignment available from any past study would be useful.

3.1 Experimental design

The car user questionnaires employed an unlabelled SC experiment where the alternatives relate to two hypothetical routes. Respondents were shown 10 choice situations each, and asked to select the route which they would most likely use if faced with these alternatives in real life. For each choice situation, respondents were also allowed to select neither route in a subsequent question.

The primary question for those generating experimental designs for SC studies is simply that of 'how best to allocate the attribute levels to the design matrix'. Traditionally, researchers have relied on the principle of orthogonality (i.e., allocate the attribute levels to the design matrix in such a way that the correlation between any two columns is zero) to populate the choice situations shown to respondents (see Louviere et al. 2000 for a review of orthogonal designs). The past decade, however, has seen fundamental changes in the methods employed to construct experimental designs underlying SC experiments. Recent new and innovative methods have been developed to allocate the attribute levels to the design matrix that do not rely on orthogonality as a design principle (see e.g., Bliemer and Rose 2006; Carlsson and Martinsson 2002; Ferrini and Scarpa 2007; Huber and Zwerina 1996; Kanninen 2002; Kessels et al. 2006; Sándor and Wedel 2001, 2002, 2005; Toner et al. 1999; Watson et al. 2000).

Primarily, these research efforts have concentrated on the concept of improving the *statistical efficiency* of experimental designs generated for SC studies. In doing so, researchers have defined statistical efficiency in terms of increased precision of the parameter estimates for a fixed sample size. In taking such a definition, statistical efficiency within the literature has therefore been linked to the standard errors likely to be obtained from the experiment, with designs that can be expected to i) yield lower standard errors for a given sample size, or ii) the same standard errors given a smaller sample size, being deemed more statistically efficient. In order to calculate the statistical efficiency of a design, Bunch, et al. (1994), Huber and Zwerina (1996), Sándor and Wedel (2001) and Kanninen (2002), amongst others, have shown that the common use of logit models to analyze discrete choice data requires *a priori* information about the parameter estimates, as well as the final econometric model form to be estimated.

Information on the expected parameter estimates is required in order to calculate the expected utilities for each of the alternatives present within the design. Once known, the expected utilities may in turn be used to calculate the likely choice probabilities. Hence, given knowledge of the attribute levels (the design), expected parameter estimate values and choice probabilities, it becomes a straightforward exercise to calculate the asymptotic variance-covariance (AVC) matrix for the design, from which the expected standard errors can be obtained. By manipulating the attribute levels of the alternatives, for known (assumed) parameter values, the analyst is able to minimize the elements within the AVC matrix, which in the case of the diagonals means lower standard errors and hence greater reliability in the estimates at a fixed sample size, or even at a reduced sample size. The linking of the experimental design generation process to attempts to reduce the asymptotic standard errors of the parameter estimates has resulted in a class of designs known as '*efficient designs*' where a design that, when used in practice, is expected to produce smaller asymptotic standard errors for a given sample size is thought of as being more '*efficient*'.

Many efficiency measures have been proposed in the literature in order to calculate an efficiency value based on the AVC matrix for the assumed model type. Typically these measures are expressed as an efficiency 'error' (i.e., a measure for the *in*efficiency), with the objective then to locate a design that minimizes this efficiency error. The most widely used measure is called the *D-error*, which takes the determinant of the AVC matrix Ω_1, assuming only a single respondent. Other measures exist, such as the *A*-error, which takes the trace (sum of the diagonal elements) of the AVC matrix, however, in contrast to the *D*-error, the *A*-error is sensitive to scaling of the parameters and attributes, hence here only the *D*-error will be discussed.

The *D*-errors are a function of the experimental design *X* and the prior values (or prior probability distributions) β, and can be mathematically formulated as:

$$D_z\text{-error} = \det\left(\Omega_1(X,0)\right)^{1/K}, \tag{13}$$

$$D_p\text{-error} = \det\left(\Omega_1(X,\beta)\right)^{1/K}, \tag{14}$$

$$D_b\text{-error} = \int_\beta \det\left(\Omega_1(X,\beta)\right)^{1/K}\phi(\beta\,|\,\theta)d\beta. \tag{15}$$

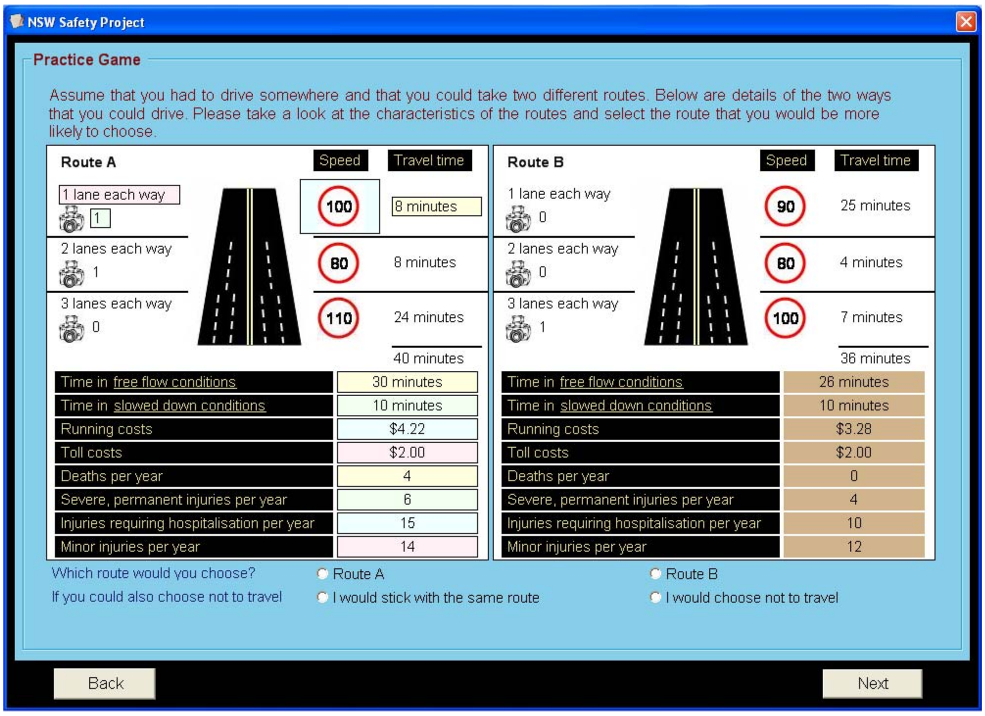
where *K* is the number of parameters to be estimated. Within the literature, designs which are optimised without any information on the priors (i.e., assuming β=0) are referred to as D_z–efficient designs (Equation (13), whereas designs optimised for specific fixed (non-zero) prior parameters are referred to as D_p–efficient designs (Equation (14)). In (Bayesian) D_b– efficient designs (Equation (15)), the priors β are assumed to be random variables with a joint probability density function $\phi(\cdot)$ with given parameters θ.

For the present study, given a lack of knowledge about the precise parameter estimates, we generated three separate Bayesian *D*-efficient designs corresponded to short (less than 30 minute), medium (less than 30 to 60 minutes) and long distance trips (greater than 60 minutes) with 60 choice tasks each. Sixty choice tasks represented the smallest number of scenarios achievable after accounting for attribute level balance and degrees of freedom, the latter based on the levels of each and every attribute in the choice set (see Table 1). The designs were generated assuming that all attributes would be treated as linear in the marginal utilities. All parameter priors were drawn using Uniform distributions with population moments as shown in Table 1. The best design located had a D_b-errors of the short, medium and long designs were 0.0012522, 0.008409, 0.002912 respectively over 1,000 Halton draws.

Within each design, the 60 choice scenarios were subsequently grouped into six blocks of 10 choice tasks recognising that an individual cannot be expected to asses all 60 choice scenarios. The process by which this was done involved calculating the correlation of each design attribute with the blocking variable, and fixing the design, varying the blocking column in such a way as to minimise the maximum correlation found. In this way, minimum confoundment with the blocks exists when estimating models based on data pooled across the blocks. The Computer Aided Personal Survey Instrument (CAPI) was then programmed to allocate a random start block to the initial respondent, and then to rotate each of the blocks over subsequent respondents. This was done to maintain as equal as possible exposure of the blocks to respondents within the data set. As such, each respondent saw a total of 10 SC screens during the survey process.

3.2 The final choice experiment

The SC experiments presented respondents with two alternative routes which differed in terms of the attributes or characteristics of the routes. The attributes and levels for each of the attributes are described in Table 1. Figure 1 shows an example SC screen.



Assume that you had to drive somewhere and that you could take two different routes. Below are details of the two ways that you could drive. Please take a look at the characteristics of the routes and select the route that you would be more likely to choose.

Route A	Speed	Travel time
1 lane each way 📷 1	100	8 minutes
2 lanes each way 📷 1	80	8 minutes
3 lanes each way 📷 0	110	24 minutes
		40 minutes

Route B	Speed	Travel time
1 lane each way 📷 0	90	25 minutes
2 lanes each way 📷 0	80	4 minutes
3 lanes each way 📷 1	100	7 minutes
		36 minutes

	Route A	Route B
Time in free flow conditions	30 minutes	26 minutes
Time in slowed down conditions	10 minutes	10 minutes
Running costs	$4.22	$3.28
Toll costs	$2.00	$2.00
Deaths per year	4	0
Severe, permanent injuries per year	6	4
Injuries requiring hospitalisation per year	15	10
Minor injuries per year	14	12

Which route would you choose? ○ Route A ○ Route B

If you could also choose not to travel ○ I would stick with the same route ○ I would choose not to travel

Figure 1: Example of a Final Stated Choice Screen

Table 1: Summary of Attributes and Associated Levels for Car Trip Experiments

Attribute	**Levels**	**Prior 1 (Lane 1)**	**Prior 2 (Lane 2)**	**Prior 3 (Lane 3)**
Number of speed Cameras (per lane: ×3)	0, 1, 2	(u,-0.4,-0.2)	(u,-0.5,-0.3)	(u,-0.6,-0.4)
Speed limits (per lane type)	60, 80 ,90, 100, 110	(u,0.02,0.04)	(u,0.04,0.06)	(u,0.06,0.08)
Travel time (per lane: ×3) [% of total reported time]	10, 20, 30, 40, 50, 60	-	-	-
Time spent in free flow conditions [% of reported free-flow time]	-25, -12.5, 0, 12.5, 25	(u,-0.14,-0.1)	-	-
Time spent in slowed down conditions [% of reported slowed down time]	-25, -12.5, 0, 12.5, 25	(u,-0.18,-0.14)	-	-
Total travel time	Sum of individual lane times	-		-
Running costs [% of estimated running costs]	-25, -12.5, 0, 12.5, 25	(u,-0.2,-0.15)	-	-
Toll costs	$0, $1, $2, $3, $4	(u,-0.35,-0.25)	-	-
Number of deaths per year	0, 1, 2, 3, 4, 5	(u,-0.2,-0.15)	-	-
Number of severe permanent injuries per year	0,1,2,3,4,5,6,7,8,9	(u,-0.1,-0.05)	-	-
Number of injuries requiring hospitalisation per year	0,1,2,3,4,5,6,7,8,9,…,19	(u,-0.2,-0.1)	-	-
Number of minor injuries per year	0,1,2,3,4,5,6,7,8,9,…,29	(u,-0.3,-0.2)	-	-

Number of speed cameras located on 1, 2 and 3 lane each way sections of the route.

Average ***Speed limits*** posted on 1, 2 and 3 lane each way sections of route.

Travel time spent on 1, 2 and 3 lane each way sections of route.

Total travel time which is the aggregate of the individual components of travel time.

Time spent in free flow conditions, where free flow is described as "Vehicles are almost completely unimpeded in their ability to manoeuvre within the traffic stream. The effects of incidents or point breakdowns are easily absorbed at this level" (level of service A).

Time spent in slowed down traffic conditions, where slowed down is described as: "Freedom to manoeuvre within the traffic stream is noticeably restricted, and lane changes require more care and vigilance on the part of the driver. Minor incidents may still be absorbed, but the local deterioration in service will be substantial. Queues may be expected to form behind any significant blockage" (level of service C).

Running costs which represent petrol costs for the trip.

Toll costs which represent the amount paid in tolls for the trip.

Number of deaths per year along the route which represent the number of people who have been killed in automobile accidents using this road in the past 12 months.

Number of severe permanent injuries per year along the route which represent the number of people who have been severely injured in automobile accidents using this road in the past 12 months, requiring hospitalisation for a long period of time and resulting in permanent disability.

Number of (non-severe and permanent) hospitalisation injuries per year along the route which represent the number of people who have been severely injured in automobile accidents using this road in the past 12 months, requiring hospitalisation after which a full recover is made.

Number of minor injuries per year along the route which represent the number of people who have been injured in automobile accidents using this road in the past 12 months, requiring some medical treatment but no hospitalisation.

To generate the SC experiment, respondents were initially asked about a recent trip that they had undertaken in terms of the travel times and costs that they experienced. Specifically, respondents were asked about the total travel time of the trip and about how much of this time was spent in free-flow or slowed down traffic conditions. The SC experiment then proceeded to vary the amount of time spent in these two traffic conditions as a percentage, ranging between minus 25 percent to plus 25 percent. Based on the new times, the total travel time for the route was then calculated and this was also shown as part of the SC experiment. Given the total travel time for an alternative, the time spent in one and two lanes was then calculated as a percentage of total time, with the remaining time allocated as time spent in three lanes. The number of lanes was predefined to vary from 1 to 3 along the trip as represented pictorially (see Figure 1); and is deemed to add realism into description of the road environment.

The running costs for the specific trip undertaken by each respondent was then calculated based on the estimated trip length provided by the respondent. The running costs for the two SC alternatives were then based on this amount, using the percentages shown in Table 1. The toll costs used in the experiment were allocated from the predetermined levels shown in Table 1, which ranged between $0 and $5. As with the toll costs, respondents were not asked about the number of fatalities or serious injuries that occurred along the route selected, with the attribute levels used being assigned from predetermined values.

4. The CAPI questionnaire layout

The data collected in the study was obtained from face-to-face interviews. All data was entered by trained interviewers directly into the CAPI system which was implemented on laptops[10]. The survey was adapted to car drivers who had undertaken a recent car trip that they could easily recall the details of. The survey consisted of eight major sections:

1. The introduction to the survey task and background on the study;
2. Questions describing a current or recent trip in terms of travel times, costs, trip purpose and those present within the car during the trip;
3. Questions related to major roads used during the trip and the usage of major roads over the past three months;
4. Questions related to perceived road safety of the roads used during the described trip;
5. Details of the vehicle used during the trip;
6. The SC experiment as described above;
7. Questions on their experiences, or experiences of close friends/relatives with regards to road accidents; and
8. Some socio-economic questions collected to establish the representativeness of the sample.

A pilot study was undertaken to test the proposed method, to investigate respondent reactions to the CAPI questionnaire, and to test the logistics of conducting the survey in

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[10] The survey instrument is designed in such a way that all information must be provided. Until each question is answered, the survey will not proceed on and a warning message appears.

the field. The pilot sample consisted of 14 car drivers interviewed by four trained interviewers. Data from the pilot questionnaires were collected and analysed, with additional comments from respondents collected after the survey was concluded. The estimated mixed logit models, based on 140 observation from the 14 respondents, provided estimates of the parameters required to finalise the efficient experiment design, which requires priors for each parameter attached to the attributes.

5. Model analysis

The total sample size sought for the study was 200. The geographical spread included trips within Sydney and the Bathurst district. The final effective sample size was 213, comprising 142 Sydney based car trips, and 71 Bathurst based car trips. Table 2 provides a summary of the sample achieved in terms of trip length and gender segments.

Table 2: Summary of Sample

		Urban Trips				**Non-Urban Trips**			
		Trip Length				**Trip Length**			
Age	**Gender**	**10-30**	**31-45**	**46-60**	**Total**	**10-60**	**61-120**	**121-180**	**Total**
19 or under	Male	4	2	0	6	1	1	1	3
	Female	3	3	0	6	7	0	0	7
	Total	7	5	0	12	8	1	1	10
20-24	Male	9	1	1	11	3	0	2	5
	Female	3	2	0	5	0	2	3	5
	Total	12	3	1	16	3	2	5	10
25-34	Male	11	1	2	14	2	2	1	5
	Female	7	4	2	13	0	1	0	1
	Total	18	5	4	27	2	3	1	6
35-44	Male	3	1	0	4	3	0	0	3
	Female	5	1	1	7	0	0	0	0
	Total	8	2	1	11	3	0	0	3
45-54	Male	2	3	0	5	2	0	1	3
	Female	3	3	1	7	2	2	1	5
	Total	5	6	1	12	4	2	2	8
55-64	Male	12	2	1	15	6	2	4	12
	Female	14	1	2	17	4	2	2	8
	Total	26	3	3	32	10	4	6	20
65 or over	Male	8	6	2	16	3	2	2	7
	Female	13	3	0	16	5	0	2	7
	Total	21	9	2	32	8	2	4	14

Mixed logit models based on the urban and non-urban automobile segments were estimated. Unlike the Multinomial logit (MNL) model, the mixed logit model is capable of estimating both non-random and random parameters, as described in Section 2.1. Non-random parameters assume homogeneity in preferences, in terms of the marginal utilities associated with an attribute across the entire sample. Random parameter distributions in the mixed logit model relax the assumption of homogeneity in preferences, allowing for heterogeneity of the marginal utilities of the model attributes.

Random parameters require that the analyst assume that the heterogeneity in preferences follow a known distribution over the population.

Table 3 presents the final urban and non-urban car model results. The final models differ in terms of the treatment of the time attribute. In the urban model, the travel time components were estimated as separate parameters whereas the non-urban model treats the two travel time components as a single attribute. This was necessary as the ratio of the travel time components for non-urban trips was such that the amount of free-flow time dominated the slowed down time attribute. No other differences exist between the final model structures.

The number of deaths, the three injury categories, travel time and cost parameters were estimated as random parameters assuming constrained triangular distributions, where the mean of the distribution is constrained to equal its spread, thus ensuring that no sign violations exist for these random parameters. The number of cameras and average speed limit parameters were also treated as random parameters; however these were drawn from normal distributions given that these attributes may exhibit both a preference for or against more of each attribute within the population. For both models, the running cost (i.e. petrol) and toll cost were found to have parameter estimates that were not statistically different, and hence were estimated as a generic parameter in the final model specification. Both models were estimated using 1,000 Halton draws per random parameter with the panel form (i.e., 10 choice scenarios per person) taken into account in estimation.

The utility expressions for urban setting, for example, are:

$U(\text{Route A}) = SC1 + \beta_{cam}\times cam + \beta_{avspd}\times avspd + \beta_{ff}\times ff + \beta_{slow}\times slow + \beta_{C}\times costg + \beta_{death}\times deaths + \beta_{inj}\times injury + \beta_{injho}\times injuryho + \beta_{injmi}\times injurymi$

$U(\text{Route B}) = SC2 + \beta_{cam}\times cam + \beta_{avspd}\times avspd + \beta_{ff}\times ff + \beta_{slow}\times slow + \beta_{C}\times cost + \beta_{death}\times deaths + \beta_{inj}\times injury + \beta_{injho}\times injuryho + \beta_{injmi}\times injurymi$

$U(\text{no travel}) = 0$

where ASCi (i=1,2) = alternative-specific constants for each of the alternatives, cam = number of cameras, avspd = average speed limit, ff = free flow time (mins), slow = slowed down time (mins), cost = running plus toll cost ($), deaths = number of fatalities per annum, injury = number of permanent severe injuries, injuryho = number of major injuries hospitalized, and injurvmi = number of minor injuries.

Table 3: Final Car Models

		Urban		**Non-Urban**	
Attributes		**Parameter**	**(*t*-ratio)**	**Parameter**	**(*t*-ratio)**
Random Parameters					
Constrained Triangular Distributions					
Deaths	Mean	-0.273	(-9.46)	-0.352	(-7.27)
Permanent Severe Injuries	Mean	-0.052	(-3.67)	-0.037	(-1.82)
Major injuries (Hospital) Non-permanent	Mean	-0.039	(-4.26)	-0.025	(-1.97)
Minor Injuries	Mean	-0.038	(-3.92)	-0.022	(-1.61)
Total Travel Time	Mean	-	-	-0.033	(-3.65)
Free Flow	Mean	-0.066	(-5.24)	-	-
Slowed Down Time	Mean	-0.099	(-8.01)	-	-
Cost	Mean	-0.322	(-9.83)	-0.090	(-2.95)
Normal Distributions					
Cameras	Mean	-0.028	(-0.72)	0.003	(0.05)
	Std Dev.	0.151	(1.84)	0.191	(1.74)
Average Speed Limit	Mean	0.007	(0.90)	-0.005	(-0.46)
	Std Dev.	0.042	(8.35)	0.042	(4.91)
Fixed Parameters					
Constant 1 (ASC1)	Mean	11.314	(13.61)	9.772	(8.15)
Constant 2 (ASC2)	Mean	11.238	(13.52)	9.785	(8.14)
Model Fits					
LL(0)		-1560.029		-780.0147	
LL(β)		-984.676		-518.749	
ρ^2		0.369		0.335	
N		1420		710	
Trip Distance					
Average		38.134		76.437	
Std Dev.		14.491		76.437	
Min.		10		10	
Max		60		180	

The final urban and non urban car models produce rho-square values of 0.369 and 0.335 respectively which are extremely favourable when compared to other discrete choice models. All the parameters are of the expected sign, with the mean of the camera and speed limit parameters not statistically significant. In both the urban and non-urban car models, the relative magnitudes of the death and injury parameters are also as expected, with the number of deaths having a larger impact on a person's preference to travel using a particular route than the number of injuries, and with more permanent severe injuries having a larger impact than lesser injury types. ASC1, ASC2 are alternative-specific constants for the mean estimate of unobserved influences relative to the no-travel option (see Figure 1). Both parameters are statistically significant, and suggest a positive source of utility associated with unknown influences on the choice of a specific trip package in contrast to not choosing to travel. The fact that the mean estimates are virtually the same is encouraging, being a test of possible sequential bias in choosing between Routes A and B. There is no evidence of any bias due to the order of the two alternative routes.

6. Deriving WTP to avoid a fatality and the value of a risk reduction

In this section, we report the empirical findings on the WTP to avoid a fatality and a class of injury in a road environment. Given that the number of deaths and injuries by category were estimated as random coefficients, it is necessary to calculate distributions of WTP within the sample data and calculate the mean of the distribution. The results for the urban and non-urban segments are presented in Table 4.

The average WTP for a reduction per death in an urban car setting is $0.92 per car trip compared to an average of $3.99 in the non-urban setting. With regards to a reduction in the number of permanent severe injuries, the average WTP in the urban sampled population was estimated at $0.18 per car trip compared with $0.42 for the non-urban segment. Major injuries requiring hospitalisation were valued at $0.13 and $0.29 per trip for the car urban and non-urban segments respectively, whereas minor injuries were respectively valued at $0.12 and $0.25 per car trip.

Table 4: Willingness to Pay Estimates

	Urban		*Non-Urban*	
Attribute	**Average**	**Std Dev.**	**Average**	**Std Dev.**
Deaths	$0.92	$0.31	$3.99	$1.12
Permanent Injuries	$0.18	$0.05	$0.42	$0.06
Major injuries (Hospital)	$0.13	$0.04	$0.29	$0.04
Minor Injuries	$0.12	$0.05	$0.25	$0.03

The higher mean estimates of WTP for non-urban settings is plausible given that average speeds are much higher, and there is high community appreciation of the greater risks and record of crashes that occur on the open road outside of the urban precinct.

7. Deriving the value of a risk reduction (VRR)

The WTP estimates are a ‘per person per trip’ valuation. To obtain the value of a reduction in risk of one fatality and one injury, we have to convert the WTP per person per trip to a WTP per person per kilometre, and then multiply by the inverse of the chance of death or injury class to obtain an aggregated VRR. The data required to identify the chance of death or injury has been obtained from a variety of sources. We need exposure data measured in terms of annual vehicle kilometres travelled by cars, and risk data in terms of the numbers of fatalities and injuries in each class per annum for persons travelling in a car (as a driver or passenger). All the evidence is in Aud$2007.

The presentation of the evidence has been stratified by urban and non-urban travel. In the current study, given the problems in disaggregating data beyond the Sydney

Statistical Division (SD) (i.e., Metropolitan Sydney and the Central Coast)[11] and the rest of NSW, we have defined the Sydney SD as urban and the rest of NSW as non-urban. We can classify the urban road environment in terms of a road hierarchy represented by four categories of Freeways/Motorways, State Highways, Other Classified Roads, and Unclassified (Local) Roads. This classification, while applicable in the non-urban context, does not provide data on exposure and risk, and hence the best we can do in the non-urban context is to treat the network as one. We have adopted the same strategy for the urban jurisdiction.

Data on fatalities and injuries for urban and non-urban jurisdictions was sourced from the Road Safety Branch of the Roads and Traffic Authority (RTA) of NSW. The source we have available is referred to as the *Crash and Casualty statistics*. These data cover crashes and casualties included in the RTA’s Traffic Accident Database (TADS) for the five year period 2001 to 2005 and updated to 2007. The crashes in TADS are confined to those crashes which conform to the national guidelines for reporting and classifying road vehicle crashes. The main criteria are:

1. The crash was reported to the police;
2. The crash occurred on a road open to the public;
3. The crash involved at least one moving road vehicle; and
4. The crash involved at least one person being killed or injured or at least one motor vehicle being towed away.

A crash is defined as ‘any unpremeditated event reported to police and resulting in death, injury or at least one vehicle towed away and attributable to the movement of a road vehicle on a road open to the public’. A casualty is ‘any person killed or injured as a result of a crash’. A fatal crash is one in which there was at least one fatality from the crash. A fatality is ‘a person who dies within 30 days of a crash as a result of injuries received in that crash’. An injury crash is ‘a non-fatal crash for which at least one person was injured’. The TADS system does not categorise injuries into severe permanent, hospitalised non-permanent or minor. A towaway crash is a crash for which there were no persons killed or injured.

We had to establish the average number of fatalities per crash and the average number of injuries in each class per crash, in order to obtain the relevant number of fatalities and injured persons. Given that injury data does not distinguish classes of injuries, a formula had to be implemented to apportion injuries to the three categories. The great majority of injuries are not serious, and do not require hospitalisation. This can be estimated using the NTID serious injury data set for the land transport (traffic accident indicated) category. Although it may not be strictly comparable with the RTA definition of road traffic crashes; for example, it may include crashes outside the road reserve such as car parks and driveways, it is the only source available. The proportional distribution of severe permanent injuries/hospitalised non-permanent injuries/other injuries is based on a range of data sources given the difficulties in obtaining a single source of data that presents the three levels of injury. The sources and calculations are provided in Table 5. The final number of injuries in each class is given in Table 6.

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[11] The Sydney Region is defined as the Sydney ABS Region and covers the area bounded by the Wyong, Gosford, Hawkesbury, Blue Mountains, Wollondilly and Sutherland local government areas.

Table 5: Calculation of Proportional Distribution of Injuries by Class

Motor Vehicles	**2003-04**
Total Injured - Motor Vehicle Occupant (A)	20800
Motor Vehicle Crash Hospitalisations - Motor Vehicle Occupant (B)	7628
Proportion of Injuries that were "high threat to life" - Motor Vehicle Occupant (C)	27.5%
Disability at 12 months, after admission to a hospital in WA following a crash. (D)	27.9%
	Motor Vehicle
Minor Injury (MI= (A-B)/A]	**63%**
Hospitalised, Permanent Impairment [HPA= D*(B/A)]	**10%**
Hospitalised, No Impairment = 1-(MI+HPA)	**26%**

Sources:
RTA, *Road traffic crashes in NSW - Statistical Statement Year Ended 31 December 2004*, Table 26.
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Table 6: Casualty Rates, Exposure and Chance of Fatality and Injury Class

Casualty Type (2007 est.)	**Degree of Casualty**					**Exposure**	**Chance of:**			
Fatality	**Fatality**	**Serious Inj.**	**Hosp. Inj.**	**Minor Inj.**	**Total**	**VKT PA**	**Fatality**	**Serious Inj.**	**Hosp. Inj.**	**Minor Inj.**
Urban Driver and Passenger	133	551	1652	6975	9311	2.309×10^{10}	5.78×10^{-9}	2.38×10^{-8}	7.15×10^{-8}	3.02081×10^{-7}
Non-Urban Driver and Passenger	220	761	1799	4360	7140	2.257×10^{10}	9.79×10^{-9}	3.37×10^{-8}	7.97×10^{-8}	1.93145×10^{-7}
Non-Urban: Urban car ratio	1.65	1.38	1.09	0.63	4.75	-	-	-	-	-

The final estimates of VRR are summarised in Table 7, based on equations (11) and (12).

Table 7: Summary of Major Findings ($2007)

VRR ($) per:	Fatality	SI	HI	MI
Car urban	**6,369,655**	**310,292**	**75,476**	**16,552**
Car urban all injuries		**44,783**		
Car non-urban	**6,298,062**	**193,883**	**56,937**	**20,312**
Car non-urban all injuries		**48,927**		

Some observations can be made about the findings in Table 7. There are more fatalities in the non-urban environment than in the urban environment for car travel (ratio of 1.654), and given the level of exposure, the chance of a fatality is also higher in the non-urban context (1.687). For injuries, the incidence is higher for the urban setting (i.e., ratio of non-urban to urban is 0.754), with the chance of a serious injury being lower in the non-urban context as well (i.e., 0.5930). Importantly, we expect the VRR for a given reduction in probability of a fatality or a class of injury to be an increasing function of the initial risk level. If we compare the mean estimates for urban and non-urban car activity, our evidence is completely consistent with this.

To establish some confidence in the evidence, albeit for fatalities only, we draw on a recent review of the value of a statistical life by Access Economics (2007). VSL estimates were identified from 244 'western' studies (17 Australian and 227 international studies) between 1973 and 2007, primarily in health, occupational safety, transport, and environment. Estimates were converted to 2006 Australian dollars. A meta-analysis was performed of the higher quality studies (i.e., more recent studies that had either a midpoint and standard deviation or other minimum-maximum range). This eliminated many of the implicit valuation studies (which helps to remove the circularity effect of future policy being based on speculative past policy). The meta-analysis yielded an average VSL of $6.0 million in 2006 Australian dollars with a range of $5.0 million to $7.1 million. Because of the greater variability shown across all the sourced studies, particularly across sectors, the suggested range for sensitivity analysis was based on the 'raw' study median values, which ranged from $3.7 million in the health sector to $8.1 million in the environment sector. Figure 2 provides a summary of the mean estimates by sector. The transport evidence in Figure 2 confirms that the previous Australian evidence in the vicinity of $1.5m for fatalities (largely based on ex post methods) is grossly low and that the evidence herein is more in line with International evidence.

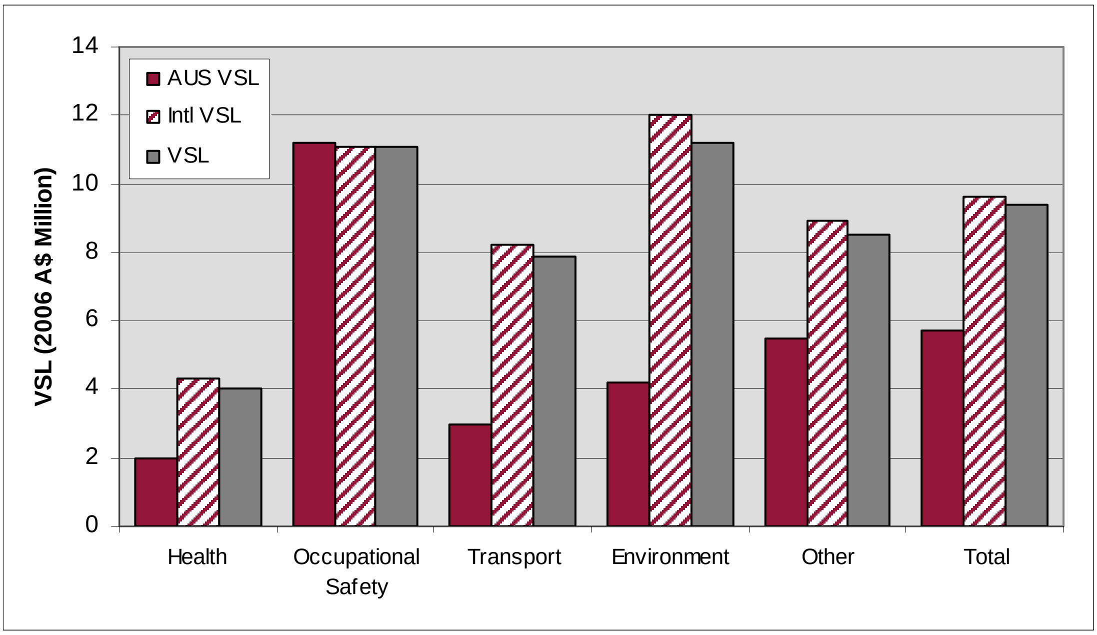

Figure 2: Summary of VSL estimates (means) by sector and Australia/international, 2006$million

Source: Access Economics (2007)

8. Conclusions

This study has developed new empirical estimates for Australia of the ex ante WTP by individuals who are drivers of cars to avoid being killed or injured, to varying degrees of severity and permanence. The *WTP* is the vehicle driver's marginal rate of substitution between income and the number of annual road fatalities or number of injuries; and *VRR* is the summation of *WTP (separately for fatalities and classes of injuries on a specific route)* over all drivers that traverse a specific road in a given year. Summing *WTP* values over all drivers (annual flow) on each route, we obtain four values - the value of fatality risk reductions and the value of injury class risk reductions for each of severe permanent injury (or serious), injuries requiring hospitalisation, and minor injury.

The empirical evidence herein is arguably a preferred set of estimates of VRR than are currently available in Australia that are based on an ex post human capital approach. Importantly, we expect the VRR for a given reduction in probability of a fatality is an increasing function of the initial risk level. If we compare the mean estimates for urban and non-urban car activity, our evidence is completely consistent with this. It is important to recognize that one should not assume similar relativities and directions when moving from an *ex post* to an *ex ante* method. The improvement in roads is linked to improving safety for each kilometre travelled, and hence the metric used to obtain VSL is the appropriate one for economic analysis of the safety benefits of improvements in the road environment.

In future research, the evidence herein can be disaggregated by road type and distance travelled to provide project-specific inputs for benefit-cost analysis, in contrast to the aggregated findings presented herein.

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