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Willingness-to-pay by car occupants for improvements in travel times, reliability and safety: Research report

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List of abbreviations

Abbreviation	Definition
AADT	Average annual daily traffic
ABS	Australian Bureau of Statistics
ANU	Australian National University
ARSD	Approximated route standard deviation
ATAP	Australian Transport Assessment and Planning
BITRE	Bureau of Infrastructure and Transport Research Economics
CBA	Cost–benefit analysis
CSA	Cost saving approach
DAE	Deloitte Access Economics
FSC	Full social cost
HC	Human capital
HHC	Hybrid human capital
ICISS	International classification of diseases injury severity scale
ISS	Injury severity score
KPI	Key performance indicator
LCV	Light commercial vehicle
MPL	Marginal product of labour
MRPL	Marginal revenue project of labour
MRS	Marginal rate of substitution
MU	Marginal utility
NISS	New injury severity score
OIA	Office of Impact Assessment
PDO	Property damage only
PGS	Pain, grief and suffering
PMC	Private material cost
RR	Reliability ratio
SC	Stated choice
SD	Standard deviation
SVCR	Subjective value of crash reductions
TMC	Third-party material cost
VBTTS	Value of business travel time savings
VMPL	Value of marginal product of labour

Abbreviation	Definition
VOR	Value of travel time reliability
VRR	Value of risk reduction
VSL / VOSL	Value of statistical life
VTTS	Value of travel time savings
WFH	Work from home
WTP	Willingness to pay

Note: Table excludes most abbreviations for sources listed in references.

Willingness-to-pay by car occupants for improvements in travel times, reliability and safety: Research report

At a glance

Purpose of the Report

- This report considers the findings of ATAP (2024a), the consultants' report by Deloitte Access Economics (DAE) on the national willingness-to-pay (WTP) survey for car occupants' values of time, reliability and safety (the national survey). Its purpose is to assist the ATAP Steering Committee to make decisions about the values to recommend for cost–benefit analysis (CBA) of road transport and infrastructure initiatives in ATAP Part PV2 *Road parameter values*.

About the national willingness-to-pay (WTP) survey

- The national survey was the first stated choice survey to cover simultaneously all three of WTP for time, reliability and safety. The survey was undertaken in two waves throughout 2021 and 2022. The survey was administered online guided by an interviewer. It generated 3844 useable responses.
- All the WTP values estimated from modelling the data were significant at the 1% level. The values are in December 2021 prices and have been indexed in this report to June 2024 prices.

Values of travel time savings (VTTS) and reliability (VOR) — chapter 3

- The estimated VTTSs per hour in June 2024 prices are: $35.59 for commuter travel, $38.37 for business travel and $21.52 for non-work travel. The values are within the bounds of other studies. The business VTTS is much lower than that in the current guidelines. Private travel time savings in the current guidelines are separated into commuter and non-work trip purposes. The commuter VTTS is quite close to the business VTTS.
- The estimated reliability ratios (VOR divided by VTTS) for the three trip purposes are: commuter 1.14, business 1.10 and non-work 1.67. These are within the bounds of values found in other WTP studies.
- *It is recommended that ATAP adopts these VTTS estimates and reliability ratios in its CBA guidance, but that reliability benefits be treated as a non-core benefit or sensitivity test as a temporary measure until such time as more experience has been gained in implementing the reliability measurement approach in ATAP (2024b).*

Value of risk reduction (VRR) (safety) — chapters 4 to 6

- The estimated WTP values to reduce crash risk for the four severity categories used the in databases of Australian jurisdictions, expressed in units of a single crash in June 2024 prices, are: fatal $4,192,504, hospitalised injury $457,717, non-hospitalised injury $28,218 and property damage only $18,308.
- These do not represent the full social cost of a crash. Impacts on third parties (mostly governments) such as forgone tax receipts, medical costs paid by governments, police, correctional services, coroners and traffic delays, need to be added on.
- It is possible that survey respondents have under-estimated, or not considered at all, the material costs they would incur in the event of a crash (forgone consumption, out-of-pocket costs of medical and long-term care, ambulance and vehicle-related costs). In other words, the WTP values from the survey may only represent the subjective cost of pain, grief and suffering from a crash.
- This report presents two options for the full social cost of a crash.

- Option 1: WTP costs are assumed to comprise costs of pain, grief and suffering and all private material costs of crashes. Third-party costs need to be added. The full social cost per crash in June 2024 prices would then be: fatal crash $4,812,396, major injury crash $611,847, minor injury crash $59,241 and property damage only crash $33,049.
- Option 2: WTP costs are assumed to comprise only the costs of pain, grief and suffering. Private material private and third-party costs need to be added. The full social cost per crash in June 2024 prices would then be: fatal crash $7,321,113, major injury crash $765,091, minor injury crash $64,119 and property damage only crash $34,654.
- There are arguments for and against both options. This report favours option 2.

Potential impacts on cost–benefit analyses

- Back-of-the-envelope calculations suggest that if the recommended values are adopted, travel time saving benefits will be some 3% higher, reliability benefits will be in the range 25% to 100% of time savings benefits, and, depending on the option adopted, safety benefits will change by some –16% or +7% if only casualty crashes are considered, and +25% or +46% if property damage only crashes are included.

Transferability to other modes — chapter 7

- The VTTS and VRR (safety) values can be transferred to other modes — the VTTSs to public transport and active travel, and the VRRs to road crashes involving motorcycles, light commercial vehicles, buses, trucks, pedestrians and pedal cyclists.

Executive summary

This report is a supplement to ATAP (2024a), the consultants' report by Deloitte Access Economics (DAE) on the national willingness-to-pay survey (WTP) for car occupants' values of time, reliability and safety (the national survey). This 'Research report' puts the values into context and makes necessary additions and adjustments. Its purpose is to assist the ATAP Steering Committee to make decisions about the values to recommend for cost–benefit analysis (CBA) of road transport and infrastructure initiatives in ATAP Part PV2 *Road parameter values*.

Chapter 2: Project context and history

The values of travel time savings (VTTS) currently recommended by ATAP are derived from an Austroads 1997 report. The report recommended a business VTTS derived using the 'cost saving approach', equal to the level of average hourly earnings plus an allowance for overhead costs, less payroll taxes. The 1997 report recommended a private VTTS valued at 40% of average earnings. The parameters in the formula for the percentage of overheads and hours worked per week have not been updated and the subtraction of payroll tax was economically incorrect. The cost saving approach itself is open to challenge because a significant proportion of business travel occurs outside of paid work hours, and mobile communications and the changed nature of work have led to increased amounts of work being done while travelling, even in cars. Reliability benefits, that is, reductions in the variability of trip times, are not currently estimated and included in CBAs of road initiatives.

The current WTP values for safety are based on a 2008 survey. The survey had a relatively small sample size and methodological issues have been identified that invalidate the values. These issues relate to conversion of the WTP values estimated from stated choice data into costs per crash, and omitting costs not included in personal WTP to obtain the full social cost of a crash.

The ATAP WTP national survey, in part, also arose from a desire to develop behavioural values for travel time savings and improvements in reliability of trip times to improve toll road patronage forecasting.

In 2014, the ATAP Steering Committee commissioned a consortium of consultants lead by Deloitte Access Economics (DAE) to undertake a scoping study. At the time, Austroads was also interested in obtaining national WTP values for safety. As a result, combining time, reliability and safety into a single stated choice survey was investigated. DAE found that it should be feasible with careful design and a significant pilot survey.

In view of the large number of variables survey respondents had to consider when making their hypothetical route choices in the national survey, the project team and consultants were acutely aware of the risks that survey responses would not represent peoples' genuine preferences. A great deal of effort and resources was invested in the lead-up to the national survey to ensure it would produce valid results.

The project proceeded in three stages:

1. survey design with initial testing
2. three pilot surveys
3. a fourth pilot survey referred to as 'the national pilot' survey, independent peer review, cognitive interviews followed by the final national survey with 3844 useable responses.

The national survey was undertaken in two waves throughout 2021 and 2022 with modelling at the end of the first wave to check that the survey was working. Delays were experienced during Covid lockdowns. Covid ruled out face-to-face administration of the survey and it was subsequently found that online administration of the survey without guidance from an interviewer did not produce satisfactory responses. The survey therefore was administered online guided by an interviewer. ‘Quota sampling’ ensured a spread across states and territories, urban/rural, driver/passenger and trip purposes in line with population proportions.

The form of model used to estimate the WTP values was a ‘mixed logit model’, which allows for variations in WTP values within the population assumed to follow a probability distribution. A large number of model specifications was tested before arriving at the final model. In the final model chosen, all the required WTP estimates were significant at the 1% level. Model results have been taken to be in December 2021 prices and are indexed in this report to June 2024 prices.

Survey respondents were asked their income band group. The income variable was found not to have a statistically significant effect on the WTP estimates.

Chapter 3: Values of travel time savings (VTTS) and reliability (VOR)

The survey distinguished between three trip purposes: commuter, business, and non-work, and between travel time in free-flow and congested conditions. Table 0.1 shows sets out the WTP estimates from the survey results in ATAP (2024a), indexing them to June 2024 prices and the reliability ratios which are the ratio of VOR to VTTS. The table also shows the ratio of commuter and non-work VTTS and VOR to their respective business values.

Table 0.1 Values of time and reliability from the survey: weighted averages of congested and free-flow traffic conditions: original and indexed

	Original: Dec 2021 $	Indexed to June 2024 $	Ratio to business	Reliability ratios
VTTS commuter	31.10	35.59	0.93	
VTTS business	33.53	38.37	1.00	
VTTS non-work	18.81	21.52	0.56	
VOR commuter	35.50	40.63	0.96	1.14
VOR business	36.87	42.19	1.00	1.10
VOR non-work	31.35	35.88	0.85	1.67

Note: VTTS = value of travel time savings, VOR = value of reliability, Reliability ratio = VOT / VTTS.

Congested versus free-flow VTTS

For business and commuter travel, the congested VTTSs were four times the free-flow VTTSs, reflecting higher levels of stress and discomfort when driving in congested conditions, and reduced ability to perform other activities. The relativity may seem high, but is consistent with other stated choice surveys. For non-work travel, the congested VTTS was below the free-flow VTTS. A possible explanation is that many non-work travellers have the ability to avoid traffic congestion by selecting off-peak hours to travel and/or locations that are not very congested.

Weighted VTTS estimates were provided as well, and it is these weighted values that are shown in Table 0.1. The weighting between the congested and free-flow VTTS values is the proportion of travel time in each traffic condition state in the survey questions. Since the attributes of the trips in the survey were developed from each participant’s response to initial questions about a recent trip undertaken, the weighting reflects the real-world experience of car occupants and is not a computer-generated artefact.

It is recommended that only the weighted VTTS values be used in practice and the not the free-flow and congested conditions VTTS values. The reason is the difficulty in fitting a functional relationship for use in practice to the two VTTS values, particularly when it is unsure how survey respondents interpreted congested traffic conditions.

VTTS by trip purpose

The ordering of the weighted VTTSs across trip purposes is consistent with expectations — the business value is greater than the commuter value, which is greater than the non-work value. The ratio of the non-work VTTS to the business VTTS of 0.56 is broadly consistent with other surveys. The large difference between the commuter VTTS and the non-work VTTS was not expected. However, there are many published WTP survey results with commuter time valued well above non-work time (see ATAP 2024a, pp. 45-46). Two explanations are offered. One is the effect of increased working from home, which a stated choice survey by Hensher et al. (2021) found effect increases commuter VTTS. Another explanation is that high housing prices are making shorter commuter travel times more valuable because they broaden the choice of house location options.

It is recommended that ATAP adopts the weighted commuter and non-work VTTS values from the ATAP WTP study because they are well within the expected range of values from Australian and overseas WTP studies.

Assuming total weekday trips by car comprise the proportions, business 10%, commuter 17% and non-work 73%, then use of the ATAP WTP VTTS values instead of the current ATAP values will increase travel time savings benefits by about 3%. The effect of the lower VTTS for business is more than offset by the much higher commuter VTTS and slightly higher non-work VTTS.

Value of business travel time (VBTTS)

The weighted VBTTS from the survey of $38.37 is 42% below the current ATAP value of $65.83 (both indexed to June 2024) derived using the cost saving approach (CSA). However, the CSA estimate is likely to be much too high. A better estimate of the VBTTS is obtainable from the ‘Hensher equation’, which adjusts the CSA VBTTS downward to allow for savings in business travel time redirected to leisure for employees undertaking business travel outside of paid working hours, and for the value of work done while travelling that does not occur due to a time saving. Substituting plausible mid-range parameter values into a simplified version of Hensher equation, a VBTTS of $45 was obtained, which is not far above the VBTTS from the survey. Substitution of low-range parameter values into the Hensher equation produces VBTTSs below the $38.37 from the national survey.

The VBTTS from the national survey is a WTP by employees. It is uncertain to what extent employee WTP reflects employer WTP, or the value to society, which includes both impacts on employers and employees as indicated by the Hensher equation. Some business trip survey respondents may fully mirror their employer’s point of view. Some may respond genuinely seeking to represent the best interests of their employer but may be misguided as to what those interests entail. Knowing their employer will pay any additional costs they incur to save time, some employees will respond on the basis of their own self-interested preferences leading to an inflated WTP estimate. Some may respond as if they themselves were paying the costs resulting in deflated values. A UK survey of employer WTP, however, provided some assurance that employee WTP values are reliable.

This report recommends that ATAP adopts the VBTTS from the national survey, because it is well within the plausibility range suggested by the Hensher equation. If the Hensher equation approach were to be adopted instead, it comes with a warning that up-to-date, accurate information about the proportion of on-costs relative to earnings, the proportion of business travel time savings likely to accrue to leisure, and the value of work done while travelling is not available.

VTTS and trip distance

Weighted VTTS values were only 6% greater for trips over 30 minutes in duration for commuter travel and 3% for business travel compared with trips for up to 30 minutes. For non-work travel, the longer trip VTTS was fractionally below that for the shorter trip. Given the strongly overlapping the confidence intervals for the VTTSs for short and long-distance trips estimated from the survey, it can be concluded that the effect of distance on VTTS was not found to be statistically significant.

Value of reliability (VOR)

The VOR values from the survey are in the expected relativities across trip purposes —the business VOR is greater than the commuter VOR, which is greater than the non-work VOR. However, from a statistical point of view, the commuter and business VOR values are close enough to be considered identical. The non-work VOR value is not much lower than the business and commuter values and the confidence intervals overlap.

The VOR for non-work travel of $35.88 per hour is only 11% below the VOR for commuters of $40.63 and 15% below the VOR for business travel at $42.19 (all indexed to June 2024 prices). Part of the explanation for the relatively small difference could be that many non-work trips are for purposes with inflexible required arrival times such as appointments with health and other professionals, pick-up times for children from daycare, and commencement times for school classes, university lectures and events.

When divided by VTTS, the reliability ratios are similar for commuter and business, at 1.14 and 1.10 respectively, but considerably higher for non-work, at 1.67, due to the much lower VTTS in the denominator of the reliability ratio for non-work travel. Similar results have been observed in the other studies.

While the reliability ratios from national survey are on the high side, they are within the bounds of values found in other WTP studies. An Australian study from 2010 estimated even higher reliability ratios.

Back-of-the-envelope calculations suggest that reliability benefits using the estimated reliability ratios could be in range of 25% to 100% of travel time savings benefits. An earlier estimate, using the ATAP reliability measurement methodology and a reliability ratio of one found that reliability benefits could be 50% to 150% of time savings benefits.

It is recommended that

- **the guidelines specify the circumstances under which reliability benefits may apply and do not apply**
- **ATAP adopts the reliability ratios from the national survey for all three trip purposes**
- **reliability benefits be treated as a sensitivity test or a non-core benefit (as with wider economic benefits) as a temporary measure until such time as more experience has been gained in implementing the reliability measurement approach in ATAP (2024b).**

Chapter 4: Allowing for crash exposure

The safety information presented to survey respondents in the national survey was expressed as numbers of crashes per year along the route of the trip for each of five crash severity levels. If modelling is undertaken with numbers of crashes as the independent variable for safety, the resulting WTP value represents the WTP per trip to reduce the number of crashes for the particular severity level by one per year, called the 'subjective value of crash reductions' (SVCR). The SVCR needs to be converted to a WTP value for a single crash (called the 'value of risk reduction' VRR), which can be used in CBAs of road transport initiatives to value changes in numbers of crashes. The conversion requires data on the annual level of crash exposure defined as the number of opportunities for a crash, given by the annual number of vehicles making the trip.

To estimate crash exposure for the particular trip in each survey response, average annual daily traffic (AADT) data was obtained from state and territory transport agencies for traffic counter locations and used to estimate the distance-weighted AADT level along the most likely route between the origin and destination suburb of the trip in each survey response. The distance-weighted AADT multiplied by 365 days in a year results in the annual crash exposure for the trip.

Dividing the number of crashes per annum along the route of a trip in each survey choice question by the annual exposure gives the probability of a crash. If this is used in the utility function in the model fitted to the data, instead of numbers of crashes, the WTP estimates will be VRRs. However, it assumes that survey respondents understand differences in crash exposures between different trips. For example, a reduction of one crash per annum on a highly trafficked route is a smaller reduction in crash probability than a reduction of one crash annum on a route with low traffic. The size of the crash probability reduction is proportionate to the traffic level.

An alternative assumption is that survey respondents focused solely on numbers of crashes in the survey questions. They would be expected to have a vague understanding of crash exposure, considering it to be around the average level for all survey responses, but have no perception of how the level of crash exposure for the particular trip in their questionnaire differs from the average. The SVCR from the model can be converted to a VRR by multiplying by the simple average crash exposures for all survey responses.

Model runs were undertaken with both the number of crashes and the probability of a crash as variables to test whether one or both was affecting WTP. Inclusion of number of crashes as a variable explained so much of respondents' choices that the crash probability variable ceased to be statistically significant for all but fatal crashes. For fatal crashes, both variables were significant. The non-significant crash probability variable was therefore excluded from the model for the four non-fatal crash severity categories.

Chapter 5: Injury cost rescaling

The survey questionnaire defined five crash severity categories termed throughout the present report as fatal, incapacitating injury, major injury, minor injury and property damage only (PDO). The WTP values from modelling of survey data are shown in Table 0.2.

Table 0.2 WTP safety values from survey ($/crash)

	Dec 2021 prices	June 2024 prices
Fatal	3,663,910	4,192,504
Incapacitating injury	1,454,850	1,664,742
Major injury	500,010	572,147
Minor injury	24,660	28,218
Property damage only	16,000	18,308

Each crash severity category was described to survey respondents prior to answering the choice questions in the national survey. For the three injury severities, a detailed example was given. The survey, therefore provides WTP values to avoid an injury crash for three points along a detailed scale of injury severity levels ranging from minor cuts to life-long quadriplegia, as well for fatal and property damage only crashes, at either end of the scale of injury severity scale.

Crash data from jurisdictions has only two injury classifications: major/serious/hospitalised injury and minor/non-hospitalised injury, dividing the scale of injury severity levels into two parts depending on whether the injury results in a hospital stay. The minor injury WTP value from the survey is for a severity point somewhere within the minor injury range of severities in crash databases. The major and incapacitating injury WTPs values from the survey are for two severity points somewhere in the major injury range of severities in crash databases.

For CBA purposes, single WTP values are required for the minor injury and major injury classifications for a severity point at the weighted average level for each classification.

Three jurisdictions, NSW, Victoria and WA, were able to provide numbers of injuries per annum for each point on the Injury Severity Score (ISS) and New Injury Severity Score (NISS) scales for hospitalised injuries. The annual average number of injuries for each point on each scale was taken over the five-year period 2016 to 2020 to smooth out year-to-year fluctuations. The WA data could not be used because it included fatalities.

No data was available for detailed severity levels for minor injury crashes so there was no choice but to accept the national survey estimate as being a satisfactory approximation for the weighted average severity for the minor injury category.

DAE provided ISS and NISS levels for the five severities in the survey (PDO: 0, minor injury: 1, major injury: 5 for ISS and 9 for NISS, incapacitating injury: 25, fatal: 75). Given the WTP values for each of the five severity categories, straight-line interpolation between points was used to obtain a WTP value for each individual level of ISS and NISS. The weighted average WTP for all injuries was taken using the numbers of injuries for each point on the scale as the weights.

For NSW and Victoria combined, the weighted average WTP using the ISS was 84% of the WTP for the major injury category from the survey and for the NISS, 79% below. The NISS is the superior of the two measures.

It is recommended that the WTP estimate for the major injury category adjusted by a scaling factor of 0.8 be taken as representative of the major/hospitalised/serious injury category used by Australian jurisdictions.

Chapter 6: Full social cost of crashes

Although the human capital and WTP approaches are sometimes considered as alternative ways to estimate the social cost of crashes, the literature unambiguously states that they estimate different components of the full social cost and that the two approaches are complementary. Estimation of the full social cost of crashes involves integration of the two methods. A recent comprehensive estimate of the human capital costs of crashes for Australia in 2020 prices is available from a report by the Australian National University commissioned by BITRE.

Although the great majority of costs from a person's death or injury in a road crash falls on the victims themselves and their relatives, a proportion falls on the rest of society. Since losses to the rest of society are not borne by the victims, people could not be expected include them in their WTP to reduce crash risk. If survey respondents were self-interested rational utility maximisers and had perfect information, the common assumption in economic models, then WTP would cover of all the private costs. These private costs are

- a material part (private material cost, PMC) including forgone consumption, medical and long-term care costs paid by individuals, cost of insurance excess paid by motorists for vehicle repairs, cost of car-hire due to vehicle unavailability, ambulance costs paid by users, and costs of premature funerals, and
- a non-material part, which is the WTP to avoid the pain, grief and suffering (PGS) from a crash.

Costs to third-parties that individuals could not be expected to include in WTP (third-party material cost, TMC) include taxes forgone by governments, medical and long-term care costs paid by governments, emergency services costs paid by governments, and costs of correctional services, coronial inquests, damage to street furniture and traffic delays. Costs of vehicle repairs paid by insurers are effectively paid by other motorists, and so are third-party costs.

The full social cost of crashes, which is required for use in CBAs, is the sum of all these components. The private material part of WTP is also part of human capital costs. Human capital costs therefore comprise the material components of WTP and third-party costs.

The largest component of human capital costs is the value of lost output from crash victims being unable to work, earn income and participate in household economic activities. It is calculated using average weekly earnings and life expectancy, discounted to the present. The portion of this that accrues to governments in income and payroll taxes is a third-party cost from the point of the view of the individual.

Since *WTP = PGS + PMC*, the full social cost of a crash (FSC) is obtained by adding the third-party costs (TMC) to WTP. Hence *FSC = PGS + PMC + TMC= WTP + TMC.* The implied cost of pain, grief and suffering is: *Implied PGS = WTP – PMC*

A view put by independent technical advisors to the project, the University of Leeds, Institute for Transport Studies, is that WTP only accounts for the pain, grief and suffering component of the cost of crashes. Survey respondents cannot reasonably be expected to estimate the expected value of the discounted present value of their future after tax earnings and the medical and long-term care costs they will incur in the event of a crash minus their value in the absence of a crash. Survey respondents will base their choices on their perceptions of the pain, grief and suffering that they and those close to them would experience from a crash. If this view is correct, then *Implied PGS = WTP* and the full social cost of a crash is *WTP + PMC + TMC*.

To assess which view is likely to be closer to the truth, implied costs of pain, grief and suffering were estimated from the WTP values and ANU human capital costs under both options.

- Option 1: WTP comprises all private costs (*WTP = PGS + PMC*), and
- Option 2: WTP comprises only costs of pain, grief and suffering (*WTP = PGS*).

The calculations are shown in Table 0.3. Option 1 is consistent with the approach in the literature but the implied PGS estimate for fatal crashes of $1.7 million might be considered on the low side. This suggests that survey respondents may not have adequately taken into account the private material costs of a crash when making choices in the survey questionnaire. The implied PGS costs for minor injury and PDO crashes, representing WTP to avoid the stress and inconvenience caused by a minor injury or PDO crash, seem high under option 2. However, they are not much lower under option 1.

The full social cost of fatal crash value under option 2 of $7.3 million implies a VSL not far above the VSL used in other sectors. The Australian Government’s Office of Impact Assessment (OIA) recommends a VSL in 2023 dollars of $5.4 million. There are on average 1.085 deaths per fatal crash. The cost of a fatal crash using the OIA VSL and adding the $619,892 in third-party material costs for a fatal crash is then $5.4 million × 1.085 + $0.6 million = $6.5 million. The option 2 cost of a fatal crash is $0.8 million above this, and the option 1 cost is $1.7 million below. It is desirable to have a degree of consistency in the VSL across sectors, however, there are valid reasons why WTP to reduce risk should differ between sectors and the OIA VSL is not the result of a survey of Australians, but merely a mid-range value taken from a literature survey of international studies.

This report favours option 2 because of the advice from the University of Leeds experts and because the implied cost of pain, grief and suffering for a fatal crash of $1.7 million under option 1, appears too low. However, ATAP could justify accepting either option.

Table 0.3 Comparisons of full social cost and implied PGS under alterative options for what WTP comprises (June 2024 $ per crash)

	Cost component	Fatal	Hospitalised injury	Non-hospitalised injury	Property damage only
Option		**Full social cost**			
1	**WTP = PGS + PMC** FSC = WTP + TMC	4,812,396	611,847	59,241	33,049
2	**WTP = PGS** FSC = WTP + PMC + TMC	7,321,113	765,091	64,119	34,654
Option		**Implied cost of pain, grief and suffering**			
1	**WTP = PGS + PMC** Implied PGS = WTP – PMC	1,683,787	304,473	23,340	16,703
2	**WTP = PGS** Implied PGS = WTP	4,192,504	457,717	28,218	18,308

Note: PGS = cost of pain, grief and suffering; FSC = full social cost of crashes; PMC = private material costs of crashes: TMC = third-party costs incurred by governments, other road users, employers and general society.

If the option 1 values were adopted, the annual total cost of crashes for Australia would be $58 billion and under option 2, $68 billion compared with $31 billion estimated by the ANU study and including an amount for pain, grief and suffering estimated from compensation payouts to crash victims.

Compared with the WTP crash costs currently in use, the national survey–ANU hybrid values represent a reduction in the total annual cost of fatal crashes of about 50% for option 1 and 30% for option 2, but the costs for minor injury crashes are higher. Based on proportions of crashes for the whole country, switching to the national survey–ANU hybrid values is estimated to change safety benefits by –16% under option 1 and +7% under option 2 for casualty crashes, and +25% under option 1 and +46% under option 2 for all crashes including property damage only.

Crash costs per person killed or injured, and per crash inside and outside major cities have been estimated.

Chapter 7: Transferability to other modes

It is recommended that ATAP adopts the VTTSs from the national survey for use in public transport as equity values. ATAP could consider whether behavioural values of the order of 25% lower should be adopted for public transport and active travel.

It is recommended that the social costs of crashes estimated in Chapter 6, be used for all types of road crashes including crashes motorcycles, light commercial vehicles, buses, trucks (rigid and articulated), pedestrians and pedal cyclists.

1. Introduction

This report is a supplement to ATAP (2024a), the consultants' report by Deloitte Access Economics (DAE) on the national willingness-to-pay (WTP) survey for car occupants' values of time, reliability and safety (the national survey). The 'Research report' puts the values into context and makes necessary additions and adjustments. Its purpose is to assist the ATAP Steering Committee to make decisions about the values to recommend for use in cost–benefit analysis (CBA) and policy analysis of road transport and infrastructure initiatives in ATAP Part PV2 *Road parameter values*. The Research report covers a number of issues that arise between receiving the results from the modelling survey of data and publishing values to use in CBAs.

ATAP (2024a) describes in detail the development and results of the nationwide survey, which obtained 3,844 useable responses. If the survey's results are accepted for use in CBAs, there will be some significant changes to important parameter values. There is a new category of vehicle user for the purpose of estimating travel time savings benefits, namely commuters. To date, commuters have been grouped with non-work travellers in the private vehicle use category, which undervalues the time sensitivity of those regularly travelling from home for work activities. Furthermore, there is a new type of benefit not normally considered in the CBAs of urban road initiatives — improvements in trip time reliability.

There are questions about the interpretation of the WTP values from the survey. The social value of business travel time is the WTP by employers plus the impacts of a saving in business travel time on employee utility. The survey has provided an estimate of WTP by employees. It is uncertain whether this represents the right balance between employer and employee interests. For WTP to reduce crash risk, it is uncertain whether survey respondents were conscious of crash exposure at the level of individual trips, and whether they understood the financial impacts on themselves in the event of becoming a crash victim.

The WTP estimates from the survey for injury crashes apply to the particular injuries described in the questionnaire. These might not be representative of the weighted average severity of an injury crash in practice.

To assist with gauging the reasonableness of the WTP values from the national survey, the report includes comparisons with estimates other WTP surveys, in particular the major WTP surveys carried out by the UK Department for Transport about 10 years ago and the recent New Zealand survey.

It should be borne in mind that WTP values from stated preference surveys are influenced by a host of factors in addition to the preferences of the average person, in particular, survey questionnaire design and administration, sample size and selection, and the modelling approach. At best, surveys can only provide indicative estimates of average WTP for the population. This is demonstrated by the wide range of values reported in the literature (Hauer 2011, p. 154).

The costs in ATAP (2024a) are in December 2020 prices. This Research report indexes them to June 2024 prices.

1.1 Chapter outline

Chapter 2 discusses the existing values used for time and safety in CBAs, including why the existing values need to be replaced, as well as providing a better understanding of the history and context of the ATAP WTP project showing the care taken to manage the risks and ensure the study was successful. The final numbers from the national survey are presented as set out in ATAP (2024a) (before indexation).

Chapter 3 discusses the values for travel time savings and reliability from the national survey, comparing them with values from other sources. It contains an extended discussion of the issues surrounding employee WTP values for business travel time and presents estimates of the likely effect of switching to the national survey values on the size of project benefit estimates.

The survey questions allowed respondents to choose between routes with different numbers of crashes per annum along the way. Chapter 4 details the method used to convert these to costs per crash for use in CBAs using information on crash exposure rates.

Chapter 5 recognises that the three injury crash specifications in the survey questionnaire apply at points along a scale of injury severity levels, and WTP values are required for the weighted average severity levels for the two injury crash categories used by Australian jurisdictions. Data was obtained from three jurisdictions for numbers of injuries by detailed severity level and weighted average WTP values calculated by interpolating between values from the survey.

Chapter 6 addresses the question of which components of the full social cost of crashes can be expected to be part of survey respondents' WTP for safety and which are not. The full social cost for each crash severity level is obtained by adding on the missing components estimated from a recent hybrid human capital cost study commissioned by BITRE.

Chapter 7 discusses use of the values for other modes of transport.

2. Project context and history

2.1 Current values for travel time savings

The most recently published edition of ATAP (2016) Part PV2 *Road parameter values* sets out VTTSs per car occupant per hour of $48.63 for business travel time and $14.99 for private travel time in June 2013 prices. These are based on Austroads (1997), which recommended that business travel be valued at average hourly earnings of the employed population plus 35% for overhead costs less 7% for payroll tax. The Austroads (1997, p. 12) formula for business (paid) travel time was

$$\frac{average\ weekly\ earnings \times (1 + 0.35 - 0.07)}{38}$$

Unpaid private travel time was recommended to be valued at 40% of average hourly earnings. The 40% figure was the proportion adopted by the UK government and was supported by a review of international and Australian literature. Weekly earnings are converted to hourly earnings by dividing by 38 hours worked per week. The values have been indexed over time using ABS's index of full-time adult ordinary time earnings. The 0.35, 0.07 and 38 parameters in the formula have not been updated.

The Austroads (1997) approach for business travel time is called the 'cost saving approach' (CSA) — the cost of labour adjusted for various on-costs (paid leave, superannuation contributions, training) and labour taxes. It is based on micro-economic theory according to which employers will hire labour up the point where the value of marginal product for a worker equals the wage rate. The value of marginal product is the output in dollars that an additional worker will produce. Expressed as an hourly rate, it is the value an employee will produce if they save an hour of travel time and use that time for working. The value should be the full cost to the employer, which would include all taxes on labour and on-costs. The subtraction of payroll tax in the Austroads formula is economically incorrect. From the point of view of the employer, payroll tax is as much a part of the cost of labour as wages and on-costs. The fact that income taxes are paid by employees out of their wages and pay-roll tax is paid by employers in addition to wages is irrelevant.

The cost saving approach requires assumptions that average earnings plus on-costs approximates the value of the marginal product of labour, that all business travel time saved goes into work not leisure, and that travel time savings do not displace work done during travel (Wardman et al. 2015, Wang and Hensher 2015). Wardman et al. (2015, p. 200) concluded that the cost saving approach "does not provide a suitable basis for valuing business travel time savings".

> *… there are at least three visible trends which make the CSA more open to challenge now than when it was invented. First, over time the digital and mobile communications revolution has increased the usability of travel time for working. Second, changes in economic structure and work occupations have promoted the advancement of the so-called 'knowledge economy', such that the proportion of business travellers in occupations and roles which enable them to use travel time productively has risen. Third, there has been a perceptible move to more flexible working contracts, whereby work may take place in or out of the office and not necessarily between nine and five. Since appraisal needs to cover a lengthy forward period such as sixty years, this raises the question of how we can best predict the future evolution of these trends which, it would seem, will make the CSA increasingly untenable for briefcase travellers. (Wardman et al. 2015, p. 201)*

Alternatives to the cost saving approach to valuing business travel time savings are the Hensher equation, employer WTP and employee WTP. These are discussed Section 3.5. For non-work and commuter travel time savings, the WTP approach is the only option (Wardman et al. 2013, p. 92).

2.2 Current values for safety

Up until the last decade, crashes were costed in Australia using the 'human capital' approach as estimated by BITRE. The human capital approach estimates the value of lost output from crash victims being unable to work, earn income and participate in household economic activities. It is calculated using average weekly earnings and life expectancy, discounted to the present. Some human capital studies also include medical/hospital costs, property damage, and other costs on society imposed by crashes (Bouga et al. 2022, p. 4). The '*hybrid* human capital' approach adds an amount for lost quality of life for victims and pain, grief and suffering for relatives and friends estimated from compensation payments to crash victims and their families and dependents.

The advantage of the human capital approach is that it is relatively simple to calculate and use. The main objection for use of the hybrid human capital approach in CBA is that people value safety principally because of their aversion to the prospect of their own and others' deaths and injury, rather than concern to preserve future levels of output and income (BTE 1996, p. 6). Further, the human capital approach has been criticised for not properly accounting for children and elderly people who have lower future earning capacities but still value their lives (Bougna et al. 2022, p. 4).

Table 2.1 sets out past hybrid human capital cost estimates, not indexed, for Australia. To help with comparisons, Table 2.2 presents the same costs indexed to June 2024 prices using the all-groups CPI. ATAP (2016) Part PV2 provides human capital costs per crash based on BITRE (2009).

Table 2.1 Past hybrid human capital estimates of the cost of crashes (not indexed)

Source	BTCE (1992)	BTCE (1993) update	BTE (2000)	BITRE (2009)	Economic Connections (2017) update	ANU (2022)
Year of estimate	1988	1993	1996	2006	2015	2020
Total social cost of crashes for Australia for one year	$6.2 billion	$6.1 billion	$15.0 billion	$17.85 billion	$22.24 billion	$27.04 billion
Cost per crash						
Fatal	$631,092	$752,400	$1.7 million	$2.67 million	$4.75 million	$3.2 million
Hospitalised/ serious injury	$94,836	$113,100	$408,000	$266,000	$287,000	$283,614
Non-hospitalised/ minor injury	$9,987	$11,900	$14,000	$14,700	$15,000	$30,530
Property damage only	$4,215	$5000	$6000	$9950	$11,000	$13,857

Table 2.2 Past hybrid human capital estimates of the cost of crashes: indexed to June 2024 prices with CPI

Source	BTCE (1992)	BTCE (1993) update	BTE (2000)	BITRE (2009)	Economic Connections (2017) update	ANU (2022)
Year of estimate	1988	1993	1996	2006	2015	2020
Total social cost of crashes for Australia for one year	17.5 billion	13.9 billion	31.2 billion	28.8 billion	28.7 billion	$32.8 billion
Cost per crash						
Fatal	$1.78 million	$1.72 million	$3.54 million	$4.31 million	$6.13 million	$3.86 million
Hospitalised/ serious injury	$267,003	$258,195	$849,031	$429,811	$370,564	$344,124
Non-hospitalised/ minor injury	$28,118	$27,166	$29,133	$23,753	$19,367	$37,044
Property damage only	$11,867	$11,414	$12,486	$16,078	$14,203	$16,812

Note: Indexation with the All groups CPI Australia A2325846C is approximate only. Ideally, individual components of each cost would be indexed separately using the most appropriate index. The ANU (2022) indexed costs differ slightly from those presented in chapter 6 because the latter have had individual components indexed.

The willingness-to-pay (WTP) approach estimates the money amount individuals would be willing to pay for a safety improvement that reduces by one, the total number of crashes of a given severity level.[1] In the case of a fatality, it is not a value of life but a value of reducing risk. Hence, it is not constrained by the discounted present value of a person's earnings (Abelson 2008, p. 5). The WTP to reduce the risk of death expressed in units of one death is often referred to as the 'value of statistical life' (VSL). If people were, on average, each prepared to pay $10 to reduce the probability of death by 1/1,000,000, then their VSL would be 1,000,000 × $10 = $10,000,000. The reason for multiplying the $10 for each individual by 1,000,000 is that the value of statistical life is expressed in units of a single life and 1 million times the probability of 1/1 million equals 1. The same approach can be extended to crashes of different severities (fatal, injury and property damage only). When referring to crashes of any severity level, the term employed is 'value of risk reduction' (VRR).

WTP values can be estimated via the revealed preference approach or the stated preference approach. The revealed preference approach seeks of model actual behaviour, for example, as how much money people spend on reducing risks to themselves or how they trade-off wages for work-related risks. The stated preference approach uses questionnaires to ask people what they are willing to pay for specified safety improvements. The revealed preference approach is theoretically better because it is not subject to hypothetical bias but it is difficult to find suitable data and assumes people correctly assess the risks they take and pay to reduce (Wijnen et al. 2009, p 327; ECMT 2001, p. 85; Evans 2009, p. 163).

The advantage of the stated preference approach is that it is possible to ask questions directly about the trade-off between risk and money, and it is possible to consider a wider and more systematic range of trade-offs than are available under the revealed preference approach. The disadvantages are that survey respondents are required to consider small probabilities, and their answers are necessarily hypothetical (ECMT 2001 p. 85; Evans 2009, p. 163). The challenges in addressing these difficulties in stated preference

[1] The reduction in the total number of crashes is one for all time, not one per annum.

surveys explains the large variations in WTP estimates across surveys (Hauer 2011, p. 154).

The WTP safety values in ATAP (2016) were derived from a stated choice survey (a stated preference survey in which people make hypothetical choices between alternatives) commissioned by the NSW Roads and Traffic Authority in 2007 and detailed in RTA (2008) and Hensher et al. (2009). The sample size was 213 respondents (142 Sydney and 71 Bathurst car trips). Interviewers administered the survey in face-to-face meetings with respondents using a 'Computer aided survey instrument' that showed the questions on a screen and into which the interviewer entered the responses.

Survey respondents were asked to choose between two alternative routes with differing attributes for travel time, costs and numbers of crashes per annum along the route for each severity level. Each respondent was shown 10 choice situations with attributes 'pivoted' around a recent trip they described at the start of the interview. Statistical modelling of data from survey responses estimated dollar amounts people would be willing to pay per trip for a reduction by one in the annual number of crashes along the route, called the Subjective Value of Crash Reductions (SVCR). The estimated SVCR values were converted to VRRs (WTP to reduce risk such that one additional crash is avoided) by multiplying by state-wide total vehicle-kilometres travelled divided by number of crashes per annum. The estimated WTP value for a fatal crash was $6.3 million in 2007 prices.

There is also the issue of what a WTP value to avoid a crash includes and excludes, and hence what needs to be added on. ATAP (2016) provides values under an 'inclusive WTP' approach that adds some components of human capital costs such as vehicle towing, emergency services and administration. Other costs incurred by governments such as medical costs and forgone income taxes were not added on either because it was not considered necessary or because they would have inflated the already high estimated cost of a fatal crash to a level where they would not have appeared credible. There are concerns that the current WTP cost of a fatal crash of around $10 million is far above the value of statistical life used by other sectors within the Australian economy even after allowing for the ratio of deaths to fatal crashes and the additional cost of a fatal crash to third parties, shown to be around $6.5 million in Section 6.4.

2.3 Project initiation and scoping

Around 2010, the Commonwealth Department of Infrastructure was concerned that failures of toll road projects were deterring private investment in toll roads. As a result, BITRE organised a symposium in 2011 and commissioned case studies which suggested that the data and models used for patronage forecasting could be significantly improved. Ways to achieve this were investigated in a consultancy by GHD in 2013 that included industry consultations with specialist modellers and users of patronage forecasts. One of the high-priority recommendations was research into WTP parameters for travel time and reliability. The aim of the research would be to produce up-to-date, soundly-based parameters for use in cost–benefit analyses (CBAs) of road initiatives as well as in the strategic four-step urban traffic models that make traffic forecasts, including toll road patronage forecasts.

In 2014, the ATAP Steering Committee (contracting through Austroads) commissioned a consortium of consultants, led by Deloitte Access Economics (DAE), to undertake a scoping study to recommend methodologies and to estimate resource requirements for obtaining values for travel time savings and reliability (TIC 2014).[2] The study featured a detailed literature review and consultation with experts. DAE recommended a stated choice survey methodology to develop WTP parameter values for travel time and reliability of passenger cars. It also recommended use of the standard deviation of trip time as the measure for reliability, known as the 'mean–variance approach'.

[2] The scoping study also addressed valuing travel time savings for freight and light commercial vehicles.

In 2015, Austroads separately published a scoping study, *Social costs of road crashes in Australia: The case for willingness-to-pay values for road safety* (Austroads 2015). This was motivated by an action item under the National Road Safety Strategy 2011–2020 to develop “a nationally agreed approach to applying the willingness-to-pay methodology to value safety”. Further, the National Road Safety Action Plan 2015-2017 had as Recommendation 5, “Apply national willingness-to-pay values for infrastructure investment and other road safety project appraisals”. The 2015 Austroads study also recommended a stated preference survey approach to estimate people’s WTP for road safety improvements.

As a result, DAE was further asked to advise in their scoping study, whether it would be possible to combine the stated preference surveys for the values of time, reliability, and safety into a single large survey. Although, having all three together in the same survey creates a risk that giving respondents too many attributes to consider at once could lead to fatigue and inconsistent choices, there are also advantages. In practice, people have to make choices in which they trade-off all three variables at once, so the survey better represents real-life situations compared with a survey that covered time and reliability only or time and safety only. Separate surveys for time/reliability and time/safety would give rise to two alternative sets of VTTS values. Having all three sets of values (time, reliability and safety) derived from the same data, methodology and model promotes consistency in benefit estimation in CBAs. CBAs support decisions in which time, reliability and safety are traded off, so it is desirable that the project benefit values that combine monetised values of all three, not be distorted by differences in the approaches to deriving the unit values used (Hauer 2011, p. 153).

DAE found that, although it has never been attempted before, it should be feasible. However, the risk that survey respondents will not fully understand the choices needed to be managed by careful design and a significant pilot survey.

To best manage the risks in this ground-breaking project, the ATAP WTP national survey was divided into three stages:

1. Survey instrument design and preliminary testing (Stage 1)
2. Pilot testing in three surveys of some 100 participants each (Stage 2), and
3. National survey (Stage 3).

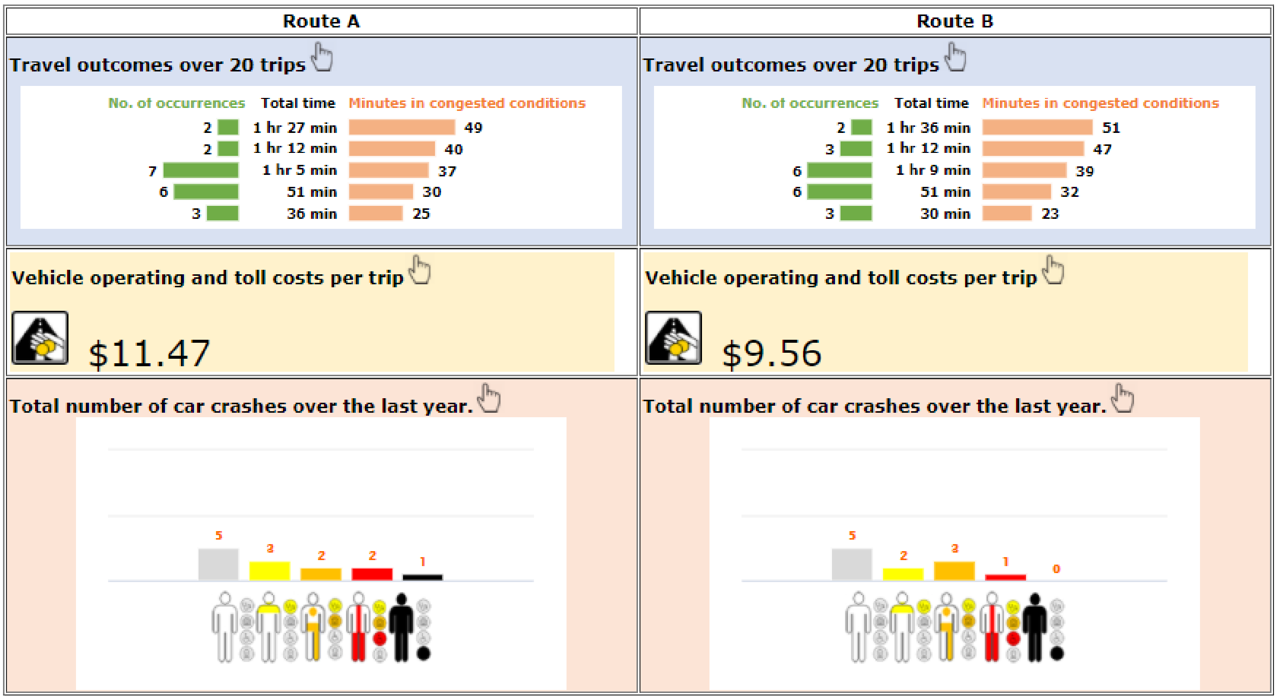
Summaries of the reports that fed into the national survey, as well as ATAP (2024a) are provided in Appendix A of this Research report

An additional stage (Stage 4) was required to develop a model and parameters for estimating changes in travel time reliability caused by road transport initiatives. ATAP commissioned a consortium of consultants lead by ARRB Group to undertake the research. The report was published as ATAP (2022b). The ATAP (2024b) guideline, *Reliability benefits of road transport initiatives*, sets out the methodology.

2.4 Development and implementation of the survey

The national survey required each respondent to make five hypothetical choices between two alternative routes for the same trip with route characteristics varying in travel time with different frequencies over 20 trips, cost per trip and safety given by total numbers of crashes per year by severity category. Before making the choices, respondents were asked to describe a recent trip they had made. The attributes of the alternative routes in the choice questions were ‘pivoted’ (small variations up or down) around the attributes of the recent trip. Figure 2.1 is a screenshot of an example choice question.

Figure 2.1 Screenshot of example survey choice question



In view of the large number of variables for respondents to consider, the project team and consultants were acutely aware of the risks that survey responses would not represent peoples' genuine preferences. A great deal of effort and resources was invested in the lead-up to the national survey to ensure it would produce valid results. Table 2.3 summarises the steps taken.

Table 2.3 Steps in survey design and implementation

Year	Activity	Sample size
Stage 1: Design		
2017	Testing on focus groups	2 groups with 10 participants
2017	External peer review by Prof. Ortúzar at Pontificia Universidad Católica de Chile	na
2017	Test on DAE employees	30
Stage 2: Pilot surveys		
2017	Victoria: Melbourne and Bendigo	130
2018	Queensland: Brisbane and Toowoomba	132
2018	WA: Perth and Bunbury	141
Tender process for Stage 3		
2018	Development of detailed work brief with advice from the University of Leeds, Institute for Transport Studies	na
Stage3: National pilot		
2018-19	NSW: Sydney and Orange	110, 105 usable
Stage3: Independent peer review		
2018-19	Review of survey instrument by Dr Ben Phillips, Social Research Centre of the Australian National University	na
Stage3: Cognitive interviews		
2020	Persons interviewed after taking the survey to assess comprehension	10
Stage3: National survey		
2021	Wave 1	722 surveyed, 199 usable
2021-22	Wave 2	3442
2023-24	Final model	3844 (including 289 from the pilot surveys)
Crash cost conversion methodology development		
2022	Working paper (ATAP 2022a) prepared by project team	na
2022	Review of working paper by University of Leeds, Institute for Transport Studies	na
Post-survey actions		
2023-24	Development of recommended WTP values (report by consultants, ATAP (2024a) and the Research report)	na

The initial survey design was tested on two focus groups and a sample of DAE employees, and was reviewed by an independent academic expert. Three pilot surveys were undertaken in Stage 2, with refinements made to the survey after each one. The results of each pilot survey were assessed against a list of performance indicators. Knowledge tests were included in the survey instrument to check how well the respondents understood the injury scenarios being presented. Results from modelling the pilot survey responses were compared with results from other Australian and overseas surveys.

The project team developed a detailed work brief for the national survey in Stage 3 with advice from the University of Leeds, Institute for Transport Studies. Stage 3 was put out to tender and the contract was awarded to a consortium of consultants lead by DAE. Other members were The Hensher Group, Enlightened Data, Community and Patient Preference Research (CaPPRe) and Taverner Research, providing the full range of expertise in modelling, survey design, sample selection, survey administration and data processing.

The project team commissioned an independent peer review of the survey from the Social Research Centre of the Australian National University to assess whether the survey respondents understood the information being presented in order to make choices that truly reflected their preferences. As well as reviewing all the reports produced by the project up to that time, and reviewing the survey instrument, the reviewer also undertook the survey himself. The reviewer's principle recommendation was to conduct 8 to 12 'cognitive interviews' in which people would undertake the survey and then be interviewed about the experience. The reviewer also recommended some presentational changes to survey instrument.

Before undertaking the full national survey, the consultants undertook 10 cognitive interviews, which lead to further changes to the survey instrument (ATAP 2024a, pp. 12-13).

A further pilot study was undertaken before commencing the full survey, referred to has the 'National Pilot'.

The target number of respondents was 4500 calculated from the standard errors of parameter estimates from the pilot surveys and the requirement that the parameter estimates from the national survey be statistically significant at the 95% level of confidence (ATAP 2018, p. 116). 'Quota sampling' ensured a spread across states and territories, urban/rural, driver/passenger and trip purposes in line with population proportions. The survey was undertaken in two 'waves' throughout 2021 and 2022, with a pause after wave 1 to allow for modelling of results to check that the survey was working.

The pilot surveys were administered via a mix of face-to-face interviews and online without guidance from an interviewer (self-complete). The onset of Covid required that all subsequent surveys to be administered online. A total of 722 respondents were surveyed in wave 1, comprised of 523 online self-complete and 199 online guided. While the online self-complete responses from the pilot surveys had been satisfactory, the advent of Covid changed this. The online self-complete responses from wave 1 failed performance checks and did not yield sensible results when modelled. The 523 online self-complete survey responses from wave 1 had to be discarded, leaving the 199 online self-guided as useable. The entire wave 2 survey then had to be administered online guided by an interviewer. The 199 usable responses from wave 1 were pooled with 289 responses from the previous pilot surveys and 3,356 from wave 2 to make a final sample size of 3,844 survey responses.

Implementation of wave 2 was delayed by the spread of the Delta Covid variant and subsequent lockdowns. Difficulties were experienced in fulfilling some quotas such as those for passengers. It was determined that a sample size of 3,300 would be sufficient to yield robust parameter estimates. In the end, a total of 3,844 useable responses where obtained from a total of 4,772 surveys administered. This followed removal of poor quality data such as unsatisfactory responses, 'speeders', data with missing items, and outliers (ATAP 2024a, p. 27).

2.5 Post-processing and modelling

While wave 2 was being undertaken, the project team investigated conversion of model results for safety to a cost per crash for use in cost–benefit analysis. The conversion methodology, injury cost rescaling and translating the safety WTPs from the national survey to the full social cost of crashes, (all which are addressed later in this report), were discussed in a working paper (ATAP 2022a). The Institute for Transport Studies, University of Leeds, UK, was engaged to review the working paper. The review team of internationally renowned experts was Prof. Richard Batley, Prof. Peter Mackie and Dr. Thijs Dekker.

The conversion methodology adopted is explained in detail in Chapter 4 of this report. In brief, it required estimation of distance-weighted average annual daily traffic levels for the trip in each survey response multiplied by 365 days per year to obtain the annual crash exposure. As the trip attributes in the survey questions were 'pivoted' around a recent actual trip made by the survey respondent, it could be expected that survey respondents would be aware of traffic levels and hence crash exposure.

The crash exposure measure can be used in two ways to obtain estimate of the value of risk reduction (VRR) for safety. One way is to divide the crash numbers in survey responses by individual trip crash exposures prior to modelling to convert the crash numbers to probabilities of a crash. The model then gives the VRR directly. The other way is the estimate the model using crash numbers and multiply the WTP result by crash exposure averaged over all trips after modelling. The appropriate way depends on survey respondents' awareness of crash exposure. Testing alternative model forms showed that they were not generally aware of differences in crash exposure except partially for fatal crashes.

The form of model used to estimate the WTP values was a 'mixed logit model'. The mixed logit model allows for 'heterogeneity of preferences', that is, a range of individual WTP values within the population. In the mixed logit model, the analysis assumes that the WTP values are distributed according to a probability distribution (for example, normal or triangular) and the modelling software estimates the mean and other parameters of the distribution. The analyst needs to test various distributions to ensure the model converges to a stable solution and that the distribution assumptions are not overly influencing the results. For further details including the particular distributional assumptions for the ATAP study, see ATAP (2024a, appendix A).

A simplified version of the equation for utility from a trip by an individual is as follows.

$$\begin{aligned} U = \beta_c \times trip\ cost + \beta_t \times trip\ time + \beta_r \times variability\ of\ trip\ time \\ + \sum_{i=1}^{5} \big(\beta_{ni} \times number\ of\ crashes\ per\ annum\ of\ severity\ i \\ + \beta_{pi} \times probability\ of\ a\ crash\ of\ severity\ i\big) \end{aligned}$$

In the final model, the probability of a crash variable was removed except for fatal crashes because of lack of statistical significance, indicating lack of awareness by survey respondents of differences in crash exposure.

WTP values are found by dividing the coefficients for each physical quantity by the coefficient for trip cost. The WTP value is the marginal rate of substitution (MRS) between money and the physical quantity. In the case of time, the VTTS is the number of dollars a traveller would be willing to give up to save an additional hour of time. The MRS of cost for time is the ratio of the marginal utility (MU) of time divided by the marginal utility of money.

$$VTTS = MRS_{tc} = \frac{MU_t}{MU_c} = \frac{\frac{\partial U}{\partial t}}{\frac{\partial U}{\partial c}} = \frac{\beta_t}{\beta_c}$$

Similarly,

$$VOR = \frac{\beta_r}{\beta_c}$$

$$\boldsymbol{VRR_i = \frac{\beta_{ni}}{\beta_c} \times average\ crash\ exposure + \frac{\beta_{pi}}{\beta_c}}$$ for fatal crashes, and

$$\boldsymbol{VRR_i = \frac{\beta_{ni}}{\beta_c} \times average\ crash\ exposure}$$ for crashes of other severities.

The crash exposure variable is explained in section 4.5 below.

From the point of view of the traveller, less is better than more for all the variables (eg. a shorter trip time is preferred to a longer trip time), which makes all the coefficients negative. Then, dividing one coefficient by another cancels out the negative signs.

Additional variables in the utility equation not shown above were trip cost interacted with personal income and the log of trip time. These allowed testing of the effect of income on all the WTP values and whether VTTS varies between short and long trips. In the event, the effects of income and trip distance were found to be small and not statistically significant. Nevertheless, post-model WTP estimates by income and trip length bands were estimated and weighted averages taken using population weights. An implication of the lack of statistical significance of income in affecting WTP is that behavioural and equity values of time and safety are identical within the road transport mode. A further implication is that there is no justification for adjusting future WTP values for changes in real incomes, only prices.

A large number of model specifications was tested before arriving at the final model. Most of the models tested were ‘all-in’ models that distinguished between VTTS and VOR for each trip purpose but not for safety, and were estimated from the entire database. An alternative approach tested was to have three separate models, one for each trip purpose (commuter, non-work and business), each estimated with only the survey response data for the particular trip purpose. The final model selected was an ‘all-in’ model. It was chosen over the alternative of three separate models because the VTTS and VOR estimates from the three separate models were similar and, due to the smaller sample sizes for the three separate models, some of the safety values were not statically significant.

Table 2.4 presents the results from the final model. All the coefficient estimates shown are statistically significant at the 1% level, as indicated by all ‘Prob |z| > Z’ values being below 0.01. Further consideration of the results and modelling is presented in the remainder of this report.

Table 2.4 Final model results (Dec 2021 $)

Variable name	Meaning	Coefficient estimate	Standard error	z-statistic	Prob |z| >Z	95% conf interval: lower	95% conf interval: upper
VTTSFFC	VTTS free-flow, commuter	15.745	2.02189	7.79	0	11.7822	19.7078
VTTSFFB	VTTS free-flow, business	17.594	2.19689	8.01	0	13.2882	21.8999
VTTSFFN	VTTS free-flow, non-work	21.5601	1.70534	12.64	0	18.2177	24.9025
VTTSCGC	VTTS congested, commuter	62.9047	6.66954	9.43	0	49.8326	75.9767
VTTSCGB	VTTS congested, business	66.4703	6.07774	10.94	0	54.5581	78.3824
VTTSCGN	VTTS congested, non-work	9.89258	2.4447	4.05	0.0001	5.10107	14.6841
WVTTSC	Weighted VTTS commuter	31.1009	2.25865	13.77	0	26.674	35.5278
WVTTSB	Weighted VTTS business	33.5318	2.2715	14.76	0	29.0798	37.9839
WVTTSN	Weighted VTTS non-work	18.807	1.35431	13.89	0	16.1526	21.4614
VORC	VOR commuter	35.5044	2.38745	14.87	0	30.8251	40.1838
VORB	VOR business	36.874	2.69687	13.67	0	31.5882	42.1598
VORN	VOR non-work	31.3544	1.85792	16.88	0	27.7129	34.9959
WTPPROP	WTP PDO	0.016	0.00321	4.98	0	0.00971	0.0223
WTPMIN	WTP minor injury	0.02466	0.00808	3.05	0.0023	0.00882	0.0405
WTPMAJ	WTP major injury	0.50001	0.08653	5.78	0	0.33041	0.66961
WTPINC	WTP incapacitating	1.45485	0.10908	13.34	0	1.24106	1.66865
WTPFAT	WTP fatal	3.66391	0.27928	13.12	0	3.11653	4.21128

Note: All VTTSs are in $/hour. All VORs are in $/hour of standard deviation of travel time. All WTP values to reduce crashes are in $ millions per crash avoided.

2.6 Indexation of values

ATAP (2024a, section 7.2) advises indexing the WTP values using the CPI and, based on the time when the majority of survey responses was obtained, that they be indexed from December 2021.

In this report, all values are indexed to June 2024 prices, unless otherwise stated. The CPI All groups, Australia (A2325846C) has risen from 121.3 in December 2021 to 138.8 in June 2024, giving an adjustment factor of 1.144270.

3. Values of travel time savings and reliability

3.1 Introduction

In cost–benefit analysis (CBA) of road infrastructure projects, travel time savings are usually, by far, the largest benefit category. If the values from the ATAP WTP study are adopted, there will be major changes to the way travel time savings benefits are calculated as well as the unit values themselves. In summary,

- The national survey value for business travel is significantly below the current value based on average before-tax earnings,
- What is currently termed ‘private travel’ will be split into two groups — commuters, with a VTTS approaching that for business travel, and non-work trips.

Furthermore, reliability benefits are not currently recognised in ATAP (2016) Part PV2 and are rarely estimated in CBAs. ATAP has developed separate guidance for estimating reliability changes from transport initiatives expressed in hours of standard deviation of trip time (ATAP 2024b). The national survey provides unit values of reliability (VORs) that can be used to estimate benefits from reliability changes.

This chapter introduces the new values with consideration of some of the issues surrounding their adoption. Comparisons are made with values from the recent New Zealand WTP survey (Denne et al. 2023), the UK DfT (2015a & b) WTP survey (also discussed in Batley et al.2019) and two Australian surveys (Li et al. 2010 and Hensher et al. 2021). This is additional to the international comparisons in ATAP (2024a), set out in a table of VTTS and VOR values from other surveys. For reasons explained in Section 3.4, the NZ survey did not estimate a business VTTS or VOR.

Questions addressed about the ATAP WTP values in this chapter include:

- What is to be done with VTTSs under different traffic conditions: congested, free-flow and weighted average? (Section 3.3)
- Is the VTTS for commuter travel too high relative to the VTTS for non-work travel? (Section 3.4)
- How would adoption the values change total time savings benefit estimates? (Section 3.4)
- Is the VTTS for business travel too low in relation the alternative ways to estimate the VTTS for business? (Section 3.5)
- What is to be done with VTTS values for short- and long-distance trips? (Section 3.6)
- Are the reliability ratios too high? (Section 3.7)
- How large will be reliability benefits be in relation to time savings benefits? (Section 3.7)
- What interaction is there between VTTS and VOR? (Section 3.8)

3.2 Indexed values and relativities

Table 3.1 lists the estimated values from ATAP (2024a) and shown above in Table 2.3 from modelling of survey data in December 2020 prices, and the values with confidence intervals indexed to June 2024 prices. The ‘ratios’ columns are referred to below in the discussion to help understand the relativities.

Table 3.1 VTTS and VOR values from survey ($/hour)

	Dec 2021 prices	June 2024 prices	Ratios		Confidence interval June 2024 prices	
			cc / ff	/ bus	lower	upper
VTTS free-flow, commuter	15.75	18.02		0.89	13.48	22.55
VTTS free-flow, business	17.59	20.13		1.00	15.21	25.06
VTTS free-flow, non-work	21.56	24.67		1.23	20.85	28.50
VTTS congested, commuter	62.90	71.98	4.00	0.95	57.02	86.94
VTTS congested, business	66.47	76.06	3.78	1.00	62.43	89.69
VTTS congested, non-work	9.89	11.32	0.46	0.15	5.84	16.80
Weighted VTTS commuter	31.10	35.59		0.93	30.52	40.65
Weighted VTTS business	33.53	38.37		1.00	33.28	43.46
Weighted VTTS non-work	18.81	21.52		0.56	18.48	24.56
			/ VTTS			
VOR commuter	35.50	40.63	1.14	0.96	35.27	45.98
VOR business	36.87	42.19	1.10	1.00	36.15	48.24
VOR non-work	31.35	35.88	1.67	0.85	31.71	40.04

Note: cc = congested conditions, ff = free flow, bus = business

3.3 VTTS and traffic conditions

In each survey question, the travel times were conveyed using two pieces of information: total trip time and minutes in congested conditions. Travel time in free-flow conditions was simply the difference between total time and congested time. The model featured time spent in congested conditions and time spent in free conditions as separate variables.[3] The weighted average values were calculated outside the model by

- Estimating the average time cost for the trip in each survey question to each respondent for the chosen route alternative as

$$weighted\ average\ VTTS = \frac{VTTS_{ff} \times time\ in\ ff + VTTS_{cc} \times time\ in\ cc}{total\ trip\ time}$$

  where *ff* = free-flow conditions and *cc* = congested conditions

- Then taking the weighted average using population weights across incomes and trip length bands.

The ratios 4.00, 3.78 and 0.46 in the first ‘ratios’ column of Table 3.1 are VTTS under congested conditions divided by VTTS under free-flow conditions for each respective trip purpose. For commuter and business travel, the VTTS in congested conditions is about four times that for free-flow conditions. This would reflect higher levels of stress and discomfort when driving in congested conditions, and reduced ability to perform other activities. The relativities are reversed for non-work travel, for which the VTTS is less than half that for

[3] In the pilot stage of the study, omitting the distinction between free flow and congested time in the modelling was tested. Maintaining the distinction was considered preferable because variability in trip time occurs only for the congested parts of trips. Free-flow time always occurs at the same speed. Without the distinction, the correlation between the total travel time and unreliability variables was too strong leading to ‘unexpected results’ when analysing the data. (ATAP 2018 pp. 103-4.)

free-flow conditions. In all cases, the VTTS estimates are significant at the 1% level.

A possible explanation for the non-work VTTS being lower for congested conditions relative to free-flow conditions is that many non-work travelers have the ability to avoid traffic congestion by selecting off-peak hours to travel and/or locations that are not very congested. Hence, they would not be prepared to pay much to reduce time travelled in congested conditions, such as using a toll road, because they can choose a quieter time and place for their non-work trips. Such flexibility, either by time of day or activity location, is not widely available for business travelers and commuters. The data collected from the survey support this interpretation because many travellers for non-work purposes reported a low congested time (23.5% of total time) relative to business travelers (32.6%) and commuters (32.5%) (ATAP 2024a, p. 56).

The four-fold difference between VTTS values for congested and free-flow conditions from business and commuter travel is quite large. In a meta-analysis of European VTTSs, Wardman et al. (2016, p. 110) derived an average ratio of congested to free-flow VTTS of **1.42**. The ratios of congested to free-flow VTTS were **1.86** = 57.24 / 30.90 for the NZ study for commuting and **1.79** = 57.07 / 31.97 for other (Denne et al. p. 13). In the UK study the ratios were **2.69** = 1.37 / 0.51 for commuters and **3.0** = 1.26 / 0.42 (UK DfT 2015a, p. 13; Batley et al. 2019, p. 614).[4] The non-work ratio for UK was higher still at **4.0** = 1.89 / 0.47. The high ratios of VTTS in congested to free-flow conditions in the UK and ATAP national surveys suggest an extremely high level of aversion to driving in congested conditions. Alternatively, as Denne et al. (2023 p. 89) suggests, it could be due to different perceptions between countries about the nature of ‘heavy traffic’ or ‘congested conditions’.

The UK survey had three traffic condition states, free-flow, light traffic and heavy traffic. The UK survey questionnaire provided written and pictorial descriptions of the three conditions. The NZ survey only refers to “time spent moving slowly in heavy traffic” (Denne et al. 2023, p. 121), leaving it up to survey respondents to interpret for themselves what this means. National survey respondents were told that “Congested conditions refer to conditions where you are consistently braking and accelerating and can only change lanes if others let you in” (ATAP 2023a, p. 90). The questionnaire included a small photo of cars in bumper-to-bumper congestion.

Despite the effort taken by the UK study (see UK DfT 2015b, p. 222) to convey to survey respondents the nature of the three traffic condition states, they recommended using the single VTTS from a survey format that did not distinguish between traffic conditions for the immediate future and that the Department undertake work to examine the case for extending the scope of VTT guidance to include multipliers for traffic conditions (p. 264). The reason was the difficulty in aligning the three alternatives in their survey (free-flow, light traffic and heavy traffic) with actual traffic conditions in relation to volume-delay functions and to interpolate between the three points (Batley et al. 2019, p. 610). It would be even more difficult in the case of the national survey because there are only two traffic condition alternatives and there is greater uncertainty about how survey respondents interpreted the questions. The NZ study did not address how the VTTS values in different traffic conditions could be translated into practice.

It is recommended that only the weighted VTTS values be used in practice and not the free-flow and congested conditions VTTS values. The main reason is the difficulty in fitting a functional relationship for use in practice to the two VTTS values, particularly when it is unsure how survey respondents interpreted congested traffic conditions. A secondary reason is the unexpected relativity for non-work time, with free-flow VTTS being higher than congested VTTS.

A possible objection to use of the weighted VTTS values from the survey is that the weights between congested and free-flow travel times come from the survey not from objective data. As noted in Section 2.5, the attributes of the trip in each survey questionnaire were obtained by ‘pivoting’ around the attributes of a recent trip described by the respondent. One of the information items about a recent trip requested in the questionnaire was the time spent in congested conditions as defined. The choices in the survey involved

[4] The 1.37 and 0.51 UK figures are multipliers not monetary values.

varying upward and downward the time spent in congested conditions to ascertain the sensitivity of respondents' choices to this variable.[5] The weights therefore reflect the real-world experience of car travelers.

3.4 VTTS between trip purposes

Considering only the weighted VTTS values, Table 3.1 shows that the ratio of VTTS for commuters to business is **0.93**, and for non-work to business **0.56**. The strongly overlapping confidence intervals for the business and commuter VTTSs in Table 3.1 indicate that, statistically, they are almost indistinguishable. The ordering of weighted VTTSs across trip purposes from the national survey is consistent with expectations — in descending order: business, commuter, non-work. The ratio of non-work to business weighted VTTS of 0.56 is comparable with the 0.40 ratio from the Austroads (1997) report that underlies the existing ATAP private VTTS value.

For UK DfT (2015, Exec sum), the ratios were **0.68** = 11.21 / 16.74 commuter to business, and **0.31** = 5.12 / 16.74 non-work to business indicating a much greater gap between business and the other trip purposes. From the survey of 389 European studies conducted between 1963 and 2011 in Wardman et al. (2016, p. 106), for the simple average across countries, that ratio for 'car commute' to 'car employer business' was **0.53**, and for 'car other' to 'car employer business', **0.46**.

No business VTTSs were estimated by the NZ study. Denne et al. (2023, p 38) considered that, because the financial costs of business trips are paid by the employer, there is a principal–agent market failure problem, in that the WTP by travelers will not correspond to the cost to employers. There is also a tax offset to complicate any WTP estimates.[6] These issues are discussed further in the next section on VTTS for business. The NZ VTTSs for commuters and non-work, averaged over all trip distances, were almost the same at NZ$38.40 for commuting and NZ$37.13 for other (Denne et al. 2023, p. 13).

There are many published WTP survey results with commuter time valued well above non-work time (ATAP 2024a, pp. 45-46). For example, the Australian stated choice study by Li et al. (2010, p. 398) obtained VTTS values in 2008 prices of $30.04 for commuters and $12.22 for 'non-commuters', citing the mixed logit model results. The commuter VTTS was 2.5 times that for non-commuters.

It could be speculated that high housing costs have increased the VTTS from commuters because shorter travel times broaden the choice of house location options. The switch to more working from home is another possible reason. From stated choice survey data collected in Sydney in late 2020, Hensher et al. (2021) found that commuter VTTS values increase with the number of days per week worked from home.

> *… not only does the mean estimate of the VoT [value of time] appear to be higher by 12.55% compared to pre-COVID-19, but that the mean estimate is higher for individuals who opt for a higher number of days WFH, and hence reducing the impost of the commute. Individuals appear to be willing to pay more to save a unit of commuting travel time when they undertake less frequent trips. The logic is very plausible and aligns with evidence in other contexts that less frequent trips for a given a trip purpose, tend to have a greater willingness to pay for a specific level of service. (p. 47)*

VTTS values for commuters found by Hensher et al. (2021) ranged from $20.39 for persons with zero days WFH to $36.95 for people with six or seven days WFH a week, with a weighted average of $25.53. The weighted commuter VTTS from the national survey of $31.10 in 2020 prices is within this range.

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[5] In cases where respondents did not face any congestion in their trip (zero minutes travelling in congested conditions), five minutes was used for pivoting purposes. Such a small value would not make much difference to the weights.

[6] Denne et al. (2023) did not elaborate on the tax offset and there is no reference to it in the UK literature.

It is recommended that ATAP adopts the weighted commuter and non-work VTTS values from the ATAP WTP study because they are well within the expected range of values from Australian and overseas WTP studies.

Whether ATAP should adopt the business VTTS WTP estimate is discussed in the next section.

Likely effect on travel time saving benefits

The values for VTTS for business and private travel in ATAP (2016) Part PV2 are $48.63 and $14.99 respectively in June 2013 prices. Indexed to June 2024 using full time adult ordinary time earnings (ABS series no. A84998729F) (adjustment factor 1.354 = 1923.4 / 1420.90), these are respectively $65.83 and $20.29. For non-work private travel, the change from the current VTTS to the national survey VTTS is small — a 6% increase from $20.29 to $21.52. For commuters, currently treated as private travel, the VTTS increases by 75% from $20.29 to $35.59. For business travel, the WTP value of $38.37 is 42% below the current value of $65.83 indexed.

Based on data from two jurisdictions, purposes for total weekday trips by car are in the proportions: business 10%, commuter 17% and non-work 73%. The proportion of non-work travel would be smaller if the proportions were for distance travelled or time spent travelling because non-work trips tend to be shorter. Nevertheless, the proportions show that non-work trips dominate followed by commuter then business. As commuter car trips outnumber business car trips, and there is only a small increase in VTTS for non-work trips, the net effect on travel time savings benefits of switching from the current to the national survey values is likely to be a small positive amount — of the order of 3%.

- Indexed ATAP (2016) values: **$24.64** = 10% × $65.83 + 17% × $20.29 + 73% × $20.29
- Weighted average national survey WTP values: **$25.38** = 10% × $38.37 + 17% × $35.59 + 73% × $21.52
- Ratio: $25.38 / $24.64 = **1.03**.

3.5 Value of business travel time (VBTTS)

Although the business trip purpose is the smallest in terms of number of trips and total distance travelled, the higher value of time makes it a significant source of benefits from road improvements. Furthermore, project benefits that reduce costs to businesses improve the productivity of the economy, which is usually a policy objective of governments. The national survey estimate of the VTTS for business (VBTTS) value of $38.37 is 42% below the current value of $65.83 (both indexed to June 2024).

There are at least four ways to obtain a VBTTS: the cost saving approach (CSA), the Hensher equation, employer WTP and employee WTP. In the lead-up to the UK DfT (2015) study, the Department engaged some of Britain's leading transport economists to investigate the merits of the alternative methods (Wardman et al. 2013). In this section, VBTTS values are calculated under CSA and Hensher equation approaches using readily available data for comparison with the WTP value. The Hensher equation approach provides a justification for adoption of a VBTTS significantly below the CSA value.

3.5.1 Cost saving approach (CSA)

The cost saving approach (CSA) [7] assumes that all savings in business travel time are used for productive

[7] Some sources refer to 'cost saving approach' and some 'cost savings approach'. There is no convention as to whether 'saving' should be singular or plural.

work and that no work is undertaken while travelling. It further assumes that average earnings plus on-costs approximates the value of the marginal product of labour (VMPL), defined as

$$VMPL = (price\ of\ a\ firm's\ output - non\text{-}labour\ costs\ per\ item) \times MPL$$

where MPL, the marginal (physical) product of labour, is the change in output from employing an additional unit of labour. Time savings used to perform additional work will produce additional output with a value equal to the VMPL.

In economic theory, employers will employ labour up to the point where the marginal revenue product of labour (MRPL) equals the cost of labour faced by the employer (wages plus on-costs), where

$$MRPL = (MR\ of\ a\ firm's\ output - non\text{-}labour\ costs\ per\ item) \times MPL$$

Marginal revenue (MR) is the increase in revenue from selling an additional unit of output. In a competitive product market, the marginal revenue equals price so *VMPL = MRPL*. In imperfectly competitive product markets, *MR < P* and hence *MRPL < VMPL*. Imperfectly competitive product markets together with mis-specification of on-costs are reasons why average earnings plus on-costs might not equal the value of marginal project of labour (Wardman 2015, p. 203). However, if average earnings were adjusted upward to allow for the effect of imperfect competition causing the value to society of additional output from saving labour time to exceed the cost to employers, this would lead to double counting with wider economic benefits from imperfect competition (ATAP 2023b Part T3 Wider economic benefits).

Data requirements for the CSA are full-time adult average weekly earnings, the percentage of on-costs and average number of hours worked per week by full-time employees. As at May 2024, ABS reported full-time adult average weekly ordinary-time earnings at $1,923.40 (Series ID. A84998729F). Internet searches indicated that the average working time of 38 hours per week for full-time employees has not changed since the VBTTS calculation in Austroads (1997). Internet searches suggested that on-costs (annual leave, long-service leave, sick leave etc., workers compensation insurance, superannuation contributions, pay-roll tax) are in the range 30% to 40%. The Austroads (1997) assumption of 35% for on-costs is at the midpoint.[8] Using the midpoint on-cost proportion, gives a CSA VBTTS of **$68.33** = $1,923.40 × 1.035 / 38.

3.5.2 The Hensher equation approach

As noted in Section 2.1, Wardman et al. (2015) concluded that the CSA is not at all suitable to estimate the VBTTS.[9] The Hensher equation adjusts the value of marginal product of labour to allow for leakage of a proportion of business travel time savings to leisure and work done while travelling.

A good deal of business travel occurs outside of work hours. An example is where an employee has to attend business meeting at a different location from their regular office and the meeting occurs at the start or end of the working day. The employee may leave home early to travel directly to the meeting or arrive home late from the meeting. Part of or all of the travel will have occurred during the employees’ leisure time and is not compensated by employers. Time savings for such trips will allow the employee to leave home later for a morning meeting, or return home earlier from a late meeting, saving time valued at the non-work rate.

There is some scope for car occupants to undertake work such as drivers using hands-free phones to make work-related phone calls, passengers using hand-held devices, and car occupants engaging in work-related

[8] Hensher and Ho (2023, p. 26) added a further five percent for overheads that would be saved when the employee is not spending time at the office. These overheads included electricity, phone calls, and the average cost of meetings avoided that are paid for by the traveller’s organisation. The CSA VBTTS calculation in this report does not add the additional five percent because there is no supporting evidence and it seems high.

[9] These views were echoed in UK DfT (2015 p. 177) and Batley et al. (2019 pp. 606-7).

discussions.

The 'Hensher equation' (Hensher 1977 and 2011; TIC 2014, pp. 4 and 104; Wardman et al. 2013; Wang and Hensher 2015, p 4) combines the perspectives of both the employer and the employee, while also accounting for the productivity of travel time and the allocation of time savings to work or leisure.

$$VBTTS = (1 - r - pq) \cdot MPL + (1 - r) \cdot VW + r \cdot VL + MPF$$

[EQ. 3.1]

where

- *r* is the proportion of business travel time saved that is used for leisure. (*1 – r*) is the proportion of travel time savings used for working.
- *p* is the proportion of travel time that is used for working while travelling
- *q* is the relative productivity of work done while travelling relative to the workplace
- *MPL* is the marginal product of labour. It equals the CSA estimate of VBTTS.
- *MPF* is the marginal product of fatigue reduction. Savings in travel time would reduce worker fatigue from travelling, which in turn increases the productivity of working hours
- *VW* is the difference between the employee's valuations of 'contracted' work time and travel time.
- *VL* is the is the employee's value of leisure time.

The first component represents the 'productivity effect', that is, the increase in productivity from spending additional time in the office. This effect is adjusted by a 'relative disutility cost' (second component) which reflects the change in utility perceived by the traveller from increasing work time compared to travel time. Typically, there is assumed to be no difference between employees' utility while working and travelling on business so *VW* = 0. The utility from allocating travel time savings to leisure activities is captured in the third component of the equation and valued at the non-work VTTS. The fourth component reflects reduced productivity at work due to fatigue from travelling. The last term, MPF, has generally been ignored due to the difficulty of obtaining data. The CSA is a restricted case of the Hensher equation where it is assumed that the CSA gives the correct value of MPF, and *p = r = 0* and *VW = 0* (Wardman et al. p. 202).

There are a number of simplified versions of the Hensher equation. The most common reduced form is

$$VBTTS = (1 - r - pq)MPL + rVL$$

[EQ. 3.2]

Where the Hensher equation has been applied, there are concerns about the accuracy with which its key parameters can be estimated (Wardman et al. 2013, p. 15).

Wardman et al. (2013 and 2015) discuss the likely values of the parameters, *r*, *p* and *q* for UK. For car travel they recommend *r = 0.4* (Wardman et al. 2013, p. 66 but *r = 0.44* on p. 125 for trips under 120 minutes) and *p = 0* (which means *q* does not matter). A survey of values in Wang and Hensher (2015) found *r* values (proportion of business travel time savings used for leisure) for car travel between 0.28 and 0.57 with a most likely (median) value of 0.45. They reported *p* values (proportion of travel time used for productive activities) for car travel of 0.03 to 0.3 with a mostly likely (median) value of 0.04, and *q* values (working efficiency time working while travelling relative to time in the workplace) for car travel of 0.32 to 1.02 with a most likely (median) value of 0.93.

Inserting the most likely (median) values for *r*, *p* and *q* from the survey of international values in Wang and Hensher (2015) into equation 3.2 along with the CSA value derived above for MPL of $68.33, and the WTP value for non-work time of $21.52, gives a VBTTS of

$$\$44.72 = (1 - 0.45 - 0.04 \times 0.93) \times \$68.33 + 0.45 \times \$21.52$$

This Hensher equation VBTTS estimate is 65% of the CSA VBTTS.[10]

Choosing the highest values for each of *r*, *p* and *q* from the survey of international values, a lower limit VBTTS estimate is

$$\$20.74 = (1 - 0.57 - 0.3 \times 1.02) \times \$68.33 + 0.57 \times \$21.52$$

Wardman et al. (2015, p. 203) notes that “Given that *VL* is expected to be somewhat less than *MPL*, … then the VBTTS generated by the HE [Hensher equation] is expected to be less than that of the CSA, and possibly considerably so”. They cite studies showing that, for car travel, the ratio of VBTTS from the equation 3.2 form of the Hensher equation to VBTTS from the CSA is 0.87 from a UK study and 0.61 from a Swedish study (Wardman et al. 2015, p. 205). The latter is quite close to the 65% just calculated for median parameter values in the Hensher equation.

3.5.3 WTP approach

Wardman et al. (2013, pp. 15-6) claimed that many commentators have recognised that a WTP estimate by the company or business travellers is a suitable basis for valuing business travel time savings. Not all travel time is unproductive and not all time savings can be converted into productive use to the benefit of the employer. In particular, the digital revolution has increased the potential for using travel time productively (Wardman et al. 2013, p. 15; UK DfT 2015 p. 177; Batley et al. 2019 pp. 606-7).

Ideally, we would like to have

- for forecasting purposes, the employee’s WTP taking into account company travel policies for the behavioural VBTTS, and
- for benefit calculations, the sum of
  - the employer’s WTP value as the measure of $(1 - r - pq) \cdot MPL + MPF$ in the Hensher equation, representing the value increased output from a time saving, plus
  - the employee’s WTP value for the other terms in the Hensher equation $(1 - r) \cdot VW + r \cdot VL$, representing the impact of a time saving on the employee’s utility.

Employer WTP studies are not straightforward due to the difficulty in identifying appropriate people within a company to interview and the much higher cost of data collection compared with employee surveys (Wardman et al. 2015, p. 203).

It cannot be assumed that an employee WTP study will capture only the impact on employees own utility. Some business trip survey respondents may fully mirror their employer’s point of view. Some may respond genuinely seeking to represent the best interests of their employer but may be misguided as to what that is. Knowing their employer will pay any additional costs they incur to save time provided they are within reason, some employees will respond on the basis of their own self-interested preferences — the principal–agent problem. In such cases, with the marginal utility of money coefficient in the logit model utility function undervalued, the WTP value will be inflated. Some may respond as if they themselves were paying the costs resulting in deflated values (Wardman et al. 2013, pp. 58 and 115).

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[10] The parameter values here are for car travel. In Section 7.1, VBTTSs for travel time in bus and train are estimated using equation 3.2 with most likely parameter values for bus and train from Wang and Hensher (2015).

The UK DfT (2015b) study addressed the concern that employees' WTP to save travel time may underestimate what employers are willing to pay by undertaking an additional revealed preference survey and an employers' business stated preference survey. Table 3.2 summarises the business VTTS estimates for travel for the different surveys. The WTP VTTS and CSA VTTS were similar for blue collar employees, who would be expected to have low productivity while travelling. For briefcase travellers, who are more likely to be productive when travelling, WTP values were lower than for the CSA (Batley et al. 2019 pp. 607-8). It was suggested that the relatively low WTP values for self-employed blue-collar employees might be due to a blurring between work and leisure for this occupational type. UK DfT (2015b) did not discuss why the WTP value from the employer survey for brief case employees at £14.05 was well below what employees are willing to pay at £20.43.

The UK DfT (2015b) discussion of the results of the surveys could be described as guarded and ambiguous (see pp. 196 and 198-200) but they come down in favour of use of employee WTP values for the business VTTS.

Table 3.2 Car business VTTS values (GBP/hour)

	Employer survey Briefcase	Employee Survey Briefcase	Employee survey Blue Collar	Self-employed survey Briefcase	Self-employed survey Blue Collar
WTP	14.05	20.43	17.45	13.03	8.55
Wage rate	20.20	22.77	14.57	23.48	13.63
CSA	23.94	26.98	17.27	27.82	16.15

Note: Briefcase travel is defined as "trips made by office-based staff travelling to conduct meetings and similar business activities but not to provide trade services" UK DfT (2015b, p. 75).
Sources: UK DfT (2015a p. 10 and 2015b p. 197).

The national survey VBTTS value of $38.37 is not far below the Hensher equation estimate of $44.72, using median values for the parameters in the Hensher equation, and well above the lower limit Hensher equation estimate using the highest parameter values of $20.74. Hence, the $38.37 WTP value from the survey is within the range of plausibility after taking adjusting the CSA value for savings in business travel time accruing to leisure and working done while travelling.

This report recommends that ATAP adopts the VBTTS from the national survey, because it is well within the plausibility range suggested by the Hensher equation. If the Hensher equation approach were to be adopted instead, it comes with a warning that up-to-date, accurate information about the proportion of on-costs relative to earnings, the proportion of business travel time savings likely to accrue to leisure, and the value of work done while travelling is not available.

3.6 VTTS and trip distance

WTP studies tend to find that the VBTTS increases with trip distance, more so than can be explained by higher proportions of higher-income people travelling longer distances (Wardman et al. 2015). In a strict sense, VBTTS varies with trip *duration* rather than trip *length*. The reasons for the relationship between VBTTS and trip duration are unclear. According to TIC (2014 p. 50), "One explanation could be the 'non-linearity in marginal utility of costs and time' effect: the marginal disutility of costs decreases more quickly than the marginal disutility of time, resulting in higher willingness to trade off time with cost as the trip length increases".

As well as travel time in free-flow and congested conditions, the utility function in the ATAP WTP model included the log of travel time in each traffic condition, activated where total trip time was longer than 30 minutes. Because the log variable is non-linear, the model was able to detect changes in the VTTS with respect to distance. The VTTS values in Table 3.1 have undergone post-model reweighting so they reflect population averages of trips distances rather than the averages for the sample (see ATAP 2024a, section 5.5 for details).

As there were fewer usable observations for longer-distance trips, especially for commuter and business purposes, so as to avoid "slicing the data too thinly, which poses a risk of reducing statistical significance", different VTTS values were provided only for trips less than and greater than 30 minutes (ATAP 2024a, section 6.5).

Weighted VTTS values were only 6% greater for trips over 30 minutes in duration for commuter travel and 3% for business travel compared with trips for up to 30 minutes. For non-work travel, the longer trip VTTS was fractionally below that for the shorter trip. Given the strongly overlapping the confidence intervals for the VTTSs for short and long-distance trips estimated from the survey, it can be concluded that the effect of distance on VTTS was found to be not statistically significant.

For business travel, the UK study estimated VTTSs in 2014 GBP for car trips of £8.21 for trips <20 miles, £15.85 for 20 to 100 miles and £28.62 for >100 miles (UK Dft 2015a, p. 13; Batley et al. 2019, p. 612). They did not report VTTS values for different trip distances for commuter and non-work trips by car.

The NZ study, which excluded business trips, found VTTS increased for commuting from NZ$37.40 for short trips, to NZ$48.60 for medium, then falling to NZ$42.54 for long (Denne et al. 2023, p. 13) without defining short, medium and long.

In 2021, the National Faster Rail Agency asked ATAP to consider a report they commissioned from consultants Economic Connections (2020) *Opportunities to refine and enhance infrastructure project evaluation frameworks*. One the recommendations made was:

> *To overcome benefit under-estimation that may result from the absence of distance-related and longer distance rail-related values of travel time savings, ATAP should commission research, using industry standard stated preference methods, desirably across four modes (air, rail, coach and car), in order to establish distance-based values of travel time savings, for business and other transport users, in the Australian context.*

The national survey has addressed this recommendation for cars but did not find statistically significant differences in WTP VTTS values over different distances.

3.7 Value of reliability (VOR)

The VOR values from the survey are in the expected relativities across trip purposes — the business VOR is greater than the commuter VOR, which is greater than the non-work VOR. However, from a statistical point of view, the commuter and business VOR values are close enough to be considered identical. The non-work VOR value is not much lower than the business and commuter values and the confidence intervals overlap.

For the ATAP WTP pay study the VOR for non-work travel of $35.88 per hour is only 11% below the VOR for commuters of $40.63 and 15% below the VOR for business travel at $42.19 (all indexed to June 2024 prices). Part of the explanation could be that many non-work trips are for purposes with inflexible required arrival times such as appointments with health and other professionals, pick-up times for children from daycare, and commencement times for school classes, university lectures and events. It is possible to schedule many non-work trips outside of congested periods of the day, which results in a reduced VTTS (as discussed in Section 3.3), but inflexibility of arrival times for trips across all three trip purposes could bring the VORs for the three trip purposes closer together. However, the reliability ratio for non-work trips has a lower denominator, leading to a higher ratio despite the similar VORs.

When divided by VTTS, the reliability ratios are similar for commuter and business, at 1.14 and 1.10 respectively, but considerably higher for non-work, at 1.67, due to the much lower VTTS in the denominator of the reliability ratio. Similar results have been observed in the other studies.

> *The mean-variance model produced a value of reliability for non-commuters of $21 per hour, which is 46 percent lower than the value for commuters. Bhat and Sardesai (2006) report a similar finding, i.e., travellers with flexible arrival times placed a lower value on reliability (almost 50 percent lower), compared with travellers with inflexible arrival times. Non-commuters have lower values of reliability (by 46 percent) and values of travel time savings (by about 60 percent) than commuters, resulting in a higher reliability ratio. (Li et al. 2010 p. 399)*

The reliability ratios from the national survey, while within the range of values found in WTP surveys internationally, are significantly above those in UK DfT (2015, p. 13; Batley et al. 2019, p. 613) of 0.33 for commuters, 0.42 for business and 0.35 for non-work and Denne et al. (2023, p. 90) for NZ of 0.69 for commuters and 0.67 for non-work. Batley et at. (2019) noted that the UK values were low by 'received wisdom' and compared with the previous WebTAG value of 0.8. Another survey undertaken as part of the UK DfT study obtained values of 0.43, 0.64 and 0.77 respectively.

Bates et al. (2001, p. 228) suggested that "Values of 1.3 [for the reliability ratio] appear plausible for car travel …." The Australian study by Li et al. (2010, p. 398) estimated a reliability ratio for commuters of 1.43 (a VOR $40.49 divided by a VTTS of $28. 28 in 2008 AUD) and for non-commuters of 1.78 (a VOR of $21.91 divided by a VTTS of $12. 31 in 2008 AUD). The comparison of values from Australian and overseas WTP studies in table 5.5 of ATAP (2024a) also shows many examples of reliability ratios above one.

In conclusion, while the reliability ratios from National survey are on the high side, they are within the bounds of values found in other studies.

Likely size of reliability benefits relative to travel time savings benefits

Prentice (2022) tested the ATAP reliability measurement methodology on a hypothetical road project in Melbourne. Assuming a reliability ratio of 1.0, he concluded that the estimated reliability benefits are substantial and could be up to 50% to 150% for the time savings benefits. Note that this applies to projects in urban areas. In non-urban areas, reliability benefits would be zero or negligible.

The following is a back-of-the-envelope calculation of the potential size of reliability benefits in relation to time savings benefits for the ATAP reliability measurement methodology and reliability ratios.

The total generalised cost for all cars on a network during a given time period is

$$TGC = VTTS \sum q_i t_i + VOR \cdot \gamma \cdot \sum q_i \sigma_i$$

[EQ. 3.1]

where q_i, t_i and σ_i are respectively the number of cars, the time taken to traverse the link and standard deviation of travel time on link *i*. γ is a 'correction factor' from the *approximated route standard deviation* (ARSD) in ATAP (2024b, section 2.5). Reliability for a route can be approximated by σ_r (where the subscript *r* denotes route) is the sum of standard deviations of travel time for the component links multiplied by a correction factor, γ, to adjust for correlations between link travel time variability and the fact that standard deviations are being summed, not variances.

$$\sigma_r \approx \gamma \sum \sigma_i$$

Equation 3.1 assumes that the same γ value can be used for all routes in the network.

From ATAP (2024b), one way of expressing the link model, which estimates standard deviation of travel time along a link given actual travel time, t, and free-flow travel time, t_f, is

$$\sigma = a\left(1 - \frac{t_f}{t}\right)^b t$$

[EQ. 3.2]

where a and b are coefficients that need to be estimated from data. ATAP (2024b, table 2.1) suggests that the value of the b coefficient is around one. Letting $b = 1$, equation 3.2 reduces to

$$\sigma = a(t - t_f)$$

[EQ. 3.3]

Substituting equation 3.3 into equation 3.1, along with $VOR = VTTS \times RR$, where RR is the reliability ratio,

$$TGC = VTTS \sum q_i t_i + VTTS \cdot RR \cdot \gamma \cdot a \cdot \sum q_i(t_i - t_{fi})$$

[EQ. 3.4]

Provided there is no generated or diverted traffic so that the q_is are constant, and there are no changes to free-flow travel times ($\Delta t_{fi} = 0 \ \forall \ i$) such as would occur for a project that only changed link capacities, the benefit from changes in travel time on one or more links (Δt_i), is

$$\Delta TGC = VTTS \sum q_i \cdot \Delta t_i + VTTS \cdot RR \cdot \gamma \cdot a \sum q_i \cdot \Delta t_i$$

[EQ. 3.5]

The ratio of reliability benefits to travel time savings benefits is

$$\frac{VTTS \cdot RR \cdot \gamma \cdot a \sum q_i \cdot \Delta t_i}{VTTS \sum q_i \cdot \Delta t_i} = RR \cdot \gamma \cdot a$$

[EQ. 3.6]

ATAP (2022b) estimated correction factors from Perth data for 22 routes with separate values for inbound and outbound (total of 44 observations) for the AM peak as ranging from 0.27 to 0.79 with median values of 0.41 for arterials and 0.45 for freeways. Values for a for the Perth data were 0.6 for arterials and 0.8 for freeways (ATAP 2024b, table 2.1). Applying the formula equation 3.6 to the range of parameter values and taking weighted averages for trip purposes using the weights given in Section 3.4, suggests that reliability benefits could range from 24% ($\gamma = 0.27$) to 96% ($\gamma = 0.79$) with median estimates of 37% for arterials ($\gamma = 0.41$) and 54% for freeways ($\gamma = 0.45$).

These back-of-the-envelope calculations suggest a smaller size of reliability benefits as a proportion of time savings benefits than the estimates in Prentice (2022) despite the higher reliability ratios, but still indicate that reliability benefits are potentially large in the relation to travel time savings benefits.

3.8 Interaction between the VTTS and VOR

The VTTS values from the survey can be considered to be based on an assumption of perfect reliability (standard deviation of trip time of zero) because unreliability is fully accounted for in the VOR. WTP studies that seek only to obtain VTTS estimates without regard to reliability may yield higher VTTS estimates due to survey respondents building in some correlation between trip time and unreliability based on experience. The literature does not appear to have addressed the question of whether inclusion of reliability in a WTP survey that yields VTTS values, affects the VTTS values.

If the ATAP WTP VTTS values are used in a CBA without estimating reliability benefits, there could be some underestimation of benefits. An option would be to publish default factors for reliability benefits as percentages of travel time benefits, which could be derived using the back-of-the-envelope method in the previous section. However, as the parameter values for the reliability measurement model in ATAP (2024b) are based on very limited evidence, this is not recommended. Instead the ATAP Guidelines could encourage practitioners to estimate reliability benefits where they are likely to occur. The *approximated route standard deviation* (ARSD) methodology from ATAP (2024b, section 2.5) can be used where full implementation of the reliability model in ATAP (2024b) is not possible because of lack of data or model unavailability, for rapid CBAs, and in situations where reliability benefits are thought to be small but not entirely negligible. It should be noted that unreliability (standard deviations of trip time above zero) only occurs in the ATAP (2024b) model in congested conditions. Projects that reduce travel time under free-flow conditions, which would include many non-urban road projects such as realignments, are not considered to improve reliability.

It is recommended that

- **the guidelines specify the circumstances under which reliability benefits may apply and do not apply**
- **ATAP adopts the reliability ratios from the WTP survey for all three trip purposes**
- **reliability benefits be treated as a sensitivity test or a non-core benefit (as with wider economic benefits) as a temporary measure until such time as more experience has been gained in implementing the reliability measurement approach in ATAP (2024b).**

4. Allowing for crash exposure

4.1 Introduction

The safety information presented to survey respondents in the national survey was expressed as numbers of crashes per year along the route of the trip for each of the five crash severity levels. If modelling is undertaken with numbers of crashes as the independent variable for safety, the resulting WTP value represents the WTP to reduce the number of crashes for the particular severity level per trip by one per year. This was the case for the model results presented in the Stage 2 report (ATAP 2018) and also for previous studies that applied the stated choice methodology to estimate WTP for safety (Rizzi and Ortúzar 2003, 2006a and b; Hensher et al. 2009). However, a WTP value to reduce by one per annum the average number of crashes along the route of a trip needs to be converted to a WTP value for a single crash, which can be used in cost–benefit analyses of road transport initiatives to value the change in numbers of crashes. This conversion requires data on the annual level of crash exposure, which is the number of opportunities for a crash given by the annual number of vehicles making the trip per.

The project team prepared a working paper (ATAP 2022a) that reviewed the relevant literature and proposed a way forward. The University of Leeds, Institute for Transport Studies was engaged to review the working paper. They agreed with the paper's recommended methodology. This chapter discusses and explains the methodology adopted. It includes material from the working paper and a technical note from the University of Leeds reviewers.

4.2 Desired endpoint

For valuing changes in risk of death in cost–benefit analyses (CBAs), the expected value of the number of lives saved is multiplied by the value of statistical life (VSL). Values of statistical life are utilised in economic evaluation of all types of scenarios that involve changes in the risk of death. These scenarios include health, natural disasters and defence as well as transport.

The concept of VSL expresses how much people are willing to pay for small reductions in the risk of premature death while engaged in an activity that involves risk. The VSL is the WTP "for improvements in safety (that is, reductions in risks) that, in the aggregate, reduce the expected number of fatalities by one" (US DOT 2021, p. 1). VSL is obtained by dividing the WTP for a change in probability of premature death by the change in the probability of premature death, that is

$$VSL = \frac{WTP\ for\ a\ change\ in\ probability\ of\ premature\ death}{the\ change\ in\ probability\ of\ premature\ death}$$

[EQ. 4.1]

It is important to divide by the change in probability associated with the WTP value because it allows the VSL to be expressed in a common unit of one statistical life. For example, a WTP of $1000 for a 0.001% probability change is equivalent to a WTP of $2000 for a 0.002% probability change. Both imply a VSL of $1,000,000.

Not all crash risks for which people are willing to pay to reduce concern fatalities. People are willing to pay to reduce the risk of a crash that will cause them an injury or just damage to their vehicle. The term 'value of risk reduction' (VRR) is used to encompass the full range of crash risks. VRR is conceptually identical to VSL but extends to all risk types. It is used in the road safety context where a crash is the unit of account rather than a life lost. A fatal crash in Australia results in 1.1 deaths on average, while injury and property damage only crashes involve no deaths. The WTP values desired for the ATAP Guidelines for use in CBAs are for a *crash* of a given severity category, not a single fatality or injury. A VRR can apply to the fatal crash category where the average number of fatalities may differ from one, to injury crashes, and to Property Damage Only (PDO) crashes.

4.3 Allowing for crash exposure in theory

The traditional stated preference approaches to estimating the VSL — contingent valuation, standard gamble and the chain method — require people to comprehend risks expressed as tiny probabilities and involve trading off risk for money to come up with a monetary value for risk. These approaches have been heavily criticised by experts in human behaviour and econometrics, and researchers have found evidence that people are unable to understand differences in tiny probabilities. A particular problem is insensitivity of WTP to the scale of change in risk, for example, the WTP for a change in exposure of 1/1000 should be 10 times larger than the WTP for a change of 1/10,000 (Andersson and Svensson 2014; Andersson and Treich 2011; Robinson and Hammitt 2016).

In the early 2000s, Rizzi and Ortúzar (2003) pioneered a new stated preference approach to estimate WTP for improvements in road safety. They undertook surveys in which respondents were asked to make hypothetical choices between alternative routes trading off toll costs, travel time and the number of fatal crashes per year along a route. Because it avoids the need for people to understand small probability differences, Rizzi and Ortúzar (2006a and b) argued that their Stated Choice (SC) approach is superior to the traditional approaches to estimating the VSL. The choices people make in a SC survey mimic the actual choices people have to make with a high degree of realism. Furthermore, the choices can be set to vary according to a statistical design aimed at maximising the precision of the estimates (Hensher et al. 2009).

The SC surveys in Rizzi and Ortúzar (2006a and b) and Hensher et al. (2009) asked respondents to make choices between alternative routes with different travel costs, time and safety attributes. The level of safety for a route was specified in terms of numbers of crashes per annum. This was the approach to safety used in the ATAP SC survey.

The simplest functional form to use in a logit model fitted to SC survey data is to express utility (*V*) from a trip as linear function of trip attributes. If the methodologies of the previous studies were followed, the utility function for the national survey, which included reliability, would be:

$$V = \beta_c \times trip\ cost + \beta_t \times trip\ time + \beta_r \times variability\ of\ trip\ time + \sum_{i=1}^{5} \beta_{ni} \times number\ of\ crashes\ per\ annum\ of\ severity\ i$$

[EQ. 4.2]

where trip cost is vehicle operating costs plus any tolls, and variability of trip time is measured as the standard deviation of trip time.

As discussed in Section 2.4, each coefficient is the marginal utility from the relevant attribute. Hence,

$$MRS_{c,ni} = \frac{MU_{ni}}{MU_c} = \frac{\partial V}{\partial ni} \Big/ \frac{\partial V}{\partial c} = \frac{\beta_{ni}}{\beta_c}$$

is the marginal WTP by the average individual surveyed to reduce by one the number of crashes per year of severity *i* on the route travelled for a trip. Rizzi and Ortúzar (2006a and b) and Hensher et al. (2009) called this the Subjective Value of Crash Reductions (SVCR). They described the SVCR as the amount of money that an individual would have to forgo to leave them just as well off, after the safety improvement that reduces crashes by one per year, as before the safety improvement.

By definition, the probability of a crash of a given severity level is given by:

$$p = \frac{f}{N}$$

[EQ. 4.3]

where *f* is the number of crashes per annum along the route of a trip for the particular severity level and *N* is the level of exposure, which is the number of trips that take place each year along the route. Each time a car makes a trip on a route with *f* crashes a year, the occupants are exposed to a risk of a crash. If there are *N* trips a year, then there are *N* instances when car occupants are exposed to the risk. It does not matter that many of the instances will be the same vehicle with the same occupants, who make the same trip multiple times during a year. Thus, *N* refers to the total number of trips made on a route during a year and measures crash exposure. The value of *N* for a route can be estimated from the average annual daily traffic (AADT) level times 365 days in a year.

Equation 4.3 can be restated in terms of *f* as

$$f = p \cdot N$$

[EQ. 4.4]

Omitting the time and reliability terms and reducing the number severity categories to one in equation 4.2 to simplify, utility as a function of trips cost and the annual frequency of crashes along the route is

$$V = \beta_c \cdot c + \beta_f \cdot f$$

[EQ. 4.5]

From equation 4.5, the WTP for a unit reduction in crash frequency or the SVCR is

$$SVCR = WTP_f = \frac{\frac{\partial V}{\partial f}}{\frac{\partial V}{\partial c}} = \frac{\beta_f}{\beta_c}$$

[EQ. 4.6]

Note that, the frequency of crashes is expressed per annum and the cost is expressed per trip, so the SVCR is expressed in dollars per trip to reduce the frequency of crashes by one per annum.

Substituting equation 4.4 into equation 4.5, utility can equivalently be defined as a function of the probability of a crash.

$$V = \beta_c \cdot c + \beta_f \cdot p \cdot N$$

[EQ. 4.7]

Then, the WTP for a unit reduction in probability of a crash, which is the VRR, can be obtained.

$$VRR = WTP_p = \frac{\frac{\partial V}{\partial p}}{\frac{\partial V}{\partial c}} = \frac{\beta_f \cdot N}{\beta_c}$$

[EQ. 4.8]

From equations 4.6 and 4.8, the relationship between the SVCR and VRR is

$$VRR = WTP_p = WTP_f \cdot N = SVCR \cdot N$$

[EQ. 4.9]

Hence, the estimated SVCR needs to be multiplied by exposure, *N*, to convert it to a VRR estimate.[11] Intuitively, if, each time they travelled on a route, people in each vehicle were willing to pay $1 to reduce the number of crashes on that route by one per year, with 5 million trips made in a year, the total WTP to avoid one crash during the year would be $5 million.

4.4 Allowing for crash exposure in practice

Rizzi and Ortúzar (2006) applied the approach in equation 4.9, converting their SVCRs for fatal crashes to VRRs by multiplying by the traffic flow in vehicles per year (effectively the total number of trips) for each of the two routes considered.

Le et al. (2011) applied the stated choice (SC) approach in Singapore. They estimated SVCRs of SGP$0.46 for a fatality and SGP$0.35 for a serious injury. They acknowledged that VRRs should be obtained by weighting each survey response by the weighted average traffic volume along the route of their nominated trip but found it impractical to implement (Le et al. 2011, p. 12). From the Singapore Strategic Transport Model, they obtained the weighted average weekday traffic levels for all links in the network, using link lengths as weights, as 13,582 vehicles per weekday. This was multiplied by the model's annual expansion factor of 300 to give an annual weekday traffic volume of 4,074,661. This was multiplied by the SVCRs to obtain a value of an avoided fatality of SGP$1,874,000 = SGP$0.46 × 4,074,661 and for an avoided serious injury of SGP$1,426,000 = SGP$0.35 × 4,074,661. A Singapore dollar is currently worth around AUD$1.1.

An important difference between Rizzi and Ortúzar (2003, 2006a and b) and the national survey is that the former surveyed only two routes and survey responses for each route were analysed separately. The two routes were Route 68 between Santiago and Viña del Mar/Valparaíso, 120km to the north-west, and Route 5 between Santiago and Rancagua, 100km to the south. The time of day was identical for each route so traffic levels would not vary between survey responses. Within the survey responses for each route, the crash exposures were therefore identical. The ATAP national survey sampled drivers and passengers from all states and territories and urban and rural trips so there was a very wide range of different exposure levels. In the case of Le et al. (2011), use of a network-wide average traffic volume for the conversion might be justified on the grounds that, because Singapore is a small and densely populated island, there would not be the large range of traffic levels on arterial roads compared with Australia.

The RTA (2008)/Hensher et al. (2009) study faced the same problem as the national survey with the survey covering multiple routes with a wide range of exposure levels. They used a different methodology to convert from SVCR to VRR, which can be summarised in the following formula,

$$VRR = SVCR \times \frac{N}{f}$$

[EQ. 4.10]

Trips in the survey had different origins and destinations and lengths and the data needed to obtain an average exposure for the trips in the survey responses was not available. They therefore used data for the whole NSW road network with separate values and calculations for the urban and non-urban parts of the network. *N* and *f* here refer to total number of trips and total number of crashes for the entire region per

11 The above derivation of the relationship between SVCR and VRR was provided by the Institute for Transport Studies, University of Leeds.

annum, the two regions being urban and non-urban NSW. The formula for estimating VRR with the derivation from equation 4.10 is as follows.

$$VRR = SVCR \times \frac{N}{f} = \frac{WTP\ per\ trip\ per\ year\ (SVCR)}{average\ trip\ kms} \times \frac{N \times average\ trip\ kms}{number\ of\ crashes\ per\ year}$$
$$= \frac{WTP\ per\ trip\ per\ year\ (SVCR)}{average\ trip\ kms} \times \frac{AAVKM \times 365}{number\ of\ crashes\ per\ year}$$

where AAVKM is average annual daily vehicle kilometres (RTA 2008, p. 48). Division by the number of crashes was necessary because the statewide exposure rates would have led to ridiculously high VRRs.

The recent New Zealand WTP survey (Denne et al. 2023) sought to avoid altogether the problem of survey respondents needing to understand small probabilities or differences in crash exposures by having respondents make hypothetical choices between increases in personal costs per year (for example, paying an additional zero, $100 or $200 per year in income taxes or rates) in exchange for road upgrades spread around the country that would reduce numbers of deaths or injuries per annum for the whole country (for example, from 250 deaths per year to 200 deaths per year).

Modelling the data gave estimates of WTP per death or injury avoided (event) per respondent shown in Table 4.1. These had to be aggregated to national WTP values by multiplying by either by the national adult population or the number of households depending on whether respondents were assumed to be stating their WTP out of individual or household budgets. The national WTP values using population were around twice those using the number of households. Due to lack of information to determine which end of the range was more likely, the New Zealand Government decided to adopt the halfway point of NZ$12.5 million per fatality as the value of statistical life (Te Manatū Waka Ministry of Transport 2023, p. 7).

Table 4.1 Safety results from New Zealand WTP survey

	WTP per event (NZ$/respondent)	Minimum national aggregate value (NZ$)	Maximum national aggregate value (NZ$)
Death	$4.3	$8.1 million	$16.9 million
Serious injury	$0.225	$429,458	$890,681
Minor injury	$0.023	$44,218	$91,707

Source: Denne et al. 2023, p. 13.

The methodology begs the question of how such a survey would fare in Australia with more than five times the population of New Zealand. Would the estimated WTP values per event per respondent be approximately five times smaller in order to guarantee plausible national aggregate WTP values? The need to multiply by either the adult population or number of households for the whole country and the wide differences in results from the two alternatives shows that New Zealand method does not sidestep the problem of converting model results to national WTP values per crash. Furthermore, while the intention of the survey is for respondents to make a ‘social choice’, survey respondents could adopt a purely self-interested point of view by considering risks to themselves under the alternative options. Survey respondents would then be considering changes in small probabilities.

4.5 Method in the national survey

The working paper ATAP (2022a) discussed options for converting SVCRs from modelling of survey results to VRRs. All the options required exposure levels to be estimated for all survey responses.

4.5.1 Exposure levels

Traffic levels vary along the roads travelled upon when making a trip. The exposure during a trip is the distance-weighted average AADT (average annual daily traffic) along the route taken times 365 days in a year.

For a trip *t* for a route consisting of *n* segments *i*, each k_i kilometres in length with $AADT_i$,

- distance for trip *t* is

$$Trip\ distance\ d_t = \sum_{i=1}^{n} k_i$$

- the annual exposure for trip *t* in trip numbers is

$$N_t = \frac{365 \sum_{i=1}^{n} k_i AADT_i}{\sum_{i=1}^{n} k_i}$$

The optimal route (shortest time) between the centroids of the origin and destination suburbs was obtained for the trip in each survey response from Google Maps. Traffic count data was obtained from state and territory road agencies, which was standardised and indexed by year. The traffic counts were for the particular locations on the road network where traffic counters were placed. The counts were ‘snapped’ to road segments along individual routes. Further details on the methodology are given in ATAP (2024a) section 3.4.2.

The survey questionnaire made no mention of exposure levels. However, as the attributes of the trip in each survey response were ‘pivoted’ around the attributes of a recent trip described by the respondent, it was reasonable to assume survey respondents were aware of the traffic levels and hence crash exposure levels for the trip they were considering.

There are two alternative assumptions about survey respondents’ perceptions of crash exposure and these affect the approach to modelling the response data. It can be assumed that they have no perception of variations of exposure levels across alternative trips or that they have full perception or some combination of these.

4.5.2 Assumption that survey respondents do not perceive variations in exposure

Under this approach, survey respondents are assumed to have focused solely on numbers of crashes in the survey questions. They have a vague understanding of crash exposure, considering it to be around the average level for all survey responses, but have no perception of how the level of crash exposure for the particular trip in their questionnaire differs from the average. Modelling would be undertaken using numbers of crashes as the explanatory variable for safety as in equation 4.2. The coefficient estimate would be a subjective value of crash risk reductions (SVCR). It would be multiplied by the simple average of crash exposures for all survey responses to obtain the VRR as in equation 4.9.

4.5.3 Assumption that survey respondents perceive variations in exposure

A different approach to modelling is required if survey respondents are assumed to perceive differences in exposure between trips. For example, say that two different survey respondents were asked to choose between routes with 2 and 4 fatal crashes per annum. The route considered by one respondent had an average annual daily traffic level (AADT) of 20,000 vehicles per day and the route considered by the other respondent had 10,000 vehicles per day. The former would be considering a difference in crash probabilities of $\frac{4-2}{20{,}000\times365} = 2.74 \times 10^{-7}$ and the latter, a difference of $\frac{4-2}{10{,}000\times365} = 5.48 \times 10^{-7}$, which is twice as large. Therefore, with different exposure rates for different survey responses, the conversion has to occur at the individual trip level prior to modelling.

For each survey response, each number of crashes has to be divided by the exposure for the trip to convert it to a crash probability, as shown in equation 4.10.

$$V = \beta_c \cdot c + \beta_p \cdot p = \beta_c \cdot c + \beta_p \cdot \frac{f}{N}$$

[EQ. 4.10]

The VRR, $\frac{\partial V}{\partial p} / \frac{\partial V}{\partial c}$, as defined in equation 4.8, can be obtained from equation 4.10 as $\frac{\beta_p}{\beta_c}$ with no post-modelling conversion required. This approach was recommended in advice from the University of Leeds, Institute for Transport Studies. Rizzi and Ortúzar (2003) applied it, although with a single crash exposure, for all survey responses on the same route.

4.6 Effect on modelling

Model runs were undertaken with both the number of crashes and the probability of a crash as variables to test whether one or both was affecting WTP. Inclusion of number of crashes as a variable explained so much of respondents' choices that the crash probability variable ceased to be statistically significant for all but fatal crashes. For fatal crashes, both variables were significant. The non-significant crash probability variable was dropped from the model for the four non-fatal crash severity categories.

The WTP for non-fatal crashes was calculated by multiplying the coefficient estimate (the SVCR) by AADT × 365 averaged across all survey responses. For fatal crashes the WTP estimate was the sum of SVCR times average AADT × 365 for all survey responses plus the coefficient for probability of a fatal crash. For crash severity *i*,

$$\boldsymbol{VRR_i = \frac{\beta_{ni}}{\beta_c} \times average\ crash\ exposure + \frac{\beta_{pi}}{\beta_c}}$$ for fatal crashes, and

$$\boldsymbol{VRR_i = \frac{\beta_{ni}}{\beta_c} \times average\ crash\ exposure}$$ for crashes of other severities.

Douglas (2021 and 2022) criticised the Rizzi and Ortuzar and RTA/Hensher surveys for not including descriptions of crash probabilities or vehicle flows in questionnaires, and the same criticism applies to the national survey. However, given the difficulty people have in understanding small probabilities, it is doubtful that this would have any made any difference. As the Rizzi and Ortuzar survey was carried out on regular users and the route, and the RTA/Hensher and national surveys had questions 'pivoted' around actual trips made by survey respondents, the respondents would have a good idea of the amount of traffic on the routes concerned. Adding a description to the questionnaire could have been confusing if it differed from the respondent's actual experience of the route.

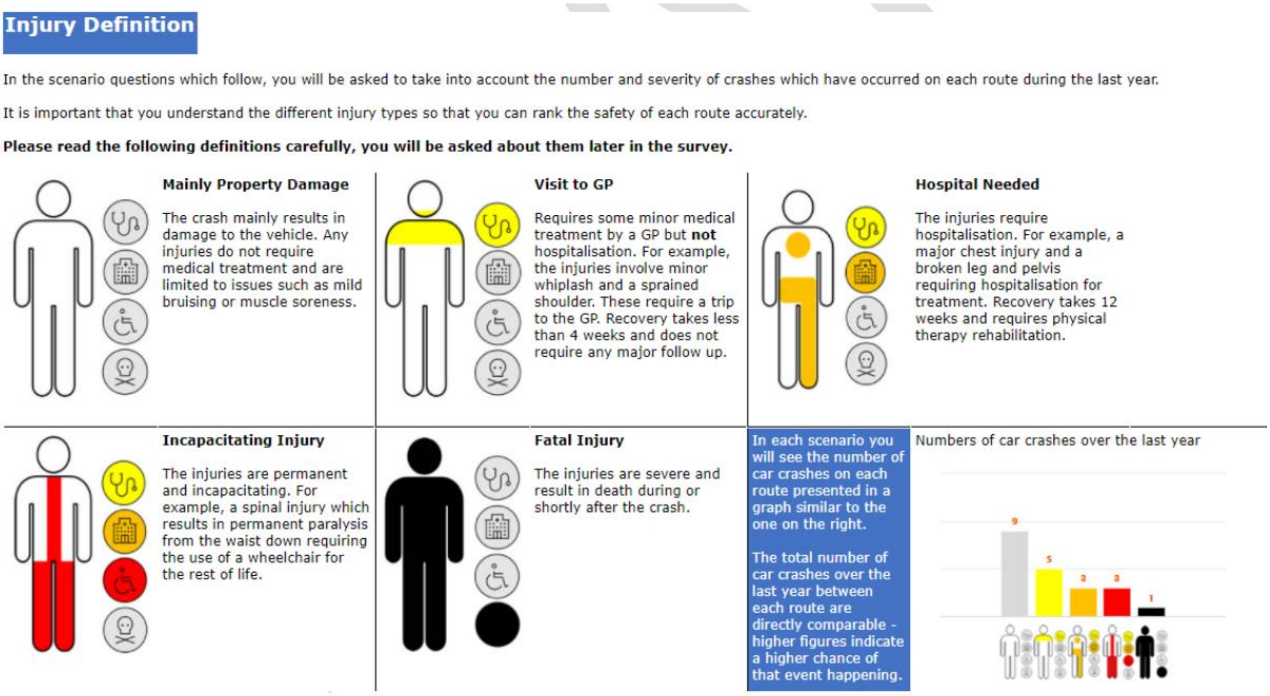
The statistical significance of the probability variable for fatal crashes suggests that, at least some survey respondents give crash exposure some consideration with regard to the most severe category of crashes. For the other crash severities and the component of WTP for fatal crashes explained by crash numbers, it can only be hoped that the average crash exposure for the whole example calculated from traffic count data broadly approximates the average level of exposure that survey respondents had in mind.

5. Injury cost rescaling

5.1 Introduction

The survey questionnaire defined five crash severity categories: (1) fatal injury, (2) incapacitating injury, (3) hospital needed, (4) visit to GP and (5) mainly property damage. These have been termed throughout the present report as fatal, incapacitating injury, major injury, minor injury and property damage only (PDO). Each category was described to survey respondents prior to answering the choice questions, and quizzes were included in the pilot surveys to gauge how well respondent understood them. Figure 5.1 is a screenshot of the injury descriptions shown to survey respondents in the questionnaire.

Figure 5.1 Screenshot of crash severity information in survey questionnaire



Source: Deloitte Access Economics

The three injury categories were described in the questionnaire with an example:

- Incapacitating: An injury that causes permanent damage where normal functioning is permanently impaired, for example, a spinal injury, which results in permanent paralysis from the waist down requiring the use of a wheelchair for the rest of life.
- Major: An injury that requires hospitalisation. For example, a major chest injury and broken leg and pelvis requiring hospitalisation for treatment. Recovery takes 12 weeks and requires physical therapy rehabilitation.
- Minor: An injury that requires medical treatment but does not require hospitalisation. For example, the injuries involve minor whiplash and a sprained shoulder. These require a trip to the GP. Recovery takes less than four weeks and does not require any major follow up. (ATAP 2024a p. 95)

The survey, therefore provides WTP values to avoid an injury crash for three points along a scale of injury severity levels from ranging from minor cuts to an incapacitating spinal injury, as well for fatal and property damage only crashes, at either end of the scale. It was essential that the survey questions be very precise about the nature of injuries. If survey respondents were simply told numbers of hospitalised and minor injury crashes, it would be left to each one to make their own assumption about where the crashes might lie along the scale. The hospitalised injury category covers an enormous range of severities from a single night in hospital to life-long quadriplegia.

Crash data from jurisdictions has two injury classifications: major/serious/hospitalised injury and minor/non-hospitalised injury, dividing the scale of injury severity levels into two parts depending on whether the injury results in a hospital stay.

- The minor injury WTP value from the survey is for a severity point somewhere within the minor injury range of severities in crash databases.
- The major and incapacitating injury WTPs values from the survey are for two severity points somewhere in the major injury range of severities in crash databases. The major injury WTP is for a severity point in the low to middle part of the range and the incapacitating injury WTP in the upper part.

To estimate savings in costs of crashes in CBAs, we require

- a single weighted average WTP value for the minor injury range of severities in databases, and
- a single weighted average WTP value for the major injury range of severities in databases.

The methodology to obtain this was:

- Using a detailed scale for measuring injury severity, obtain the value on the scale for each of the three injuries in the survey and for fatal crashes.
- Plot the four points on a chart with the severity measure along the horizontal axis and WTP on the vertical axis. Then, interpolating between the points, obtain a functional relationship between WTP and the severity measure. This enables a unique WTP value to be specified for each level of the detailed severity scale from no injury up to a fatality.
- Obtain from jurisdictions the number of injuries from road crashes per year for each detailed level of the severity scale.
- Compute the weighted average WTP for the minor and major injury ranges of the scale.

Such a methodology has not been implemented for other WTP surveys. Without it, there is a risk that the a WTP value from the survey for an injury with specified characteristics will not be a good approximation for the weighted average for the category.

The RTA (2008)/Hensher et al. (2009) study similarly had three injury categories and WTP estimates from the study for all categories, indexed to 2013 dollars are reported in ATAP (2016, Part PV2, p. 25). It was not made transparent how these were converted to the WTP values for two injury categories, ‘serious injury’ and ‘other injury’ for the different jurisdictions in subsequent tables in ATAP (2016). It appears that highest and lowest of the three categories from the RTA (2008)/Hensher et al. (2009) were taken for the ‘serious injury’ and ‘other injury’ values respectively with indexation and other adjustments.

5.2 Indexed values and relativities

Table 5.1 lists the original values from ATAP (2024a) as shown previously in Table 2.3 from modelling of survey data in December 2020 prices, and the values with confidence intervals indexed to June 2024 prices. The ‘ratios’ column shows ratios to the fatal crash cost. Indexation of the WTP from the survey (multiplying by 1.122012) takes the WTP for a fatal crash to just over $4 million.

Table 5.1 Safety values from survey ($/crash)

	Dec 2021 prices	June 2024 prices	Ratios	Confidence interval June 2024 prices	
				lower	upper
Fatal	3,663,910	4,192,504	1.000	3,566,153	4,818,843
Incapacitating injury	1,454,850	1,664,742	0.397	1,420,108	1,909,387
Major injury	500,010	572,147	0.136	378,078	766,215
Minor injury	24,660	28,218	0.007	10,092	46,343
Property damage only	16,000	18,308	0.004	11,111	25,517

The 'ratios' column shows the value for each severity category divided the value for the fatal severity category.

5.3 Approach taken

ATAP (2024a) provided the severity levels for each injury class using four scales.

- Disability weight. Disability weights are defined by the World Health Organisation as "a weight factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (equivalent to death)" ATAP (2024a p. 64).
- International classification of diseases injury severity scale (ICISS). It measures the threat to life. It is the ratio of the number of patients with that injury code who died to the total number of patients diagnosed with that code. Each patient's ICISS score (survival probability) is the product of the probabilities of surviving each of their injuries individually
- Injury severity score (ISS). For the ISS, the body is divided into six regions: head and neck, face, thorax, abdomen, extremities (including pelvis), and external. Each injury on the body is assigned an abbreviated injury scale (AIS) score (1 to 5) and only the highest score in each region is used. The ISS is the sum of squares of the highest three AIS scores. Untreatable injuries that will result in death are automatically given the maximum score of 75 = 25 + 25 + 25. A more detailed explanation is in ATAP (2024, Appendix A.5).
- New injury severity score (NISS). The NISS is calculated in the same way as the ISS except that the squares of AIS scores are summed for the three most severe injuries regardless of the body region injured.

Table 5.2, reproduced from ATAP (2024a) shows the descriptions and severity measures for the five categories in the survey.

Table 5.2 Injury severity levels for crash categories in survey

Severity category with description	Disability weight, ICISS and ISS
Mainly Property Damage The crash mainly results in damage to the vehicle with any injuries not requiring medical assistance of any kind. *General description for survey:* The crash mainly results in damage to the vehicle. Any injuries do not require medical treatment and are	*Estimated disability weight:* 0 *Estimated ICISS:* 1 *Estimated ISS/NISS:* 0

Severity category with description	Disability weight, ICISS and ISS
limited to issues such as mild bruising or muscle soreness.	
Minor injury An injury that requires medical treatment but does not require hospitalisation. Examples include minor whiplash, minor cuts, or bumps. *General description for survey:* Requires some minor medical treatment by a GP but not hospitalisation. For example, the injuries involve minor whiplash and a sprained shoulder. These require a trip to the GP. Recovery takes less than 4 weeks and does not require any major follow up.	*Estimated disability weight:* Neck pain: acute, mild = 0.04 *Estimated ICISS* Injury of muscle and tendon at neck level = 1 *Estimated ISS/NISS* Skin/subcutaneous/muscle abrasion of neck = 1
Major injury An injury that requires hospitalisation. Hospitalisation can include day or overnight stay. Follow up care could also be required and may take the form of out of hospital treatments such as ongoing psychological support. Examples include major bleeding, major broken bones and ongoing psychological distress. *General description for survey:* The injuries require hospitalisation. For example, a major chest injury and a broken leg and pelvis requiring hospitalisation for treatment. Recovery takes 12 weeks and requires physical therapy rehabilitation.	*Estimated disability weight:* Fracture of patella, tibia or fibula, or ankle: short term, with or without treatment + Fracture of pelvis: short term + Severe chest injury: long term, with or without treatment = 0.0807+ 0.39 + 0.056 = 0.5267 *Estimated ICISS* Other fracture of shaft of tibia * Fracture of pelvis, part unspecified * Crushed chest = 0.9906* 0.8859 * 0.875 = 0.7679 *Estimated ISS* Serious Tibia fracture NFS + laceration NFS of thorax = $2^2 + 1^2$ = 5 *Estimated NISS* Tibia fracture NFS + pelvic ring fracture + laceration NFS of thorax = $2^2 + 2^2 + 1^2$ = 9
Incapacitating Injury An injury that causes permanent damage where normal functioning is permanently impaired. Examples include permanent brain injury or permanent paralysis. *General description for survey:* The injuries are permanent and incapacitating. For example, a spinal injury, which results in permanent paralysis from the waist down requiring the use of a wheelchair for the rest of life.	*Estimated disability weight:* Spinal cord lesion at neck: untreated = 0.673 *Estimated ICISS* Multiple fractures of cervical spine = 0.8592 *Estimated ISS/NISS* Complete spinal cord injury of the cervical spine= 5^2 = 25
Fatal Injury Death within 30 days of crash *General description for survey:*	*Estimated disability weight:* 1 *Estimated ICISS:* 0 *Estimated ISS/NISS:* 75

Severity category with description	Disability weight, ICISS and ISS
The injuries are severe and result in death during or shortly after the crash.	

Source: ATAP (2024a) pp. 113-115.

The project team asked jurisdictions whether they could provide data on numbers of injuries by severity level and under which measures. Three jurisdictions, NSW, Victoria and Western Australia, were able to provide data against ISS and NISS measures.[12]

Civil and Schwab (1989) showed that early calculation of the ISS (within 24 hours), after a complete and thorough physical examination, had an accuracy for predicting length of stay in hospital of 95%. Samin and Civil (1999) argued and used data to demonstrate that the NISS is superior to the ISS as a predictor of length of hospital stay.

Data on numbers of persons injured in road crashes and hospitalised, by ISS and NISS, was requested and supplied for five years 2016 to 2020, the same five-year period used by in ANU (2022) to average crash data (used in Chapter 6). The reason for averaging over a five-year period was to smooth out random fluctuations in the data.

No data was available for non-hospitalised injuries so it was not possible to undertake any rescaling for the minor injury category. **There is no choice but to assume that the minor injury WTP value applies to all minor/non-hospitalised injury crashes.**

The WA data could not be used because it included fatalities. Deaths can occur at scores well below 75. The NSW and Victorian data includes only people who survived past the cut-off point that defines a fatal crash of death within 30 days of the crash.

Table 5.3 summarises the data for the five-year averages. The differences in total numbers of injuries between the two jurisdictions are mainly a reflection of population sizes. The ratio of NSW to Victorian population sizes is of 55:45. The distributions across scores between the jurisdictions may be affected by differences in the way the scoring systems are applied. The distribution across injury scores is highly skewed with the great majority of injuries at the low end of the ISS and NISS scales.

[12] This analysis could not have been completed without the assistance of the jurisdictions of New South Wales, Western Australia, and Victoria. The author thanks these jurisdictions for their assistance, in particular:

- Susan Fletcher and Emma Shearer from Transport for NSW
- Kirsty Kirman, Joanne Penaranda and Sarah Newett from the Road Safety Commission of Western Australia
- Mishra Suryaprakash, Renee Schuster and David Young from the Transport Accident Commission Victoria, and
- Michael Nieuwesteeg and Jess Olivera from the Austroads Road Safety and Design Program.

Table 5.3 Overview of ISS and NISS data supplied: annual averages for five years 2016 to 2020

	ISS			NISS		
	NSW	VIC	Combined	NSW	VIC	Combined
Total injuries	55,279	40,094	95,373	55,279	40,081	95,360
% of total injuries	58%	42%	100%	58%	42%	100%
Distribution of injuries by score						
0-4	54%	69%	60%	48%	58%	52%
5-9	30%	17%	24%	29%	17%	24%
10-19	11%	10%	11%	16%	16%	16%
20-74	5%	4%	5%	7%	8%	7%
75	0.1%	0.0%	0.1%	0.3%	0.5%	0.4%
Summary statistics						
Median score	4	4	4	5	6	5
Weighted average score	6.2	5.0	5.7	7.5	7.0	7.3

Table 5.4 shows the ISS, NISS and WTP values (original, not indexed) for all five severity levels in the survey with the slopes and intercepts for straight lines connecting each adjacent pair. Since the focus is on injury crashes and the slopes of the lines connecting the PDO and minor injury categories are quite different from the other slopes, the PDO data points were ignored.

Table 5.4 Relationships between ISS, NISS and WTP (December 2021 $, not indexed)

	ISS	NISS	WTP ($m)	Connecting lines			
Property damage only	0	0	0.016	ISS slope	ISS intercept	NISS slope	NISS intercept
Minor injury	1	1	0.02466	0.0087	0.0160	0.0087	0.0160
Major injury	5	9	0.50001	0.1188	–0.0942	0.0594	–0.0348
Incapacitating injury	25	25	1.45485	0.0477	0.2613	0.0597	–0.0371
Fatal	75	75	3.66391	0.0442	0.3503	0.0442	0.3503

Figures 5.2 and 5.3 show plots of WTP values against scores for the injury and fatality categories with the connecting straight lines will slopes and intercepts shown in Table 5.4

Figure 5.2 Plot of WTP against ISS with connecting straight lines

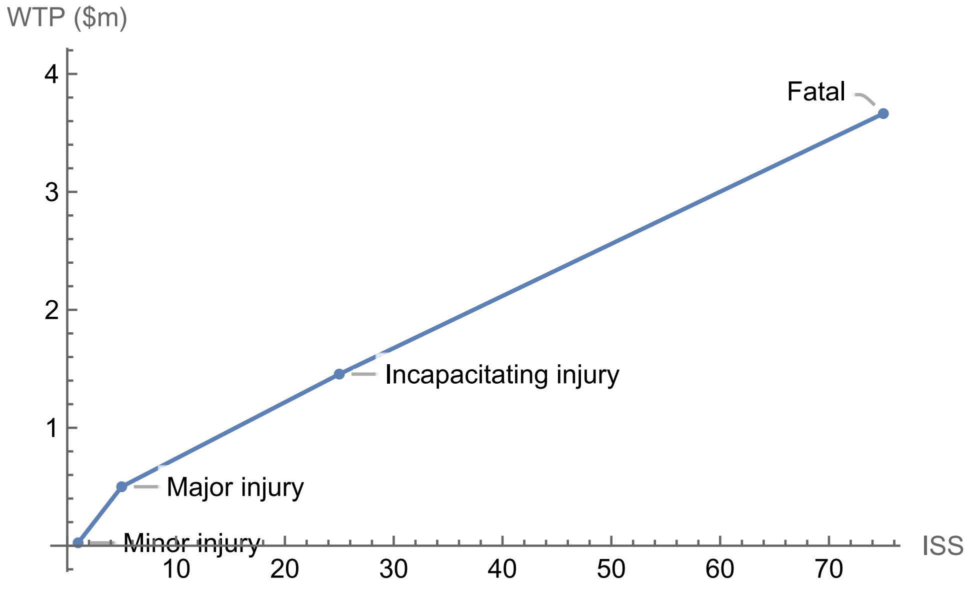
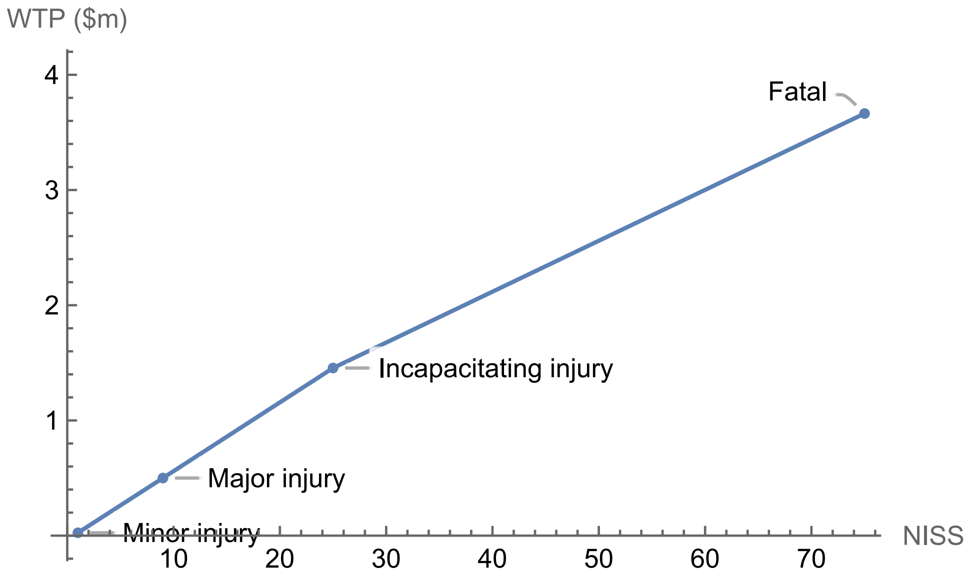


Figure 5.3 Plot of WTP against NISS with connecting straight lines



The methodology adopted was to

- Estimate a WTP value for each individual ISS and NISS value (75 values for each) by interpolating between the four values from the survey using the connecting straight lines with slopes and intercepts shown in Table 5.4, and then
- Take the weighted average WTP for all major/hospitalised/serious injuries using numbers of injuries for each severity score as the weights.

To illustrate the interpolation method, the WTP value in for an ISS of 4 would be 0.1188 × 4 – 0.0942 = $0.381 million, interpolating between the $0.02466 million and $0.50001 million WTP values from the survey for minor and major injury crashes respectively. The WTP value for an NISS of 15 would be 0.0597 × 15 – 0.0371 = $0.858 million, interpolating between the $0.50001 million and $1.45484 million WTP values from the survey for major and incapacitating injury crashes respectively.

Injuries with zero scores are part of the hospitalised injury category and so were included. They were assigned the WTP value for a property damage only crash.

5.4 Results and recommendation

Table 5.5 shows the weighted average WTP values for each of the two jurisdictions and for both combined, as well the ratios of these to the WTP estimate for major injuries of $500,010. There is more variation between the jurisdictions for the ISS than the NISS. The combined ISS weighted average WTP value and all of the NISS WTP values indicated that the weighted average WTP value for hospitalised injuries is around 80% of the WTP estimate for major injuries. It is noted that NISS is considered the superior measure.

Table 5.5 Weighted average WTP values for hospitalised injuries (December 2021 $, not indexed)

		NSW	VIC	Combined
ISS	Weighted average WTP	$459,138	$363,913	$419,106
	Ratio to $500,010	0.92	0.73	0.84
NISS	Weighted average WTP	$406,107	$384,050	$396,836
	Ratio to $500,010	0.81	0.77	0.79

Note: $500,010 is the estimated WTP value for the major injury category before indexation.

It is recommended that the WTP estimate for the major injury category adjusted by a scaling factor of 0.8 be taken as representative of the major/hospitalised/serious injury category used by Australian jurisdictions.

The value of risk reduction for the hospitalised injury category becomes $400,008 in December 2021 prices or $457,717 in June 2024 prices.

This means that the WTP estimate for incapacitating crashes will not have any further use. It has, however, served two important purposes. First, it allowed the survey to include two points in the large range of severity levels within the hospitalised injury category. Second, it was an input to the calculation of the weighted average WTP values in Table 5.5.

6. Full social cost of crashes

6.1 Introduction

Although the human capital and WTP approaches are sometimes considered as alternative ways to estimate the social cost of crashes, the literature unambiguously states that they estimate different components of the full social cost and that the two approaches are complementary (Wijnen et al, 2009, p 327). Estimation of the full social cost of crashes involves integration or a combination of the two methods (Bougna et al. 2022, p 4; Wijnen 2021, pp. 293-4). Although the great majority of costs from a person's death or injury in a road crash fall on the victims themselves and their relatives, a proportion falls on the rest of society. Since losses to the rest of society are not borne by the victims, people could not be expected include them in their WTP to reduce crash risk (ECMT 2001, p. 85; Evans 2009, p. 163; ANU 2022, p. 114). The WTP values are therefore not the full cost to society and need to have some costs estimated by human capital studies added on. The possibility is raised in this chapter that survey respondents are unable even to understand the costs to themselves beyond the pain, grief and suffering involved.

Fortunately, the Bureau of Infrastructure and Transport Research Economics (BITRE) recently commissioned the Australian National University (ANU) to estimate the social cost of crashes using the hybrid human capital approach, replicating and extending the previous study undertaken by the BITRE (2009). ANU (2022) provides estimates of the complete list of social costs of crashes including amounts for pain, grief and suffering based on compensation payouts to crash victims.

This chapter addresses the question of what costs the WTP values for safety obtained from the national survey include and exclude, and adds the excluded costs as estimated by the ANU study.

6.2 Australian National University hybrid human capital cost estimates

As explained in Chapter 2, the human capital approach estimates the gross production loss from crash victims being unable to work, earn income and participate in household economic activities. It is based on the production potential of the deceased or disabled individual during their lifetime in the absence of a road crash. Some human capital studies include medical/hospital costs, property damage, and other costs on society imposed by crashes (Bouga et al. 2022, p. 4). The 'hybrid human capital' approach adds a further amount for lost quality of life for victims and pain, grief and suffering for victims, relatives and friends estimated from compensation payments to crash victims and their families and dependents.

Table 6.1 shows the total social cost of crashes per annum for Australia estimated by ANU (2022) using the hybrid human capital approach broken down by components and severity level in the original 2020 dollars. Table 6.2 shows the annual numbers of crashes used to derive these cost estimates. The numbers of crashes per annum were averaged over the five calendar years 2016 to 2020 to smooth out fluctuations. Numbers of non-hospitalised injury and property damage (PDO) crashes were factored up to adjust for estimated numbers of unreported crashes. Dividing the costs in Table 6.1 by the numbers of crashes in Table 6.2 gives the costs per crash set out in Table 6.3. This detailed breakdown provides amounts that can be added to WTP estimates to obtain full social costs. Table 6.4 shows the adjustment factors used to index the costs per crash to June 2024 dollars and Table 6.5 shows the indexed values. The last rows in Tables 6.3 and 6.5 give the pure human capital costs after deducting the costs of pain, grief and suffering estimated from compensation payments to crash victims.

Table 6.1 Total cost of crashes per annum for all Australia (2020 $ millions)

Cost component	Fatal	Hospitalised injury	Non-hospitalised injury	Property damage only	All
Repair costs	13	350	861	9,292	10,515
Workplace and household losses	2,856	4,662	91	0	7,609
Medical related costs	19	1,545	755	0	2,319
Insurance administration	30	406	286	928	1,650
Long term care costs	0	1,447	89	0	1,536
Travel delay and operating costs	19	97	223	969	1,309
Pain, grief and suffering (PGS)	444	507	0	0	952
Vehicle unavailability	1	43	64	415	523
Ambulance	6	79	92	0	177
Fire and emergency response services	2	58	0	0	60
Police services	2	61	14	0	77
Legal costs	8	84	0	0	92
Externality cost of crash-induced pollution	1	5	10	48	64
Correctional services	62	0	0	0	62
Street furniture	0	3	6	71	80
Premature funeral	9	0	0	0	9
Recruitment and re-training	3	5	0	0	8
Coronial costs	2	0	0	0	2
Total cost (HHC)	3,479	9,351	2,491	11,723	27,044
Total cost excluding PGS (HC)	3,034	8,843	2,491	11,723	26,092

Notes: PGS = pain, grief and suffering, HHC = hybrid human capital, HC = human capital.
Sources: ANU (2022), p. 91 and calculation spreadsheets provided to BITRE

Table 6.2 Average numbers of crashes per annum: 2016–2020

	Fatal	Hospitalised injury	Non-hospitalised injury	Property damage only	All
Number of crashes	1,093	32,968	81,573	846,049	961,683
Proportion of all crashes	0.1%	3.4%	8.5%	88.0%	100.0%
Proportion of casualty crashes	0.9%	28.5%	70.5%		

Note: These different slightly from ANU (2022) Table p. 17 because of inconsistencies in their calculations.

Source: ANU (2022).

Table 6.3 Cost per crash (2020 $)

Cost component	Fatal	Hospitalised injury	Non-hospitalised injury	Property damage only
Vehicle repair costs	11,827	10,620	10,549	10,983
Workplace and household losses	2,613,335	141,414	1,112	0
Medical related costs	17,785	46,849	9,252	0
Insurance administration	27,798	12,301	3,504	1,097
Long term care costs	0	43,890	1,088	0
Travel delay and operating costs	17,355	2,940	2,738	1,146
Pain, grief and suffering (PGS)	406,599	15,387	0	0
Vehicle unavailability	1,239	1,313	782	490
Ambulance	5,424	2,391	1,129	0
Fire and emergency response services	1,773	1,773	0	0
Police services	1,858	1,858	172	0
Legal costs	7,222	2,538	0	0
Externality cost of crash-induced pollution	690	137	128	57
Correctional services	56,931	0	0	0
Street furniture	71	79	79	84
Premature funeral	7,879	0	0	0
Recruitment and re-training	2,757	138	0	0
Coronial costs	2,205	0	0	0
Total cost (HHC)	3,182,747	283,629	30,532	13,857
Total cost excluding PGS (HC)	2,776,148	268,242	30,532	13,857

Notes: PGS = pain, grief and suffering, HHC = hybrid human capital, HC = human capital.
Source: Calculated from Tables 6.1 and 6.2

Table 6.4 Indexation factors applied to ANU costs

Cost component	Index	Base date	Adjustment date	Base value	Adjustment value	Adjustment factor
Vehicle repair cost	CPI repair cars	Jun-20	Jun-24	116.8	136.96	1.173
Workplace and household losses	Earnings	May-20	May-24	1713.9	1923.40	1.122
Medical related costs	CPI health	Jun-20	Jun-24	140	162.77	1.163
Long term care costs	CPI health	Jun-20	Jun-24	140	162.77	1.163
Vehicle unavailability	CPI repair cars	Jun-20	Jun-24	116.8	136.96	1.173
Ambulance	CPI health	Jun-20	Jun-24	140	162.77	1.163
All other cost components	CPI All groups	Jun-20	Jun-24	114.4	138.80	1.213

Sources: ABS All groups CPI A2325846C; Health CPI A2331111C; Maintenance and repair of motor vehicles CPI A2328771A; Earnings, Persons, Full Time, Adult, Ordinary time earnings A84998729F.

Table 6.5 Cost per crash after indexation (June 2024 $)

Cost component	Fatal	Hospitalised injury	Non-hospitalised injury	Property damage only
Vehicle repair costs	13,869	12,453	12,371	12,879
Workplace and household losses	2,932,778	158,700	1,247	0
Medical related costs	20,677	54,467	10,756	0
Insurance administration	33,727	14,925	4,251	1,331
Long term care costs	0	51,028	1,265	0
Travel delay and operating costs	21,057	3,567	3,322	1,390
Pain, grief and suffering (PGS)	493,321	18,669	0	0
Vehicle unavailability	1,453	1,540	916	575
Ambulance	6,306	2,780	1,312	0
Fire and emergency response services	2,151	2,151	0	0
Police services	2,254	2,254	209	0
Legal costs	8,763	3,079	0	0
Externality cost of crash-induced pollution	837	167	155	69
Correctional services	69,073	0	0	0
Street furniture	86	95	95	102
Premature funeral	9,560	0	0	0
Recruitment and re-training	3,344	168	0	0
Coronial costs	2,676	0	0	0
Total cost (HHC)	3,621,931	326,044	35,901	16,346
Total cost excluding PGS (HC)	3,128,610	307,375	35,901	16,346

Notes: PGS = pain, grief and suffering, HHC = hybrid human capital, HC = human capital.
Source: Calculated from Tables 6.3 and 6.4.

6.3 Comprehensiveness of WTP values for safety

According to Wijnen et al. (2009, p. 327), the WTP approach includes a material component (consumption loss) and an immaterial component (human losses). The human capital approach is restricted to material losses (gross production loss). The consumption loss should be deducted from the value of statistical life (WTP to avoid a fatal crash) to obtain 'human losses'. Bougna et al. (2022, p. 3) elaborated as follows: "The material part [of WTP] … consists of the loss of consumption in the life years lost … whereas the immaterial part represents things that have no (market) price such as the loss of joy of life and the value of pain, sorrow and distress of the casualties and their relatives, also called human losses." Following this approach, Wijnen et al. (2009, p. 330) obtained a total social cost of road crashes estimate for the Netherlands by combining the human costs (calculated as WTP minus consumption losses) with the production costs (before deducting taxes) and medical, property damage, emergency services and traffic delay costs. The term 'human costs' in the literature cited corresponds with the cost of pain, grief and suffering used in ANU (2022) and the present report.[13]

Using the list of costs in the ANU study, the relationship between the human capital and WTP costs consistent with the literature is summarised by the Venn diagram in Figure 6.1. The set on the left is material or human capital costs split according to whether they are incurred by crash victims and their families (private) and by other members of society (third party). The set on the right is the individual's WTP cost (private) split into material costs and the non-material cost of pain, grief and suffering. The union of the two sets is the full social cost of a crash. The private material costs are in the intersection of the two sets.

This division of costs is based on the common assumption in economic models that people are self-interested rational utility maximisers and have perfect information. Being rational utility maximisers, in responding to a stated choice survey, they will consider only impacts on themselves and their relatives. The full rationality and optimising behaviour of the theoretical construct called 'economic man' or 'homo economicus' does not extend to complete information (Urbina and Ruis-Villaverde 2019, p. 66). For a WTP estimate for safety to correctly incorporate financial impacts such as forgone consumption, and out-of-pocket medical, long-term care and vehicle costs, there is a further requirement to assume that people know the expected value of the present value of these costs over their actuarial lifespans with and without the death or injury.

For the individual crash victim, there are also third-party human costs in the form of pain, grief and suffering to other family members, relatives and friends. It is assumed that respondents to the national survey would have considered the impact of a crash on their families, relatives and friends when answering the choice questions. Hence, the pain, grief and suffering component of WTP includes individuals' concern for the impacts of a crash on others. This is distinct from altruistic WTP by which is meant WTP by other family members, relatives and friends to reduce the risk of a crash by the individual (Abelson 2008, p. 16; Tooth 2010). The principle that altruistic WTP should not be included in CBAs rules this out of consideration.[14]

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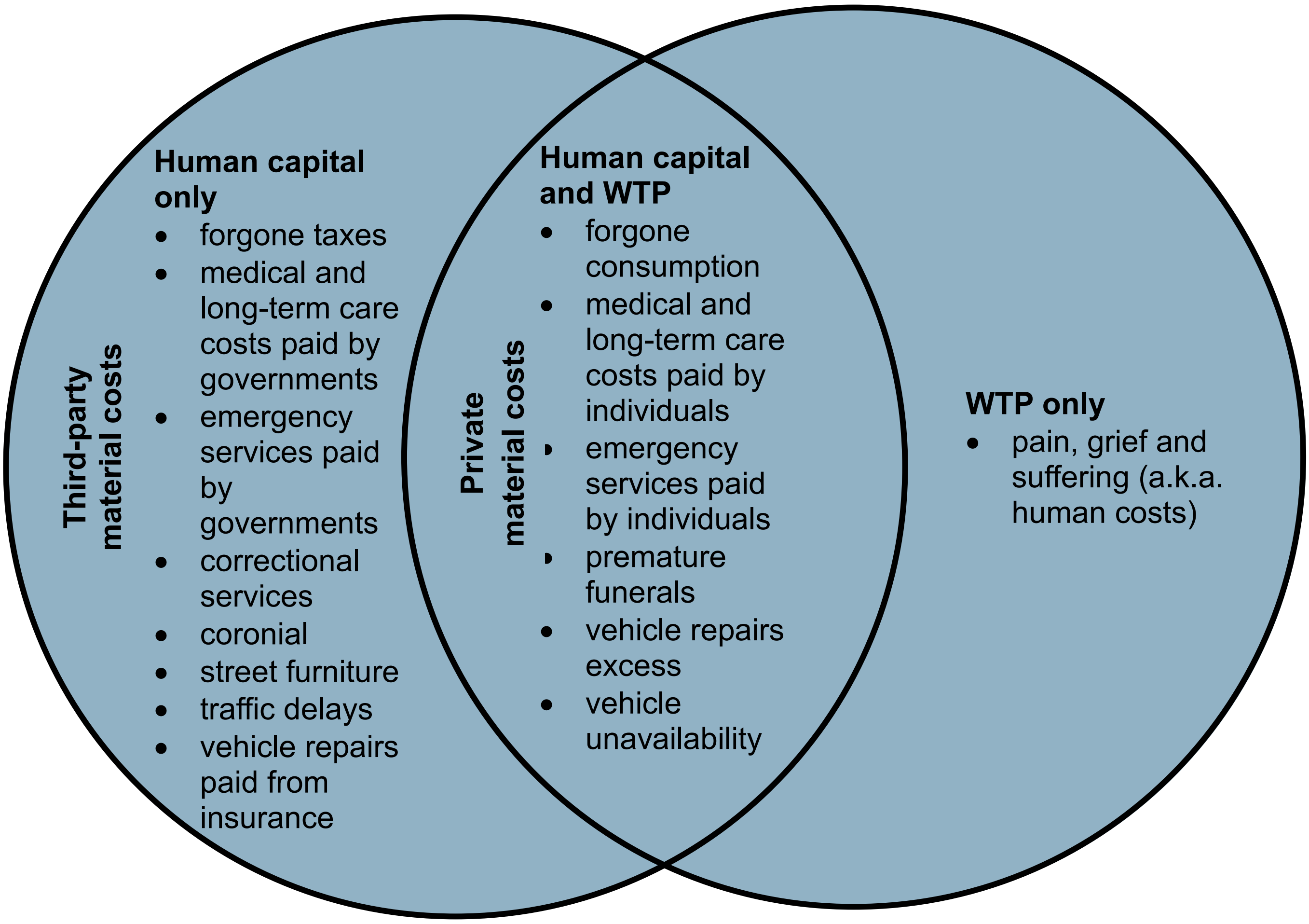
[13] Douglas (2022, p. 23) states that "Unit crash costs … are an amalgam of human, property and other costs, but with the main component being the 'human costs' of pain, grief and suffering, wage loss and reduced household productivity".

[14] To allow for altruistic WTP, Jones-Lee (1992) suggested that social values of statistical life should be 1.1 to 1.4 times the values for purely self-interested individuals. Lindberg (2001) recommended a factor of 1.4. The reason altruistic WTP is not counted in CBAs is that the increase in utility for the altruist from reducing the crash risk for others would be offset by the loss of utility to the altruist from others having to pay more for safety (Andersson and Treich 2011, p. 12).]

The largest component of human capital costs is gross production losses, which ANU (2022) terms ‘workplace and household losses’. Gross production lost is the lost value added or income an employed person produces. Part of this accrues to the government in income taxes and the remainder is available to the employee for consumption. In Figure 6.1, the gross production loss is split into forgone consumption, which is in the intersection area, and forgone taxes, which is in the human-capital-only area. ANU included in workplace and household losses, estimates of the value of unpaid household output and volunteer work, which does not give rise to tax receipts.

Medical and long-term care costs in Australia are borne partly by governments and partly by individuals and so are split between the human-capital-only and intersection areas. Costs of emergency services are partly paid for by governments and partly by individuals. Correctional services, coronial, street furniture and traffic delays are altogether outside WTP. Costs of premature funerals, the excess in insurance policies to cover the cost of vehicle repairs, and vehicle unavailability are material costs borne by individuals and so appear in the intersection. The cost of vehicle repairs paid out of insurance is shared among all motorists and so is not incurred by crash victims.

Figure 6.1 Venn diagram showing components of human capital and WTP costs



The cost of pain, grief and suffering, or 'human costs' as it called in the literature, is in WTP only. WTP, according to the literature, is the sum of human costs and consumption losses (ECMT 2001, p. 86; Evans 2009, p. 164; Wijnen et al., 2009 p. 327; Bougna et al. 2019, p. 4; Wijnen 2021, p. 294). In the ANU and previous BITRE hybrid human capital cost studies, pain, grief and suffering costs were estimated from compensation payments to crash victims. The survey in crash costs in European countries by Wijnen et al. (2019, p. 324) found that human costs are much higher in countries that use the WTP approach (obtained by subtracting the consumption loss from the WTP amount). Values based on compensation payments are based on judgements of law courts, insurance companies and governments rather than the risk valuation of the individual involved. The WTP approach is superior for estimating human costs, but calculation of human costs requires consumption losses to be deducted from WTP.

While the literature is clear about which costs are included in WTP and which need to be added based conventional assumptions about economic man, there are different views in applications. Figure 6.2 is a stacked Venn diagram illustrating four such views. The outer circle *A* represents the set of the all components of the full social cost of crashes. There is a view that WTP estimates cover the full social cost with no additions needed (circle *A*). It relies on assumptions that respondents to WTP surveys make their choices considering all costs to society and that they have an adequate understanding of the magnitude these costs.

The recent New Zealand WTP study (Denne et al. 2023) appeared to take this view as it makes no mention of a need to add further costs. In subsequent consideration of the survey's findings, Te Manatū Waka Ministry of Transport (2023) added the cost of lost output from time spent in hospital and time off-work after discharge from hospital for injury crashes. For all three of fatal, serious and minor injury crashes, they added the full medical costs, regardless of whether they are paid by crash victims or the government. For all four crash severities (adding non-injury or property damage only crashes to the list), they added costs of police, legal, correctional services, vehicle repairs, and street furniture. The implicit assumption is that survey respondents took into account the entire cost of lost production to the economy except for work time lost recuperating from an injury, but not medical costs. For costs of lost production, medical care and vehicle repairs, no distinction was made between components incurred by crash victims (and so already in WTP) and by third parties (government and other motorists through insurance payments).

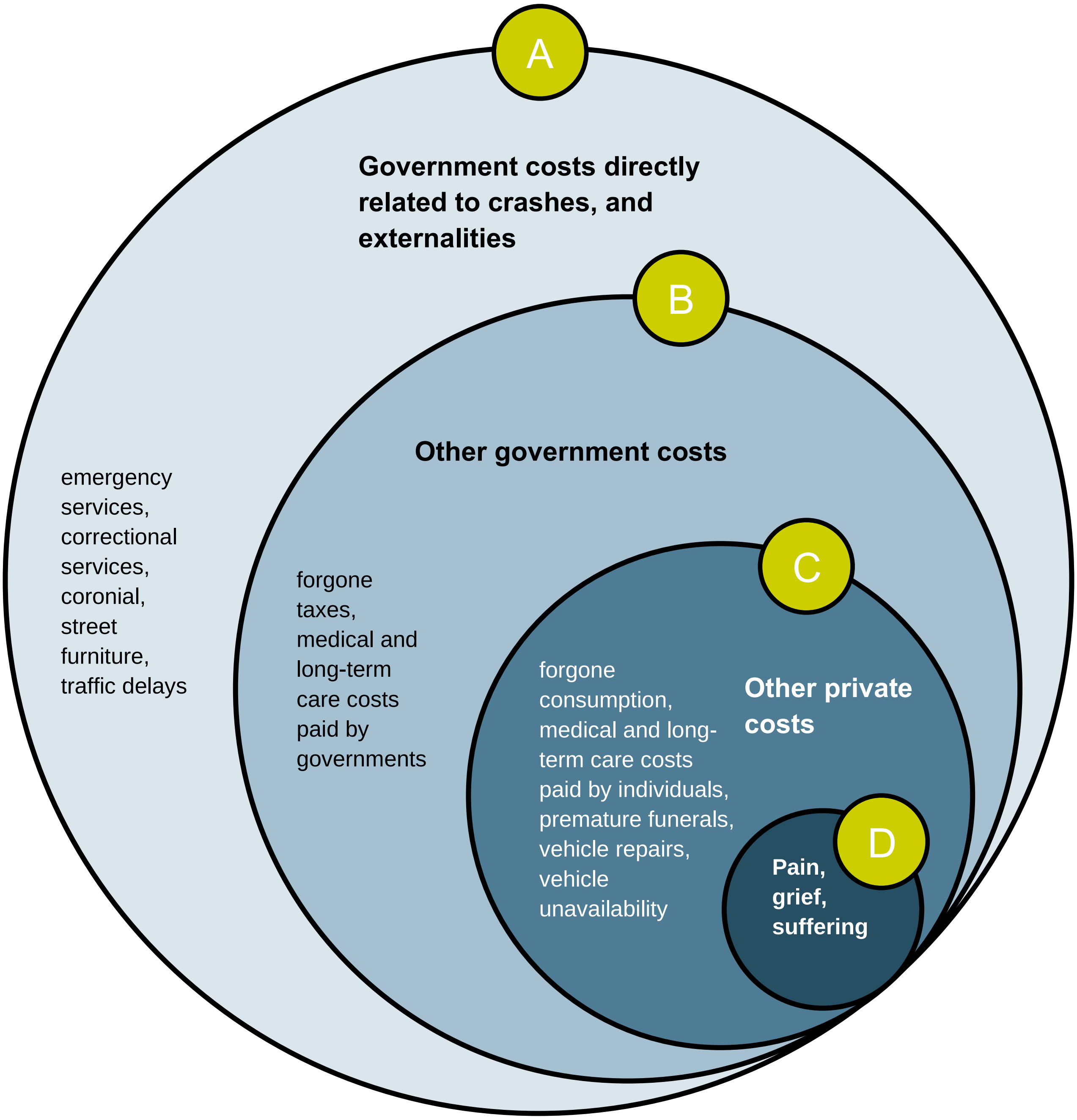
Having surveyed a number of overseas and Australian WTP studies, Austroads (2015, p 5) observed that

> *None of the studies examined included additional costs involved in, for example, site clean-up, emergency services and in the actual WTP estimation. Where these were estimated (New Zealand, Norway and the UK), this was undertaken separately from the WTP estimation and added to the values.*

This indicates a mix of views that no additional costs need to be added (circle *A*) to WTP and that costs directly related to crashes are missing from WTP and so need to be added (circle *B*). The missing costs, according to the circle B viewpoint (*A* – *B*), include emergency services, correctional services, coronial, street furniture, traffic delays. This view underlies the 'inclusive WTP' values provided in ATAP (2016) Part PV2 (Tables 15 and 20), which "includes vehicle and general costs, e.g. vehicle towing, emergency services, administrative, etc, as calculated under the human capital approach", added to the values from the WTP survey reported in RTA (2008) and Hensher et al. (2009).

Austroads (2015, p. 22) noted that "Consultation with all relevant experts has confirmed that these additional crash site and other related costs are outside the nature and scope of a WTP exercise." "Furthermore, because additional costs normally calculated by BITRE such as police and emergency services, vehicle towing and crash site cleaning, road furniture rehabilitation/replacement, traffic delays, legal and administration costs were not included in the RTA NSW study, these should be added to the RTA WTP estimates" (Austroads 2015, p. 73). Medical and other costs were not added to the RTA estimates because the value of statistical life estimate was thought to be high enough without them included (Douglas 2022, p. 10).

Figure 6.2 Four alternative views about what a WTP value for safety includes and excludes



There is no logical reason or support in the literature for the distinction between the government costs in circle *A* directly related to crashes (*A* – *B*) and the government costs in circle *B* of forgone taxes and medical and long-term care costs (*B* – *C*). Under the common assumption that underlies much economic analysis, that people are fully rational, self-interested and have perfect information, their WTP to reduce crash risk should be based on costs they and their relatives would incur as a result of crash, that is, the private costs in circle *C*. The circle *C* view of the composition of WTP corresponds to the view represented in Figure 6.1.

If WTP is taken to represent all the costs in circle *C*, forgone taxes, medical and long-term care costs paid by governments (*B* – *C*), as well the costs directly related to crashes (*A* – *B*) need to be added to the WTP value to obtain the full social cost. The costs in circle *C*, that is, the private costs, comprise forgone consumption, which is the same as after-tax earnings, that part of medical and long-term care costs that is born by individuals, costs of premature funerals, vehicle repairs and unavailability, and the circle *D* cost of pain, grief and suffering.

There is yet one more view about what WTP comprises — that it only accounts for the pain, grief and suffering component in circle *D*. This view dispenses with the strong assumptions that survey respondents are perfectly rational and informed, maintaining instead that survey respondents cannot reasonably be expected to estimate the expected value of the discounted present value of their future after tax earnings and the medical and long-term care costs they will incur in the event of a crash minus their value in the absence of a crash. Survey respondents will base their choices on their perceptions of the pain, grief and suffering they and those close to them would experience from a crash. This was the advice given to the project team from Prof. Richard Batley, Prof. Peter Mackie and Dr. Thijs Dekker from the Institute for Transport Studies at the University of Leeds, UK.

> *"We would be inclined to argue that the SP [stated preference] and its interpretation should be restricted to the pain, grief and suffering (or VOSL) component of the total, with vehicle damage costs, lost economic output and health care costs imported from other sources. This is partly because we doubt that the individual is best placed to assess these components, and partly because the social value of lost output (which is what you want) is very likely to diverge from the private value." (Communication dated 18 May 2022)*

BTE (2000, p. 38) stated "… there is uncertainty as to whether these [WTP] values include all or part of the income and production losses in addition to quality of life itself." In a webinar on the ATAP WTP project organised by the Australasian Transport Research Forum on 19 August 2024, Professor David Hensher gave an opinion that survey respondents are likely to have excluded the private material costs of crashes and that the full human capital costs should be added to the WTP values (Transcript of webinar).

While we were unable to locate any academic literature that supports this view, there are well-known concepts in the social sciences that explain why people might undervalue or ignore the future financial costs of a crash.

- Bounded rationality: Individuals making decisions have limited information available, limited time to acquire information, and limited computational capacities and capabilities to process the information. That makes it necessary for them to employ heuristics, simplified decision rules often based on past experience, to achieve satisfactory albeit not optimal outcomes. (For further discussion see Fiori 2011.)
- Cognitive bias: Individuals create their own subjective reality, based on their own perceptions, not objective inputs (facts), which can lead to perceptual distortions, inaccurate judgement, illogical interpretation and irrationality. A large number of types of cognitive bias have been identified (see for example, Wilke and Mata 2012). Possibly, the type of cognitive bias most relevant to the question of whether WTP includes private material costs is 'salience bias' — individuals focusing on information that is more prominent, visible, or emotionally striking when making decisions (Bordalo et al. 2022). The pain, grief and suffering caused by a crash is likely to be more salient in the minds of survey respondents than the financial impacts.
- Myopic behaviour: Individuals having higher discount rates for payoffs in the near future than in the distant future, so that they favour short-term gains that entail long-term losses (Gintis 2000, p. 313). In the context of WTP to avoid future income loss due to crashes, myopia in temporal discounting can lead individuals to undervalue the potential future financial consequences of a crash.

6.4 Alternative views about what the ATAP WTP values comprise

ANU (2022) provided a table of shares, reproduced here as Table 6.6, of each component of the its social cost of crashes estimate that is included in WTP because it is born by crash victims (private costs) and not included because it is borne by third parties. Tables 6.7 and 6.8 split the material human capital costs (excluding pain, grief and suffering) estimated by ANU in Table 6.5 into private and third-party material human capital costs by multiplying by the percentage shares in Table 6.6.

Table 6.6 Cost components included and not included in WTP

Hybrid human capital cost component	Included in WTP (private cost)	Share (%)	Not included in WTP (third-party cost)	Share(%)
Repair cost	vehicle insurance excesses	8.0%	rest of repair costs (imposed on all insured motorists)	92.0%
Workplace and household losses	all forgone after-tax earnings and all household and voluntary work losses	85.0%	income and payroll taxes forgone by governments	15.0%
Medical - hospitalised	part incurred by individuals and families	14.7%	part incurred by governments	85.3%
Insurance administration	–	0.0%	all (imposed on all insured motorists)	100.0%
Long-term care costs	part incurred by individuals and families	14.7%	part incurred by governments	85.3%
Travel delay and operating costs	–	0.0%	all (imposed on other road users)	100.0%
Pain, grief and suffering	all	100.0%	–	0.0%
Vehicle unavailability	all	100.0%	–	0.0%
Ambulance	part incurred by individuals and families	11.0%	part incurred by governments and part by people with ambulance insurance	89.0%
Fire and emergency	–	0.0%	incurred by governments or all vehicle operators	100.0%
Police	–	0.0%	all (incurred by governments)	100.0%
Legal costs	–	0.0%	all (incurred by governments)	100.0%
Externality cost of crash-induced pollution	–	0.0%	all (imposed on general society)	100.0%
Correctional services	–	0.0%	all (incurred by governments)	100.0%
Street furniture	part incurred by individuals and families where governments bill damage to identified at-fault motorists (assumed to be none)	0.0%	Part incurred by governments	100.0%
Premature funeral	all	100.0%	–	0.0%
Recruitment and re-training	–	0.0%	all (incurred by employers)	100.0%
Coronial costs	–	0.0%	all (incurred by governments)	100.0%

Source: ANU (2022), p. 115.

Table 6.7 Private material human capital costs per crash (June 2024 $)

Cost Component	Fatal	Hospitalised injury	Non-hospitalised injury	Property damage only
Vehicle repair costs	1,110	996	990	1,030
Workplace and household losses	2,492,861	134,895	1,060	0
Medical related costs	3,039	8,007	1,581	0
Insurance administration	0	0	0	0
Long term care costs	0	7,501	186	0
Travel delay and operating costs	0	0	0	0
Vehicle unavailability	1,453	1,540	916	575
Ambulance	694	306	144	0
Fire and emergency response services	0	0	0	0
Police services	0	0	0	0
Legal costs	0	0	0	0
Externality cost of crash-induced pollution	0	0	0	0
Correctional services	0	0	0	0
Street furniture	0	0	0	0
Premature funeral	9,560	0	0	0
Recruitment and re-training	0	0	0	0
Coronial costs	0	0	0	0
Total private material cost (PMC)	2,508,717	153,245	4,878	1,605

Source: Derived from Tables 6.5 and 6.6 with pain, grief and suffering costs omitted.

Table 6.8 Third-party material human capital costs per crash (June 2024 $)

Cost Component	Fatal	Hospitalised injury	Non-hospitalised injury	Property damage only
Vehicle repair costs	12,760	11,457	11,381	11,848
Workplace and household losses	439,917	23,805	187	0
Medical related costs	17,637	46,460	9,175	0
Insurance administration	33,727	14,925	4,251	1,331
Long term care costs	0	43,527	1,079	0
Travel delay and operating costs	21,057	3,567	3,322	1,390
Vehicle unavailability	0	0	0	0
Ambulance	5,612	2,474	1,168	0
Fire and emergency response services	2,151	2,151	0	0
Police services	2,254	2,254	209	0
Legal costs	8,763	3,079	0	0
Externality cost of crash-induced pollution	837	167	155	69
Correctional services	69,073	0	0	0
Street furniture	86	95	95	102
Premature funeral	0	0	0	0
Recruitment and re-training	3,344	168	0	0
Coronial costs	2,676	0	0	0
Total third-party material cost (TMC)	619,892	154,129	31,023	14,741

Source: Derived from Tables 6.5 and 6.6 with pain, grief and suffering costs omitted.

With this information, private material human capital costs of crashes can be deducted from the WTP values from the national survey to obtain the implied cost of pain, grief and suffering or human costs (Wijnen et al. 2009). If the implied level of pain, grief and suffering or human costs, is too low to be credible, this is evidence that survey respondents may not have adequately allowed for the private material costs of a crash when completing the survey.

Two options are presented using the method of assessing the plausibility of the implied cost of pain, grief and suffering.

Option 1: WTP comprises all private costs

Option 1 is that the WTP values from the survey represent all private costs — circle *C* in Figure 6.2. Then, *WTP = PGS + PMC* where PGS is the WTP cost of pain, grief and suffering and PMC is the private material costs calculated under human capital method, and shown in Table 6.7. The costs to third-parties (mostly governments, circles *A – C*) need to be added to WTP to obtain the full social cost of a crash. The full social cost is *FSC = PGS + PMC + TMC = WTP + TMC*, where TMC is the third-party material costs from Table 6.8. The implied pain, grief suffering cost is then, *Implied PGS = WTP – PMC*. The calculations for the full social cost and implied cost of pain, grief and suffering in dollars per crash follow.

Cost component	Fatal	Hospitalised injury	Non-hospitalised injury	Property damage only
WTP	4,192,504	457,717	28,218	18,308
+ third-party material cost (TMC)	619,892	154,129	31,023	14,741
= Full social cost (FSC)	**4,812,396**	**611,847**	**59,241**	**33,049**
WTP	4,192,504	457,717	28,218	18,308
– private material cost (PMC)	–2,508,717	–153,245	–4,878	–1,605
= Implied PGS cost	**1,683,787**	**304,473**	**23,340**	**16,703**

Option 2: WTP comprises only costs of pain, grief and suffering

Option 2 is that WTP from the survey represents only the costs of pain, grief and suffering — circle *D* in Figure 6.2. Since *WTP = PGS*, *Implied PGS = WTP*. To obtain the full social cost of a crash, the entire human capital (material) cost, both private and third party, needs to be added on (circles *A – D*). *FSC = WTP + PMC + TMC*. The calculations in dollars per crash follow.

Cost component	Fatal	Hospitalised injury	Non-hospitalised injury	Property damage only
WTP = implied PGS cost	**4,192,504**	**457,717**	**28,218**	**18,308**
+ private material cost (PMC)	2,508,717	153,245	4,878	1,605
+ third-party material cost (TMC)	619,892	154,129	31,023	14,741
= Full social cost (FSC)	**7,321,113**	**765,091**	**64,119**	**34,654**

Discussion

Table 6.9 compares the full social costs and implied PGS costs under the two options. Option 1 is consistent with the literature and illustrated in Figure 6.1. It assumes survey respondents are perfectly rational and informed. Hence, they are able to estimate the expected values of the discounted present values of their private costs in the event of a crash. Option 2 is consistent with the recommendation from the University of Leeds experts and an opinion given by Professor David Hensher. It assumes that survey respondents do not take into account the material costs they will incur in the event of a crash.

It is uncertain which cost components, if any, survey respondents would factor into their WTPs to reduce crash risk and which costs they would exclude. For the cost components included, it is uncertain how well or how poorly survey respondents understand their magnitudes and expected present values. The literature offers no guidance, simply assuming that survey respondents are perfectly rational and informed. The most likely scenario is that survey respondents will have a range of perspectives and levels of myopia and knowledge. If we exclude the possibility of major over-estimations of the material costs of crashes, the answer for the average survey respondent probably lies somewhere in between the option 1 and option 2 scenarios. The question has not been researched so there is no way to know for sure. If the truth lies somewhere in between, that is, the WTP values include part of 'other private costs' and exclude the other parts, treating the WTP values as pain, grief and suffering only will lead to over-estimation due to double counting of the other private costs in WTP, and treating the WTP values as the full private costs will lead to under-estimation due to excluding the private costs missing from WTP.

We believe the only practical approach is examine the estimates of full social cost and implied PGS under the two options and select the one that looks more reasonable. A similar approach was taken by the consultants in ATAP (2024a, p. 29) where they noted that whether the model led to expected results was one factor considered when choosing between alternative models.

Table 6.9 Comparisons of full social cost and implied PGS under alterative options for what WTP comprises (June 2024 $ per crash)

	Cost component	Fatal	Hospitalised injury	Non-hospitalised injury	Property damage only
Option		**Full social cost**			
1	**WTP = PGS + PMC** FSC = WTP + TMC	4,812,396	611,847	59,241	33,049
2	**WTP = PGS** FSC = WTP + PMC + TMC	7,321,113	765,091	64,119	34,654
Option		**Implied cost of pain, grief and suffering**			
1	**WTP = PGS + PMC** Implied PGS = WTP – PMC	1,683,787	304,473	23,340	16,703
2	**WTP = PGS** Implied PGS = WTP	4,192,504	457,717	28,218	18,308

Note: PGS = cost of pain, grief and suffering; FSC = full social cost of a crash; PMC = private material costs of a crash: TMC = third-party costs incurred by governments, other road users, employers and general society.

The implied costs of pain, grief and suffering under both options appear plausible, except that some might judge the fatal crash estimate of $1.7 million to be on the low side. For minor injury and PDO crashes, the implied PGS estimates under option 2 might seem high at $28,000 and $18,000 respectively, however, a crash with minor or no injuries is a stressful experience and a source of inconvenience, and the option 1 values for implied PGS are not much lower at $23,000 and $17,000.

The full social cost of fatal crash value under option 2 of $7.3 million implies a VSL not far above the VSL used in other sectors. The Australian Government's Office of Impact Assessment (OIA, 2023) guidance note recommends a VSL in 2023 dollars of $5.4 million. OIA did not discuss what its VSL represents — whether it comprises only pain, grief and suffering, all private costs or the full social cost. We assume it represents all private costs. From BITRE (2024), over the ten years 2014 to 2023, there were 11,867 deaths in Australia from 10,942 fatal crashes, an average rate of 1.085 deaths per crash. The cost of a fatal crash using the OIA VSL and adding the $619,893 in third-party material costs (TMC) for a fatal crash from Table 6.8 is then $5.4 million × 1.085 + $0.62 million = $6.5 million, which is $0.8 million below the $7.3 million cost of a fatal crash under option 2. The option 1 cost of crash of $4.8 million is $1.7 million below the $6.5 million calculated from the OIA VSL.

It is desirable to have a degree of consistency in the VSL across sectors. However, it should be noted that the OIA VSL is merely a mid-range value taken from a literature survey of international studies of $3.5 million from Abelson (2008), indexed to 2023. It is not based on a stated preference survey of a sample of Australians.

Furthermore, there is no reason to expect the WTP to reduce the risk of death to be the same across sectors. Context factors may influence WTP for risk reduction:

- Whether or not the risk is under the control of the individual, for example, driving versus air travel
- Whether or not the risk is assumed voluntarily, as for example, driving versus risk from nuclear power stations

- Whether or not the risk is the individual's responsibility
- Whether the risk is borne at ground level versus below or above the surface of the earth. (BTE 1998, p. 18)

Since driving is an activity undertaken voluntarily, is under the control of the individual and occurs at ground level, WTP to reduce risk on the roads could be expected to be below that for other sectors. Studies have found that WTP to reduce the risk of cancer mortality is significantly higher than for road crashes (Kenkel, 2003; McDonald et al. 2016). However, the Australian survey article by Ananthapavan et al. (2021, p. 12) found the evidence to be unclear and recommended using a consistent VSL across risk contexts until further evidence on the preferences of the Australian population becomes available. The material costs would differ between contexts and sectors.

Forgone consumption would be higher for people with higher incomes and lower for older people because they have fewer life-years ahead of them. If option 1 was correct, forgone consumption would comprise 59% of the WTP for fatal crashes and 29% for hospitalised injury crashes. Consequently, there should be a positive relationship between income and WTP and a negative relationship between age and WTP. The positive relationship for income would be strengthened by the expected positive relationship between income and WTP to avoid pain, grief and suffering. However, ATAP (2024a) found no statistically significant relationships between WTP and income or between WTP and age. This is further support for option 2, that survey respondents fail to take into account their private material costs.

For a fatal crash, the option 2 value is quite close to the minimum value from the recent New Zealand study shown in Table 4.1 of A$7.5 million = NZ$8.1 million × 0.92AUD/NZD. For hospitalised injuries, the option 2 value is close to the maximum NZ value (minimum A$395,101 = NZ$429,458 × 0.92, maximum A$819,427 = NZ$890,681 × 0.92). For non-hospitalised injuries, the values under both options are about midway between the minimum (A$40,681 = NZ$44,218 × 0.92) and maximum (A$84,370 = NZ$91,707 × 0.92) NZ values.

Option 1 is consistent with the literature and is the more conservative approach. However, it assumes high levels of knowledge and perception on the part of survey respondents. The implied PGS cost for fatal crashes of $1.7 million under option 1 might be considered too low. Option 2 aligns with expert advice, produces a fatal crash cost more in line with the VSL used in other sectors, and the lack of statistically significant relationships between WTP and the income and age variables suggest that survey respondents did not take account of forgone consumption. However, option 2 might be viewed as radical and it makes the high full social costs of a crash for injury and PDO crashes under option 1 even higher.

This report favours option 2, however, ATAP could justify accepting either option.

6.5 Total social cost of crashes for Australia

ANU (2022) aimed to estimate the total annual social cost for Australia whereas the national survey aimed to estimate costs per crash for use in CBAs. The first row of Table 6.10 shows the ANU (2022) total hybrid human capital costs of crashes from Table 6.5 indexed to June 2024 prices. The full social cost (FSC) rows show, for each option, the result of multiplying the new hybrid WTP–human capital social costs per crash in Table 6.9 by the numbers of crashes in Table 6.2. The total annual cost of crashes for Australia, estimated by ANU at $31 billion under the hybrid human capital approach, increases by a factor of 1.9 to $58 billion under option 1 and a factor of 2.2 to $68 billion under option 2 for the hybrid WTP–HC values estimated here.

PDO crashes account for 44% of the total hybrid human capital cost, 48% of the total option 1 cost and 43% of the total option 2 cost. Due to the high level of unreported PDO crashes, the total annual number of PDO crashes in ANU (2022) is an estimate based on insurance industry data (ANU 2022, pp. 25-6) and is highly approximate. If only casualty crashes are considered, the total annual cost of crashes for Australia is $18 billion under the hybrid human capital approach and ranges from $30 billion to $38 billion under the hybrid WTP–HC approach.

Table 6.10 Total annual social cost of crashes for Australia (June 2024 $ millions)

	Fatal	Major injury	Minor injury	Total casualty	Property damage only	All crashes
ANU HHC	3,959	10,749	2,929	17,636	13,829	31,466
FSC option 1	5,260	20,171	4,832	30,264	27,961	58,225
Ratio option 1	1.3	1.9	1.7	1.7	2.0	1.9
FSC option 2	8,002	25,224	5,230	38,456	29,319	67,775
Ratio option 2	2.0	2.3	1.8	2.2	2.1	2.2

Note: HHC = hybrid human capital, FSC = full social cost, Ratio = FSC estimate divided by ANU HHC estimate.
Sources: Calculated from Tables 6.2, 6.6 and 6.9.

Likely effect on size of safety benefits

For comparative purposes, Table 6.11 shows the ATAP (2016) *PV2 Road Parameter* values, Table 15, indexed to June 2024 prices using the CPI all-groups. The inclusive WTP values have vehicle and general costs added on e.g. vehicle towing, emergency services, administration costs added on. The national survey–ANU hybrid values represent a reduction in the value for fatal crashes of about 50% for option 1 and 30% for option 2, but the costs for hospitalised and minor injury crashes are higher.

Using the split of crash numbers between ‘major city’ and ‘outside major city’ from ANU (2022) for the urban/non-urban split, and the costs per crash in Table 6.9, the total annual cost of casualty crashes using the current ATAP values is $36 billion. The option 1 cost of casualty crashes in Table 6.10 of $30 billion is 16% lower. The option 2 cost of casualty crashes in Table 6.10 of $38 billion is 7% higher. Assuming similar ratios between the three crash severity categories apply at individual locations, this gives an indication of how much switching to the new hybrid WTP–HC option 1 and option 2 values will change safety benefits in CBAs.

For PDO crashes, ATAP (2016, p. 25) recommends a human capital cost of $9,257 in 2013 prices, which becomes $12,499 in June 2024 prices. The new hybrid WTP–HC option 1 and 2 values in Table 6.8 of $33,049 and $34,654 increase PDO costs by a factor of more than 2.5. The increase is due to the national survey providing an estimate of WTP to avoid the stress and inconvenience from having a PDO crash.

If the new hybrid WTP–HC values are adopted, the total annual cost for all crashes including PDO, will rise from $46 billion under the current ATAP values to $58 billion under option 1 (from Table 6.9), a 25% increase, and $68 billion under option 2 (from Table 6.9), a 46% increase.

Table 6.11 ATAP PV2 inclusive WTP values indexed to June 2024

	Urban ($)	Non-urban ($)	Weighted average
Value of statistical life	10,225,580	10,112,890	10,153,409
Value of serious injury	711,021	527,788	640,558
Value of hospitalised injury	135,601	104,847	45,129
Value of minor injuries	42,854	48,770	12,499

Note: The values are from ATAP (2016) Part PV2 Road parameter values, Table 15, p. 25. They were indexed from June 2013 $ to June 2024 $ using CPI all groups. The indexation factor was 1.350 = 138.8/102.8. From ATAP (2016, Table 20, p. 30), the 'serious injury' category is equivalent to our hospitalised injury category.

6.6 Other ways to express crash costs

6.6.1 Cost per casualty and injury crash

For some applications crash rates will only be available in for casualty (fatal + injury) or injury (hospitalised + non-hospitalised) crashes. These have been calculated in Table 6.12 by estimating the total annual costs for casualty and injury crashes from the costs per crash and numbers of crashes, and dividing by numbers of crashes per annum.

Table 6.12 Costs per casualty and injury crash

		Casualty crashes	Injury crashes
Option 1	WTP	$190,033	$151,839
	+ TMC	$71,688	$66,457
	FSC	**$261,720**	**$218,296**
Option 2	WTP	$190,033	$151,839
	+ PMC	$70,845	$47,582
	+ TMC	$71,688	$66,457
	FSC	**$332,566**	**$265,878**

6.6.2 Cost per person

As there is, on average, more than one person is killed or injured in a crash, the VRR per death or injury will be lower than the VRR per fatal or injury crash, respectively.

The national survey questionnaire presented respondents with numbers of crashes per year along the route of the trip, not numbers of deaths and injuries. As a result, the estimated VRRs must be interpreted as WTP to avoid a crash, not a death or an injury. This was also the case for the surveys in Rizzi and Ortúzar (2003, 2006a and b). They divided the VRRs per crash by the average rates of deaths per crash or injuries per crash to obtain VRRs per death and per injury. The Hensher et al. (2009) and Denne et al. (2023) surveys specified numbers of deaths and injuries. The resultant VRR estimates were therefore expressed per person and had to be multiplied by average rates or deaths or injuries per crash to obtain VRRs for crashes. Survey respondents are expected to exhibit a WTP to reduce risk for those travelling in the car with them, which is reasonable, particularly given that those travelling with them will often be family members, relatives or friends. Some supporting evidence is that Rizzi and Ortúzar (2003) found that young males travelling alone had a lower WTP for safety than the other survey respondents.[15]

The question of whether survey respondents are able to understand the difference between numbers of crashes and numbers of persons has not been researched. The VTTS and VOR estimates from the survey have been interpreted as being expressed per person. When used in CBAs, they would be multiplied by average vehicle occupancy rates to obtain values per vehicle. Hence, the assumption that car occupants have in mind for the safety of others in the car with them does not extend to savings in time and travel time variability for others in the car.

From ANU (2022) numbers, there were 1.086 deaths per fatal crash and 1.177 persons injured per injury crash, whether hospitalised or minor. Dividing by these conversion factors, costs per person can be calculated from the full social costs per crash in Table 6.9. The costs per person are shown in Table 6.13.

Table 6.13 Social crash cost per person (June 2024 $)

Per person	Fatal	Hospitalised injury	Non-hospitalised injury
Conversion factor	1.086	1.177	1.177
Option 1	4,431,304	519,968	50,345
Option 2	6,741,356	650,201	54,491

Source: Table 6.13 costs per crash divided by conversion factors.

6.6.3 Cost per crash in urban and non-urban areas

ATAP (2016) Part PV2 contains separate costs per crash for urban and non-urban areas. Separate urban and non-urban values were not estimated in the final model for the national survey. Part of the reason was the difficulty in drawing a clear distinction between trips in urban and non-urban areas. Many trips were made partly in built-up areas with 60km speed limits (including regional towns) and partly on non-urban roads with 100km speed limits. Furthermore, it is not clear whether urban roads in regional towns with 60km speed limits should be classed as urban or non-urban. While crashes on non-urban roads can be more severe due to higher speeds and poorer roads, survey respondents were not required to take this into account. Crash severities by frequency were specified to the respondents in the survey questions. Respondents were not required to estimate crash frequencies for themselves. When the VRRs are used in the CBAs to estimate safety benefits, higher rates of more severe crashes on non-urban roads should be taken into account via the crash rates used in the CBAs, not the unit costs per crash.

[15] Survey respondents having a WTP to reduce risk for others in the car with them is not the same as WTP by family members, relatives and friends not in car to reduce risk for those in the car. The latter is altruistic WTP, which was discussed in Section 6.3.

ANU (2022) estimated human capital costs for crashes inside and outside major cities defined according to the ABS Remoteness Structure. The structure divides the Australian landmass into five classes of remoteness of which the least remote is termed ‘Major cities of Australia’. The major cities area includes all the capital cities except Hobart and Darwin. ANU grouped the other four remoteness categories together under the heading ‘Outside major cities’. Five of ANU’s cost categories had different costs per crash between major cities and outside major cites: vehicle repair costs, travel delay and operating costs, vehicle unavailability, ambulance and the externality cost of crash-induced pollution. This provides part of the basis for deriving separate urban and non-urban values.

The other basis is the fact that the average number of persons killed and injured in a crash differs between urban and rural areas. Based on ANU (2022), persons per crash have been calculated for the major cities and outside major cities remoteness areas and are shown in Table 6.14.

Table 6.14 Person and crash numbers per year by remoteness area

	Major cities	Outside major cities	Total
Fatalities	413	774	1187
Fatal crashes	393	700	1093
Deaths per crash	**1.051**	**1.106**	**1.086**
Hospitalised injuries	23,664	15,130	38,794
Hospitalised injury crashes	20,290	12,678	32,968
Persons injured per crash	**1.166**	**1.193**	**1.177**
Non-hospitalised injuries	58,553	37,436	95,989
Non-hospitalised injury crashes	50,204	31,369	81,573
Persons injured per crash	**1.166**	**1.193**	**1.177**

Sources: ANU (2022) and calculation spreadsheets provided to BITRE.

Using the information in Table 6.14, WTP and material costs that are related to persons were scaled up or down for the two remoteness areas. The following notation is used.

- c_t, c_i and c_o = average cost of a crash respectively in all regions, inside major cities and outside major cities
- a_t, a_i and a_o = total annual numbers of crashes respectively in all regions, inside major cities and outside major cities
- $a_t\ c_t$, $a_i\ c_i$ and $a_o\ c_o$ = total annual crash costs respectively in all regions, inside major cities and outside major cities
- p_t, p_i and p_o = total annual numbers of persons killed or injured in crashes respectively in all regions, inside major cities and outside major cities.

The aim is estimate c_i and c_o, given the average value across the whole country of c_t. The cost for *a person* is assumed to be the same inside and outside major cities. The difference between the cost *per crash* inside and outside major cities is assumed to be solely due to different numbers of persons involved. So equation 6.1, which ensures equal costs per person, must hold.

$$\frac{a_i c_i}{p_i} = \frac{a_0 c_0}{p_o} = \frac{a_t c_t}{p_t}$$

[6.1]

The total cost of crashes must be the same whether estimated for whole country using the average national cost or summing the totals for the two areas, that is, equation 6.2 must hold.

$$a_i c_i + a_0 c_0 = a_t c_t$$

[6.2]

Solving equations 6.1 and 6.2 together to obtain expressions for c_i and c_o,

$$c_i = \frac{p_i a_t}{a_i p_t} c_t \ and \ c_o = \frac{p_o a_t}{a_o p_t} c_t$$

[6.3.1 and 6.3.2]

To illustrate the application of equations 6.3.1 and 6.3.2, for the WTP VRR for a fatal crash of $4,192,504 for all crashes, the values for inside and outside major cities, adjusted for differing average numbers of fatalities per crash are

$$\$4{,}056{,}957 = \frac{413 \times 1{,}093}{393 \times 1{,}187} \times \$4{,}192{,}504 \ and \ 4{,}268{,}604 = \frac{774 \times 1{,}093}{700 \times 1{,}187} \times \$4{,}192{,}504$$

The three WTP values — inside major cities, outside major cities and in total — all imply the same cost person as required by equation 6.1. Dividing the WTP values per fatal crash by deaths per crash from Table 6.14,

$$\frac{\$4{,}056{,}957}{1.051} = \frac{\$4{,}268{,}604}{1.106} = \frac{\$4{,}192{,}504}{1.086} = \$3{,}860{,}494$$

From equation 6.2:

$$393 \times \$4{,}056{,}957 + 700 \times \$4{,}268{,}604 = 1{,}093 \times \$4{,}192{,}504 = \$4{,}582 \ million$$

Equations 6.3.1 and 6.3.2 were applied to all cost components expected to be proportional to numbers of persons, that is, workplace and household losses, medical related costs, long-term care costs, premature funerals, recruitment and retraining, and coronial costs.

Table 6.17 shows the cost per crash for major cities and outside major cities for the two options, with the intermediate calculations in Tables 6.15 (original from ANU (2022) and 6.16 (June 2024 prices).

Table 6.15 Cost per crash by remoteness (June 2020 $)

Cost Component	Fatalities		Hospitalised injuries		Non-hospitalised injuries		PDO	
	Major cities	Outside major cities	Major cities	Outside major cities	Major cities	Outside major cities	Major cities	Outside major cities
Repair cost *	11,488	12,018	11,088	9,869	11,065	9,723	11,474	9,923
Workplace and household losses #	2,528,844	2,660,770	140,163	143,416	1,102	1,127	0	0
Medical related costs #	17,210	18,107	46,434	47,512	9,170	9,383	0	0
Insurance administration	27,798	27,798	12,301	12,301	3,504	3,504	1,097	1,097
Long term care costs #	0	0	43,502	44,512	1,079	1,104	0	0
Travel delay and operating costs *	19,068	16,393	3,174	2,566	2,956	2,390	1,315	780
Vehicle unavailability *	1,407	1,145	1,498	1,019	972	477	547	368
Ambulance *	4,843	5,762	2,032	2,962	946	1,418	0	0
Fire and emergency response services	1773	1773	1773	1773	0	0	0	0
Police services	1858	1858	1858	1858	172	172	0	0
Legal costs	7,222	7,222	2,538	2,538	0	0	0	0
Externality cost of crash-induced pollution *	1,031	498	172	81	160	75	72	25
Correctional services	56,931	56,931	0	0	0	0	0	0
Street furniture	71	71	79	79	79	79	84	84
Premature funeral #	7,625	8,022	0	0	0	0	0	0
Recruitment and re-training #	2,667	2,807	137	140	0	0	0	0
Coronial cost #	2,134	2,245	0	0	0	0	0	0
Total	**3,098,567**	**3,230,020**	**282,136**	**286,015**	**31,204**	**29,453**	**14,590**	**12,277**

Note: Costs that differ between remoteness areas estimated by ANU (2022) are indicated by '' and estimated from equations 6.3.1 and 6.3.2 by '#'.*
Sources: ANU (2022) and calculation spreadsheets provided to BITRE.

Table 6.16 Cost per crash by remoteness (June 2024 $)

Cost Component	Fatalities		Hospitalised injuries		Non-hospitalised injuries		PDO	
	Major cities	Outside major cities	Major cities	Outside major cities	Major cities	Outside major cities	Major cities	Outside major cities
Repair cost	13,471	14,093	13,003	11,574	12,975	11,403	13,455	11,637
Workplace and household losses	2,837,959	2,986,012	157,295	160,947	1,236	1,265	0	0
Medical related costs	20,008	21,052	53,985	55,238	10,661	10,909	0	0
Insurance administration	33,727	33,727	14,925	14,925	4,251	4,251	1,331	1,331
Long term care costs	0	0	50,576	51,750	1,254	1,283	0	0
Travel delay and operating costs	23,135	19,890	3,851	3,114	3,586	2,900	1,596	946
Vehicle unavailability	1650	1343	1756	1194	1139	560	641	431
Ambulance	5631	6699	2362	3444	1100	1649	0	0
Fire and emergency response services	2151	2151	2151	2151	0	0	0	0
Police services	2254	2254	2254	2254	209	209	0	0
Legal costs	8763	8763	3079	3079	0	0	0	0
Externality cost of crash-induced pollution	1251	604	209	99	194	91	88	31
Correctional services	69073	69073	0	0	0	0	0	0
Street furniture	86	86	95	95	95	95	102	102
Premature funeral	9251	9733	0	0	0	0	0	0
Recruitment and re-training	3236	3405	166	170	0	0	0	0
Coronial cost	2589	2724	0	0	0	0	0	0
Total	**3,034,234**	**3,181,609**	**305,709**	**310,035**	**36,702**	**34,615**	**17,213**	**14,478**

Source: Calculated from Tables 6.15 and 6.4.

Table 6.17 Cost per crash in and outside major cities (June 2024 $)

	Fatalities		**Hospitalised injuries**		**Non-hospitalised injuries**		**PDO**	
	Major cities	Outside major cities	Major cities	Outside major cities	Major cities	Outside major cities	Major cities	Outside major cities
Option 1								
WTP	4,056,957	4,268,604	453,668	464,199	27,968	28,618	18,308	18,308
+ TMC	606,431	627,464	153,581	155,004	31,601	30,094	15,495	13,116
FSC	**4,663,388**	**4,896,067**	**607,248**	**619,202**	**59,569**	**58,711**	**33,803**	**31,424**
Option 2								
WTP	4,056,957	4,268,604	453,668	464,199	27,968	28,618	18,308	18,308
+ PMC	2,427,804	2,554,146	152,128	155,031	5,101	4,521	1,718	1,362
+TMC	606,431	627,464	153,581	155,004	31,601	30,094	15,495	13,116
FSC	**7,091,191**	**7,450,213**	**759,376**	**774,234**	**64,670**	**63,232**	**35,521**	**32,786**

Note: FSC = full social cost of a crash; PMC = private material costs of a crash: TMC = third-party costs incurred by governments, other road users, employers and general society.

7. Transferability to other modes

Although the national survey was undertaken for car occupants only, to ensure all transport initiatives affecting different modes are appraised on a consistent basis, it is desirable that comparable values be adopted for other modes to ensure comparability. Relevant other modes are public transport and active travel. VORs do not need to be transferred because reliability is measured differently for public transport (ATAP 2021, Part M1 Public Transport, s. 5.2.1). Unreliability for public transport is measured in minutes late with multipliers specified, and reliability is not considered as a benefit for active travel. Crashes are relatively rare for public transport. ATAP (2021) does not provide crash rates or values for public transport. Thus, the question of transferability arises for VTTSs to public transport and active travel, and VRR to active travellers and other road vehicles (motorcycles, trucks).

Transferring values from the national survey to other modes may be preferable to investing the time and resources required to undertake further stated choice surveys targeting public transport users and active travellers. WTP values from different surveys are strongly influenced by differences in the methodologies applied as well as the actual preferences of the sampled populations. In case of safety, model results are factored up enormously by the rate of crash exposure. As the discussion in Chapter 4 has shown, crash exposure is difficult to define and measure and it is uncertain how much survey respondents are aware of differences in exposure. WTP values are therefore highly approximate and, to a high degree, an artefact of the methodology used to obtain them.

7.1 Values of travel time savings

Methodological considerations aside, reasons why WTP values for VTTS will differ between modes include differences in users' average incomes and ages, differences in the comfort and conditions of travel, (Wardman 2004) and differences in the preferences of people choosing particular modes. People choosing a slower, cheaper mode are more likely to come from the lower end of the distribution of VTTS values and conversely — a sorting effect. The distribution of VTTS values between modes would therefore arise from differences in income and personal characteristics, and preference heterogeneity. The lack of statistical relationships between WTP values and income found when modelling the national survey data indicates that values do not need to be adjusted for differences in average income when transferred to other modes.

In the case of public transport, ATAP (2021) Part M1 recommends multiplier values to apply to in-vehicle time (IVT) (time spent seated on board the bus, train, tram or ferry) and for time spent under a range of conditions — waiting, transferring, crowded conditions, minutes late, access/egress walking (Table 18). So there is no need to make adjustments in the present report for time spent in different conditions.

For CBAs, ATAP (2021, p. 47) and ATAP (2023a, p. 24) recommend that same VTTSs from ATAP (2016) Part PV2 for cars be used as equity values for both public transport and active travel. If this practice is to continue and the values from the national survey are adopted, ATAP will need to update the VTTSs in Parts M1 and M4.

Because of influence of survey methodologies on WTP values, comparing one survey with another has limited value. Meta-analyses are a more reliable source of information on underlying WTP differences between modes. They are able to distinguish between factors influencing survey results by regression analysis of results from a large number of studies. The meta-analysis by Shires and de Jong (2009) found that VTTSs for bus travel were typically 22% below car and train VTTS for business, 19% below for commuters and 35% below for leisure. Wardman's (2004) meta-analysis found that IVT was valued similarly by car and train users, but "bus is regarded as being somewhat inferior to train and car travel" (p. 372) at 28.6% lower. Time spent walking was found to be valued 30.6% below car and train.

In Section 3.5.2, the VTTS for business (VBTTS) was estimated using the Hensher equation and most likely parameter values for car travel from Wang and Hensher (2015). If the most likely values for car, bus and train are substituted into equation 3.2,

$$VBTTS = (1 - r - pq)MPL + rVL$$

$$VBTTS_{car} = \$44.72 = (1 - 0.45 - 0.04 \times 0.93) \times \$68.33 + 0.45 \times \$21.52$$

$$VBTTS_{bus} = \$39.41 = (1 - 0.55 - 0.05 \times 0.93) \times \$68.33 + 0.55 \times \$21.52$$

$$VBTTS_{train} = \$27.94 = (1 - 0.53 - 0.24 \times 0.95) \times \$68.33 + 0.53 \times \$21.52$$

The VBTTS values for bus and train are respectively 12% and 38% below the VBTTS for car of $44.72 estimated from the Hensher equation. This is further evidence that VTTSs for public transport are lower than for car.

The recent NZ survey included choice questions for public transport as well as private car transport, so the car and public transport VTTS estimates would have been obtained using the same methodology. Public transport VTTS estimates were well below the VTTS estimates for car travel. For commuter trips, the public transport VTTS seated was 26% of the VTTS for car travel in free-flow conditions. For other (non-work) trips, the public transport VTTS seated was 21% of the VTTS for car travel in free-flow conditions. For standing, the respective public transport VTTS estimates were 38% and 33% of the VTTS for car travel (Denne et al. 2023, p. 86). The NZ VTTSs for public transport are exceptionally low. However, this is just one survey.

The UK DfT (2015) study recommended a bus travel VTTS of 85% of the ‘all-modes’ VTTS for commuters and 83% for other (non-work) for time spent seated without having to sit next to anyone. The ratios were 95% and 100% for ‘other public transport (UK DfT 2015a, p.14; Batley et al. 2019, p. 613). The differences between modes were therefore quite small.

The car VTTSs from the national survey improves upon the current values in ATAP (2016) because, in the case of business travel, they reflect leakage of business travel time savings and work done while travelling, and for commuting, higher values compared to non-work time due to working from home and high housing costs. It is desirable that these updates are carried across to the VTTSs for other modes. However, there is a range of evidence that public transport VTTSs are below those for car travel.

It is recommended that ATAP adopts the VTTSs from the national survey for use in public transport as equity values. ATAP could consider whether behavioural values of the order of 25% lower should be adopted for public transport and active travel.

7.2 Values of risk reduction (safety)

Only two WTP surveys were found for pedestrian safety and none for cyclists. The NSW RTA (2008) stated choice study discussed previously with regard to car occupants, also included a survey of pedestrians. The pedestrian survey was discussed in detail in Hensher et al. (2011). Survey respondents were asked to choose between walking routes that included crossing a major road with different pedestrian infrastructure (for example, without and with an overpass), travel times, increases in rates paid per month and numbers of deaths and injuries per annum. The sample size was 99. The WTP estimates from the car and pedestrian surveys were combined to produce values for all deaths and injuries in NSW. Fatality VRRs for pedestrians were slightly below those for car travellers (14% below for urban and 4% below for non-urban) but injury VRRs were much higher (ranging from 87% to 433%) (RTA 2008, p. 32). However, the pedestrian study employed the same conversion formula as the car study discussed in Section 4.4 above. The exposure assumption was a general population average of one one-way pedestrian trip per day with an average length of one kilometre (Hensher et al. 2011, p. 88).[16]

The nature and context of pedestrian and cycling crashes could well lead to different VRRs than for car occupants, however, it would require multiple surveys to confirm this and the result from each survey would be highly influenced by the way it addressed exposure. As noted in Section 6.4 above, Ananthapavan et al. (2021, p. 12) found the evidence for different VSLs in different contexts to be unclear, even between cancer and road trauma, and recommended using a consistent VSL across risk contexts until further evidence on the preferences of the Australian population becomes available.

The ANU (2022) study, the source of the material costs of crashes in Chapter 6, covered all types of road crashes including those involving motorcycles, light commercial vehicles, buses, trucks (rigid and articulated), pedestrians and pedal cyclists. So the material costs added to the WTP values already take into costs of other types of crashes.

It is recommended that the social costs of crashes estimated in Chapter 6, be used for all types of road crashes including crashes motorcycles, light commercial vehicles, buses, trucks (rigid and articulated), pedestrians and pedal cyclists.

[16] The same methodology to estimate VRRs for pedestrians was employed in Niroomand and Jenkins (2017) for North Cyprus.

Appendix A Summaries from interim reports

This appendix reproduces the 'At a glance' sections of the reports for the scoping study and the stages of the WTP survey, and the conclusion from the peer review of the survey instrument.

A.1 A scoping study for future research into values of travel time savings for project appraisal and toll road patronage forecasting, June 2016

In the process of updating the National Guidelines for Transport System Management (NGTSM), Austroads has identified the need to commission new research in four areas:

- The value of travel time reliability;
- The distribution of values of travel time savings;
- The value of time savings for freight; and
- The value of time savings for light commercial vehicles (LCVs).

To prepare for commissioning research, this report provides a detailed literature review which identifies a number of options for research in each area.

A preferred methodology for each area of research is identified based on consultations with a range of industry experts.

The preferred methodologies are:

- A stated preference survey to establish the reliability ratio accompanied by a statistical analysis to provide an updated and possibly simplified model of travel time variability.
- A stated preference survey to establish values of travel time savings for both work and non-work travellers. For non-work travellers this should be supported by some revealed preference data analysis. For work travellers this should build on an update of the currently used cost saving approach (CSA) and a pilot study on the applicability of the Hensher equation to Australian data.
- A stated preference survey targeted at areas throughout the freight supply chain to obtain a holistic understanding of the freight task and values of time saving for different participants.
- Maintaining the CSA approach for the value of time savings for LCV combined with an industry survey of vehicle use patterns to better inform application of the value of time savings.

A detailed scope for each preferred methodology is provided which is designed for use in developing requests for quote.

Consultations indicate that it would be feasible to combine the stated preference surveys for the value of travel time reliability and travel time savings (and possibly include the value of safety). This could present significant budget savings over commissioning separate pieces of research.

A.2 Stage 1 Willingness to pay survey design and test, June 2017

This report presents the first step in undertaking a national willingness-to-pay (WTP) survey for the value of travel time savings, the value of reliability improvements and the value of increased road safety for passengers and drivers in private vehicles. The first step covered in this report involves the design and initial testing of the survey instrument.

This project has been undertaken by Deloitte Access Economics in partnership with Prof. David Hensher, Prof. John Rose and Dr. Chinh Ho. Expert advice was also provided by Prof. Simon Washington. Prof. Juan de Dios Ortuzar was the peer reviewer of this study.

A brief literature review has been conducted to inform the survey design and to identify the range of parameter values seen in the literature.

Designing the stated preference survey is complicated because it needs to balance simplicity for respondents against a desire for gathering detailed information, as well as accounting for statistical issues. There are often many potential approaches to the design. The major issues addressed and the resulting decisions are set out in detail in the report.

The survey itself was designed as an online survey with the options presented being reflective of a recent trip that the respondent has undertaken. The values presented to respondents are designed to provide the most efficient set of data from the available sample.

A number of tasks have been undertaken to test the proposed survey design. These involved: receiving feedback from project steering group members, running focus groups, extensive in-house testing, trial data analysis and a peer review. The design of the survey instrument was iteratively revised based on feedback received.

Trial data analysis was undertaken to demonstrate that the survey instrument was generating data in a reliable manner. It should be noted that this trial data analysis is not meant to be representative of or provide parameter values for use in appraisals.

The trial data analysis generated results that are broadly consistent with other results seen in the literature with good performance in terms of how parameter estimates align with expectations and previous experience. Performance in terms of statistical significance was also acceptable given the small sample size.

We have considered three options that are available to Austroads at this stage: proceeding to a pilot using the current instrument, adding some additional testing functionality to the survey before proceeding to a pilot, and splitting the survey before proceeding to a pilot. Each option presents particular risks and benefits which are considered in the report.

Overall, we recommend that Austroads proceeds to a nationally representative pilot survey using the current survey instrument. The pilot survey can be used to further test the survey instrument and also to better parameterise and budget for a full national survey.

Specific items to include in the RFP for the pilot and issues for consideration by Austroads before the pilot stage are identified in the report.

A.3 Stage 2 Willingness to pay survey pilot final report, October 2018

This study focuses on a Pilot of a Willingness-to-Pay (WTP) survey to provide estimates of the value of travel time savings, reliability improvements, and improvements to road safety for drivers and passengers of privately owned motor vehicles.

Deloitte Access Economics undertook this project in partnership with Prof. David Hensher and Dr. Chinh Ho of The Hensher Group, Taverner Research, Prof. John Rose of Community and Patient Preference Research (CaPPRe). Dr Angela Watson of CARRS-Q also provided expert advice.

The Pilot ran from October 2017 until June 2018 in three jurisdictions and involved iterative reporting and review of the survey instrument.

A number of specific design decisions and updates were made to the survey throughout this period. These focused on reviewing injury descriptions, updating the reliability chart, adding a post-survey questionnaire, adding a pre-survey quiz, re-optimising attribute levels and manually checking choice sets.

An initial sampling and recruiting plan was established and delivered throughout the project. This involved implementing quotas on trip duration, region and purpose. The final sample was reflective of initial goals but did show some biases in terms of socio-demographics.

The pilots were implemented in Victoria (Melbourne and Bendigo), Queensland (Brisbane and Toowoomba) and Western Australia (Perth and Bunbury). Implementation was done using both face-to-face and online methods. Implementation occurred sequentially in each location.

Given the significant changes and improvements to the survey instrument, the data analysis for Western Australia provides the main results for the pilot.

The results for Western Australia are broadly consistent with other results seen in the literature with good performance in terms of how parameter estimates align with expectations and previous experience and in statistical significance.

It is recommended that ATAP undertakes a well-structured National Survey, which could commence in early 2019. This would allow time for a post pilot to confirm results for Western Australia and for enhanced online methods to be trialled.

This report identities specific items to include in the request for proposal (RFP) for the National Survey and issues for consideration by ATAP before the national stage.

A.4 Initial survey – New South Wales, April 2019

50 face-to-face interviews were conducted in Sydney during the period of 3-6 of December and 55 in Orange during the period of 10-12 December, 2018, inclusive.

Data analysis on the face-to-face interview responses was undertaken, resulting in the estimation of the following main values:

- Mean Value of Travel Time Savings (VTTS) of $13.22;
- Mean Value of Reliability (VOR) of $29.54; and
- Willingness-to-pay (WTP) values per car trip to reduce the risk of various crash categories: Property damage only ($0.24); minor injury ($0.36 not statistically significant); major injury ($0.15 not statistically significant), incapacitating injury ($1.04); fatality ($1.65).

The estimated VTTS and VOR values are in the range of what was expected and are commensurate with values in the literature.

The safety WTPs derived are within the expected range, with the exception of the major injury category. Values for fatality and incapacitating injury are statistically significant at the 5% level and the property damage category is statistically significant at the 10% level. The minor and major injury categories were not statistically significant.

Survey participants' feedback, collected through post-questionnaire questions, show that respondents had a good understanding of the survey. This is highlighted in the high average overall rating for the survey of face-to-face respondents, which was 9.4 out of 10.

Overall, 6 of 9 Key Performance Indicators (KPIs) reached target. Under-performing KPIs were related to the level of statistical significance of the parameter estimates and the magnitude of the value for the major injury category.

Analysis of the data for the NSW initial survey suggests that simpler models which are more appropriate for the sample size available generate results that perform better in terms of statistical significance. This suggests that the survey instrument in its current form is likely to be appropriate for use in a national undertaking. These results indicate that the larger sample size from a national survey will likely address issues relating to statistical significance that arise in the more complex models presented as the main results in this report.

The results of analysis when pooling data for NSW and WA indicate strong improvements in performance. This further suggests that existing issues are likely due to sample size related issues rather than issues with the survey instrument itself.

Data already collected from NSW and Western Australia can likely be included in the National Survey. Online data from Western Australia appears to be of an acceptable quality but could be excluded from the National Survey without significant financial or statistical consequence.

A.5 National willingness-to-pay survey for travel times, reliability and road safety: provision of peer review, January 2019

Report prepared by the Social Research Centre at the Australian National University

This report provides peer review for the WTP Survey, which will form part of the ATAP Guidelines, providing values for travel time savings and crash costs for application to project appraisals (ATAP Steering Committee 2017:3). The survey's WTP values will remain valid for an 8-10-year period (Naude et al. 2015:2). The core of the WTP Survey is a set of five stated preference choice tasks that ask the respondent to choose between two alternatives where travel time, reliability, safety and travel cost are systematically varied. Travel time, reliability and safety have not been previously combined in a stated preference task. The focus of the peer review is to assess whether survey respondents understand the information presented to make choices that truly reflect their preferences and whether the statistical results are a true representation of average preferences. I judge that there is insufficient evidence that survey respondents understand the travel time and reliability information presented to them and, thus, that there is insufficient evidence that the statistical results are a true representation of average preferences. I am persuaded that the injury items are, in broad terms, understood by respondents.

My primary recommendation is to conduct a rapid round of 8 to 12 cognitive interviews to determine whether respondents understand the information presented to them and whether they take into account all the information presented to them in the choice tasks. Cognitive interviewing is the gold standard for determining how respondents understand survey items. Cognitive interviewing would resolve, one way or another, whether survey respondents understand the travel time and reliability information that they are presented and whether they take into account all the information they are presented when completing the choice tasks.

I also recommend simplifying two aspects of the choice task to remove extraneous cognitive load: removing the bar graph showing the amount of time in congested traffic and providing a single sum of travel cost in the place of the separate toll and running costs currently presented. I am cautiously optimistic that, by removing time in congested traffic and the distinction between tolls and running costs, it will be possible to effectively combine safety with travel time and reliability in a way that respondents understand. I also recommend small changes to simplify language and remove the use of contractions on the travel time and reliability chart. To ensure that individual respondents understand the travel time and reliability chart in the survey, I recommend adding questions similar to those used to test for understanding of the injury categories to test for understanding of the presentation of travel time and reliability. If necessary, such questions could be used to identify and filter out respondents who did not understand the choice task.

To provide additional context to the crash/injury counts, I recommend adding a statement that makes it clear that the crash/injury profile of the two routes in each choice task are directly comparable.

Because there is a gradient of attention to information displayed on a screen, with respondents paying greater attention to the top of the screen, I recommend randomising the location of the travel time and reliability and safety data between the top and bottom of the screen across respondents. This will ensure that there is no systematic bias in favour of travel time and reliability data due to its location on the screen.

I also recommend removing unnecessary icons throughout the survey as these can have unintended consequences. I make exceptions for the crash/injury data and the illustrations of congested traffic and built-up areas. The ATAP Steering Committee should, however, satisfy itself that the image used to illustrate a built-up environment is appropriate. I believe that respondents will use this as an indicator of the minimum degree of urbanisation for an area to be considered built-up and want to ensure that the image matches the ATAP Steering Committee's understanding of what is a built-up area.

I have concerns about interviewer effects and recommend that the research team test pilot data and that of the soft start to the main study for interviewer effects. I also recommend ensuring that interviewers are carefully briefed and regularly monitored to ensure that interviews are conducted in a standardised fashion to minimise interview effects. I draw attention to two interviewer behaviours that I observed in the context of being interviewed that could lead to interviewer effects.

The WTP Survey's sampling frame was not described in the material I reviewed. I surmise—perhaps incorrectly—that the same almost certainly unrepresentative sampling frame used for face-to-face interviews in the pilot (recruiting databases) would be used in the main WTP Survey effort. If so, coverage error would be a near certainty and the ability of the sample to represent the Australian population would be questionable.

I recommend reporting response rates for the main WTP Survey and provide references to various guidelines for disclosure of research methods for published research.

It was unclear from the information that I reviewed whether the WTP Survey data would be weighted. I recommend that weights be created and used in analyses and describe the factors that would typically be weighted for in a national survey in Australia, together with other factors that may be appropriate given the topic of the WTP Survey.

A.6 Stage 3 report

Deloitte Access Economics was engaged by Austroads to update the values of travel time savings and risk reduction for car users on Australia's roads and produce a value of reliability based on users' willingness-to-pay (WTP) values. This study seeks to update Australian guidelines from the current approach to a willingness-to-pay approach, in line with international standards.

The willingness-to-pay values were derived through a nation-wide survey (the National Survey), utilising a discrete choice experiment.

The project was undertaken between 2018 and 2022, with the timeline being significantly longer than anticipated because of interruptions that occurred due to the COVID-19 pandemic.

The responses of 3,844 survey respondents were used to develop the final set of WTP values. The groups were weighted to ensure the resulting values and parameter estimates were proportionate to the expected distribution of incomes and trip distances.

Separate values for travel time savings and reliability improvements were estimated for three trip purposes — commuting, non-work travel and business travel. The travel time saving value was also distinguished by traffic conditions — congested and free-flow — with an additional weighted value being derived for each trip purpose.

The weighted average values for travel time savings were $31.10/hour for commuting, $33.53/hour for business travellers and $18.81/hour for non-work travellers.

The value of reliability was measured in dollars per hour of standard deviation of travel time. The values were $35.50/hour for commuting, $36.87 for business travellers and $31.35 for non-work travellers.

The ratio of the value of reliability to the value of time is known as the reliability ratio. These were 1.1 for commuting, 1.1 for business travellers and 1.7 for non-work travel.

The value of risk reduction was split into five categories of road crash severity: property damage, minor injury, major injury, incapacitating injury and fatality.

The findings for the value of safety were that there is a willingness-to-pay of $16,000 to prevent a crash that only results in property damage, $24,660 per crash to avoid minor injury, $500,010 per crash to avoid major injury, $1.455m per crash to avoid incapacitating injury and $3.664m per crash to avoid a fatality. These do not represent the full social cost of a crash.

The survey and data analysis have been documented in detail to enable replication of the study in the future.

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