Approaches to valuing injury and mortality risk in transport assessments
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Abbreviations and acronyms

BITRE	Bureau of Infrastructure, Transport and Regional Economics
CBA	cost-benefit analysis
CPI	Consumers Price Index
DALY	disability adjusted life year
ETS	Emissions Trading Scheme
GDP	gross domestic product
LYL	life years lost
MVQ	monetary value per QALY
NPV	net present value
NZIER	New Zealand Institute of Economic Research
PT	public transport
QALY	quality adjusted life year
RP	revealed preference
SNZ	Statistics New Zealand
SP	stated preference
Transport Agency	NZ Transport Agency
VKT	vehicle-kilometres travelled
VOSL	value of statistical life
VPF	value of preventing premature fatality
VSLY	value of statistical life year (lost or gained)
WTA	willingness to accept (compensation for increase in risk)
WTP	willingness to pay (for reduction in risk)

Contents

Executive summary

The purpose of this research, which was conducted between August 2014 and January 2015, was to provide guidance on approaches for valuing injury and mortality risks distilled from international literature on theory and practice. It was also to consider whether the current approach to estimating the value of statistical life (VOSL) in transport evaluations in New Zealand, established in 1991, is still appropriate, and also whether and how to fill gaps in current knowledge, regarding:

- the relative value of safety and other non-market impacts of transport
- whether VOSL should vary with age and life expectancy of those at risk
- whether VOSL in transport should be aligned to value of safety in other risk contexts.

The research focused on the human or welfare cost of injuries and fatalities, not the financial costs such as medical expenses and lost productivity. These items are included in transport appraisals but are out of scope for this report. Their value is dwarfed by the human costs of fatal and non-fatal injuries, reflecting the pain, suffering and aversion to the risk of such injuries.

The research benefited from a number of meta-analyses of valuing injury risks conducted by the Organisation for Economic Co-operation and Development (OECD) and elsewhere. New Zealand's transport VOSL values fatalities prevented according to the population's mean willingness to pay (WTP) for small reductions in the risk of fatality (ie the marginal rates of substitution of wealth for risk of death). The literature review indicates this approach is appropriate, and is even called 'the standard method' in some publications.

New Zealand was one of the first countries to adopt this approach. Since then, the techniques of non-market valuation used to infer values of risk changes have advanced considerably and now offer scope to value multiple facets of risk and other factors in evaluation of investment choices.

The literature indicates that key determinants of the VOSL are the level of income of the affected population and the starting level of risk. There is international evidence that WTP to reduce involuntary risks is greater than for those which people assume voluntarily and exercise some control over. Since its establishment in 1991, New Zealand's VOSL has been updated with reference to the ordinary wage rate as a proxy for changes in income. However, over the same period the number of road deaths in New Zealand has reduced from about 19 per 100,000 population to less than 7 in 2014, changing the underlying risk. Since the income and starting level of risk have both changed over time, the value determined in 1991 no longer reflects the current public value of reducing risk.

On the basis of this review, a new study to update the VOSL estimate for current conditions in New Zealand would be timely. This would present opportunities for extending the survey to obtain new information with uses in both transport and other policy applications. However, the recommendations made here are primarily from the perspective of values of use for transport assessments.

The findings on the three research questions can be summarised as follows.

1 *Should valuations of non-market impacts within the transport sector be aligned?*

The relative value of VOSL with other non-market values in transport analysis is most apparent in the literature with respect to the value of non-fatal injuries, the value of non-acute risks of long-term health impairment or premature death (environmental health risk) and the value of travel time.

Non-fatal injuries in New Zealand are valued at a fraction of the VOSL, at 10% for serious injury involving hospitalisation and 0.4% for minor injuries. This fraction was determined in a previous study in New Zealand and corroborated with a similar fraction found in two studies overseas. The evidence base is thin but consistent, and an updated VOSL could confirm those fractions and explore the feasibility of broadening the range of non-fatal injury categories beyond two.

Non-acute risks of morbidity and mortality have arisen overseas particularly with respect to transport's contribution to emissions and air quality deterioration which aggravates ill-health of those with respiratory conditions and can also shorten lifespans. This gives rise to the need for values to account for risk of premature mortality at some time in the future, and also for impaired living in the interim years. Overseas stated preference studies have shown how this can be done to establish relative values of VOSL for acute risk of immediate fatality and latent risk of long-term life years lost, although few countries have yet put this into practice in their transport appraisals. It could be worthwhile considering estimating such relativities for New Zealand, if data are sufficient to establish the links between emissions, air quality, ill-health and fatalities.

The relative values of fatality risk and time have received relatively little attention in the international literature. As base risk and income are the principal drivers of VOSL, and the value of time varies with user type and trip characteristics, it is uncertain whether linking VOSL and value of time through the same survey vehicle will guarantee the production of consistent relative values of the two impacts. Further research in this area is therefore required to understand whether such an approach is possible. In addition, there are current issues in the valuation of travel time that need to be resolved independently of revising the VOSL.

2 *Should VOSL vary with age and life expectancy of those at risk?*

The literature is ambiguous over whether and how VOSL varies with age or should be adjusted for life expectancy. Some suggests VOSL rises to middle age and then declines, but others suggest individuals' risk aversion and WTP for safety increases in older age cohorts, reflecting their greater accumulated wealth and fewer expected years in which to use it. For many ex ante transport assessments that affect risks and save lives of anonymous individuals across a network or system, age-related VOSL is irrelevant and a single VOSL suffices. However, for choices between age-cohort-specific policies (such as child restraints versus older driver policies) it would be useful for VOSL to reflect the public's preferences for reducing risks to different age groups. The literature suggests child-specific policies may require a separate VOSL that is unlikely to be less than that for adults, which may reflect consideration of life expectancy or simply affection for children.

A directly estimated value of a life year has potential application to policies that affect the risks of long-term chronic health conditions and foreshortened future lifespans, such as decisions on emissions or the promotion of active modes like cycling and walking that can raise risks of accidental injury while reducing long-term health risks. Such a value would replace the current practice of calculating a value per life year as the annualised equivalent of the VOSL, as if VOSL is the net present value of a stream of future life years. The VOSL is not currently calculated as a net present value and the annualised value implies a constant value over time which is probably incorrect. Directly estimated values per life year are therefore preferable.

This recommendation attaches lesser priority to putting a dollar value on quality weighted constructs such as quality adjusted life year (QALY) or disability adjusted life year (DALY), as these are not created equal, and reflect a wide variety of health states that would be difficult to apply in transport assessments. Where health outcomes are easier to predict, as in choices for medical interventions, there may be more merit in valuing QALYs or DALYs, although the implicit assumption that all QALYs and DALYs are the same when they are in fact products of varying longevity and health status is challenging for valuation and even where monetary value is not used, as in cost-effectiveness analysis. Empirical literature shows that gains in longevity are valued higher than gains in life quality, so valuing longevity without complications of quality adjustment would be useful. It could also be useful to estimate value per life year at varying levels of life quality (perhaps with broad categorisation) to account for those conditions that affect life quality strongly with relatively low change in longevity.

3 *Should VOSL be aligned between injury sectors in New Zealand?*

Because VOSL is affected by base risk and income of the affected population, a VOSL is not likely to be the same in transport and other risk domains, such as workplace safety or health interventions. Ideally therefore separate VOSLs should be determined for each domain reflecting its particular characteristics of risk. However, a transport VOSL could provide an anchor or benchmark for these other risk areas, with appropriate adjustment if the value relativity between different risks is appropriately estimated. Because VOSL is estimated for road transport, with a perception of individual control associated with a lower VOSL than in cases of involuntary risk, the transport VOSL is unlikely to overstate the societal value of averting other public safety risks and can be viewed as a lower bound for value in those other settings.

The method chosen to estimate the new transport VOSL would be a stated preference valuation study. It could be either a contingent valuation survey (as in 1989/90 and in 1998/99) to estimate public WTP for specific scenarios of risk reduction, or choice modelling in which relative preferences for different travel attributes are estimated. Benefit transfer, or the use of existing studies from elsewhere applied to New Zealand situations, is not ideal, as it depends on the population preferences in one country and context being closely similar to those in the other.

Whichever method is chosen, it should be tailored to the information needed to inform practical policy and project appraisal. This would be done in developing the survey questionnaire, once the scope of the survey and the policy issues it needs to serve have been determined. Estimation of attribute values will be useful only where the data on these attributes are available or will be available in the future.

In brief the recommendations of this report are:

1 New Zealand’s approach to valuing fatal and non-fatal injuries in transport in terms of public WTP for small changes in risk is appropriate and widely used across OECD countries.

2 A principal determinant of VOSL is baseline risk which has changed since the New Zealand VOSL was established in 1991, so an update is now overdue.

3 As VOSL varies with risk characteristics, in principle each area of public policy on injury risk (eg transport, workplace safety, health services, leisure) should have its own customised VOSL, but as a default the transport VOSL can be used in these areas, perhaps adjusted by a mark-up (or down) informed by the relativities of different VOSLs in analogous contexts from overseas or surveys.

4 The practice of valuing non-fatal injury as a fraction of the VOSL (as in New Zealand transport appraisals) is also appropriate, albeit based on thin empirical literature which it would be useful to re-estimate when VOSL is updated.

5 The literature suggests little reason to expect fixed relativities between values of safety and other non-market effects of transport; the VOSL and the values of time have both been updated in line with wages so their relativity will not have changed over time. However, further research in this area is required to understand whether linking VOSL and value of time through the same survey vehicle will guarantee the production of consistent relative values of the two impacts.

6 Literature is ambiguous on whether and how WTP-based VOSL varies with the age of the affected population but it does show differences in value of reducing acute risks of immediate injury and latent risks of long term impacts on life expectancy, so in updating VOSL consideration should be given to direct valuation of these different types of risk to calculate new VOSL and value of statistical life year (VSLY), and to identification of whether VSLY varies with different broad levels of quality of life arising from an injury.

7 A stated preference valuation method is preferable for New Zealand because of the flexibility it offers in testing risk scenarios and less formidable data requirements than the principal alternative of revealed preference methods, but further detailed consideration should be given to stated preference design and the choice between contingent valuation and choice modelling approaches. Time, environmental health impacts and non-fatal injury could all be valued by stated preference study, but not necessarily the same study which could be overloaded by multiple questions.

8 In updating VOSL, all extensions to valuing life years or different risk contexts are dependent on data available being sufficient to build credible risk scenarios and on there being practical policy uses for the values obtained.

Abstract

This report describes a review of literature on approaches to valuing injury and mortality risk in transport assessments. It provides background on why injury and fatality risk need to be valued in transport risk, and how New Zealand has arrived at its current practices in using a value of statistical life (VOSL) in transport policy and project appraisals. It examines theoretical and empirical literature on the scope of valuations and what methods are used for application in both transport and other safety contexts, and the policy implications of the current state of methods. Drawing on the literature and some recent meta-analyses of values, this review makes recommendation on the updating of the current value and what additional information would be a priority for supplementing the basic VOSL.

1 Introduction

1.1 Purpose

The purpose of the research was to provide guidance on approaches for valuing injury and mortality risks in New Zealand, derived from an updated review of relevant literature from New Zealand and overseas. It considered whether the current approach to estimating value of statistical life (VOSL) in transport evaluation, established in 1990, remained appropriate, or if not what rationale was there for estimating it differently? In particular, it considered the implications of three information gaps and what it would take to overcome them:

- What should the value of safety be relative to other non-market impacts of transport investments (eg travel time and environmental impact)?
- Should VOSL vary with age and life expectancy of those at risk, and what are the policy implications of so doing?
- Should VOSL be aligned between injury sectors (eg transport safety, workplace safety and health sector)?

Specific objectives of the research were to understand:

- the opportunities and merits of aligning valuations of non-market impacts within the transport sector, by identifying how people trade-off between safety and other transport impacts, and identifying methods to value transport impacts, their feasibility and policy implications
- whether adjustment should be made for the number of life years remaining when valuing loss of life and life quality, by examining methods for determining the value per life year and the treatment of non-fatal injury risks and loss of life quality, and policy implications of such methods
- the opportunities and merits of aligning valuations of injury and mortality risk across different injury areas in New Zealand, by considering the applicability of common values for all mortality areas and policy implications of such a move.

1.2 Summary of key issues

The current VOSL used in transport evaluation in New Zealand, on which the social values of loss of life and injuries affected by transport activities are based, was established in 1991 from a survey of New Zealand residents (over 18 years of age). The VOSL has been updated in line with average ordinary time wage adjustments since then. This value is also the basis for assigning value to risks of non-fatal injury in transport evaluations, and it has also been used as a guide to the value of health and safety changes in other contexts such as aviation regulation, the health sector, environmental policy, and assessment of earthquake risks and precautions.

The use of an old transport-related value in different contexts depends on whether the VOSL established in 1991 is still valid, in view of changes in baseline risk level, income, demographic characteristics and other factors that might affect the value society places on public safety. Further issues are:

- whether the VOSL should be adjusted for differences in expected remaining life-years at the time of premature death in different policy settings
- whether the VOSL used in transport can be used in other areas of risk to safety and health
- whether it is possible to understand how people trade-off between road safety and other non-market effects used in transport appraisals, such as in the value of travel time
- if an update is to be undertaken, how should it be done in view of advances in the processes of economic valuation of non-market effects?

In short, this report sets out to provide an assessment of the validity of the current approach to VOSL and what can be done to improve it, given current understanding of people's responses to risk and methods to assess value from changes in risk.

1.3 Approach to analysis

We approached this analysis by undertaking a literature review of recent theoretical and empirical papers on the valuation of risks of injury and fatality, and also of papers on the current policy practice on these matters internationally. The literature review drew on NZIER's in-house library resources to identify the latest thinking on what matters in the valuation of injuries and fatalities.

We started the literature review by conducting a series of searches using electronic bibliographic databases such as Econlit, REPEC, JSTOR and international bodies such as the OECD, International Transport Forum, Transport Research Institute and the Bureau of Infrastructure, Transport and Regional Economics (BITRE) and Google Scholar. Search terms included 'value of statistical life (VOSL)', 'transport', 'value of travel time', 'willingness to pay (WTP)', 'quality adjusted life year' (QALY), 'choice modelling', 'cost-benefit analysis' (CBA) and 'cost of injuries and fatalities'. We supplemented these searches by doing some citation searches on key recurring references that appeared frequently in the bibliographies of recent articles and reports that surveyed the topic area.

We assessed papers initially through high-level screening which divided them according to their focus and their relevance for this research:

- We ascribed high relevance to papers that:
  - focus on multi-country surveys and studies that reflect similarity to New Zealand social conditions (car ownership, use patterns etc) and concern road transport
  - illuminate the relative values of injury and fatality, road casualties and other casualties, immediate risk and long-term risk
  - explain or justify the reasons for choice of valuation approach
  - demonstrate valuation techniques applicable to specific risks.
- We ascribed lower relevance to papers that:
  - are primarily about details of methodology development
  - use the wage-risk approach (which is not most relevant for transport) and other ad hoc methods

- describe applications in contexts not similar to New Zealand (eg motor-cycle safety in developing countries)
- are general text books and articles on CBA and transport with only passing reference to valuing injury and fatality risks
- are sources more than 15 years old (unless frequently cited by recent papers).

We examined high-relevance papers more closely to identify the key findings and considerations for valuing transport safety risks. From this we prepared a synthesis of key issues and parameters from the literature, from which to draw policy implications and relevance for the situation faced in New Zealand. We considered whether a new estimate of the value of safety was required and how it might be developed in broad terms, with practical recommendations for further development.

1.4 Scope of the research

The research reviewed literature and explored approaches for valuing injury and mortality risks in New Zealand, with particular focus on transport applications but with reference to other areas of safety policy, where relevant. We have not provided an updated VOSL or detailed proposals for conducting a new study to estimate a new VOSL or some other measure.

The focus was solely on the validity, scope of and methods for assessing the economic value of changes in risks of injury and fatality, the principal components of the value of safety. How to predict the change in safety outcomes from proposed policy or infrastructure changes which may affect appraisals, and the non-injury related components of the cost of crashes, were beyond the scope of the research.

2 Background

Whenever a project or policy is likely to affect public health and safety, one consideration in the decision-making process is an assessment of the costs and benefits. Such an assessment ideally requires all significant effects to be compared in the common metric of dollar values, which creates the necessity for monetary values for changes in fatal and non-fatal injuries that are expected as a result of the policy or project. Transport appraisals in New Zealand have been subject to a formal CBA procedure since the National Roads Board issued its TR9 procedures in 1986 (Bone 1986). Values for fatalities and non-fatal injuries avoided have been derived for this purpose.

In the context of public investment in transport infrastructure and services, the VOSL is simply a planning statistic showing society's (or government's) preparedness to pay for projects that will reduce premature fatalities and injuries to people on and around that infrastructure. It forms part of the crash cost savings which, along with reduced travel time and vehicle operating costs, are the principal tangible benefits in any economic appraisal of such projects. It is also used in assessing the merits of policies that have a road safety aspect.

What is required for transport safety appraisals is a guideline or indicator of government's (or society's) preparedness to incur costs in making transport safer. It is a before-the-event valuation of anonymous lives saved through a reduction in the general level of risk across the population at large. After-the-event valuations, when risk has materialised and individuals at risk are identified, can be very much higher, which means that actual compensation and damages awards or insurance pay-outs made after an event do not yield values directly applicable to most assessments of prospective public policy or investment projects.

2.1 Why value injury and mortality risk?

Finite resources drive the need to make trade-offs across a range of policy and infrastructure investment options that involve risks to human life. VOSL is one approach to quantifying such trade-offs. Failure to quantify and monetise risks of death and injury leaves decision makers with no systematic basis for weighing up options in relation to safety risks. This view is supported by van Wee and Rietveld (2013) who debate the ethics of pricing human safety and conclude that on-balance pricing is reasonable and ethical when it is accepted that trade-offs are unavoidable. Other economists concur:

> *Despite the rhetorical appeal of designating such risk-related effects as being "priceless", failing to monetize them at all may make them worthless from the standpoint of benefit-cost analysis. Moreover, in any meaningful economic sense, small reductions in fatality risks are not priceless. Due to society's limited economic resources, it is not possible to make an unbounded commitment to risk reduction, implying that eventually some trade-offs must be made.* (Viscusi 2014, p388).

Even if risks to life are not explicitly valued, the default position is that protecting lives will be valued implicitly in the decisions that are made. Implicit values can vary widely between decisions, which lead to inefficiency if it results in misallocation of resources and effort to activities where it is costly to save lives, instead of to other activities which are less costly and where more lives could be saved.

A study of existing or proposed public safety policies in the 1980s revealed implied values per life saved ranging from around $2,000 for search and rescue services to around $400,000 for pool fencing regulations (Propper 1983). Implicit valuations can also display political influences or interest group capture of decision processes, for instance different values for saving lives in measures that predominantly benefit men compared with those that benefit women. Explicit economic evaluation of life can remove some of the apparent inconsistencies which emerge when decisions are made implicitly.

To the general public, it may seem presumptuous of economists to 'value' something as precious as human life. At best it seems an abstruse exercise; at worst it may seem morally offensive. But this is to misunderstand the nature of the process, which is simply being explicit about the trade-offs that are inevitable when decisions are made about applying limited resources to desirable ends.

The VOSL does not purport to place a value on any identified individual's life. When undertaking cost-benefit appraisals of roading projects, the safety benefits are expressed as some change in the risk of accidental injury. A reduction in risk of death by 1 in 10,000 is equivalent to saying that in a population of 10,000, one accidental death is expected to be avoided over the specified timeframe for which risk is calculated. In that sense only is the statistic used an expression of a life's value – the value of a statistical life saved of an anonymous individual within a specified population and timeframe. Another way of expressing this is the value of preventing a statistical fatality (VPF) which some researchers prefer to use.

In summary, the VOSL is a parameter that is needed to bring safety into the appraisal with an appropriate weighting. In an economic analysis the appropriate measure is the welfare change brought about by a change in safety, which is reflected in the value of risk of injury.

2.2 Concepts and terms for considering the issues

There is now broad agreement about the components of safety valuation used in CBA, although terminology varies across the literature. The broad components of safety benefits are:

1. Avoidance of **direct costs** of injury (eg medical treatment costs and attendance at injury-related crashes) – these are the costs of resources diverted by society to dealing with injuries that would be avoided with greater safety achievement.
2. Avoidance of **indirect costs** of injury (principally the forgone production and non-market outputs caused by people taking time off to attend to injuries) – these are opportunity costs in the form of forgone benefits borne by society.
3. Avoidance of **'human' or welfare costs** to society – these are pure disutility costs of the pain, grief and suffering caused by crashes, injury and fatality, and the violation of people's sense of security that detracts from people's well-being.
4. Avoidance of **averting behaviour** in response to perceptions of risk – these are the opportunity costs to society arising from things not done because of risk aversion, eg not travelling because of perceived riskiness.

The summation of these different components provides the total costs of accidental injury. Incremental changes in these are the subject of CBA of measures that affect safety.[1] The conditions under which these different types of value are compatible for adding together in a general equilibrium setting (as distinct

[1] The total social cost of crashes is larger still, with the addition of property damage and costs of disruption while the crash scene is investigated and cleared.

from the partial equilibrium perspective of most CBAs) are rarely questioned in the literature and we have not explored this here.

Although the scale of direct and indirect costs can be compiled from public agencies and market-based data, the human cost involves values that are not expressed in market terms. Depending on how they are measured, these non-market value components may be substantial and greater than the market components combined. The research questions for this project, and the literature reviewed, predominantly relate to these human or welfare costs to society, and other cost components are only considered to the extent that they affect that welfare cost.

Current practice internationally commonly bases the welfare value to society (bullet 3 above) on an estimate of public WTP to reduce risks to safety using a non-market valuation method, and market or cost-based methods to estimate direct costs of injury (bullet 1) and (less commonly) the indirect costs of injury (bullet 2). Non-market value estimates of welfare are the dominant component of the cost of injuries, usually far exceeding their direct costs (OECD 2014). Estimates of the cost of injury commonly show the indirect costs to exceed the direct costs, particularly if they lead to long-term conditions or diseases where indirect costs can persist and accumulate over a large number of years (eg long-term reduction in productive capabilities). In the context of transport crashes, where most of the injuries are minor or short term, indirect costs need not have such a significant cumulative effect but may still exceed the direct costs.

Ex ante evaluations often miss the cost of averting behaviour, things done or forgone because of perceptions of riskiness (van Wee and Rietveld 2013). If a policy or project is expected to reduce averting behaviour, this gives rise to a benefit measured in the CBA; conversely a policy that causes averting behaviour gives rise to a cost.[2] But averted behaviour in the status quo is generally not observable so may not be appropriately considered in an appraisal. Some people may invest more than is required to comply with regulation because of risk aversion, in which case the additional cost is treated as a private benefit and commonly not included in CBAs of regulations. The extent to which risk aversion is included or excluded in an appraisal can change assessment of net benefits, but there is little literature addressing this matter. In assessing small risk changes at the margin such aversion costs would not be significant for CBAs, but could be more significant if policies or projects cause a non-marginal change in perceptions of risk that influence behaviour.

2.3 How are injury and mortality risk currently assessed?

The main methods[3] identified in the literature for deriving a welfare value for fatal injury risk can be summarised as follows:

- Indemnity or insurance values have been suggested, but these are about *ex post* compensation for injury after it occurs, not the *ex ante* value of precaution or prevention that guides most safety policy.
- Human capital, or the present value of earnings forgone for a fatally injured casualty deprived of achieving average life expectancy:

[2] An example of averting behaviour is introduction of mandatory cycle helmets, the inconvenience of which reduces participation by users who incur the costs of less active travel.

[3] See appendix A1 for related literature review.

- This is used as the main component of welfare cost in some jurisdictions for simplicity and apparent precision.
- But it does not provide values for non-earning casualties, which must be valued by other arbitrary adjustments, and it may overstate the lost value by not allowing for labour market adjustments to make good the loss of individuals' outputs.

- VOSL based on people's WTP for small reductions in risk which in aggregate indicate society's WTP to save anonymous lives across the community:[4]
  - Revealed preference (RP) methods infer a value for accepting increase or reduction in risk from observations of actual market behaviour which affects risk.
  - Stated preference (SP) methods infer a value for reducing risk by asking questions of a sample about their WTP to reduce risks in hypothetical settings.

Most OECD countries now draw their welfare values from WTP-based VOSL, although some countries still retain human capital as a substantial component in the whole, notably Australia where a hybrid of human capital with add-ons for pain and suffering is used for transport (BITRE 2009). Some academics and agencies support adopting a WTP-based VOSL (Perovic and Tsolakis 2008; Tooth 2010). Some countries draw values from other countries, such as Norway which adapts values transferred from primarily other Nordic and European countries for its purposes (OECD 2012). VOSL may also be based on willingness to accept (WTA) compensation for increased risk, which in theory should be close to WTP but in practice is often estimated to be considerably greater than WTP, for reasons examined in appendix B of this report.

2.3.1 Current international practice in valuing statistical lives

There is now broad agreement in the literature that the appropriate valuation of mortality is by estimating a value of statistical life derived from aggregating individuals' WTP for small reductions in the risk of premature death. Following extensive work and meta-analyses of studies at the OECD, there is now a set of guideline values for VOSL of US$1.5 million to US$4.5 million with a mid-point of US$3 million (as at 2005) (OECD 2014; Lindhjem et al 2011; Lindhjem and Navrud 2011; 2010).There is no such agreement on the standard method for measuring the value of non-fatal injury risk or reductions in morbidity from a given source (OECD 2014). Two studies suggest the value of serious injuries is about 10% of the VOSL (Jones-Lee et al 1985; OECD 2014).

In North America, RP studies predominate in guiding values for transport, workplace and environmental safety. The US Department of Transport set its VOSL at US$9.2 million in 2014, based on 15 hedonic wage-risk studies (US DOT 2014). OECD (2012) notes the US Office of Management and Budget recommends VOSL in the range of US$1 million to US$10 million, and the Environmental Protection Agency uses a central estimate of US$7.5 million. Canadian wage-risk RP studies suggest a range of C$6.2 million to C$9.9 million, while SP studies give lower values between C$3.4 million and C$6.3 million (OECD 2012, citing Chestnut and de Civita 2009).

SP studies are more prevalent in Europe, where EU guidelines suggest a VOSL range of €1 million to €2 million, and a value per lost life year of €50,000 to €100,000 for use on long-term latent risk from air

[4] For instance, if across the community the average WTP to reduce fatality risk by 1:100,000 is $20, the VOSL is $20÷0.000001 = $2 million, ie this is society's willingness to sacrifice other things to save an anonymous life.

pollution (OECD 2012). The UK in 2007 had SP-based VOSL of £1.08 million, and it appears to be the only EU country that has so far put the valuation of life years lost into practice. A recent review endorsed continued use of the UK's approach (NERA 2011).

New Zealand's current VOSL aligns with the European approach, with a WTP-based VOSL based on a SP survey study. The current VOSL is NZ$3.95 million at June 2014 prices, and value of life quality lost due to a serious injury set at 10% of this value. New Zealand's value was towards the middle in international dollar values among 13 countries compared in 2008 (MoT 2009).

Among countries New Zealand commonly compares itself with, Australia is an exception in that the VOSL is still based on a hybrid of human capital valuation supplemented by an additional amount for the human costs of pain and suffering (BITRE 2009). Its transport VOSL is similar to that of New Zealand, at A$2.5 million in 2011.[5] But New South Wales has adopted a higher value of A$6.5 million in 2011 terms, based on results of a 2008 SP WTP survey updated by the Consumers Price Index (CPI) (Douglas and Brooker 2013). Outside the transport field, the Office of Best Practice Regulation recommends higher values for use in regulatory impact statements, which at December 2014 were A$4.2 million for VOSL and A$182,000 for value of statistical life year (VSLY) (OBPR 2014). These values have been drawn from reviews of international research and appear influenced by wage-risk studies.

2.3.2 Alternative approaches to assessing changes in health and safety

Internationally most of the SP-based work on estimating VOSL has been in the field of road transport, where there is extensive data on use and crash rates on which to assess risks, and where the public involvement in road network management creates a strong need for guidance on the social value of safety improvements. Other transport modes have different incentives and regulatory imperatives to guide their safety provision. Aviation and maritime services operate under safety procedures stipulated by international agreements, and have strong commercial incentives to operate safe services to avoid adverse market reaction should a crash involving multiple casualties occur. The regulatory policy analyses are, however, still required for domestic operations at lower scales, ie helicopter, small aircraft operations, operation of small vessels and water-based recreation. Rail services are more responsive to domestic regulation, often strongly guided by workplace health and safety considerations. These other transport modes sometimes use VOSL to demonstrate safety value comparable to that in roads and other activities, but this is less frequently required for regulatory assessments than is the case for travel.

The predominant health and safety issue in road provision has been the risk to travellers of traffic crashes and the severity of injuries and fatalities associated with them. In this case, travellers face a risk of injury in the immediate future when using transport infrastructure, and it is the value of changes in such risks that is measured by the VOSL. Some transport appraisals may also need to take account of risks to health that happen over longer periods, such as transport's contribution to local air quality which affects the risk of chronic respiratory disease and the latent risk of a shortening of some people's lives at some time in the future. In that case, the welfare cost of ill-health includes both the foreshortening of lifespan at some future date, and the disutility of ill-health in the intervening years.

[5] In purchasing power parity terms, the Australian value in 2011 would be about NZ$2.5 million, compared with a New Zealand VOSL of $3.6 million in that year. On the same basis the higher value adopted in New South Wales would be NZ$6.4 million.

Such chronic, long-term and latent risks to health are not covered in current approaches to VOSL, which creates a possibility of other approaches to injury risk being used to supplement the VOSL. Life-year measures[6] have emerged from the health literature that focus on changes in expected longevity, in particular:

- Life years lost (LYL) – a simple measure of changes in expected longevity, which can be assigned an economic value using similar methods to VOSL – known as the value of statistical life year (VSLY).
- Quality adjusted life year (QALY) – a measure pioneered by Zeckhauser and Shephard (1976) of changes in expected longevity weighted by a subjective index of quality of life (sometimes derived from preference surveys of samples of the population), which may be given monetary valuation, either directly from SP surveys or derived from VOSL estimates.
- Disability adjusted life year (DALY) – a measure of changes in expected longevity weighted by an index of disability or impairment, which incorporates an age weighting to life years at different ages (to distinguish condition-specific disability from age-related impairment), so the origins of disability and quality of life weights differ significantly and DALYs are regarded as less subjective than the quality weighting of QALYs (Sassi 2006).
- Life quality index (LQI) – a method originating in Canada to weight life years by an assessment of quality, but designed by engineers (rather than medical specialists as in QALY and DALY weightings), and according to one review, based on assumptions about human preferences that are far too simple to make it a serious competitor to other established methods (NERA 2011).

Monetary values for such units as LYL or QALY have been derived by assuming the VOSL is the capitalised value of a stream of remaining life years at the average age of premature fatality, as used by O'Dea and Wren (2010) and Wren and Barrell (2010). Although this approach appears to have been widely used for pragmatic purposes, even its advocates acknowledge there is little support for this practice in the specialist theoretical and empirical literature in the field (Abelson 2008). The VOSL as estimated is a WTP to reduce the risk of immediate fatality and does not depend on how long a person expects to live after averting the immediate risk. A value per QALY or LYL can be estimated by direct surveying as for VOSL. This is complicated by the QALY being a multi-dimensional unit in which not all QALYs are created equal, and surveys suggest people place higher value on extension of longevity than they do on improvements in quality (Ryen and Svensson 2014).

2.4 A history of the value of statistical life used in New Zealand transport

In New Zealand, the social cost of a road crash or a road injury includes the following components:

- loss of life and life quality (the human or welfare cost)
- resource costs comprising medical costs, loss of output due to temporary incapacitation, legal costs, and vehicle and property damage costs.

[6] See appendix A2 for related literature review.

New Zealand currently uses a VOSL based on the public WTP to avoid risks of fatality to cover the human or welfare cost (see section 3.1.3 for further explanation) That value was derived from a survey of adult New Zealand residents undertaken in 1989/90 (Miller and Guria 1991) and successively updated in subsequent years by indexing to the average ordinary time wage rate. New Zealand was the third country to adopt this approach for valuing fatalities in transport appraisal, after pioneering efforts in the UK and Sweden.

The VOSL at June 2014 prices is $3.95 million (MoT 2014). The values of non-fatal injuries are set at fractions of the VOSL, with average value for serious injury (involving hospitalisation) set at 10% of the VOSL and for minor injuries at 0.4 %. The VOSL is the largest unit value component in crash costs.

In the 1980s, the then National Roads Board was prompted to review its valuation procedures after its CBAs failed to endorse the public clamour for extending median barriers on Auckland’s motorways, after a series of well-publicised head-on crashes. The conventional method of valuing lives lost in crashes in New Zealand as well as in most European and North American countries was then based principally on the lost output caused by premature death of the victims, the so called ‘human capital’ approach. Because people’s consumption is reckoned as part of their enjoyment of life, human capital is usually calculated as gross accumulated output without deducting consumption.

The background to the decision to adopt the WTP approach in New Zealand is covered in a report prepared for the National Roads Board (Clough and Meister 1990). This outlined the necessity of applying economic values to lives saved in public policy analysis, either explicitly or implicitly, and the advantages of explicit valuation in ensuring greater consistency than in implicit valuations. It compared various approaches, for example:

- Insurance values or cost of indemnity are oriented towards ex post compensation in the event of death rather than ex ante valuation of its avoidance.
- The so-called ‘human capital’ approach of valuing a death in terms of the forgone lifetime earnings caused by the premature death, which although giving the appearance of being actuarially precise, provides no values for those not in paid employment and underestimates the extent to which labour markets and people’s work adjust to make up the productive loss of individual lives.
- WTP (or willingness to accept compensation) for reductions (increases) in the probability of a fatality on the roads, estimated with either RP or SP techniques.

Although the human capital approach uses market data and is compatible with the national accounts used for compiling data on gross domestic product, it ignores the psychological component of the value of being alive. That psychological component is arguably reflected in people’s WTP to protect their lives and reduce risks of premature death.

The adoption of the WTP-based VOSL replaced the human capital element from New Zealand’s assessment of crash costs, but a small lost output component is retained to account for productivity loss from temporary incapacitation for permanent impairments.

Recent international literature broadly confirms New Zealand’s approach (OECD 2011). That report ascribes to the economist Jacques Drèze (1962) the insight that the human capital approach that many countries used to gain an objective measure of economic worth was at odds with the welfare valuation basis of other items in transport appraisal, and that the value of risk aversion was a more appropriate basis.

The literature shows much refinement of methods to estimate WTP for risk reduction. Particularly in SP methods, there has been a proliferation in techniques and refinements in statistical processing to reduce the various well-documented biases of these methods. There has also been increased interest in applying choice modelling techniques to ascertain the relative values of multiple attributes of the travelling experience, building on the long application of conjoint analysis in transport.

Given that the broad approaches appear to be settled, issues still remain over what each approach covers, what types of questions each are most suited to, and how best to refine it to cover any gaps. These questions are examined in appendix A.

3 Valuing safety and other non-market impacts in transport

3.1 Problem definition and research questions

The problem around non-market impacts of transport safety risks is fundamentally about the compatibility of different approaches to non-market valuation, with each other and with the market-based values elsewhere in transport evaluations. A subsidiary issue is that transport evaluations are becoming more sophisticated, for instance by recognising the contribution of transport to external effects such as changes in environmental conditions. Non-market values are required to give due weight to these externality effects in a way that reflects public preferences for outcomes other than safety.

The fundamental research question therefore is: are the valuations of non-market impacts compatible with the VOSL or any changes that might be made to it, and if not, what adjustments need to be made to make them compatible? Three particular non-market impacts need consideration here:

1 The value of travel time savings relative to improvements in safety

2 The value of impacts on the natural environment

3 The relativity between non-fatal and fatal injury risk.

3.1.1 Safety and travel time changes

Higher speeds reduce travel times but also increase injury risks, and a large part of safety investment is directed at controlling speeds that are excessive for the conditions on the road. Injury risk increases disproportionately as speed increases (Patterson et al 2000), so a reduction in average travel times will be accompanied by a more than linear increase in the marginal damage of injuries that occur, more fatalities and more severe non-fatal injuries. Examining drivers' behaviour with respect to speed is one way to infer their value of safety, as 'Rational drivers will tend to select speeds that balance the gains from more rapid transport against expected losses, due to greater crash risk and other costs, when speeds increase' (Strand 2005). In this theoretical paper, Strand develops two models for examining the trade-offs which he concludes would understate the estimated VOSL because the method does not account for any value in reducing risks to others. In a third approach Strand overcomes this by assuming road authorities know the true WTP for safety and optimally set speed limits. Ashenfelter and Greenstone (2004) apply the same approach to empirically estimate VOSL from observed driver responses to speed limit changes, but their results are overstated by not accounting for non-fatal injury and other factors.

When a survey to update the New Zealand VOSL was undertaken in 1998–99 and suggested that around a doubling of the value would be in order, one of the arguments raised against its adoption was that such a value would change the relativity with the value of travel time, and by implication change allocation of resources into transport towards more safety features and less investment in time savings and de-congestion. (Similar arguments were raised against the adoption of the original WTP-based VOSL in 1991, which had resulted in a nine-fold increase in the VOSL.) A fundamental research question then is: do the relative values of safety and time need to be calibrated relative to each other, whether or not the VOSL is updated?

3.1.2 Safety and environmental changes

The impacts of transport on the environment are through changes in air quality, greenhouse gas emissions, noise and (less well reported) water quality and biodiversity. Giving these matters due attention and weight is important for avoiding resource misallocation in transport policy and investment, as occurred for instance in the EU with tax changes to favour light diesel vehicles which had the unforeseen effect of increasing these vehicles' contribution to particulate matter and worsening localised air quality with adverse effects on human health.

Fundamental research questions relating transport safety to environmental changes are:

- Are transport's effects on the environment that impinge on human health and safety given adequate weight in transport assessments (ie are transport's impacts on long-term morbidity and mortality risk treated comparably to acute short-term risk of accidental injuries?)
- Would the current valuations of environmental effects be improved if their values were established in conjunction with other non-market impacts (eg safety and travel time)? Can such an approach be implemented theoretically and practically?

The international literature has explored the first bullet above in examining the VOSL with respect to long-term latent fatality risk, and the health impairment of chronic exposure to environmental risk. There is no literature addressing the second bullet or examining the relative values of safety and environmental gain. Safety and environmental improvement can be complementary, for instance slower driving is generally safer and also reduces adverse environmental effects such as greenhouse gas emissions within a range of speed bands.

3.1.3 Value of fatal and non-fatal injury risks

To the extent that transport projects and policy development have some scope for distinguishing fatal and non-fatal injury outcomes (ie between roundabouts and traffic light intersections) it is desirable that public preferences for avoiding fatal and non-fatal injuries be reflected in assessments.

In reviewing the value of safety relative to other non-market impacts, it is necessary to understand how such decisions might affect the approach to valuing non-fatal injuries.

3.2 Methods for valuing multiple impacts of transport

3.2.1 Safety and travel time changes

Travel time savings are the biggest component of road project evaluations, in particular regarding projects to add capacity and reduce congestion. Time savings are currently valued in the NZ Transport Agency's *Economic evaluation manual* (EEM) by equating work time with the average wage rate. Values used for time spent commuting to work are a fraction of the wage rate (ca 30%–40% depending on traveller type) and for leisure time a smaller fraction (ca 20%–34%) of the same base rate. The origins and rationale of these proportions and their variation across different types of road user are explained in Beca Carter Hollings & Ferner et al (2002).

Although both the VOSL and value of time have been updated by means of an average wage index (as an indicator of change in WTP for safety) and labour cost index (for value of time), it is not obvious that the relativity of VOSL with value of time was initially correct (because the two set of values were established in isolation of each other at that time). If a new study of WTP for both safety and time were to show that underlying preferences have changed, it would indicate the need for changing one or both of values of time and safety. Apart from the relativity between unit values, the general weighting of safety and travel time values could change in project evaluations if there has been a significant change in the proportions of work, commuting and leisure travel.

However, the relationship between time and safety is not often considered in the international literature. Clearly there is a relationship between higher speeds and higher risks (Patterson et al 2000) and attempts have been made to infer the relative values and trade-offs between time and safety in theory (Strand 2005), but there have been few empirical attempts to estimate these relativities (Ashenfelter and Greenstone 2004) and the results do not account for all influential variables. When it is systematically examined in WTP surveys, value of time appears higher when traded off against money than when traded off against safety (Hess et al 2012), which suggests the relationship may not be stable or else methods for eliciting SPs between them are not specified correctly.

Although the value of travel time appears relatively robust, being based on a market value of labour, there are serious questions being asked in the literature about the valuation of travel time itself, quite apart from the relativity with value of safety. Mackie et al (2001) discuss the problems and advantages of the pragmatic valuation of small time savings summed across a large number of people as being equivalent to larger time savings for fewer people. Metz (2004 and 2008) in noting that duration of the average commute to work in UK has remained the same over a long period of years despite investment in travel time savings, argues that people have used time ‘savings’ to travel further rather than travel less, implying that travel time improvements are not appropriately valued by summing small reductions in the opportunity cost of time spent in travel.

Other authors have suggested value of time varies with circumstance. Time savings are likely to be valued less for private short distance journeys with no time specific deadline than for long distance commercial journeys with a specific deadline (Patterson et al 2000). Variations in the value of travel time savings for different types of traveller in New Zealand are discussed in O’Fallon and Wallis (2012). If the relativity between safety and time values is of concern, it is first necessary to establish the appropriate and consistent basis for valuing time, alongside safety, for use in transport appraisals.

In rail and air passenger transport safety is ranked as a higher priority than time (Patterson et al 2000). Studies have also found that non-trading and lexicographic behaviours cause problems in estimating safety trade-offs with time from SP surveys (Hess et al 2012).

The literature also discusses the nature of value of time per unit based on the size of travel time saved[7].

In choosing methods to estimate the relativities between safety and time, the international literature suggests RP methods through analysis of driver responses to speed limit changes (as in Ashenfelter and Greenstone 2004) have yet to adequately cover all influences on observed behaviour. SP methods have resulted in different values for trade-offs between safety and time and safety and money (Hess et al 2012). The number of studies investigating safety and time trade-offs is very small, and as the predominant influences on value of safety are income and risks perceived, there is little reason to expect a systematic relationship between the values of safety and time.

[7] See appendix A4. Relative value of reducing injury risk and time saving.

3.2.2 Safety and environmental changes

International literature provides little guidance on the relative value of transport safety and environmental effects. Anecdotally, some people switch transport modes for the purpose of reducing emissions of greenhouse gases or impacts on local air quality, but there is no hard evidence on the extent of such behaviour or its implications for relative values of safety and environment. To the extent that slower speeds improve safety and also within certain speed bands[8] reduce vehicle emissions, safety and environmental improvements may be complementary. The relativity between their respective values has not been a priority for research.

Recent international literature has more to say about the impacts of transport on environmental effects that affect long-term chronic and latent risks of future disability and foreshortening of life. This has particularly focused on the impacts of transport on air quality and to a lesser extent on water quality.

Within current transport assessments in New Zealand, greenhouse gas emissions are valued with a standard price related to (although not very rigidly) the value of emission credits in the emissions trading scheme. Noise impacts tend to be not given a dollar valuation but treated in a more qualitative assessment based on the severity of impacts. This is because the RP techniques for estimating a noise premium on prices of properties require larger datasets and greater control for localised variables than has been readily feasible in New Zealand property markets. SP methods would be feasible but have yet to be widely used in New Zealand.

Transport's impacts on local air quality are through:

- raising probability of immediate illness (asthma attacks) for those with existing respiratory conditions
- long-term exposure leading to chronic health conditions
- latent health impact of cumulative long-term exposure bringing forward the date of future deaths.

Dollar valuations for air quality impacts in New Zealand for transport assessments are currently calculated as 0.1% increase over the background mortality for exposed populations per 1 microgram per m^3 increase in PM10, the resulting figure being multiplied by the VOSL.[9] This does not cover latent risk of premature mortality. But the transport VOSL has been used to inform wider environmental policy in the introduction of National Environmental Standards for Air Quality, providing the value per life lost can be attributed to periodic poor air quality events (exacerbated by all sources, not just transport).

Reviewing recent findings in the international literature on environmental health, Hunt and Ferguson (2010) found that adequate data exists for monetary valuation of 14 health conditions brought about by outdoor air pollution, and that the appropriate valuation method may vary depending on the source of pollution. They also found that studies of the impact of noise are almost exclusively focused on annoyance as a catch-all measure for disutility, as data is insufficient to estimate bio-physical impacts (eg contribution to deafness or hypertension). They conclude that none of the health impacts examined have sufficient studies using state of the art method and sample size greater than 500 to warrant receiving a high rating for reliability.

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[8] Fuel efficiency (and emissions) typically improve as speeds increase to around 80km/h (varying between vehicles), but worsen at higher speeds and at very low speeds as in congested traffic flows.

[9] *Economic evaluation manual*, appendix A9.4

Valuation of air quality or any other environmental effects depends on the availability of adequate biophysical data to predict the contribution of transport to changes in environmental condition and its impact on human population. Internationally air quality is the impact that has the most suitable data, and detailed consideration of the adequacy of such data in New Zealand would be needed before using it for generalised values of effects on health in New Zealand.

3.2.3 Value of fatal and non-fatal injury risks

There is now broad agreement in the literature that the appropriate valuation of mortality is by estimating a value of statistical life derived from aggregating individuals' WTP for small reductions in the risk of premature death. There is no such agreement on the standard method for measuring the value of injury risk or reductions in morbidity from a given source (OECD 2014).

The international literature supports the valuation of risks of non-fatal injuries as a fraction of VOSL, the same approach and about the same level (10%) for serious injuries as that used in New Zealand (Jones-Lee et al 1985; OECD 2014). Similar conclusions have been reached by a recent review of UK practice (NERA 2011). The current proportions of VOSL being used in New Zealand are supported by the latest New Zealand survey carried out in 1997/98 (Guria et al 2003; Lindhjem and Navrud 2010). The evidential basis for the current proportions of VOSL, however, rests on very few studies.

Whereas fatality is a definite and uniform outcome of crashes, non-fatal injury has a number of different attributes – temporary or permanent, major or minor, varying physiological effects – which make its standardised valuation more difficult. In particular, adapting measures such as QALYs and DALYs and values of LYL for application in transport policy requires dealing with a multiplicity of different outcomes arising from the context of different crashes, requiring a greater complexity than the uses of these measures in non-transport assessments, particularly in health where there are clear trade-offs in treatment options between longevity and quality of life.

As explained in section 2.3.2, the valuation of these measures as an annualisation of VOSL on the assumption it is the net present value (NPV) of a life at the average age of premature fatality, although widely practised for pragmatic purposes, has weak empirical basis and is inferior to direct valuation of life years through WTP techniques like those used for deriving VOSL (OECD 2012).

Ryen and Svensson (2014) show QALYs and DALYs are multi-dimensional constructs of longevity and quality, and neither QALYs nor DALYs are uniform units amenable to standard valuation. The dimensions of longevity and quality are differently valued: an increase in longevity is valued higher than an increase in life quality, and the monetary value of a QALY also varies according to the size of a QALY gain.

Direct valuation of people's WTP now for an extra year of life decades in the future is very low (Johannesson and Johansson 1995), but more recent work (Desaigues et al 2011) suggests a higher value per additional life year; direct valuation from SP surveys also makes it possible to distinguish values between different groups of respondents, eg according to their initial state of health (Chilton et al 2004).

3.3 Can values of non-market effects of transport be aligned?

3.3.1 Safety and travel time changes

Although the value of travel in work time can be linked to market value of wages and productivity, other types of travel time such as commuting and leisure cannot and need to be treated as a non-market effect. Direct valuation of travel time savings would be possible, and we understand other work commissioned by the Transport Agency is investigating this and other issues around the valuation of travel time.

Internationally, the relative value of travel time and safety has not attracted much research attention. Injury risk increases disproportionately as speed increases (Patterson et al 2000), and attempts have been made to infer the relative values and trade-offs between time and safety both in theory (Strand 2005), and empirically (Ashenfelter and Greenstone 2004) but the results do not account for all influential variables. In theory relative values and trade-offs between safety and travel time can be examined through SP studies, but in practice issues of survey complexity and burden on respondent mean it is not easy to extract the relative values. As the literature (see appendix A4) suggests, VOSL is affected more by factors such as base risk and income. It is not obvious that VOSL needs to be tied to value of time or that a survey needs to be complicated by valuing both time and safety. Further research in this area is required to understand whether such an approach is possible.

3.3.2 Safety and environmental changes

Literature does not provide any guidance on the relative value of safety and environment, or how people value or choose between these two consequences of travel. As slower speeds often improve safety and reduce the level of greenhouse gas and other emissions from transport, in many cases these things are complementary rather than a cause of competition or trade-offs. Literature has more to say about ways in which transport can change the environment with effects that detract from well-being and raise risks to health and safety, for instance by impacting on air quality or water quality. This literature distinguishes the acute risks of injury in the short term from the longer-term chronic and latent risks of lingering impairment and shortening of life at some point in the future. If these longer term effects are significant and need to be accounted for in analysis they can be valued with non-market methods.

Bureau and Glachant (2006) identify various obstacles to the application of non-market values to health impacts of environmental conditions. The principal ones are quantification uncertainties, high cost of new studies, ethical concerns around value transfers between locations and entrenchment of cost effectiveness analysis in environmental and public health decision processes.

OECD (2014) builds on its meta-analysis of safety valuation and other work on VOSL to recommend continuing use of the VOSL derived from individuals' valuation of their WTP to reduce the risk of dying as the standard method for calculating the cost of mortality. But it also stresses the importance of the development of sector specific evidence consistent with new epidemiological findings, on which to base defensible estimates of the economic cost of air pollution from road transport.

3.3.3 Value of fatal and non-fatal injury risks

There is a public aversion to the risk of sustaining non-fatal injury (which may still be serious or life-changing) as there is for the risk of fatality. Ideally, the fatal and non-fatal injury risks would be valued in comparable ways, so WTP to reduce risk is equally an appropriate basis for valuing fatal and non-fatal injuries in transport assessments.

3.4 Ways to proceed

3.4.1 Valuation of safety and time

Time savings are currently valued on the basis of a quasi-market value (wage rates), although non-work time values are not and their validity as indicators of societal value of travel time savings benefits is open to challenge. There are questions around valuation of time, particularly for non-work travel and useable travel time. In addition travel time values differ between trip characteristics and road user types. This means it would be extremely complex to extract the relative valuation of safety and time for all situations. There is also a question of how these relativities (if they can be established) change over time. As VOSL varies with base risk level, it is unclear how it relates to the value of travel time from the limited evidence so far. On the evidence of this review it is not practical to derive relative values for safety and time with the knowledge and tools available to date.

The policy implication is that valuation of travel time and savings should be considered separately, as the factors and circumstances that affect the valuation of time and safety are independent. Thus the relativity between time and safety can vary depending on the situation. There is not enough evidence to draw conclusions on any type of standardised relativity; instead the evidence indicates that is better practice to value them separately.

3.4.2 Safety and environmental changes

The effects of transport on air quality can affect human health through acute risks of immediate fatality and non-fatal attacks, development of chronic conditions through repeated exposure, and latent risk of premature death at a future date. Whereas VOSL could be directly used as a benchmark for the first of these impacts, acute risks, it does not indicate the public preferences for reducing latent risks for long-term fatality or the disutility of ill-health in the years leading up to it. So for any new study to update the VOSL, consideration should be given to its extension to include estimates of WTP values for health impacts outside the individual’s control, the disutility of morbidity effects, and the public WTP to reduce the risk of foreshortening life in the future. This depends on whether the biophysical evidence of air quality in New Zealand and causative links to ill-health and fatality are sufficient to prepare credible scenarios of the conditions and risks to be valued.

The policy implication is that consideration of alignment or relativity of safety and environmental changes is not a major concern in international literature. A more pressing concern is the relative value of reducing risks to short-term safety and risks of long-term health effects from environmental effects. Valuing the latter is not possible without sufficient evidence on the health impacts of environmental effects over time, given the latent effect of environment externalities and the complexity of establishing causality from a range of confounding factors. SP methods have been used to value changes in air quality in overseas studies, prompted by transport’s contribution to air quality impacts.

3.4.3 Value of fatal and non-fatal injury risks

Whereas fatality is a definite outcome whose risk can be calculated with some accuracy, non-fatal injuries are many and varied in their effects – different body parts, different duration of injuries, different levels of long-term impairment – and determined by localised factors and chance effects which are difficult to predict. Precise valuation is problematic at highly disaggregated level, and broad and simple categorisations like serious (with hospitalisation) and minor (non-hospitalised) are likely to continue to be most practical at present.

A new study to update the VOSL should consider a supplementary section to re-examine the relativities between fatal and non-fatal injuries. In designing that section, consideration should also be given to the desirability and feasibility of applying a finer gradation of non-fatal injuries, than the serious and minor categories that are currently used. That would depend, however, on data being available which could define other categories of injury in a consistent and comprehendible way.

4 Valuing safety in different public policy contexts

4.1 Problem definition and research questions

A recurring question with the VOSL is whether a common value can be used for analysis in any policy context. In New Zealand the VOSL used across most, if not all, policy contexts is the value estimated from the WTP for a reduction in the risk of a road transport fatality. It is generally accepted in the international literature dealing with the VOSL that value will vary depending on the policy context. There are some approaches to dealing with this challenge but the area of knowledge is still developing. It is also accepted internationally that values can be applied directly from different contexts in the absence of time and resources to conduct a new context specific study or make some adjustments to existing values. The rationale for this approach is that it is better to have an approximation of the value for the purpose of policy analysis rather than an information gap. It is crucial that the effect of variation in value on the results of the analysis is tested with sensitivity analysis. This will provide insight into how important the value is to the strength of the policy analysis.

4.2 Key factors affecting the value of safety in different contexts

Risk, public expectations of the existing regulatory framework, dread and social aversion to mega events can all influence VOSL. There is evidence that people may value some types of risks less than others. Braathen et al (2009) give the following examples:

- when there is a time lag between risk exposure and the effects of exposure
- when individuals believe they have more control over the risk
- when the risk change occurs in old age
- when individuals have prior experience of high levels of risk.

Variation in risk affects society's value of safety or compensation for higher risk exposure. For example, workers require compensation for higher levels of risk exposure. Risky jobs will demand higher relative wage rates or other forms of compensation. Without this compensation, workers would be disadvantaged and they would be better off taking a job with similar wages but a lower level of risk exposure. The implication is that estimates of VOSL should be tailored to the level of risk exposure and updated as the level of risk exposure changes over time. It is not always practical to conduct a new VOSL study or update a long-standing estimate, in which case benefit or value transfer contexts may be used. One of the most well-researched fields of crashes and safety is in road transport. There are extensive databases for analysis of trends and causative factors. Other safety contexts, including non-road transport, workplace safety, leisure activities (sport and recreation), home safety and health cover more diverse and fragmented activities making it more difficult to draw general conclusions about risks and the value attached to them. This presents a challenge for policy makers seeking to develop safety interventions that are designed for specific situations while applicable to broader contexts.

While in SP valuations of environmental matters society's WTP or WTA may be influenced by the public perception of what the existing regulatory framework is designed to achieve, no literature on transport risk in this review has found public views on existing regulation to be an influence on the value of safety. But there is some support for public expectations placing higher value on safety in air travel or public transport relative to travelling in a private vehicle, because of the perception of involuntary risk in such mass transport modes.

Other transport activities also operate under different regulatory regimes to roads, which are provided and managed as if they are public goods. Railways are usually operated as private corporations where workplace safety regulations have a major role on safety management and outcomes. Air services are largely governed by the commercial imperatives to protect reputation of both airlines and aircraft manufacturers, with an overlay of regulatory direction from the International Civil Aviation Organization which is implemented as appropriate by national regulators. Marine services are also influenced by domestic and international agreements and rules. However, there are domestic operations/activities outside these international obligations for which domestic policy needs to be devised and subject to CBA, particularly with respect to light aircraft and general aviation operations.

4.3 Comparison of different methods currently in use

There are two broad groups of methods for dealing with different policy contexts. There are context specific methods of some situations like the risk of cancer, the health effects of air pollution, or mega fatality incidents like airline crashes. When a context specific value has not been developed the benefit transfer approach can be used to apply existing values to a different context.

The UK's Health and Safety Executive (HSE 2001) suggests the VOSL may vary by risk environment. However, the HSE has suggested using the VOSL for road safety measures as a benchmark for valuing fatality risk in other contexts, by default at the same value as the road value. But in evaluating matters that affect the risk of cancer, HSE recommends a VOSL which is twice as much as that used for road safety. In support of this view, OECD (2010) notes there is a dread and suffering premium for deaths in some situations, eg lung cancer due to environmental effects, although some empirical studies suggest the dread premium is much smaller than previously thought (Chilton et al 2006).

Not so well addressed in the literature is the question of how WTP varies with the risk context or environment. What emerges from the literature is:

- Individual WTP appears to be higher for situations in which people have little control over their safety, which has been used to explain higher cost safety measures applied to transport modes with lower risk of fatality than road transport.
- There is an aversion to high-fatality events, which makes politicians prone to respond less to more frequent low-fatality accidents than to less frequent high-fatality accidents with the same total number of casualties.
- WTP studies of the relative value of different types of fatality risk – in individual vehicles, in multiple-passenger transport, different transport modes or between transport and other activities – have yet to be done.
- The idea of fates worse than death (quadriplegia, high degree burns) has been raised in the literature, but there is no evidence of how they affect the WTP value to avoid such fates.

These variations value of avoiding fatality risk in different contests can be examined directly through SP methods, or with reference to benefit (or value) transfer, which uses values derived in one context in another context with similar characteristics (see section 6.2). The use of life year measures like QALYs and DALYs in non-transport contexts has been discussed in section 3.2.3.

4.4 The implications of using a common value across policy areas

Using a common value across policy areas means an implicit assumption has been made that society's value for risk reductions is uniform across those policy areas. There is evidence that society's value is not uniform. For example, society appears to express high value for risk reductions for cancer and airline accidents. It is preferable to use a value for safety improvements that matches the specific policy context. This can be achieved by conducting a new study, but this is costly and time consuming; so it is not always appropriate. In this case, the second best approach is to use the benefit transfer, preferably fitting a function or using adjusted values from similar policy contexts as discussed above. If neither of these options is feasible then the simple unit value transfer approach can be applied. Sensitivity analysis should be applied in all of these approaches, especially for the simple unit value transfer approach.

4.5 Ways to proceed

Research has shown that realistic responses to questions on WTP can be obtained if the survey presents realistic questions. Past New Zealand studies on estimation of VOSL made the questions realistic.

While variations in VOSL due to the type of risk exposure cannot be ruled out, no definite indication is given in the literature other than a higher value for cancer. Subject to data availability, there is scope for exploring the possible variation in VOSL across different risk contexts in New Zealand, and establishing the relativity between transport risk-based VOSL and VOSL in other policy contexts.

However, pending completion of such studies, which depend on there being adequate data, clear policy needs and collaboration between agencies in establishing consistent values, the transport value can be used in all contexts until different New Zealand values for other contexts are established. Unless there are sufficient time and resources for obtaining customised values for the specific policy contexts, benefit transfer approaches can be applied, as discussed in section 6.2.

5 Valuing effects on remaining life years in transport

5.1 Problem definition and research questions

Safety improvements reduce the number of premature deaths and injuries. Some argue that death as such is not prevented but rather longevity is increased. Therefore, the benefit is the number of life years gained. This is an important issue, in particular, for changes in risk of non-fatal injury.

Life years gained are also relevant to improvement in medical treatment. There can be intervention choices which result in different combinations of longevity and quality of life (eg between kidney transplants and on-going dialysis).

In CBA, it is necessary to monetise the benefit of safety and health improvement policies, (eg vehicle safety standard, medical treatment). For this it is necessary to estimate the amount of money society is willing to pay to gain longevity or better quality of life or a combination of these two attributes, which may be measured by QALY. In transport this is apparent in the assessment of walking and cycling, which are considered good forms of exercise and promoted for improvement in public health (WHO 2010). An evaluation of health policies can be done in the same manner as in any other transport mode, use or physical activity, ie identifying and monetising costs and benefits. With these active modes the health benefits come from reducing long-term chronic and latent risks of disability and death, but there can be some increase in short-term acute risks of injury in a mixed-traffic environment (see appendix A3). Such benefits can be monetised using VOSL and annual values for non-fatal risks (Genter et al 2008).

The first question is what is the value per life year or per QALY? This also leads to further questions on possible variation of the monetary value:

- Should the monetary value of a life year or a QALY be the same in all circumstances? Some of the possible reasons for variation can be:
  - Age. The value per year of life may not be the same at all ages
  - Magnitude of life years gained. The value of first year's life may be more valuable than the next year and so on, as value of second year's life can be considered only if the person survives to that point. Thus, there can be diminishing marginal values of life year, or QALY.
- Should the value per year be related to VOSL?

These are the main questions related to use of life years or quality of life years gained. The research on these areas is as yet limited internationally and scope exists for further research relevant to New Zealand.

Another area is the estimation of WTP values of multiple attributes from surveys in which respondents are required to choose between packages of attributes instead of single attributes, eg safety. Some studies report possible bias toward a specific attribute or action in the packages of attributes and hence respondents giving more weight to them and ignoring the importance of other attributes (Hess et al 2010).

5.2 Methods used for valuing life years lost

Usually one of the following two methods is applied to estimate the VSLY and value per QALY for estimating the social costs of injuries or health conditions in order to use them in CBA.

1. From an established VOSL considering VOSL as the discounted present value of future life years
2. Direct estimates through SP surveys. In this case, the WTP-based estimates are obtained from questions providing options for gaining one or more years of life (see appendix A2).

In both cases, most studies assume the value per life year or value per QALY is the same in all circumstances.[10] Some studies find VOSL varies by age; in other cases, no such age impact is observed. In either case, it is not logical for estimates of value per life year to remain constant; life years secured in the near future are worth more because as well as creating utility in themselves, they are the base for reaching further life years in the more distant future.

Estimating VSLY as an annualisation of VOSL for remaining life expectancy has its roots (and some logic) in the human capital approach to the VOSL, as there is an annualised equivalent to the net present value of any future value stream. However, this approach means that if VOSL is held constant, the equivalent life years increase over time and rapidly appreciate the closer they get to the expected end of life. Conversely, if the VSLY is held to be constant into the future, the corresponding VOSL must decline to the point where it equals the VSLY in the last year of life expectancy. The discount rate applied and on the remaining life expectancy assumed are critical influences on such calculations.

Recent reviews by the OECD recognise the appropriate basis for VOSL is the WTP for small risk reductions across the population and that direct estimation of WTP for variations in expected longevity is the appropriate way to value life years and the extent to which such values vary with age (OECD 2012). But the reviews also tacitly accept that, even if weakly based in theory, the annualisation of VOSL is widely used and applied to VOSLs not based on human capital.

Some studies have used an estimate of value per QALY to estimate the VOSL for a specific age group, assuming VOSL is the discounted present value of future QALYs. Such estimation procedure gives very high VOSL for children and low for elderly, which is not observed in SP studies on WTP. Such monetary value per QALY (MVQ) or DALY adjustment to VSLY is problematic, however, as these are multi-dimensional indexes that are not all equal. Studies suggest people value extending longevity more than improving quality, so two conditions with the same QALY but different longevity/quality characteristics can have quite different values (Ryen and Svensson 2014).

QALYs and DALYs were developed for use in cost effectiveness comparisons of medical interventions where there can be well-defined choices between the longevity/quality dimensions. In themselves these measures do not indicate the economic surplus from the different states which is necessary to measure benefits in a CBA: weightings are assigned to specific states, not inferred from behaviour or SPs of those affected. While WTP for change in QALYs and DALYs can be measured directly with similar methods to

[10] Note that although the QALY may be based on VSLY it is not the same measure, and estimated values of a life year with and without quality adjustment should be expected to differ. Ideally the value of a QALY should be estimated directly with SP methods similar to those used on the VOSL, but a few studies claim to estimate the value of QALYs indirectly from the VOSL, although whether this adequately accounts for quality adjustment is open to debate.

those used to estimate VOSL, the wide range of outcomes from non-fatal injuries in transport suggests that valuing all potential outcomes at a disaggregated level would be a costly and difficult process.

5.3 Does the value of statistical life vary with age?

To answer the question whether VOSL should be adjusted by life expectancy, it is necessary to establish whether VOSL varies with age and life expectancy and if so how.

The main findings from the literature regarding to whether VOSL varies with age are summarised below.

- Wage-risk studies suggest WTP for safety follows an inverted U shape, peaking around the age of 40, broadly following the pattern of individual health and fitness, and career progression from physical and relatively risky work at younger ages to more sedentary and supervisory activities in mid-career
- This pattern of VOSL rising and declining also reflects the trajectory obtained from the human capital approach to valuing fatalities – if remaining life-years are factored into the calculation, the VOSL will decline for older age groups
- In studies basing VOSL on WTP from SP surveys the pattern is more ambiguous, and at least one study finds people's WTP for safety improvement is higher for the elderly, given their high accumulated wealth and lower financial constraint on their ability to pay for their safety (as discussed in Lindhjem et al 2011)
- As children are not in control of all actions concerning their safety, and lack the means and comprehension to answer WTP surveys about risk, their safety is dependent on their parent's WTP and income, which is relatively low for young parents with small children and constrains their ability to pay for risk reduction – so there is an externality argument for countering parental constraints
- While WTP estimates of VOSL are based on individual responses related to their own safety and ability to pay, VOSL used in policy evaluation is the social value. As far as children are concerned, it is unlikely that a society would consider their safety at a lower value than for adults (Estreen and Friberg 2005)
- Studies also show that people are more altruistic to non-related children than to non-related adults.

5.4 Implications of valuing safety in transport using VSLY rather than VOSL

In New Zealand transport, injuries are currently classified as fatal, serious (involving hospitalisation) and minor (no hospitalisation), as in some other countries (eg UK). The values of prevention of these injuries are estimated as percentages of VOSL. For serious injuries with long-term consequences, an alternative way would be to estimate the number of LYL and then estimate the monetary value of those life years. As in the health sector, it would be appropriate to estimate the number of QALYs in each category and then estimate the monetary value (MVQ) of those. This approach of using QALY and MVQ is important as the longevity may not be reduced as a result of many injuries though there would be loss of life quality (eg some minor injuries like whiplash that have lasting impacts on quality of life).

While the proportion of VOSL for prevention of injuries is relatively straightforward, there can be complications in using a QALY/MVQ approach to estimate the value of loss or gain of life quality. For example, if projects/policies target some specific user groups, the value of a life year gained for them could be significantly different from the average value. To start with this would require a different system of record keeping so that age distributions of injuries are available to estimate life years (QALYs) lost due to these injuries. It is a very important issue since inappropriate estimates of QALYs lost due to serious injuries, for example, would give wrong estimates of social cost and thereby distort CBAs.

Some studies in New Zealand have estimated value per QALY from the VOSL, assuming VOSL is the discounted present value of LYL at the average of age of death in road transport. The resulting VSLY varies with the life years remaining and the discount rate, which is commonly at a lower rate than the opportunity cost of capital used in the main CBA. If VOSL is treated as constant for all age groups, the corresponding VSLY will increase as the number of life years remaining decreases, climbing quite steeply towards the last years. If the value of a life year is treated as constant for all ages, the corresponding VOSL declines with increasing age until VOSL and VSLY are the same in the last year of life expectancy. These patterns are the results of arithmetic constructs set by assumption rather than reflecting actual behaviour (such as higher VOSL expressed by some older people).

Application of a general VSLY estimate to a specific age group (eg children or elderly) is wrong since VSLY or MVQ would be different if separately estimated for each age group. So to use VSLY or MVQ in CBA requires not only the age distribution of current injury sufferers but also appropriate values of VSLY (or MVQ). Studies show the likelihood of these values varying by age (Aldy and Viscusi 2008).

5.5 Ways to proceed

The WTP-based VOSL used in New Zealand was established in 1991 based on an SP survey carried out in 1989/90, and it has since been updated each year. There has been considerable progress on road safety during the 25 years since then. During this period the number of road deaths in New Zealand has reduced from about 19 in 100,000 population in 1991 to less than seven in 2014. The baseline risk is substantially lower now than in 1991.

It would be appropriate to make new estimates of VOSL. While there may not be obvious advantages of using VSLY or MVQ in estimating social costs of traffic injuries, it is logical to consider life years and life quality gained as benefits of saving injuries. The main problem here is the monetisation of life years and QALYs gained.

For valuing injuries with a long-term effect, both a fraction of VOSL (as current practice in New Zealand transport) and VSLY are possible options that could be used, depending on the situation and the data available. In such cases the choice depends on practical issues. Some prefer the use of VSLY on the philosophical grounds that avoiding premature death is a shortening of longevity rather than prevention of fatality. This perspective does not appear to have influenced official treatments of VOSL to date, and its acceptance depends on further development and testing of studies such as that of Cameron and DeShazo (2013) that purport to provide a common method for estimating VSLY and VOSL for acute risk.

The next step in this area should be to collect more empirical evidence as to how VOSL varies in different circumstances (by age and by size of risk, for example).However, cost and practicality issues around the data held on age-related incidence of different injuries or health conditions, as discussed in section 5.4 above, suggest that such investigations would not currently be a priority for policy purposes.

6 Discussion

Recent reviews conducted at the OECD have endorsed the appropriateness of basing VOSL on WTP for risk reduction. New Zealand was one of the first countries to adopt this practice but in the 25 years since a number of factors have changed that the literature suggests may affect the VOSL, such as the starting risk level and population characteristics such as age, ethnicity and risk aversion. If New Zealand were to update the VOSL, what methods would it use and what refinements might be made to improve the values used in project and policy-related assessments in transport and other public functions?

Table 6.1 summarises the linkages between the current VOSL for road transport and other potential uses of a value for statistical life or LYL.

Table 6.1 Possible extensions of the current approach

	Injury risk				
	Acute	*Chronic*	*Latent*	*Method*	*Pre-requisites*
Road transport					
Fatality	VOSL			SP WTP	
Non-fatal Serious	0.1 VOSL			SP WTP	Mode-specific injury data
Non-fatal Minor	0.04 VOSL			SP WTP	Mode-specific injury data
Other transport					
Aviation					
Maritime					
Rail					
Fatality	VOSL			SP WTP	
Non-fatal Serious	0.1 VOSL'				Mode-specific injury data
Non-fatal Minor	0.04 VOSL'				Mode-specific injury data
Transport externalities					
Active travel health effects					
Mortality	VOSL*		VSLY		Exercise & mortality data
Morbidity	UALY	UALY	UALY		Exercise & morbidity data
Air quality					
Mortality	VOSL*		VSLY	SP WTP	Air quality & mortality data
Morbidity	UALY	UALY	UALY	SP WTP, VOSL/T	Air quality & morbidity data
Noise					
Morbidity	UALY	UALY	UALY	SP WTP, VOSL/T	Noise and morbidity data
Safety risks beyond transport					
Accident prevention	VOSL^	UALY	VSLY, UALY	SP WTP, VOSL/T	
Occupational safety	VOSL^	UALY	VSLY, UALY	SP WTP, VOSL/T	
Public health	VOSL^	UALY	VSLY, UALY	SP WTP, VOSL/T	

Note: the symbols ‘, * and ^ signify a different issue specific VOSL is preferable to a general transport VOSL.
VOSL=value of statistical life, VSLY=value of statistical life year, UALY=utility adjusted life year, SP=stated preference, WTP= willingness to pay, T=life years remaining
Source: NZIER

The current VOSL is based on costs of traffic crashes, so it is valuing the acute risks of short-term injury. The value for serious non-fatal injuries is an average that also covers some risk of chronic morbidity and latent mortality at some future date, but the VOSL and the questions on which it is based do not explicitly consider the value of risk other than those in the short term. Other transport modes can (and sometimes do) use the road-based VOSL as a value of risk in their sectors, although their values for non-fatal injury ought to reflect the costs incurred in their particular crash characteristics rather than those of road traffic crashes.

If VOSL is required for transport externalities or for applications outside the transport field, in principle different values should be used, based on the empirical evidence of factors that have been shown to influence the values obtained. A VOSL to apply to transport's environmental externalities may be greater than the VOSL for vehicle drivers or occupants, because the lesser control and greater involuntary exposure to risk from environmental conditions. For a transport effect such as air quality that raises acute, chronic and latent risks, a VOSL may be applied to account for its impact in raising acute risks such as asthma attacks that result in death. A separate VOSL would ideally be required to account for the latent risk of shortening lives in future with repeated exposure, and a quality-weighted life year value would be required to account for its impact in raising chronic risk of aggravating respiratory ill-health over years ahead. Ideally these monetary values would be estimated through direct valuation rather than derivation off a standard VOSL.

Other safety risk areas beyond transport could also require their own VOSL to reflect acute risks, a VSLY for long-term latent fatality risk, and a utility adjusted life year for risks to morbidity in successive years. Different relativities between fatal and non-fatal injury risks in these areas could also be established. The extent to which these values can build on, or be anchored to, the transport VOSL, determines the scope and shape of any revised study to update the VOSL. The principal issues under valuation methods are:

- Which method to use to estimate VOSL?
- What changes need to be made to accommodate new information requirements considered desirable in the literature?

Another related issue is the updating of VOSL following movement in the average ordinary time wage rate. Besides the length of time over which the 1991 value has been updated, is this the most appropriate method for updating?

6.1 Methods for generating new primary values

Even though most OECD countries use VOSL, the methods used vary across countries and applications. A simple distinction between the two broad categories of valuation – RP and SP methods – is that RP methods are based on observed market behaviour but are limited by data availability and consideration of market conditions, whereas SP methods can address a wider range of valuation questions but are based on hypothetical questioning which may not reflect actual market behaviour. Literature on valuation methods is roughly evenly split between studies using RP methods (mostly from North America) and those using SP methods (which predominate in Europe). There are limitations to both approaches.

The most widely used RP technique is hedonic pricing, which either examines the wage differentials for jobs of different riskiness or variations in house prices for properties with different environmental characteristics. Most RP studies relating to safety are from wage risk trade-offs observed at work places. Wage-risk studies have been widely used in North America enabling conclusions to be drawn on their strengths and weaknesses (NERA 2011). Such methods are data-intensive and they predominate in North America because of the broad range of state and federal data available which enables analysis of policies across different settings, but they are difficult to replicate in less data rich countries. They require strong assumptions about workers' knowledge of the risks they face, how they trade off risks against other job characteristics, and how such trade-offs are influenced by distortions in the labour market (eg market power in wage bargaining). They are more pertinent to employment settings than decisions about transport use and behaviour, and have limited application to injury and fatality risk in transport. The main problem with RP studies is that there are many factors (tangible and intangible) for which quantified data is not available. So the trade-offs observed could have measurement errors.

To avoid this problem, SP studies create hypothetical market situations, so that responses on specific risk changes can be obtained. Most SP studies on VOSL use surveys with questionnaires on transport risk changes. This approach provides estimates of marginal rate of substitution of wealth for change in fatality risk. The VOSL is estimated as the weighted average of marginal rates of substitution. Because it is based on hypothetical market situations, one criticism of SP is that the responses can be hypothetical.

A summary of strengths and weaknesses of RP and SP methods of valuing WTP is presented in table 6.2.

Table 6.2 The strengths and weakness of revealed preference and stated preferences methods

	Revealed preference	**Stated preference**
Strengths	Based on actual behaviour[a, b] Some research finds consensus that wage is responsive to risk[c]	Flexibility to control for many variables includes risk context [a] Can elicit preferences for non-observable attributes [l] Can be representative of population if well designed [f]
Weaknesses	Insensitive to context, but risk valuations context specific [a, f, g, h] Some research finds that the wage-risk relationship is spurious [e, g] Difficult to account for non-risk determinants of wage variation[a, f, h, i] Panel data only gives cross-individual rated of substitution[d] High transaction costs means that workers are not at the wage-risk equilibrium [k] Not fully representative of the population[f] Estimates are distorted by the gap between actual and perceived risks[a, f, i]	Based on hypothetical behaviour [a, h] Lack of systematic responses to very small risk changes [a, f, k, l]

[a] Hauer (2011); [b] Cnann and Kang (2011); [c] Ruser and Butler (2010); [d] Grüne-Yanoff (2009); [e] Mrozek and Taylor (2002); [f] OECD (2012); [g] Miller (2000); [h] Kochi et al (2006); [i] Viscusi and Aldy (2003); [k] McConnell (2006); [l] Goldberg and Roosen (2007)

Source: Milligan et al 2014

While SP approaches present serious challenges to obtaining reliable responses, these are in principle amenable to research and resolution. The approaches can be divided between contingent valuation, which through various techniques directly questions respondents about their WTP for specified outcomes or pre-set scenarios, and choice modelling which asks respondents their relative preferences for varying combinations of attributes, which can be tied back to trade-offs of value to derive a marginal price for changes in each attribute.

Meta-analyses of WTP studies by the OECD (Lindhjem et al 2011) suggest the following:

- People value risks to themselves higher than risks to wider society.
- People value risks they view as under their control (like when driving) less than the risks they view as out of their control (like exposure to air quality).
- People's valuation of safety risks rises with their incomes.
- People's valuation of safety risks shows no clear pattern of varying with age, although one study shows a higher value for people older than 60.
- Dichotomous choice (Yes-No) CV questions typically give higher values than open-ended CV and other formats, but of all the elicitation mechanisms this is also the approach that is most proof against strategic bidding.
- Voluntary payment instruments give higher values (due to the 'warm glow' of giving) than those implying compulsory payments.
- The higher the response rate the lower the WTP values, since the survey captures responses from more less-interested respondents.

It can be difficult to validate the results of SP estimates due to the hypothetical nature of the response, particularly for specific matters (like travel risk) where there are no close market analogues. Such studies often exhibit a scoping issue in which, contrary to expectations, the higher the risk change being examined, the lower the implied VOSL, because stated WTP increases relatively less than the risk change, and because income constraints become more binding for bigger changes in risk.[11] Many studies have derived WTP values that are proportionately insensitive to the size of risk change being examined (Hammitt 2007; Hunt and Ferguson 2010; Lindhjem et al 2011). Because the base risk in such studies is not what people experience every day, it is necessary to pose realistic questions to provide realistic responses (Mitchell and Carson 1989; Ekstrand and Draper 1999). People may also experience difficulty in assessing numerical value of risk changes, finding it easier to respond to percent changes in base risks.

Some respondents display 'lexicographic preferences', which occurs when they are unresponsive to some changes because they evaluate alternatives on the basis of a subset of attributes, such as when they always choose the cheapest or fastest alternative (Hess et al 2010). Lexicographic behaviour may be choosing a simplifying heuristic to reduce transaction costs in decision making, but in some contexts (such as environmental valuation) it can represent a distinct form of preference that places a very high (or low) value on particular outcomes which is non-negotiable over a wide range. Where lexicographic preferences are widespread in responses, valuation of marginal risk change can be distorted.

Measures such as QALYs, DALYs and VSLY have been used in some circumstances and valued in some cases using SP techniques comparable to those used for VOSL. People are not indifferent between a long extension of life at reduced quality and a short extension of life at high quality, and some empirical

[11] In practice the VOSL is computed by first estimating WTP for a specified risk reduction, ΔR, and then by dividing WTP by ΔR, so the larger the ΔR the smaller the VOSL, when WTP is limited by income constraint (OECD 2012).

evidence suggests people value improvement in longevity more than of quality of life (Ryen and Svensson 2014). Also, the value of QALY may not change proportionately with its size. QALYs and DALYs were developed to assist comparison between specific health interventions in a similar area with differences in longevity and quality outcomes, and they have a role to play in such limited comparison of options. They are less suited as standard measures of outcomes in transport accidents where the mix of longevity and quality outcomes may be quite variable and context-specific.

If transport assessments are to take account of long-term latent effects that shorten life expectancy at some future data, a VSLY is required. It is most appropriate to value this directly through a SP method, which could also be designed to identify if the estimated VSLY varies with different levels of life quality in the intervening years, to account for those conditions that affect life quality more than they affect longevity.

6.2 Benefit transfer and secondary valuation

If generating new primary estimates of VOSL, VSLY or values for non-fatal injuries is too complex or costly to undertake, an alternative is to use existing value estimates from elsewhere (either New Zealand or overseas) in assessments of other contexts with similar characteristics. Formally this process is known as “benefit (or value) transfer”. The simplest benefit transfers consist of taking a value from one context and using it in the second, with or without some adjustment to the values. More sophisticated approaches take the function used to derive the estimated value and apply it to the second context, so that contextual factors such as base risk and income level may be taken into account. For a more extensive discussion of benefit transfer techniques see OECD (2012).

Variants on benefit transfer techniques include:

- Simple unit value transfer, which assumes that the benefit (marginal utility) from a risk reduction in context of a single study is the same in any policy context so the value can be applied directly to other policy contexts. This simplifying assumption is not always correct so this approach should be used cautiously and tested with sensitivity analysis, and it should not be used to apply values from other countries directly as the economic and social parameters that underpin the VOSL will be different.

- Unit value transfer with income adjustments, commonly by GDP per capita differentials to adjust values from other countries for differences in income and economic conditions. This approach does not deal with differences in individual risk preferences, baseline risk levels, cultural factors or institutional arrangements, and is best used on values from a country with similar risk, population and social parameters to minimise the unknown effect of these factors.

- Unit value transfer with age cohort adjustments are an exception to the assessments of policies that have non-age discriminating public good benefits (as in most transport policies), but are made in policy contexts that focus on children. Sensitivity analysis should be done when age-based adjustments are performed, including a scenario with no adjustment for age.

When time, information and resources allow it is better to use statistical parameters when applying the benefit transfer approach, because this means more information on factors that cause variation can be taken into account. Two variants are single study benefit function and meta-analysis of multiple studies. There have been a number of international meta-analyses (for example, MoT 2009; Braathen et al 2009; Biausque 2010; Lindhjem and Navrud 2010; Mrozek and Taylor 2002; Viscusi and Aldy 2003).

As part of the OECD's review of non-market valuation relevant to health and safety, Lindhjem and Navrud (2010) look at methods that can be used to screen estimates for use in benefit transfer, and they also compare different approaches to the process. Choosing one such estimate as a benchmark, they compare multiple approaches of benefit transfer with varying sophistication to assess their ability to achieve the benchmark result. Their main findings are:

- Transferring a raw, unadjusted mean VOSL value from a full sample or one that has been reduced for similarity with the policy site produces relatively high transfer errors (92%–163%).
- Transfer error can be reduced to almost acceptable levels (around 40%) by using simple screening procedures and/or adjusting for GDP differences between countries.
- Using values derived from meta-analysis models of VOSL produces lower transfer errors than just transferring mean VOSL estimates.
- The meta-analysis models are not overly sensitive to the screening procedures used or to issues such as trimming and weighting, and they do a 'fairly good job' of predicting VOSL estimates.
- The two most important variables for explaining variation in VOSL estimates and hence for benefit transfer adjustments are the base risk level and the level of per capita GDP.

This and other OECD reports (Lindhjem et al 2010) support the common practice of adjusting for differences in GDP when using values from other countries for benefit transfer. They do not provide guidance on the problematic issue of VOSL's insensitivity to the size of risk change being valued.

OECD (2012) describes an eight-step procedure for conducting benefit transfer. The eight steps are:

1. Identify and describe the change in mortality risk to be valued in the policy context.
2. Identify the affected population in the policy context in terms of size and socioeconomic characteristics.
3. Conduct a literature review to identify relevant primary studies.
4. Assess the relevance/similarity and quality of the values available.
5. Select and summarise the available information from the studies relevant to the policy context.
6. Transfer the values from the studies to the policy context.
7. Perform the quantitative policy analysis.
8. Assess the effects of uncertainty and perform sensitivity analysis.

6.3 General adjustments to the values

In completing its review of VOSL methods, the OECD (2012) has produced guidelines on how to use the findings of its meta-analysis. A summary of its guidance is provided in table 6.3, along with commentary about implications for the New Zealand VOSL.

Table 6.3 Recommendations for adjusting VOSL

Issue	OECD (2012) recommendation	The implications for New Zealand
Population characteristics		
Income	No adjustment within a country or group of countries due to equity concerns. For transfers between countries use GDP per capita to the power of an income elasticity of VOSL of 0.8 with a sensitivity analysis range of 0.4.	No adjustment within a country or group of countries due to equity concerns.
Age	No adjustment for adults due to inconclusive evidence. Adjust for children if the policy specifically targets the safety of children. The VOSL for children should be a factor of 1.5-2.0 higher than the adult VOSL.	While the evidence is inconclusive the literature and New Zealand based studies do not support applying a VOSL for children that is lower than adults for the purpose of policy analysis due to equity concerns. There may be a justification to increase the VOSL for children in the investigation of safety policies focused on child safety. Be aware of the influence of parental altruism and household budget constraints for young families in survey results. Societal altruism for children's safety can also be a factor
Population health status and base risk	No adjustment due to limited evidence.	No adjustment due to limited evidence.
Risk characteristics		
Timing of risk (latency)	No adjustment due to limited evidence.	No adjustment due to limited evidence.
Risk perception (source or cause)	No adjustment due to inconclusive evidence. Apply sensitivity analysis for lower values in the environmental sector relative to the health and transport sectors.	No adjustment due to inconclusive evidence. Apply sensitivity analysis to model the impact of uncontrollable risks.
Cancer or dread (morbidity prior to death)	No adjustment to VOSL. Morbidity costs prior to death should be added separately.	No adjustment to VOSL. Morbidity costs prior to death should be added separately.
Magnitude of risk change	No adjustment, but since changes in risk affect VOSL the variation in the risk levels should be reflected in sensitivity analysis.	No adjustment, but since changes in risk affect VOSL the variation in the risk levels should be reflected in sensitivity analysis.
Other adjustments		
Safety-focused altruism and public vs private risk	No adjustment due to limited evidence and unresolved issues. Use private risk to set the base VOSL and perform sensitivity analysis.	Results depend on who is surveyed and how the questions are asked. It is important to be aware of instrumental and strategic bias.
Discount for stated preference studies hypothetical bias	No adjustment due to limited evidence.	No adjustment due to limited evidence.
Correction for inflation	Adjustment based on the national CPI.	The social cost of a fatality is adjusted annually and is reported in real terms.
Correction for increased real income over time	Adjust VOSL in line with changes in GDP per capita.	The average ordinary time wage rate is used for adjustments in New Zealand to obtain a contemporary 'real value' to a new base year. This should be reviewed.

Source: OECD 2012, NZIER based on the literature

Having identified the evidence from the meta-analysis of the influence on VOSL of factors like income, age, health status, risk perception and dread, OECD finds in most cases insufficient evidence to adjust the guideline values obtained from the meta-analysis for specific applications. Two exceptions are adjusting old VOSL by change in real GDP per capita to obtain an updated real value, and further adjusting by the CPI to account for inflation over time to obtain nominal current values. Mostly this recommendation of no adjustment is due to insufficient evidence of significant influence, which in some cases indicates very few studies applied to the issue.

In drawing conclusions about average findings from the reviews, these recommendations do not coincide with the practice in all OECD countries. In particular, the UK has applied a 2xVOSL figure to assessments involving the dread effect of cancer. It has also used value of LYL for matters of long-term latent fatalities from air quality. The OECD (2012) suggests no adjustment for either of these, noting that morbidity effects prior to death can be added separately in assessments of cancer risk, although not indicating how that would be done.

The OECD guidance contains some recommendations at odds with prominent findings in the literature. For instance, in considering risk perception (source or cause), individuals' lack of control over exposure to environmental risk might be expected, ceteris paribus, to imply a higher VOSL than in transport, not lower values as implied by the guidance (apart from the effect of discounting the value of deaths that occur in the distant future). The guidance suggests adjusting VOSL by CPI even though it acknowledges CPI is not an ideal index, as VOSL is not included in the basket of goods on which CPI is based. The two adjustments for CPI and income are superfluous if a single index can cover the change in real value of VOSL over time.

6.4 Implications for New Zealand

With respect to New Zealand, current procedures around the VOSL provide a value for fatality, a fraction of that value for serious and minor injuries, but no value for long term injury effects that form part of the serious injury category. The VOSL has been used in other transport contexts (eg for aviation regulations), and for some environmental contexts (eg CBA of the national environmental standards for air quality), but there has been no specific adjustment for the long-term latent effect of air quality on premature mortality in the future.

The current literature suggests New Zealand's approach to VOSL, based on SPs, is appropriate in terms of current practice, at least in transport. The figure used is now rather old, and its updating would create opportunities for extending the information obtained from a new survey. In particular some of the contextual influences on SPs might be investigated, such as whether there is a significant difference in the values stated by respondents for risks that are within or beyond their control.[12]

Air quality is an issue in overseas jurisdictions that, if brought into New Zealand transport assessments, would require explicit valuation of VSLY and morbidity measures for future years (eg QALY or DALY). However, that can only be done if local data is sufficient to link air quality to mortality and morbidity. New Zealand statistics do not currently record air quality as a cause or contributory factor in mortality so further investigation would be needed to establish how this could be done.

[12] Estimates will only be unambiguous if baseline risks are similar. The Chilton et al (2006) paper is confined to causes of death with similar risk, and finds little dread premia because of dread being cancelled out by baseline risk, rather than from causes not being dreaded.

Whether to adjust for other factors like age depends on there being age-specific policy measures that are tailored to different age groups. As the literature suggests societal VOSL for children is unlikely to be less than for adults, and that the WTP for risk reduction of the elderly may be greater than that for the average adult, the evidence for the common presumption of VOSL for the old being lower than the average is weak and there is no need to deviate from a standard VOSL for all ages.

VOSL represents societal risk aversion, so it is not just individual WTP for private risk reduction, but includes altruistic WTP for risk reductions for others. The extent to which VOSL reflects safety-focused altruism depends on how the questions in an SP survey are phrased, which could be a useful area to clarify in any future survey.

The current practice of updating VOSL by indexing it to average ordinary time wage rate should also be looked at. Most meta-analyses consider per capita GDP as an important factor for variation in VOSL estimates between countries. A logical implication is that VOSL can be updated using per capita GDP. In either case, a new study should be carried out periodically to take account of changes in people's valuation of risk with improvement of safety levels over time.

Recent literature demonstrates advances in methods and technologies for conducting SP surveys, such as web-based surveys, which have potential to increase the scope and reduce the cost of conducting estimation studies. These technical matters of methods have not been examined in detail in this review.

Although this report provides no detailed consideration of cost and practicality of the three approaches raised in the request for proposals, some general implications are:

- Aligning valuations of non-market transport impacts would potentially be a costly approach, as it could require multiple SP surveys run concurrently to ensure a constant context in which to establish relativities. There are limits to how many questions can be practically included in SP surveys before people lose focus and give wayward results, so establishing relative values for safety, time, and any other values deemed important would require multiple surveys. Establishing such relativities between values has not been a high priority in international literature.
- Making adjustments for the number of life years remaining could be approached by some add-ons to a survey on general VOSL, to establish how WTP for risk reduction varies if the risk is further away in time, or if it varies with respondent age. Valuing individual life years with a quality adjustment would be more expensive, particularly if it was aiming to distinguish between a wide range of utility conditions with varying trajectories. It would be more feasible to estimate values on a simplified scale of high, medium or low quality. This would reduce the apparent accuracy of the values, but great accuracy may not be required in the context of transport appraisals where it may not be possible to accurately predict the morbidity effects of non-fatal injuries or chronic exposures to which these life years would be applied.
- Aligning valuations of injury and mortality risk across risk sectors could be costly and data dependent to do properly, as values depend on perceived risks in different settings. However, some minor add-ons to an updated VOSL could provide information on the value of avoiding voluntary and involuntary risks which would provide generic guidance to the value to apply in different contexts.

7 Summary and conclusion

This report has examined approaches for valuing injury and mortality risks in New Zealand, drawing on a review of relevant literature from New Zealand and overseas. It provides guidance on the suitability of the current approach to estimating the VOSL and values of injuries in transport evaluation, and what would be required to close specific information gaps. These include the relative value of safety and other non-market values in transport, whether VOSL should be aligned between transport and other injury sectors, and whether VOSL should vary with age and life expectancy of those at risk.

The current VOSL was established in 1991 and was based on a survey of New Zealand residents' attitudes towards safety risks on the roads. It has since been updated annually indexing it to the average ordinary time wage rate. International literature indicates that VOSL estimates vary in particular with levels of income or GDP per capita, and with the starting risk faced by the population. Since the New Zealand VOSL was established New Zealand incomes have risen and the risk of fatality on the roads has reduced, so the VOSL no longer reflects the public value of risk reduction and requires more fundamental updating than index adjustment.

The international literature confirms that the approach behind the current VOSL, basing it on public WTP to reduce fatality risk on the road inferred from a SP survey of the affected population, is the appropriate way of valuing changes in public safety risk. But the empirical literature also highlights a number of reasons why the 25-year-old estimate is likely to be out of date. It also shows that techniques for establishing such values have developed over this period and can now be customised to yield a wider range of related value information than the current VOSL.

In considering whether and how to fill gaps in current knowledge, this report finds:

- The relative value of safety and other non-market impacts of transport: this is most apparent in literature showing patterns of relative values of changes in fatal and non-fatal risks, acute risks of immediate injury (as in crashes) and latent risks of future reduction in life expectancy (environmental and health risks); but literature on the values of safety and time shows results vary with how the estimates are made
- Whether VOSL should vary with age and life expectancy of those at risk: the empirical literature is ambiguous, with some showing VOSL rising to middle age then declining, while other studies show individuals' WTP for safety increases in older age cohorts; for assessing transport measures that affect general safety risk age of potential casualties is irrelevant and a single VOSL suffices, but for child-specific policies literature suggests a separate child-specific VOSL is unlikely to be less than that for adults, due to society's altruism and protective attitudes towards children
- Whether VOSL in transport should be aligned to value of safety in other risk contexts: as literature finds that VOSL is affected most by base risk and income of the affected populations, the value of safety in transport and other domains like workplace safety or health interventions is unlikely to be the same; but a transport VOSL could provide a benchmark for these other risk areas, with appropriate adjustment for differences in risk characteristics.

The theoretical and empirical literature indicates that different safety realms facing different risks in principle should use customised VOSLs. In practice most countries use a common VOSL or variants on a common VOSL base. The same could apply to New Zealand around the transport VOSL, with greater usefulness if the new value established some parameters around how VOSL changes with varying contexts.

On the basis of this review, a new survey to update the VOSL estimate for current conditions is now overdue. This presents opportunities for extending the survey to obtain new information that can be used in both transport and other policy applications. However, the recommendations made here are primarily from the perspective of values of use for transport assessments. Priority has been assigned according to those values that are likely to have practical uses in policy evaluation, those that can be implemented with the existence of reliable base data, and those which have attracted most attention in international literature.

The first priority of a new survey is to establish and update public WTP to reduce the acute risk of fatality in road transport crashes. Closely associated with this would be establishing the relative value of reducing risk of non-fatal injuries and fatal injuries. The value of a statistical serious injury is currently set at 10% of the VOSL on the basis of previous survey results, which could be confirmed and updated. An alternative approach would be to estimate the value of lost life years or QALYs due to serious injuries. This approach has considerable problems in estimating the value per life year or per QALY. Another approach would be to consider more disaggregated range of severity categories instead of just serious and minor injuries.

There is currently limited evidence to support putting priority on establishing the relative valuation of safety and time. The international literature indicates VOSL is most affected by factors such as base risk and income, and the value of time varies with user type and trip characteristics. Only two identified research papers investigate the relative values of safety and time. There are practical limitations to deriving relative values for safety and time with the knowledge and tools available at present. Therefore, further research in this area is required to understand whether such practical limitations can be overcome to make the approach viable.

The international literature provides little evidence to suggest that systematic relativities exist between VOSL and other non-market values, or that these values need to be updated simultaneously using similar methods. However, in designing an updated survey, consideration should be given to extending it to enable separate VOSLs to be inferred for risks which respondents have some control over (as in car driving) and those where they do not (as for passengers in public transport). There is international evidence that people's WTP to reduce involuntary risks is greater than those over which they exercise some control and voluntary choice, and if confirmed for New Zealand this could provide guidance for valuing risks for which people are involuntary third parties (such as exposure to environmental pollutants).

The current approach of using a VOSL for fatalities and a percentage of VOSL for non-fatal injuries is for acute risks of crashes with immediate injurious effects, but coverage is not so clear for long-term effects of exposure to chronic risks (such as air quality). However, a further potential extension to consider would be establishing the WTP for changes in latent risks to longevity (that is changes in risk of losing years of life at future dates beyond the acute risk of immediate death in a road crash). This would give a directly estimated value of a life year, which has potential application to policies that affect the risks of chronic health conditions that foreshorten lifespans in the future. Such a value would replace the current practice of calculating a value per life year as the annualised equivalent of the VOSL, as if VOSL is the NPV of a stream of future life years. The VOSL is not currently calculated as a NPV and the annualised value implies a constant value over time which is probably incorrect, so obtaining directly estimated values per life year could have wide application in environmental or health effects of transport that affect chronic and latent risks.

This recommendation attaches less priority to putting a dollar value on quality weighted constructs such as QALYs or DALYs, as these are not created equal, and reflect a wide variety of health states that would be difficult to apply accurately in transport assessments. Where health outcomes are easier to predict, as in choices for medical interventions, there may be more merit in valuing QALYs or DALYs. As empirical studies suggest gains in longevity are valued higher than gains in life quality, it would be useful to estimate value of life years without the complication of quality adjustment, and then see how that changes when distinguishing between broad categories of quality of life.

Consideration should be given to designing a new survey to estimate WTP for acute and latent risk, and also the value of life year under different circumstances of respondent age and broad quality of life level. To fully understand the cost and practicality of such a survey would require consideration of a range of factors (such as the number of questions required and size of sample) that is beyond the scope of this report but some indications of the relative cost of different approaches have been identified. Aligning valuations of non-market impacts of transport is potentially very costly as it would require multiple surveys, and valuing QALYs is potentially even more so because of the wide range of potential trajectories of long term injury and impairment. But relatively limited add-ons to a survey to update the general VOSL could derive alternative values for latent risks that are more distant in time, and test for differences in value between voluntary and involuntary risks, that could provide indicative guidance beyond road transport.

Nor do we recommend putting priority on establishing the relative valuation of safety and time. The international literature indicates VOSL is most affected by factors such as base risk and income, and there is no reason to expect changes in risk to be tied to the value of time. Nor does that literature give much research attention to the relative values of safety and time, and where it has been examined the results have been ambiguous and showing no stable or significant relationships, despite management of traffic speed being a major component of road safety programmes.

The method chosen to update the VOSL would be a SP valuation study. This could be either a contingent valuation survey to estimate public WTP for specific scenarios of risk reduction, or choice modelling in which relative preferences for different attributes are estimated to infer marginal WTP values for each one. Of other potential methods, RP techniques such as wage-risk studies have tenuous application to transport safety and are also data intensive. Benefit transfer, or the use of existing studies from elsewhere applied to New Zealand situations, depends on the population preferences in one country being closely similar to those in the other.

Whichever method is chosen it should be tailored to the information needed to inform practical policy and project appraisal. This would be done in developing the survey questionnaire, once the scope of the survey and the policy issues it needs to serve have been determined.

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Appendix A: What does the literature show?

A1 Approaches to valuing injury and fatality risk

There are three groups of approaches to the valuation of risks to human life.

A1.1 Implicit values

First, the implicit valuation approach, which suggests that valuation of risk to life can be inferred from public policy decisions on expenditure designed to preserve life. Two examples of preventative expenditure are the costs of fencing dangerous animals or balcony rails on a second storey balcony. As both these actions reduce the risk of injury, the cost of implementing them can be compared to the risk reduction to derive a value per prevented injury.

In a wide range of policy settings such decisions may be made without any deliberate assessment of the benefits obtained and costs of achieving them so the valuation is implicit rather than explicit. Often the values implied in different contexts vary widely, as revealed in a New Zealand study by Propper (1983) which showed the value of saving a life implied by public expenditure decisions was many times higher in fencing swimming pools or funding coronary care units than it was in supporting search and rescue activities. When such decisions are informed by detailed analysis of the expected cost and benefits (e.g. explicit comparison of the costs of balcony rails and how they change the likelihood of injury) the approach has similarities to RP analysis, where value is inferred from observed behaviours.

In response to major crashes with multiple facilities, the urge to show a response can cause policy to be developed with little regard to the implied value of safety improvements. Chilton et al (2002) report two studies that estimate preference-based values of rail safety, domestic fires and fires in public places that occurred before and after a major rail crash. These studies showed that the public perceptions of risk changed in response to the crash, but by much less than the value differentials observed in some public policy making, suggesting politicians responses to major accidents imply higher values for risk reduction than those held by the public at large.

A1.2 Human capital approach

The second group is the human capital approach, which derives the value of risk to human life from measures of the cost of lost productive output. Thus, the value of a human life can be measured by the discounted sum of lost income between the age at premature death and the average life expectancy at the time of premature death. The theoretical foundations of this approach are weak. Income is an incomplete measure of the utility derived from a lifetime of consumption. Furthermore, the human capital approach ignores the willingness of others in society such as friends and family to contribute to the safety of an individual.

The human capital approach also struggles to reconcile the safety of children and the retired or indeed stay-at-home parents with their lack of income. Proponents argue the human capital approach can at least provide a conservative estimate of the lower bound of the value of risks to life. Opponents point to the weak theoretical foundation of the approach and argue that is it a poor proxy for more complete measures for WTP for a reduction in risks to human life.

There are several variants of the human capital approach, which have been reviewed previously by BERL (2002). However, none of these overcome the fundamental problem that human capital calculations do not measure social welfare, and are hence incompatible with the principles of CBA. Even agencies that use a hybrid human capital approach to value fatalities on the road recognise that it is not equivalent to WTP-based estimates (BITRE 2009).

A1.3 Willingness to pay

The third group, the WTP approach is firmly established as the most appropriate measure of the value of risks to human life and has been endorsed by a recent series of OECD studies (Lindhjem and Navrud 2010; Lindhjem et al 2011). WTP is based on the opportunity cost of reducing risks to human life. It goes beyond the measures of income and it can include the willingness of people to forgo consumption to reduce risks to others. WTP is a more complete measure of value in reducing the risk to human life than the avoided loss measured by the human capital approach.

Willingness to accept (WTA) (compensation for increased risk) is a related measure. While in theory WTP and WTA should be the same for equivalent risk changes, in practice disparities are observed (Hanemann 1991; Guria et al 2005). Estimates of willingness to accept an increase in risk are typically higher than measures of WTP to reduce risk by an equivalent amount. One reason is WTP is limited by a consumption budget constraint (of either the individual or others) whereas willingness to accept is limitless, and there is also a commonly observed ‘endowment effect’ whereby people seem more reluctant to give up something they have than they are willing to pay for an equivalent gain. Asymmetric preferences are predicted by prospect theory, in which uncertainty over the likelihood of different outcomes can skew preferences away from symmetry for opposite results (Tversky and Kahneman 1992). Availability of substitutes also influences the difference between WTP and WTA (Hanemann 1991; Shogren et al 1994).

RP methods for estimating the WTP seek to infer the value of safety from the cost and characteristics of consumption purchases or other transactions. They infer the value of non-market effects by observing the prices of related marketed goods and services associated with varying levels of the non-market attribute. Isolating the safety component of purchases can be challenging. The most widely applied RP technique used to reveal the value of safety looks at wage-risk differentials across a variety of jobs, using econometric analysis to identify the risk premium attached to wages in risky jobs. RP methods rely on the assumption that people are able to accurately estimate risks and the effectiveness of their consumption choices to reduce that risk. In the wage-risk studies it also assumes that employees have sufficient bargaining power in the labour market to negotiate a wage that adequately compensates them for the risk.

SP methods seek to estimate WTP based on responses to questions about hypothetical markets. These methods ask respondents directly about their WTP for improvement in a non-market attribute of goods or services. SP surveys are influenced by the framing of the questions and the respondent’s ability to conceptualise their response to a hypothetical situation. SPs are prone to instrument bias and strategic bias and are difficult to validate against actual behaviour. Therefore, RP estimates, based on responses to actual risks, may be viewed as preferable and also more informative than SP estimates based on hypothetical risks, although RP methods have their own strong assumptions and inferences about how people respond to risk (Lindhjem et al 2011). RP practitioners in particular stress the limitations of hypothetical questions and responses in SP methods.

> *Estimating trade-offs based on individual choices focuses on the revealed preferences regarding actual risks, which are likely to be more informative than stated preferences regarding hypothetical risks* (Viscusi 2014, p391).

> *The principal drawback of stated preference studies is that there is no assurance that hypothetical choices reflect the trade-offs people would make in actual market situations* (Viscusi 2014, p399).

However, RP methods depend on strong assumptions and require large datasets that can be analysed in different ways. North America, with its mix of Federal and state-level data with common measurement approaches, but also variations in state policies that provide a range of natural experiments in policy variation is well placed to implement RP methods, but in less data-rich settings they have fewer uses.

With few exceptions (notably Australia), most of the countries New Zealand usually compares itself with – UK, USA, Canada, Sweden and most other EU countries – have adopted WTP for risk avoidance as the basis for valuing fatality risk. The valuation method used varies across countries. In North America, RP studies dominate the estimates used by the Environmental Protection Agency and other safety agencies, whereas in Europe WTP based on SP studies is more prevalent and has been the focus of a suite of reports from the OECD that describes a major meta-analysis of values used to assess fatality risks and their policy implications (Lindhjem et al 2010; OECD 2012; OECD 2014). A similar, though more academic, meta-analysis has been undertaken by the Tinbergen Institute in the Netherlands (de Blaeij et al 2003). The suitability of WTP, human capital and QALY for use in transport appraisals has been examined by Wijnen et al (2009), but this does not provide conclusive policy advice.

For a cross country comparison of VOSL estimates used in policy development, see MoT (2009). The VOSL varies widely between countries and in Europe tends to be lower than in North America: this may reflect the differences in the predominant method used, as even in North American studies RP methods result in higher VOSL estimates than SP methods (OECD 2012). There appears to be some academic support for standardising the valuation approach (if not the value) across the EU area (Holz-Rau and Scheiner 2011), and for Australia to adopt the WTP approach (Perovic and Tsolakis 2008; Tooth 2010).

A1.4 Altruism – the willingness to pay for the safety of others

Most WTP studies show that people are willing to pay something towards a reduction in the risk of injury or death for other people. The extent of this altruism varies with different societies and situations. It may also differ between those living nearby and those living far away. Viscusi et al (1988) found evidence that people are more altruistic towards people in the same state in the USA compared with people in other states. Dickie and Messman (2004) and Dickie (2005) show there is intra-household altruism between parents towards their children's safety. The results of SP studies on the VOSL for children (such as Hammitt and Haninger (2010); Blomquist et al 2011) indicate that society may value risks to the lives of children higher than risks to the lives of adults. Lindberg (2001) estimated the level of altruism in Sweden is about 7% of VOSL and about 17% of the value of injury prevention.

Jones-Lee (1991) argues that only altruism exclusively focused on the safety of others (pure safety-focused altruism) is relevant to include in VOSL. There is a question of how much of this WTP for others is altruism or in fact a manifestation of the free-rider problem (Jones-Lee et al 1985). What may appear to be altruism may also be disguised self-interest, as individuals may express preference for collective goods that they will also benefit from. The provision of safety instruments on public roads is non-excludible, as all users experience benefits for infrastructure safety improvements. As a result, there is potential strategic bias in SP surveys and overstatement in the WTP for the safety of others (Johannesson et al 1996).

A1.5 Pricing risks to human life is ethical

Finite resources drive the need to make trade-offs across a range of policy and infrastructure investment options that motivate the valuation of risks to human life. VOSL is one approach to such trade-offs, as valuation of those risks is a useful research tool. Failure to quantify and monetise risks of death and injury leaves decision makers with no quantitative basis for making trade-offs between options in relation to safety risks. This view is supported by van Wee and Rietveld (2013) who debate the ethics of pricing human safety and conclude that on balance pricing is reasonable and ethical when it is accepted that trade-offs are unavoidable.

> *Despite the rhetorical appeal of designating such risk-related effects as being "priceless," failing to monetize them at all may make them worthless from the standpoint of benefit-cost analysis. Moreover, in any meaningful economic sense, small reductions in fatality risks are not priceless. Due to society's limited economic resources, it is not possible to make an unbounded commitment to risk reduction, implying that eventually some trade-offs must be made* (Viscusi 2014, p388).

Even if risks to life are not explicitly valued, the default position is that protecting lives will be valued implicitly in the decisions that are made. Implicit values can vary widely between decisions, which is inefficient as it implies that more lives could be saved by reallocating resources from where it is costly to save lives to where it is less costly.

A2 Value of risk avoidance across different injury sectors

A2.1 Environmental effects measured by VOSL and QALY

Monetary values of environmental effects have been used by researchers either through QALY (or DALY in some cases) or VOSL. In the first case, QALYs gained from a reduction in pollution level are estimated. Many cost effectiveness analyses use money spent per QALY gained as a basis for evaluating projects and policies that reduce pollution levels.

It is common to use VOSL estimates in economic evaluation of health and safety projects or policies in transport and environmental areas according to some researchers (Lindhjem et al 2011; Hammitt 2002). However, QALYs have been used in some studies.

Studies in New Zealand have used both approaches. For example, Fisher et al (2007) estimated QALYs and monetised these using the New Zealand VOSL for both losses of life and life quality. A recent study (Kuschel et al 2012) revisited the issue and used VOSL for loss of life and fractions of VOSL for loss of life quality.

Some studies (and countries) use higher VOSL to measure the social cost of a fatality due to environmental effects than that used for traffic fatalities. The US Environmental Protection Agency, for example, recommends that VOSL should be US$7.4 million at 2006 prices updated to the year of analysis (National Center for Environmental Economics 2014), whereas the Department of Transport was using US$6 million at 2009 prices in 2009 (US DoT 2011). One reason for the up-scaling of VOSL for environmental risks is that many of such risks are unavoidable and out of the control of individuals affected, whereas transport risks are commonly regarded as at least partly attributable to individuals' decisions about transport mode, speed and timing. Also, some jurisdictions may use a higher VOSL for chronic conditions involving long, lingering increase in pain and suffering (HSE 2001).

Fisher et al (2007) estimated the value per year of life considering VOSL as the discounted present value of LYL in road accidents at the average age at death. This was then applied to the elderly age group, where the average LYL would be relatively small. Abelson (2008) reviewed these approaches and found that treating VOSL as the capitalised stream of life-years gained, was a useful and pragmatic method, although acknowledged the theoretical and empirical support for this practice is weak.

The Australian Environmental Protection Council recommended a VOSL of AU$6 million in 2009 (NEPC 2009) based on a meta-analysis by Access Economics (2008).

The VOSL indicates what society is willing to pay to avoid a premature death. When avoiding a premature death simply gains few more years of life for a person, it might be argued that the benefit of reducing the number of fatalities is the increase in life expectancy of those whose premature death is prevented. Hammitt (2007) distinguishes two approaches to estimating the societal value of avoiding a premature death. One is through VOSL and the other is through the VSLY. Hammitt argues that air pollution regulation primarily benefits people who have less than average life expectancy, ie elderly people. Therefore, the use of VOSL may give a higher estimate of the gain due to regulation. Hammitt notes that the Office of Management and Budget in the USA encouraged the Environmental Protection Agency to use both lives saved and life years saved methodologies to estimate the benefit of pollution regulation.

According to Desaigues et al (2011), the value of a life year is gaining importance in valuation of mortality due to environmental effects, as the benefit of lower pollution is primarily an increase in life expectancy (although improvements in, say, air quality can also have other qualitative benefits, such as improved visibility, reduced odour, and reduction in days when air quality detracts from other activities like outdoor recreation). They argue that number of deaths is not an appropriate measure of total mortality impact of air pollution, as air pollution cannot be identified as a primary cause of a death. It is only a contributing factor so the use of VOSL would provide relatively high estimates.

A2.2 Estimation of monetary value of a life-year

To estimate VOSLY for European Union countries, Desaigues et al (2011) conducted a contingent valuation (CV) survey covering nine countries: France, Spain, UK, Denmark, Germany, Switzerland, Czech Republic, Hungary and Poland, and had a total sample size of 1,463. They recommended €40,000 per life year saved, with a minimum value of €25,000 and a maximum value of €100,000.

Chilton et al (2004) make direct estimates of the value of a life-year in the UK using the contingent valuation method. They examine the differences in values for those starting in poor health or good health. The policy implication is about targeting policy and resources to where they are needed.

Nielsen et al (2010) describe an empirical study investigating people's preferences over three different risks to survival, by examining programmes that deliver the same change in life expectancy by reducing risks in the immediate short term and those in the longer term with different rates of reduction. This novel approach passed validation checks and revealed three different preference orderings of programmes, distributed evenly across the respondents, indicating that respondents may have distinct preferences for the timing of how safety improvements are delivered.

Cameron and DeShazo (2013) present results of a choice model to elicit WTP for a sequence of prospective future health states, and hence to enable VOSL to be estimated for various reductions in risk of outcomes with different degrees of latency in premature death and different trajectories of morbidity before death. The model requires different profiles for morbidity and mortality to be examined, and also be compared and reconciled to the special case of risk of immediate death in the current period (the standard VOSL). Its structural model could potentially be extended to provide consistently calculated WTP estimates of immediate and latent risks, and to distinguish variations in results with factors such as respondent income, age and disease latency.

In health economics, the QALY concept is used to evaluate projects and policies. The main argument in favour of QALY is that death is not prevented but rather longevity is increased by medical treatments and there can be intervention choices which result in different combinations of longevity and quality of life (eg between kidney transplants and on-going dialysis). QALY takes into account both longevity and health quality. Ryen and Svensson (2014) note there has been a rapid increase in use of cost effectiveness analysis using QALY as an outcome measure. They also note that monetary valuation of QALY using the WTP approach is also increasing.

Cost effectiveness analysis compares the costs of alternative means of achieving the same outcome, so using QALYs in this context implicitly assumes that all QALYs are the same. This has been debated in the literature (Ryen and Svensson 2014; Guria and Yeabsley 2014). The empirical literature suggests that not all QALYs are created equal, and that when attempts have been made to estimate the WTP value of QALYs, the relative mix of longevity and non-longevity qualitative outcome makes a material impact on the values derived.

A CBA using QALY as one of multiple outcome measures requires a monetary valuation of QALY to compare with other outcomes. There have been studies estimating monetary value per QALY from VOSL (eg Mason et al 2009; Hirth et al 2000).

Ryen and Svensson (2014) reviewed 24 studies on monetary valuation of QALY providing 383 estimates. All of these were contingent valuation studies. They found that the monetary value of QALY was higher if the QALY gained was due to an increase in longevity rather than to an increase in the quality of life. They also found that the monetary value per QALY varied with the size of QALY gain.

There have been many studies on the estimation of monetary value per QALY from the VOSL, considering VOSL as the discounted present value of remaining life years (Hirth et al 2000). Mason et al (2009) applied the conventional models (eg VOSL divided by the LYL in traffic deaths and using the discounted present value approach) and developed a new approach where marginal rate of substitution is a function of remaining life expectancy. Using an inverted U-shaped relationship of the marginal rate of substitution with age observed by Jones-Lee et al (1985), they estimated a monetary value per QALY using only the downward sloping part of this relationship. While this study provides a different approach, it also provides only one estimate of monetary value per QALY for all.

Some countries have threshold values per QALY. If the cost per QALY gained is less than that threshold value then the project/treatment is considered cost effective. Shiroiwa et al (2013) notes these values for a few countries.

A3 Relative value of risks of fatal and non-fatal injury

Risks to life and limb can radically influence an individual's utility function and are not the same as financial risks. The valuation of the risk of sustained illness, disability, impairment and conditions leading to premature death is fundamentally different from valuing the risk of monetary losses which are reversible. The benefits from consumption can be radically and irreversibly truncated by impairment or serious illness which changes the marginal utility derived from income and consumption. Therefore, the valuation of a non-fatal injury can be complex, case specific and vary widely depending on the nature of the injury (Viscusi 2014).

Wijnen et al (2009) compare the use of VOSL, human capital and QALY approaches and conclude that policy often understates the value of injury risk, both because practical assessments currently use a VOSL that is lower than that found in scientific research, and because human losses of the seriously injured – which, although lower than VOSL in per person terms, are much more frequent than fatalities in road transport crashes – are understated. A recent OECD study (2014) on valuation concluded that serious non-fatal injury was on average about 10% of that of a fatality, but that further empirical work into the relativity of fatal and non-fatal injuries would be warranted.[13] This result is consistent with Jones-Lee et al (1993) who estimated that the valuation of preventing a serious injury should be about 9.5% of the valuation for a fatality.

The valuation of chronic disease deals with similar complexities to the valuing of serious injuries, because the impact of disease on the utility function can vary substantially. A range of studies have been done to find out how much people are willing to pay to avoid the risk of pain, suffering and death from cancer. For example, a SP study about the risk of bladder cancer from contaminated water (Viscusi et al 2014) found the WTP to avoid suffering before death was a 21% premium on top of the median VOSL for road crashes.

However, there are questions about the ability of individuals to estimate the impact of impairment on their utility function. Sloan et al (1998) showed that contingent valuation estimates for hypothetical multiple sclerosis (MS) were 50% above the estimates of people who lived with MS. This could indicate a tendency to overstate the impact in the case of the risk of serious illness. Another possible interpretation is that individuals may underestimate the ability to adapt to the illness which could lessen the impact on the utility function (Viscusi 2014), although adaptation does not necessarily maintain the level of utility or well-being. It could also reflect a common observation in SP studies in the environmental area that focusing on a particular threat can elicit a far higher value response than observed behaviour towards similar threats, so that the study is creating a value rather than eliciting a pre-existing preference response (Diamond and Hausman 1994; Hausman 2012).

While walking and cycling have health benefits, there are risks of death and injuries while doing these exercises, including the risks of injury from being in mixed-traffic environment. Some of those who take up walking and cycling as exercises might have changed from some other form of exercise. In that case, it is important that only the net benefit is considered which is additional to what would have been achieved through those exercises that walking and cycling replaced, and any offsetting effects of short-term risk needs to be accounted for.

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[13] The OECD reviews have focused on VOSL with brief reference to non-fatal injury in the few studies where it occurs. They do not examine the valuation of different degrees of non-fatal injury.

Another benefit of walking and cycling is reduction of CO_2 emissions through replacement of motorised travel and hence reduction in energy use. While promotion of walking and cycling activities has potential to reduce energy use, some studies find only small impact on CO_2 emission from provision of infrastructure for walking and cycling (Brand et al 2014).

We have discussed applications of VOSL and VSLY to estimate the social value of health benefits. The same can be applied here for improved health conditions. Rutter et al (2013), for example, look at 'relative risk of all-causes of mortality among regular cyclists' to estimate the number of deaths averted due to regular cycling.

A4 Relative value of reducing injury risk and time saving

Safety improvement and savings in travel time are the two major components of benefits in most transport improvement projects. Social values of these (value of travel time or VTT and value of statistical life or VOSL) are usually estimated independently based on the WTP approach, although VTT may also be valued as an opportunity cost of alternative activity, based on wage rates for work time or fractions thereof for community and leisure travel. Questions have been raised on the relativity of these two values, which have high shares in project benefits. There is very little in the literature on the relativity between these two important attributes. Papers that we have come across in this context are discussed below.

Both the value of time and the value of safety have been estimated by RP and SP approaches. In the first case people's actual behaviour is analysed to see how they exchange money for time or safety. In the second case, people are asked to express their WTP for savings in travel time and improvement in safety. In most cases these are estimated separately.

A4.1 Relative value of saving time and safety

Ashenfelter and Greenstone (2004) estimate the relativity between travel time and safety following a RP approach, examining how people behaved when they had the opportunity of increasing their travelling speed on interstate highways in the USA after the federal government in 1987 abandoned a uniform speed limit of 55 miles per hour (mph). Forty states out of 47 states that had interstate highways increased the speed limit to 65 mph, raising both the average speed and the number of fatalities on those interstate highways. Ashenfelter and Greenstone (2004) estimated from 21 states' data that the average speed increased by about 4%, ie 2.5mph and the fatality rate increased by 35%. From this, they estimate that about 125,000 hours were saved per life lost, and estimate the VOSL using average wage rate for the time saved. Although there is evidence of a state's willingness to accept higher risk in exchange for time savings, this does not necessarily indicate an individual's willingness to accept risks, as the maximum legal speed limit can become a norm which influences the speed chosen by risk averse drivers. The study did not take into account the effect on injuries, in particular serious injuries, which lead to loss of life quality.

Strand (2005) presents a theoretical exposition of three RP methods for inferring VOSL from observations of driver behaviour in response to speed limit changes. Two of them he considers reflect individual risk and therefore understate the societal VOSL by excluding the possibility of altruism. A third overcomes that limitation by assuming roading authorities know the true VOSL and optimally arrange their speed limits (a result which requires speed limits that vary with road conditions). This is similar to an approach used by Ashenfelter and Greenstone (2004) to empirically estimate a VOSL from driving behaviour observed across states following the lifting of a federally imposed open road speed limit in the mid-1980s. They found a 4%

increase in speed resulted in a 35% increase in fatality rate, but the implied VSL was overstated as the method did not take account of influencing factors, such as the risk of non-fatal injury or the distortion caused by a speed limit becoming a target or norm rather than a ceiling under which speed choices are made.

A different approach is followed by Hess et al (2012), who discuss time savings and safety trade-offs by using mental accounting processes. They conducted a survey with three choice components – trading time against cost, trading safety against cost and trading safety against time – to test fungibility between time, safety and money, and 'whether a trade-off for one pair of attributes could be reliably obtained on the basis of the two remaining trade-offs' (p1515). They found their direct estimate of monetary value of time was higher when estimated as the trade-off between time and money, and lower when it was estimated as the trade-off between time and safety using the direct estimate of monetary value of safety. Similarly, the direct estimate of the value of safety was lower than that estimated from the time-safety trade-off using the direct estimate of value of time.

Why people speed or what psychological considerations are made in drivers' speed choice has been a subject of psychological analysis. In a recent paper Schmidt-Daffy (2014) introduces a new approach called prospect balancing theory and applies this to driving speed and risk of a crash. 'Prospect balancing theory postulates that drivers' choice of speed differs systematically from a choice that conforms to the requirements of utility maximization.' Schmidt-Daffy states 'it is expected that drivers have a tendency to overvalue a potential loss (such as the costs of a crash) and to over-weight low probabilities (eg the likelihood of a crash)'. Using a driving simulator and recording the speed choice of 24 male volunteers Schmidt-Daffy found the average speed was lower than the speed to achieve the maximum monetary pay-out, considering time, crash risk and risk of being caught of travelling at higher than the posted speed limit. The behaviour at a simulator may not necessarily indicate how the person would have behaved on the road. So this may not indicate the real-life situation.

While there is relatively little literature addressing the value of safety relative to travel time savings, there is literature questioning the approach to value time saving that affects that relativity. Mackie et al (2001) question the use of a value for non-work time based on wage rates, and suggest a 'social weighting' is required to produce shadow prices that are adjusted to account for persistent unemployment.

Related to the issue of relativity between values of time and safety, the literature shows controversies on the nature of value of time itself, whether value of time per unit varies with circumstances. It is convenient to use the same value per hour in economic evaluation for all amounts of travel time saved. Some studies support this view (Fowkes 1999; Mackie et al 2001; Mackie et al 2003). However, many studies also find value of time varying by amount of time saved (Thomas and Thompson 1970; Henscher 1976; Gwilliam 1997; Hulkrantz and Mortazavi 2001; Fosgerau 2006). Though this issue is outside the current study, it is an important matter in this context and has obvious implication in the relativity issue.

Metz (2004; 2008) notes UK data shows empirically that average travel time per person day across a population has been stable for decades, despite substantial investment in transport infrastructure to save travel time. People appear to use travel time improvements to travel further rather than travel less, which is still clearly a source of value for them, but conventional valuation of travel time as time saving based on opportunity costs in paid employment is not the right basis for estimating the social value of benefit obtained.

A4.2 The perspective of utility theory

Another way of explaining the trade-off between time savings and risk increase is through utility maximisation theory. People buy goods and services because of their usefulness or utility in satisfying their needs or wants. In economics it is often assumed that, within a given budget, consumers facing options and choices among different goods and services choose that package of goods and services which maximises their utility.

This can be true in choice of route, vehicle, speed of travel, safety measure, time of travel and even mode of transport. With constrained budgets spending more on one item leaves less to spend on other items, a gain in utility from one item, and loss of utility from others. This can also happen where the utility is obtained from non-monetary transactions.

Blomquist (1986) developed a model on travel safety behaviour with a utility maximisation objective, assuming risk compensation in human behaviour when pursuing multiple objectives with limited resources. Risk compensation and risk homeostasis[14] have been debated in the literature. While risk homeostasis theory presented by Wilde (1982) may be an extreme case, some risk compensation is likely. People do drive at high speed knowing that it increases their risk of a crash and also they do slow down when the road surface is slippery due to rain or some other factor. This indicates travel time is traded off for safety.

Reduction in speed to avert risk of a crash also reduces the travel utility of reaching a destination earlier. Matsuo and Hirobata (2010) discuss driving behaviour considering speed and safety and how valuation of safety measures involves consideration of safety and travel utility.

The utility maximisation objective is also an important factor in discrete choice models of SPs. As Train (2009) explains this consideration 'has important implications for the specification and normalization of discrete choice models'. These models help identify trade-offs between different factors, eg time, reliability, safety and other factors.

The process can be very complex as discussed by Hess et al (2010). They find that some people have a tendency of non-trading in the sense that they always choose the same alternative (eg car over other modes of travel, or un-tolled over tolled route) regardless of how choice sets change. Another complexity is that some people exhibit lexicographic behaviour, with choices based on only one attribute, eg always choosing the faster or cheaper option irrespective of changes in other attributes. This may reflect either heuristic simplicity or a genuine strong preference for particular attributes or outcomes.

A5 How much does the value of safety vary with age?

Should the VOSL vary by age? This question arises from the issue of longevity of safety improvements, and the idea that the value of safety measures is dependent on their impact on longevity of those affected. If safety is about deferring inevitable death, preventing premature mortality among children would be worth more than those in older age groups, because of the greater longevity that confers. This issue is closely related to the question of valuing life years lost (or gained).

Some studies find VOSL and age have an inverted U shaped relationship (eg Jones-Lee et al 1985; Alberini et al 2004; Aldy and Viscusi 2008). In this case VOSL is low at early ages (for children), gradually increases to middle age (around 40 years of age) and then it declines. As VOSL is based on what people are willing

[14] Risk compensation is the notion that behaviour changes in response to changes in perceived risk conditions, and homeostasis is the extreme form that such changes maintain a constant level of risk as external conditions change, which implies that no interventions to reduce risk will have significant improvement in safety in the long term.

to pay for their safety, for children without the means or comprehension of risk to express their safety preferences, VOSL depends on their parents' WTP. Since parents with small children are relatively young and have relatively low disposable income, the VOSL for such families is relatively small (Leung and Guria 2006). Leung and Guria also find that the average VOSL for those without small children is considerably higher than those with children. In families with small children no clear indication was observed by them on whether VOSL for children was higher or lower than VOSL for adults.

Some studies consider VOSL to be higher for children. In support of such a view, Viscusi (1992, p30) notes that: 'the young have more to lose than the old and the special societal concern with averting risks to children reflects this difference'. It may also reflect externality argument and protective attitudes towards children who are less experienced or able to assess risks than competent adults, and also disguised self-interest in social settings where children are a source of social prestige or a source of future income. While this can be a factor in society's valuation of children's safety, children's VOSL based on parents' WTP may not be as high as that for all adults due to parental income constraints.

Altruism plays an important role in estimating VOSL for children in particular. Society is more willing to pay for others' children than for non-related adults and also people are more willing to pay for those close to them than others (Viscusi et al 1988). In a SP study on fatal disease risks from pesticide residues on fruit and vegetables, Hammitt and Haninger (2010) found that risks to the lives of children were valued twice as highly as risks to adults. Blomquist et al (2011) found that the valuation of reduced risks of asthma was highest for children.

Estreen and Friberg (2004) report a transnational joint project on 'transport-related health effects with a particular focus on children' in 2003, involving six countries (Austria, Switzerland, France, Sweden, The Netherlands and Malta). A series of workshops concluded that there was no specific VOSL for children, but no society would prefer a smaller VOSL for children than for adults, so the project recommended using the same VOSL for children as for adults, until a separate VOSL is established for children.

There are some studies that attempt to do this, although not apparently adopted officially for policy appraisals. Dickie and Messman (2004) describe SP estimates that find parents place value on alleviating children's illness attributes at about twice the level of their own. Dickie (2005) examined data on individual children and sibling pairs to examine family health choices, finding WTP to be higher among single parents and those without insurance, but also that income elasticity appeared to be low. Gerking and Dickie (2013) reviewed literature on valuation of environmental risks to children's health, finding parents willing to pay more for reductions in absolute risk for their children than for corresponding risk reductions for themselves, partly reflecting their perceptions of risk, and partly to signal behaviour for positive approval of others.

Alberini and Ščasný (2011) report a conjoint choice experiment in Italy and the Czech Republic that investigates the effect on the estimated VOSL of varying contexts such as cause of death (respiratory, cancer, road crash) and mode of achieving risk reduction (public program or private provision). They found child and adult VOSLs differed and concluded heterogeneity in VOSL is driven mainly by characteristics of risks, mode of delivery and income, while other characteristics are less important. In a later study Alberini and Ščasný (2013) found the VOSL increased with 'dread', risk exposure and respondents' assessment of baseline risks.

Chilton et al (2006) also report the development and application of a novel approach to estimate the value of changes in both baseline risk and the variation in 'dread' of premature death by different causes. They found that although aversion to dread does exist, in many cases it applies to low baseline risks and rarely materially affects the value of reducing risks of specific causes.

Johansson-Stenman and Martinson (2008) tested ethical preferences for safety enhancing road investments in Sweden using a choice modelling approach that obtained 1,382 responses. They found the relative value of a saved life decreased with age, but also that older respondents were willing to pay more to save older lives than younger respondents. Respondents of all ages were agreed that the value of saving a pedestrian's life is worth up to almost a third more than that of a car driver of the same age.

Baker et al (2008) discuss the ethical implications of using a standard VOSL that does not differentiate by income, age or other factors that might be expected to cause heterogeneity in WTP for risk reduction, arguing that it might be justified by the objective of seeking a common survival probability, but this would be a departure of the standard assumptions of CBA. Arguing against this however inevitably implies redistribution of safety investment and resources towards some (eg the young) and away from other social groups.

Because elderly people have relatively low remaining life expectancy, many consider the VOSL for them should be lower than the average. Some recent study results challenge this view. Given increase in life expectancy and people's ability to be productively active for a longer period, combined with the level of endowments people of an advanced age acquire over time, mean the amount of money they would be willing to pay to reduce their risk of death is not necessarily lower than that of the younger population, as discussed in OECD (2010). That review finds no strong evidence that VOSL varies consistently with age, although it does report that a study found those older than 60 years were willing to pay more for risk reduction than those in younger groups.

Despite many papers presuming that the value of avoiding a fatality follows an inverse U pattern, increasing to a high point in mid-life then declining with age, the empirical literature presents a more complex picture, with studies showing WTP increasing in later life reflecting higher disposable incomes and a higher marginal utility in the diminishing stock of years of remaining life expectancy (OECD 2006). Ascribing value to the lives of children who have limited ability to pay and little influence over many decisions affecting the risks they face is addressed by some papers but to date there appears no compelling alternative to the practice of treating all lives protected with the same VOSL, irrespective of age.

The relevance of differentiating VOSL by age depends on there being policy choices that can act on such differentiation. In health intervention contexts there are many choices that can take age into account, because interventions are generally determined with respect to identified individuals or specific age groups (eg vaccination programmes). In transport policy this sometimes occurs (eg child safety restraints in vehicles) but many transport safety improvements across the network affect risks of unknown individuals and save anonymous lives, differentiating by age serves less useful purpose.

Appendix B: Other matters

B1 Willingness to pay (WTP) and willingness to accept (WTA)

To evaluate a project improving safety (and/or health conditions), a value for safety is required to enable comparison of benefits to society of this improvement and the cost of implementing the project. The VOSL is the value used in current transport appraisals in New Zealand. The VOSL is the amount of money (wealth) society is willing to pay (WTP) for the improvement which is expected to save one statistical life.

Policies or projects can achieve some social objectives but at the same time increase the risk of death and injury, or worsen health conditions. This risk increase reduces welfare of those affected. To be equally well off as before the change in risk, the individuals would require a compensation that would give them the same level of utility as before. This is the willingness to accept (WTA) amount. The WTA-based VOSL is the amount of compensation a society needs to accept the risk increase resulting in one more premature statistical death.

Should the WTP- and WTA-based VOSLs be the same or should they differ?

The expectation of WTP and WTA to be equivalent or very close appears to have arisen from Willig (1976) and Randall and Stoll (1980), which show that alternative measures of consumer surplus, the compensating (C) and equivalent (E) variations, should be fairly close. Hanemann (1991) relates these to WTP and WTA stating 'The conventional welfare measures for price changes are the compensating (C) and equivalent (E) variations, which correspond to the maximum amount an individual would be willing to pay (WTP) to secure the change or the minimum amount she would be willing to accept (WTA) to forgo it' (p635).

However, many empirical studies show that WTA responses are substantially higher than WTP responses not only for safety but also for familiar everyday goods (Kahneman et al 1990; Hanemann 1991; Bateman et al 1997; Guria et al 2005). As explained by Isoni et al (2011, p991) 'These findings have received sustained attention because they seem to conflict with one of the most elementary propositions of consumer theory – that an individual's indifference curves can be specified independently of her endowment and budget constraint'.

Some studies show 'if individuals are given sufficient time to reflect carefully on the issue, or by using an "incentive-compatible" elicitation device then WTP and WTA responses will tend to converge, at least in the case of "everyday goods" such as chocolates, ball-point pens or coffee mugs' (Chilton et al 2010, p3). However, they note that for complex goods, eg health and safety, the WTA value is substantially higher than the WTP value 'even when individuals are given the time and opportunity to consider their responses in a careful and well-informed manner' (p3).

There have been several explanations of this disparity between WTP and WTA estimates. One explanation is that WTP is limited by a consumption budget constraint (of either the individual or others) – an income effect – whereas WTA is limitless (Hanemann 1991). It is argued by Hanemann that the divergence between WTP and WTA is largely due to substitutability of the good. If it is easily substitutable then the two values converge but the gap can be infinite if no substitution is possible.

Asymmetric preferences are predicted by prospect theory, in which uncertainty over the likelihood of different outcomes can skew preferences away from symmetry for opposite results (Tversky and Kahneman 1992). They argue that the value functions for gains and losses are different. Whereas it is normally concave for gains, it is convex for losses and the function is steeper.

Another explanation related to the prospect theory is that there is a commonly observed 'endowment effect' whereby people seem more reluctant to give up something they have than they are willing to pay for an equivalent gain (Kahneman et al 1990). This means 'underlying preferences may not conform to the standard neoclassical assumption of smooth and continuous substitutability between goods and may instead display "kinks" reflecting the fact that gains from a "status quo" are treated in a fundamentally different way from losses' (Chilton et al 2010). While such a possibility is not ruled out by Chilton et al, they argue that the observed disparity is due to diminishing marginal utility and budget constraints and hence consistent with neoclassical theory.

Some recent and widely cited empirical work by Plott and Zeiler (2005) used a new procedure for elicitation which showed no significant gap in WTP and WTA results for the same object. They concluded that observed WTA–WTP gaps are caused by subject misconceptions arising from the specific elicitation procedures used in previous studies, and that variation in procedures between these earlier studies may also exacerbate variation in results. However, Isoni et al (2011) found that Plott and Zeiler omitted a result on lotteries contradicting that conclusion on grounds there may have been data contamination. When Isoni et al (2011) replicated Plott and Zeiler's procedure they found a WTA–WTP gap was still present for the result on lotteries, even after ensuring no data contamination. So the widely reported empirically observed difference in WTA and WTP cannot be entirely explained by elicitation procedures that fail to correct respondents' misconceptions.

There is evidence that WTA–WTP disparities tend to decline as survey respondents gain experience of buying and selling (Shogren et al 1994). Isoni et al (2011) also postulate that the nature of the object being valued may create systematic differences in results, eg between valuations for a consumption good that can be obtained with certainty, and valuations of sums of money received with some uncertainty (as in a lottery). Thus the nature of the thing being valued and familiarity with the trade-offs required to obtain it may all affect the results obtained from SP valuation surveys used to elicit WTA and WTP.

Thus while theoretically WTP and WTA values for small changes in risk are expected to be close, the disparity observed in empirical studies, including one in New Zealand (Guria et al 2005) is much larger and can be due to one or more factors as discussed above. In some situations, risk is reduced in one area but it is increased in another area as a consequence (projects diverting traffic, for example). Use of two different values, ie WTP and WTA may be confusing and add complexity in CBA. Since projects and policies aim to reduce risks in most cases, it is appropriate to use WTP in all cases. If projects or policies to achieve non-safety objectives increase risks, it may be worthwhile to use WTA values.