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# ECONOMIC CONNECTIONS

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Australian  
Automobile  
Association

## Benefits of reducing the age of Australia's light vehicle fleet

July 2017



*Economic Connections Pty Ltd has prepared this report for the Australian Automobile Association. The authors of the report are Phil Potterton, Anthony Ockwell and Jamie Cross, in collaboration with Stuart Newstead, Monash University Accident Research Centre and Adam Pekol, Pekol Traffic and Transport.*

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*The report is based on the information and industry advice available at the time of writing. We acknowledge the use of published information as background material in the preparation of this report.*



# Executive summary

In February 2017, the Australian Automobile Association commissioned Economic Connections (ECON), with Pekol Traffic and Transport and Monash University Accident Research Centre, to undertake an analysis of the road safety and environmental benefits that could accrue from a one year reduction in the average age of the light vehicle fleet, i.e. passenger vehicles and light commercial vehicles and excluding motorcycles. Identification and assessment of policy options to put in place a younger vehicle fleet, including the costs of any options, are outside the study's scope.

The study supports the goals of the association in ensuring that Australian motoring is safe and affordable. It complements a recent study for the AAA, which estimates the cost of road trauma in 2015 to the Australian community and to government (ECON 2017).<sup>1</sup>

The study methodology is in five parts. Firstly, a future light vehicle fleet is estimated under a 'business as usual' case and under two scenarios to achieve the one year average age reduction: a 'short take up' (four year phase-in) scenario and a 'long take up' (eight year phase-in) one, with the reduced average age retained for the remainder of a 20 year analysis period. The second and third parts involve estimating quantified road safety impacts and vehicle emissions impacts for the business as usual case and for each scenario. Benefits analysis follows, fourthly, with economic valuation of: the reduction in fatalities, disabilities and other costs (road trauma); avoided mortality and morbidity (pollutant emissions); and avoided climate damage (greenhouse gas emissions). Finally, financial savings to government resulting from these benefits are, where feasible, estimated.

## Future light vehicle fleet

Tomorrow's vehicle stock is a function of today's, plus new sales, less scrapped vehicles. Using a stock adjustment model, based on vehicle-related and socio-economic data, the future light vehicle stock is estimated to increase, in the business as usual case, from 16.5 million in the project reference year, 2014, to 25.2 million in 2034 (Table ES1), the final year of the analysis period. The vehicle fleet is projected to grow at an average annual growth rate of 2.1 per cent, with LCVs increasing faster than passenger vehicles. Total vehicle kilometres travelled are estimated to increase by 1.6 per cent a year (passenger vehicles) and 2.2 per cent a year (LCVs), with the differential reflecting the faster growth of the LCV category.

**Table ES1 Size of the light vehicle fleet, 2014 and projected 2034**

Year	Passenger vehicles	Average annual growth	LCVs	Average annual growth	Total	Average annual growth
2014	13,607,737	2.0%	2,909,596	2.9%	16,517,333	2.1%
2034	20,037,502		5,171,769		25,209,271	

The average age of today's light vehicle fleet is approximately 10 years. The fleet average age was reduced by 10 per cent (one year age reduction proxy) by increasing the number of new vehicles and accelerating the vehicle scrappage rate, thereby keeping the number of vehicles in

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<sup>1</sup> Economic Connections 2017, *Cost of road trauma in Australia 2015*

the fleet (and vehicle kilometres travelled) unchanged between the business as usual case and the two scenarios. The lower average age was then retained, using the same method, for the remainder of the 20 year analysis period. For the short take up scenario, an average of an additional 233,000 passenger cars (an extra 29 per cent of annual new cars and 1.7 per cent of the 2014 fleet size) and an extra 53,000 LCVs were added for each of the first four years, with a similar number of older vehicles withdrawn (Table ES2). For the long take up scenario, some 146,000 cars were added and withdrawn for each of the first eight years (33,000 LCVs).

**Table ES2 Additional new and scrapped vehicles, scenario take up periods**

Additional vehicles per year (take up)	Short (4 year) take up		Long (8 year) take up	
	Passenger vehicles	LCVs	Passenger vehicles	LCVs
New	232,913	53,282	145,572	33,302
Scrapped	232,913	53,282	145,572	33,302

## Road trauma scenarios

Future road trauma is a function of estimated vehicle exposure (indicated by the number of vehicles and vehicle kilometres travelled, as outlined above), the risk of crash involvement and the rate of injury, including severity, per crash.

The study identified and tabulated crashes involving passenger vehicles and LCVs, by year of manufacture, for the reference year 2014, to generate crash risk estimates. Future year crash risk was adjusted to reflect progressive fleet penetration by two primary safety technologies of proven effectiveness, Electronic Stability Control (ESC) and Autonomous Emergency Braking (AEB). ESC has been mandated in new Australian passenger cars from 2012, while the fitment rate for LCVs is expected to reach 100 per cent by 2020. The AEB fitment rate was projected to follow the trajectory of ESC take up, approaching 90 per cent in the early 2020s, with LCVs reaching this level in the later 2020s.

The study selected the total secondary safety index,<sup>2</sup> which rates vehicles on the basis of the risk of death or serious injury to all people involved in a crash (i.e. including pedestrians, cyclists and motorcyclists), to measure the rate of injuries per crash. Estimates to 2014 are available by make and model of vehicle and by year of manufacture. The index assumes the relative risk between years of manufacture are the same for deaths as for hospitalised injuries. The estimates to 2034 assumed that past trends of improvement by year of manufacture would continue into the future.

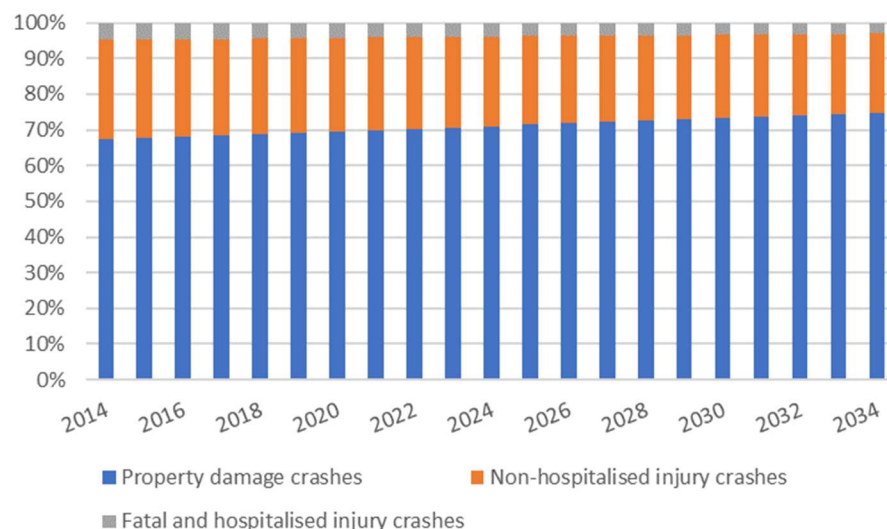
In the business as usual case, the total number of crashes is held constant, but with their severity reducing.<sup>3</sup> Fatal and injury crashes decline by 36 per cent over the 20 year period, from 4.8 per cent of all crashes in 2014 to 3.2 per cent of all crashes in 2034 (Figure ES1).

<sup>2</sup> Newstead, S, Watson, L and Cameron, M 2016, *Vehicle Safety Ratings Estimated from Police Reported Crash Data: 2016 Update. Australian and New Zealand Crashes During 1987-2014*, Report No. 328, Monash University Accident Research Centre, Melbourne

<sup>3</sup> Alternative 'crash increase' and 'crash reduction' business as usual cases were also modelled, prior to selection of an intermediate 'fixed crashes' case. While absolute numbers differ, percentage crash reductions under the two scenarios are the same, regardless of the choice of business as usual case option.

Non-hospitalised injury crashes also fall, from 27.9 per cent to 22.8 per cent. In contrast, property damage crashes increase from 67.3 per cent in 2014 to 74 per cent in 2034. Fatal and hospitalised injury crashes fall by a further seven per cent in the short take up scenario (Table ES3) and six per cent in the long take up scenario (Table ES4).

**Figure ES1 Change in distribution of crash severity, business as usual case**



**Table ES3 Reduction in the number of road crashes, short take up**

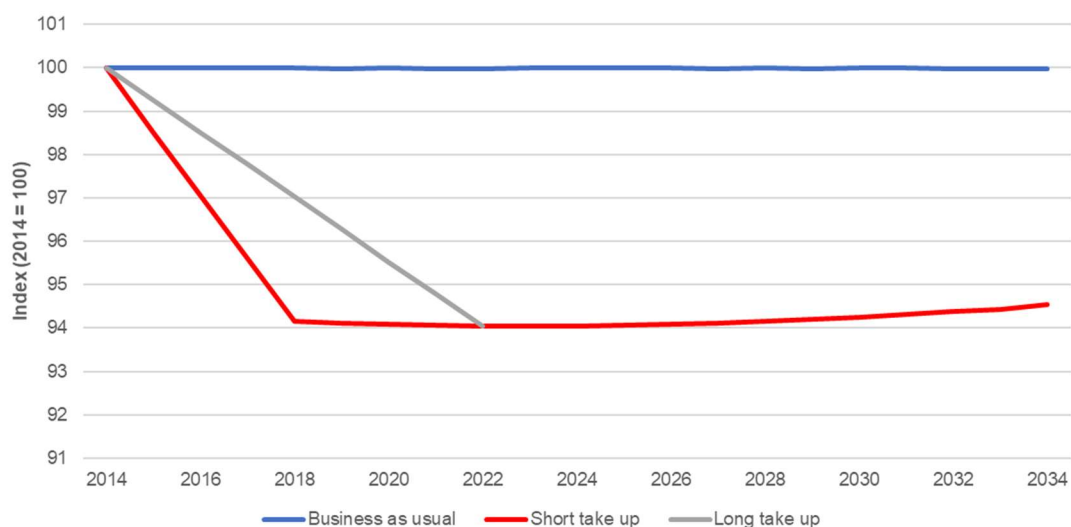
Crash type	Passenger vehicles			LCVs			Total		
	Business as usual 20 year total crashes	20 year scenario reduction	% change	Business as usual 20 year total crashes	20 year reduction	% change	Business as usual 20 year total crashes	20 year scenario reduction	% change
Fatal	15,155	-1,134	-7.5%	2,498	-129	-5.2%	17,653	-1,263	-7.2%
Hospitalised injury	435,467	-32,592	-7.5%	71,769	-3,706	-5.2%	507,236	-36,298	-7.2%
Non-hospitalised injury	2,913,318	-192,478	-6.6%	471,355	-20,654	-4.4%	3,384,673	-213,131	-6.3%
Property damage	8,287,843	-442,397	-5.3%	1,389,775	-38,561	-2.8%	9,677,619	-480,958	-5.0%
TOTAL	11,651,783	-668,601	-5.7%	1,937,895	-63,050	-3.3%	13,589,678	-731,651	-5.4%

**Table ES4 Reduction in the number of road crashes, long take up**

Crash type	Passenger vehicles			LCVs			Total		
	Business as usual 20 year total crashes	20 year scenario reduction	% change	Business as usual 20 year total crashes	20 year scenario reduction	% change	Business as usual 20 year total crashes	20 year scenario reduction	% change
Fatal	15,155	-992	-6.5%	2,498	-115	-4.6%	17,653	-1,107	-6.3%
Hospitalised injury	435,467	-28,513	-6.5%	71,769	-3,290	-4.6%	507,236	-31,804	-6.3%
Non-hospitalised injury	2,913,318	-170,131	-5.8%	471,355	-18,479	-3.9%	3,384,673	-188,610	-5.6%
Property damage	8,287,843	-396,590	-4.8%	1,389,775	-35,007	-2.5%	9,677,619	-431,597	-4.5%
TOTAL	11,651,783	-668,601	-5.7%	1,935,397	-63,050	-3.3%	13,587,180	-653,117	-4.8%

In terms of annual impacts, estimated crash savings peak at the point where the full maximum age reduction is delivered and diminish slightly thereafter (Figure ES2). This trend reflects that the general crash base to which the age change savings apply diminishes slowly over time as the general trend in improving safety of the vehicle fleet continues. Hence the absolute crash and injury savings, which are proportionate to the change in safety level, diminish also after the fleet age change is fully implemented.

**Figure ES2 Total road crashes, business as usual and scenarios**



## Emissions scenarios

Future passenger vehicle emissions modelling is based on: emission factors which take account of mandated Euro 5 noxious emissions standards for new vehicles, introduced progressively between 2013 and 2016; fuel specification and average consumption rates (based on in-service data in the Australian Bureau of Statistics Survey of Motor Vehicle Use); distance travelled by vehicle age, with each influencing the rate of catalytic converter deterioration; climatic conditions; and other factors. Euro 6 standards, which would tighten regulation of the two most harmful pollutants for human health, oxides of nitrogen (NOx) and particulate matter (PM), are



currently under consideration and are not included in the modelling. Similarly, mandatory fuel efficiency standards, which would reduce carbon dioxide emissions, are also not included.

### Pollutant emissions

In the business as usual case, continuing reductions are projected in levels of oxides of nitrogen, as with carbon monoxide and sulfur dioxide. Particulate matter emissions (PM<sub>2.5</sub> and PM<sub>10</sub>)<sup>4</sup> are expected to be largely stable over the 20 year period. The business as usual trajectory, with an equal weighting of each pollutant, is shown in Figure ES3.<sup>5</sup>

Total vehicle pollutant emission reductions over the 20 year analysis period range from 0.7 per cent for sulfur dioxide (SO<sub>2</sub>) to 11.6 per cent for hydrocarbons and volatile organic compounds (HC/VOC) in the short take up scenario (Table ES5). The corresponding reductions are 0.6 per cent (SO<sub>2</sub>) and 8.6 per cent (HC/VOC) in the long take up scenario (Table ES6).

**Table ES5 Reduction in pollutant emissions, short take up scenario, tonnes**

Pollutant	Passenger vehicles			LCVs			Total vehicles		
	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change
CO	2,581,452	-244,320	-9.5%	1,655,726	-172,169	-10.4%	4,237,178	-416,489	-9.8%
HC/VOC	263,145	-30,646	-11.6%	128,754	-14,688	-11.4%	391,900	-45,333	-11.6%
NO <sub>x</sub>	826,564	-70,219	-8.5%	662,576	-41,602	-6.3%	1,489,140	-111,820	-7.5%
PM <sub>2.5</sub>	58,192	-590	-1.0%	32,275	-1,343	-4.2%	90,467	-1,933	-2.1%
PM <sub>10</sub>	100,199	-621	-0.6%	49,554	-1,413	-2.9%	149,754	-2,035	-1.4%
SO <sub>2</sub>	27,415	-94	-0.3%	3,993	-119	-3.0%	31,408	-213	-0.7%

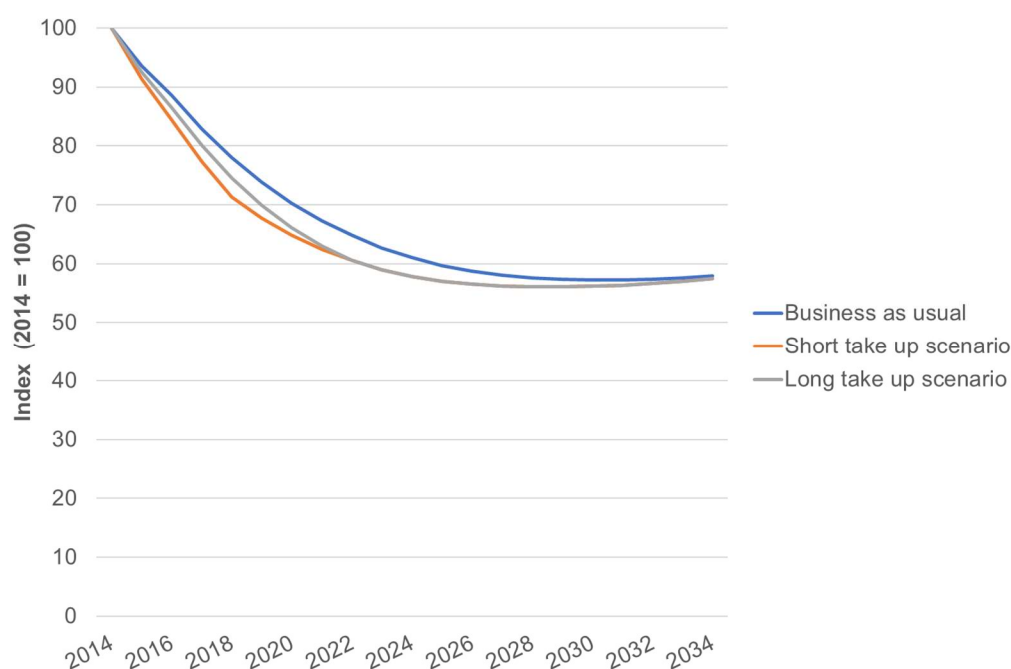
<sup>4</sup> Particulate matter of up to, respectively, 2.5 and 10 micrometres in diameter.

<sup>5</sup> Equal weighting of pollutants mitigates what, under a simple totalling approach, would be the high impact of the preponderant volumes of carbon monoxide, a less harmful pollutant for human health and, conversely, the low impact of the small volumes of particulate matter, the most harmful pollutant.

**Table ES6 Reduction in pollutant emissions, long take up scenario, tonnes**

Pollutant	Passenger vehicles			LCVs			Total vehicles		
	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change
CO	2,581,452	-182,056	-7.1%	1,655,726	-135,322	-8.2%	4,237,178	-317,377	-7.5%
HC/VOC	263,145	-22,746	-8.6%	128,754	-11,088	-8.6%	391,900	-33,834	-8.6%
NO <sub>x</sub>	826,564	-52,955	-6.4%	662,576	-34,214	-5.2%	1,489,140	-87,169	-5.9%
PM <sub>2.5</sub>	58,192	-490	-0.8%	32,275	-1,140	-3.5%	90,467	-1,630	-1.8%
PM <sub>10</sub>	100,199	-516	-0.5%	49,554	-1,200	-2.4%	149,754	-1,716	-1.1%
SO <sub>2</sub>	27,415	-84	-0.3%	3,993	-103	-2.6%	31,408	-187	-0.6%

**Figure ES3 Pollutant emissions, business as usual and scenarios**



Note: The index is constructed by equally weighting the volumes of each pollutant. See also Footnote 5.

### Greenhouse gas emissions

Carbon dioxide (CO<sub>2</sub>) emissions are closely linked to vehicle fuel consumption rates and total vehicle distance travelled and, consistent with Australian Government projections, are projected to continue to increase in the business as usual case.

Carbon dioxide equivalent (CO<sub>2</sub>-e) emissions, which include small quantities of methane and nitrous oxide, in addition to carbon dioxide, the predominant greenhouse gas, are estimated to reduce minimally, by 0.1 per cent in both scenarios (tables ES7 and ES8). This result includes a small increase in LCV carbon dioxide emissions, reflecting the impact of the influx of new LCVs. The fuel consumption rate of new petrol-fuelled LCVs is projected to continue to decline, with

the trend for diesel LCVs either flat or increasing. Scenario reductions are almost too small to be discernible in Figure ES3.

**Table ES7 Reduction in greenhouse gas emissions, short take up scenario, 000 tonnes**

Greenhouse gas	Passenger vehicles			LCVs			Total vehicles		
	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change
CO <sub>2</sub>	1,034,558	-1,713	-0.2%	385,236	175	0.05%	1,419,794	-1,538	-0.1%
CH <sub>4</sub>	469	-48	-10.3%	108	-15	-13.9%	577	-63	-8.0%
N <sub>2</sub> O	2,852	-139	-4.9%	2,022	-41	-2.0%	4,874	-180	-2.8%
TOTAL (1)	1,037,879	-1,901	-0.2%	387,365	120	0.03%	1,425,244	-1,781	-0.1%

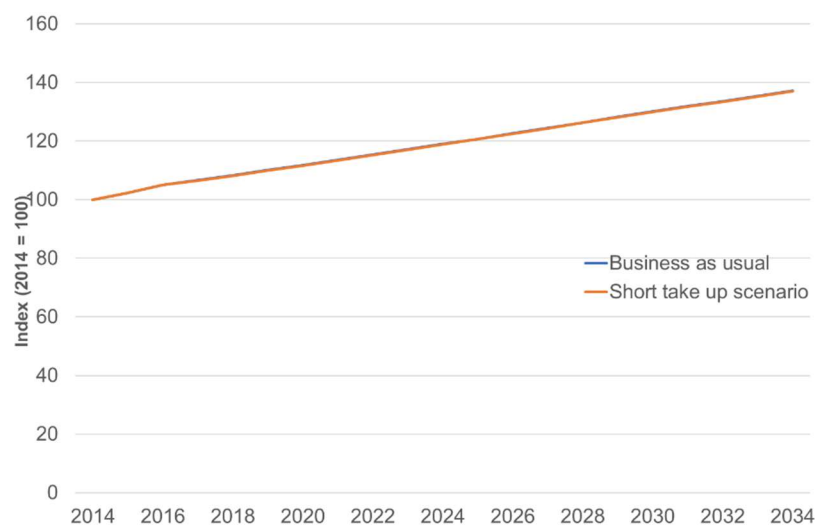
(1) Total is calculated in carbon dioxide equivalent (CO<sub>2</sub>-e) terms.

**Table ES8 Reduction in greenhouse gas emissions, long take up scenario, 000 tonnes**

Greenhouse gas	Passenger vehicles			LCVs			Total vehicles		
	Business as usual 20 year total emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change
CO <sub>2</sub>	1,034,558	-1,395	-0.1%	385,236	167	0.04%	1,419,794	-1,229	-0.1%
CH <sub>4</sub>	469	-34	-7.3%	108	-12	-10.8%	577	-46	-8.0%
N <sub>2</sub> O	2,852	-103	-3.6%	2,022	-33	-1.6%	4,874	-136	-2.8%
TOTAL	1,037,879	-1,533	-0.1%	387,365	122	0.03%	1,425,244	-1,411	-0.1%

(1) Total is calculated in carbon dioxide equivalent terms.

**Figure ES4 Greenhouse gas emissions, business as usual and short take up scenario**



Note: The long take up scenario is distinguishable from the short take up only from the second decimal point onwards and is accordingly not shown separately here.

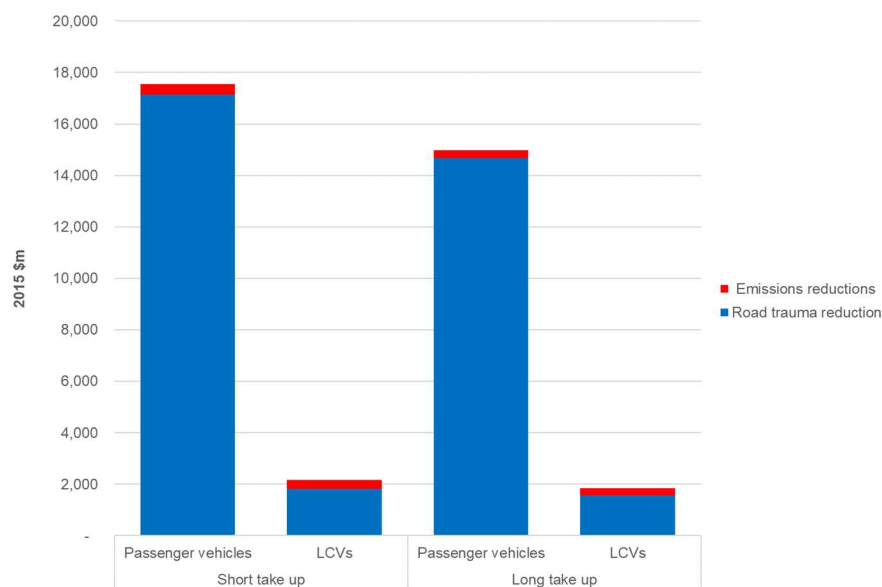
## Economic valuation

Valuation of reductions in road trauma is based on Economic Connections' update (ECON 2017), using 2015 data, of estimates by the Bureau of Infrastructure, Transport and Regional Economics (BITRE) of the cost of road trauma in 2006.<sup>6</sup> ECON 2017 adopts the 'willingness to pay' based valuation of statistical life recommended by the Australian Government Office of Best Practice Regulation (\$4.41m in 2015 prices), in preference to the BITRE 2009 'hybrid human capital' valuation (\$3.44m in 2015 prices). The study valuation is, however, lower than one based on estimates of the willingness to pay for road safety in Australia that is included as a sensitivity test in BITRE 2009 (\$7.94m in 2015 prices).

With regard to pollutant emission valuation, this study primarily follows the values for health and mortality impacts used in the Australian Government's draft regulation impact statement on introduction of Euro 6 light vehicle emission standards.<sup>7</sup> Valuation of carbon dioxide equivalent emissions, reflecting climate damage, is based on values for the social cost of carbon used by the United States Environmental Protection Agency in relation to environmental rulemaking.

At a three per cent discount rate, selected for consistency with ECON 2017 and BITRE 2009, the present value of benefits totals \$19,749.9m under the short take up and \$16,880.5m under the long take up (Figure ES5).<sup>8</sup> Under each scenario, road trauma reductions comprise 96 per cent of total benefits, with emissions reduction impacts making up the balance. Passenger vehicles account for the greater part of benefits under both scenarios (90-92 per cent of road trauma benefits, 76-78 per cent of emission benefits).

**Figure ES5 Present value of total benefits, short and long take up, 3% discount rate**



<sup>6</sup> Bureau of Infrastructure, Transport and Regional Economics 2009, *Cost of road crashes in Australia 2006*, Report 118

<sup>7</sup> Department of Infrastructure and Regional Development 2016, *Vehicle emissions standards for cleaner air*, Draft Regulation Impact Statement, Ministerial Forum on Vehicle Emissions

<sup>8</sup> The study uses a 'present value' measure rather than 'net present value', as costs of scenario introduction are not considered.

## Sensitivity tests

Sensitivity tests are undertaken using, in relation to safety benefits, the BITRE 2009 hybrid human capital valuation of statistical life (ECON proxy) approach, Sensitivity 1 in Table ES12 and also the BITRE 2009 willingness to pay for road safety approach, Sensitivity 2.

With regard to emissions benefits, all values are varied by plus and minus 50 per cent, as in the Australian Government draft regulation impact statement (in respect of pollutant emissions). The wide sensitivity range acknowledges the significant uncertainty regarding the actual health cost effects.

Under the Sensitivity 1 approach, the present value of benefits for the short and long take ups total \$17,542.9m and \$15,026.7m. Corresponding benefits are \$26,598.2m and \$22,692.9m under the Sensitivity 2 approach.

**Table ES12 Total benefit sensitivity tests, alternative valuations, 3% discount rate, 2015 \$m**

Scenario	SENSITIVITY 1 (1)			STUDY ESTIMATES			SENSITIVITY 2 (2)		
	Passenger vehicle	LCV	Total	Passenger vehicle	LCV	Total	Passenger vehicle	LCV	Total
Short take up	15,734.9	1,808.0	17,542.9	17,544.0	2,160.7	19,704.7	23,606.6	2,991.6	26,598.2
Safety	15,533.4	1,636.0	17,169.5	17,141.0	1,816.7	18,957.8	23,002.2	2,475.6	25,477.8
Emissions	201.5	172.0	373.5	402.9	344.0	746.9	604.4	516.0	1,120.4
Long take up	13,465.1	1,561.6	15,026.7	14,988.8	1,857.0	16,845.8	20,127.4	2,565.5	22,692.9
Safety	13,307.4	1,422.4	14,729.7	14,673.4	1,578.5	16,251.9	19,654.1	2,147.8	21,801.9
Emissions	157.8	139.2	297.0	315.4	278.5	593.9	473.3	417.7	891.0

(1) This involves, for road safety, an ECON proxy of the BITRE hybrid human capital approach and, for emissions, a 50 per cent reduction of all study values.

(2) This involves use of the BITRE 2009 willingness to pay for road safety sensitivity approach and, for emissions, an increase in study values of 50 per cent.

Sensitivity tests were also conducted at an alternative higher discount rate (seven per cent).

Total benefits are approximately 30 per cent below the results at a three per cent discount rate: \$12,763.8m and \$10,504.4 for the short and long take ups respectively, under the Sensitivity 1 approach and \$19,429.3m and \$15,921.2m under the Sensitivity 2 approach.

## Financial savings to government

Government finances are not exempt from the impact of both road trauma and pollution-induced mortality and morbidity, particularly through the lasting effects they have on workforce participation and earnings and, in consequence, on government taxation revenues and income support expenditure outlays. Other costs to government include emergency services costs and health and disability care costs not covered by private insurance arrangements.

Savings to government over the 20 year period were calculated using the 'cost to government' estimates in ECON 2017 (p. 39ff). About one third of the savings to government arising from the reduction in road trauma in each year accrue immediately, i.e. within twelve months of the crash. These include health system and emergency services savings, as well as initial taxation revenue and income support expenditure savings. The balance, predominantly forgone taxation and additional income support and disability care costs, accrue over a lengthy future period of

90 plus years, by which time the youngest person killed or disabled in a road crash, over the 20 year projection period, would otherwise, on actuarial assumptions and absent the road crash, have ceased either paid work or reliance on disability-related income support.

Expressed as a present value, discounted at three per cent real, savings to government from reduced road trauma, across taxation, income support, health services, emergency services, legal and other areas of government, are estimated at \$3,308.3m (short take up) and \$2,822.2m (long take up), both in 2015 prices. Savings to government resulting from lower passenger vehicle emissions, due to reduced adverse health effects and reduced climate damage, were not estimated due to lack of comparably detailed and disaggregated data on impacts.

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# Abbreviations

AAA	Australian Automobile Association
AEB	Autonomous Emergency Braking
ABS	Australian Bureau of Statistics
ADR	Australian Design Rule
BAU	Business as usual (scenario)
BITRE	Bureau of Infrastructure, Transport and Regional Economics
CH <sub>4</sub>	Methane
CNG	Compressed natural gas
CO	Carbon monoxide
CO <sub>2</sub>	Carbon dioxide
CO <sub>2</sub> -e	Carbon dioxide equivalent, as measured through greenhouse gas Global Warming Potential values
DIRD	Department of Infrastructure and Regional Development
ESC	Electronic Stability Control
HC/VOC	Hydrocarbons/Volatile organic compounds
ITF	International Transport Forum
LCV	Light commercial vehicle
LPG	Liquefied petroleum gas
MUARC	Monash University Accident Research Centre
N <sub>2</sub> O	Nitrous oxide
NO <sub>x</sub>	Oxides of nitrogen
OECD	Organisation for Economic Cooperation and Development
PM	Particulate matter
PTT	Pekol Traffic and Transport
SMVU	(Australian Bureau of Statistics) Survey of Motor Vehicle Use
SO <sub>2</sub>	Sulfur dioxide
SUV	Sports utility vehicle
TSSI	Total secondary safety index
VKT	Vehicle kilometres travelled
ULP	Unleaded petrol
USEPA	(United States) Environmental Protection Agency



# 1. Introduction

## 1.1 Research study objective and context

In February 2017 Economic Connections Pty Ltd (ECON), with Pekol Traffic and Transport (PTT) and Monash University Accident Research Centre (MUARC), was commissioned to undertake an analysis of the safety and environmental benefits that could accrue from a reduction in the age of the passenger vehicle fleet. The study supports the goals of the Australian Automobile Association (AAA) in ensuring that Australian motoring is safe and affordable. It complements a recent study for the AAA, which estimates the cost of road trauma to the Australian community and to governments (ECON 2017).

## 1.2 Study scope

The study estimates the safety and environmental benefits that could accrue from a one year reduction in the average age of the light vehicle fleet. The 'light vehicle fleet' for this study comprises all passenger vehicles, i.e. cars, station wagons, people movers and sport utility vehicles (SUVs), light commercial vehicles (i.e. utilities and vans) and excludes motorcycles.<sup>9</sup>

The safety analysis also separately considers the passenger vehicle category in terms of three market sub-groups: small and light, medium, large and people mover; and sport utility vehicles (SUV).

Two scenarios for implementation of the younger vehicle fleet are analysed: a shorter take up period of four years and a longer one of eight years.

The study also includes an estimate of the savings to government budgets resulting from the benefits of a one year light vehicle fleet age reduction.

Implementation of a younger vehicle fleet would entail policy measures to both introduce larger numbers of new vehicles into the fleet and to remove from it and dispose of larger numbers of older vehicles. Policy options to achieve a younger vehicle fleet, including the costs of options, are outside the study's scope.

## 1.3 Existing studies

Savings (undiscounted) of \$4.9 billion have been estimated from a scenario involving introduction of a more modern heavy vehicle fleet, with an average age of eight years and with a maximum of five per cent of trucks purchased before 1996 (Truck Industry Council 2013). More than half the savings (57 per cent) comprised vehicle operating costs and more than a third (38 per cent) consisted of avoided health costs from reduced local pollutant emissions. Estimated safety savings comprised three per cent.

Extensive research by MUARC (Newstead et al 2008, 2012) demonstrates the improvement in vehicle crashworthiness that is associated with more recent year of vehicle manufacture. Over the decade of the 2000s, the average crashworthiness of the Australian light vehicle fleet improved by an estimated 27 per cent, representing a saving of around 2,000 deaths over the

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<sup>9</sup> A motorcycle is a light vehicle in respect of the gross vehicle mass threshold, either 3.5 tonnes or 4.5 tonnes, that separates light from heavy vehicles.

period (Budd, Newstead et al 2015). The Centre of Automotive Safety Research (University of Adelaide) has applied the MUARC framework to the South Australian vehicle fleet. It estimated that in South Australia, where the average vehicle age, at the time of the study, was 11.2 years, compared with a national average of 9.9 years, three per cent more drivers were seriously injured or killed in road crashes, compared with the national average (Anderson et al 2009). Other MUARC research has established that reducing the maximum operating age of taxis and hire cars in Victoria from the current 6.5 years to 5 years would save around six annual injury crashes involving taxis and hire cars, or around two per cent – a small, but measurable, impact (Newstead et al 2015).

Finally, Castalia (2015) includes safety and environmental impacts in modelling the net benefits of options to relax restrictions on personal imports of new and used vehicles. All scenarios considered reduce the average age of the light vehicle fleet by small amounts (e.g. by one to two months). Safety and environmental impacts are positive in most scenarios, but are not material to the outcomes of the analysis, which are driven by cost reductions.

## **1.4 Methodology overview**

The study combines five distinct modelling modules, each with its own methodological requirements.

The first module involves estimating the size and composition of the future light vehicle fleet, including a fleet age adjustment process for the study's two change scenarios.

The second module estimates the number of future road crashes of differing severity, with and without the impact of a younger passenger vehicle fleet, while the third entails estimating future passenger vehicle pollutant emissions and greenhouse gas emissions in the business as usual case and under the change scenarios.

The fourth methodological stream involves benefits analysis, involving economic valuation of the quantitative reductions in road trauma and emissions, based on measures of the value of: avoided fatalities, disabilities and injuries (road crashes); reduced mortality and morbidity (pollutant emissions); and avoided harmful climate change (greenhouse gas emissions).

Finally, there is government cost analysis, comprising estimation of the financial savings to government that are associated with the economic benefits of vehicle fleet age reduction.

Each of these modules commands a section of this report.

## **1.5 Study approach**

Pekol Traffic and Transport undertook the vehicle fleet modelling and the emissions modelling and analysis for the study, while Monash University Accident Research Centre had responsibility for the road trauma modelling and analysis. Economic Connections undertook the economic analysis and the financial savings to government analysis.

The study team consulted the Bureau of Infrastructure, Transport and Regional Economics during the project and its co-operation is gratefully acknowledged. Study findings were also presented to a meeting of the Australian Automobile Association's Public Policy Forum.

## **1.6 Report outline**

The remainder of this report is set out as follows:

Section 2: The case for a younger light vehicle fleet

Section 3: Future light vehicle fleet

Section 4: Road trauma impacts

Section 5: Emissions impacts

Section 6: Benefits analysis

Section 7: Financial savings to government.

## 2. The case for a younger light vehicle fleet

As context for the study, this section provides an overview of the case, in terms of road safety impacts and emissions impacts, for a reduction in the average age of the Australian passenger vehicle fleet.

### 2.1 The road safety case

#### 2.1.1 Road safety strategic context

The 2011-2020 Australian National Road Safety Strategy aims to reduce the annual number of road crash fatalities and serious road crash injuries by at least 30 percent over its period of operation (ATC, 2011). As noted in the strategy:

Formulation of the strategy was guided by the internationally recognised 'Safe System' approach formally endorsed by the OECD. This approach accepts that people using the road network will make mistakes and therefore the whole system needs to be more forgiving of those errors. This means there must be a focus on roads, speeds, vehicles and road user behaviour as well as a range of associated activities, including performance monitoring and reporting. (ATC, 2011)

Road safety strategies in Australia have included a broad range of programs aimed at reducing road trauma. In the area of road infrastructure, large programs of accident blackspot treatments have been funded at both state/territory and Commonwealth levels, addressing high crash risk areas, whilst audit processes for road safety performance have been implemented for new and existing infrastructure. Setting of appropriate speed limits on various types of infrastructure and reflecting adjoining road use such as schools and shopping centres has supported these programs. Encouraging safe behaviour amongst road users has been another key platform. Changes to regulations governing safe road use such as helmet use and lowering alcohol limits have been made. Enforcement is a major component supporting current and new regulations with automated enforcement programs, including speed and red light camera programs expanding rapidly in most jurisdictions. Alcohol and, more recently, drug enforcement have also been used extensively and effectively. Mass media programs supporting enforcement have also proved effective. Underpinning these initiatives have been continuing improvements in vehicle safety since 1970.

#### 2.1.2 Vehicle safety and the reduction of road trauma

Safe vehicles are a key pillar of the Safe System, providing a system component that both assists in avoiding crashes in the event of human error (primary safety), as well as managing transfers of energy during a crash to mitigate injury (secondary safety). Safety of the light vehicle fleet is a dominant driver of overall vehicle safety in the safe system. This is because analysis of Australian crash data (for this study) shows that a light vehicle is involved in well over 90 per cent of all crashes reported to police and hence has some role in determining injury outcomes in the crash.

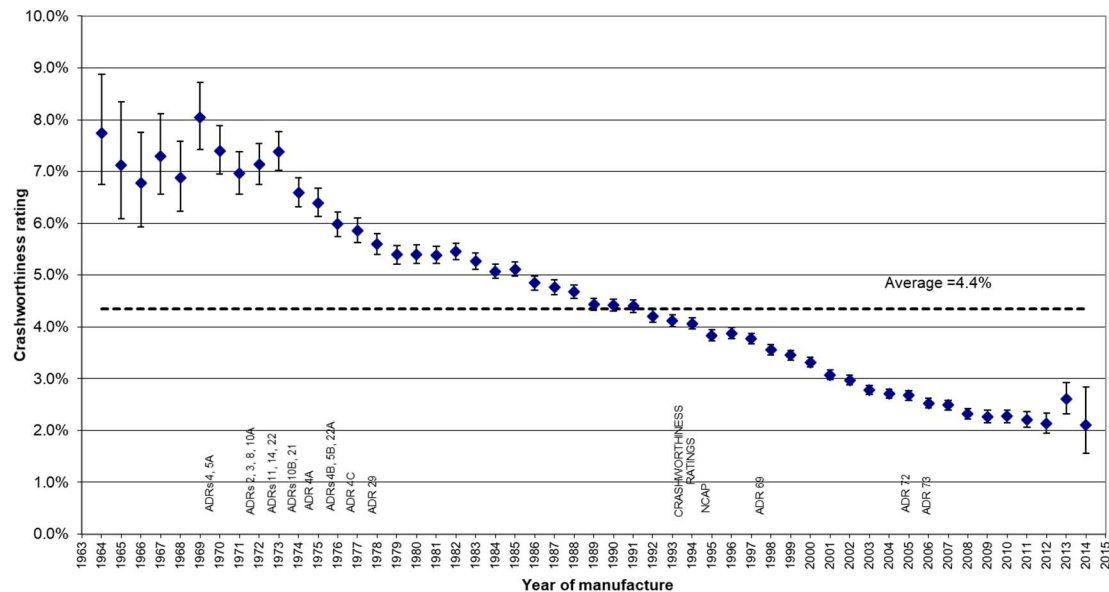
The national strategy notes that improving vehicle safety has made a significant contribution to reducing road trauma in Australia. It is anticipated vehicle safety will also provide a significant contribution to meeting future goals. Research evidence exists to support this expectation. MUARC has conducted a significant body of work evaluating vehicle safety improvement and assessing how these have impacted the safety of the light vehicle fleet as a whole and how this has contributed to national road safety targets.



Figure 1 shows the estimated improvement in vehicle crashworthiness (secondary safety) for light vehicles with increasing year of manufacture, as estimated by Newstead et al (2016). Crashworthiness measures the risk of death or serious injury to vehicle occupants in the event of a crash standardising for crash circumstances and occupant characteristics. It shows that over a 50 year period of new vehicle design improvement, the risk of death or serious injury in a crash has fallen by nearly 75 per cent from around eight per cent in the 1960s to around two per cent in 2015. A large part of this improvement was driven by the introduction of Australian Design Rules (ADRs) for vehicles mandating the inclusion of safety features or safety performance requirements. Early ADRs implemented in the 1970s focused on vehicle specification requirements including fitting basic safety equipment such as seatbelts, collapsible steering columns, head restraints, interior padding and removing sharp fittings from the vehicle exterior. Later ADRs implemented in the last 20 years have been performance based standards based not on fitting specific technologies, but on achieving specified occupant protection standards in various crash types. Features such as airbags have been used as a mechanism for complying with the performance standards.

In more recent times, improvements have also been driven by consumer information programs such as the Australian New Car Assessment program (ANCAP) and the Used Car Safety Ratings program. The latter publishes crashworthiness ratings based on real world crash outcomes for a large range of makes and models of vehicles.

**Figure 1 Crashworthiness by vehicle year of manufacture in the light vehicle fleet, 1963 to 2015**



Note: Crashworthiness is defined as the risk, following a crash, of death or serious injury to vehicle occupants. Vertical bars represent 95 per cent confidence limits.

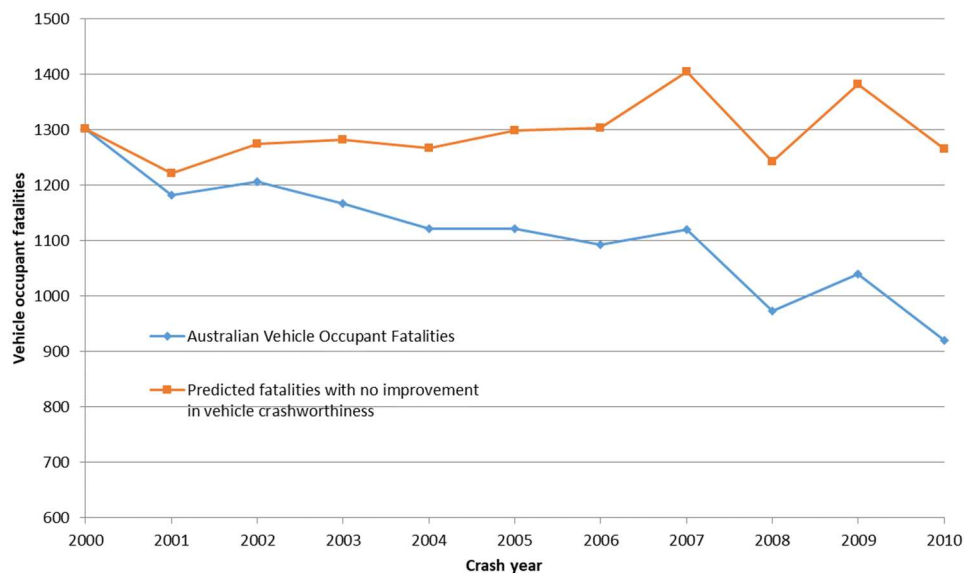
Source: Newstead et al 2016

Vehicle safety contributes to strategic safety goals in the national strategy through bringing newer safer vehicle into the fleet and replacing older, less safe vehicles from use. Reflecting the

improved occupant protection performance of newer vehicles, this process of regeneration improves the average safety of the fleet as a whole.

Recent MUARC research (Budd et al, 2016) has estimated the benefits from fleet regeneration on reducing serious road trauma in Australia. Figure 2 shows total annual actual fatalities amongst light vehicle occupants involved in crashes over the years 2000 to 2010 against the expected number of fatalities had the fleet not regenerated (i.e. had the mix of vehicles in the fleet by year of manufacture stayed the same as in 2000). This analysis shows the benefits of fleet regeneration on fatalities through the introduction of newer, safer vehicles into the fleet and the removal of older less safe vehicles. It indicates an annual saving of around 350 fatalities after 10 years.

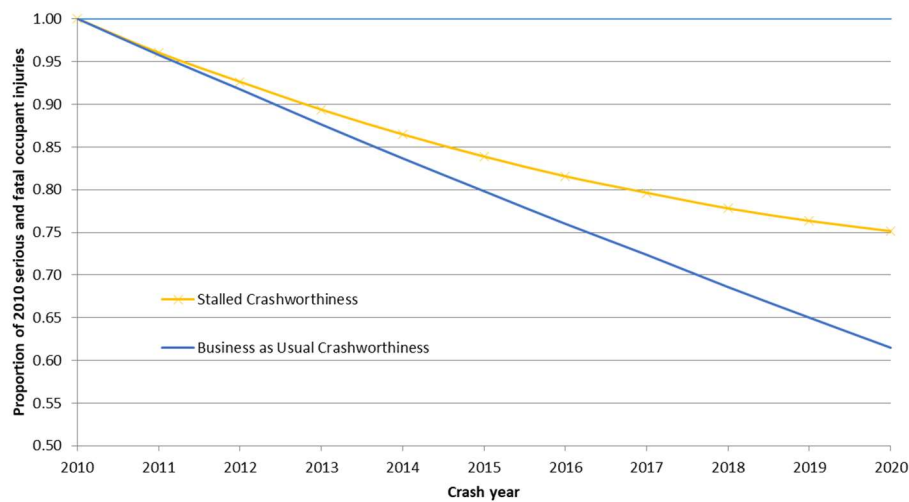
**Figure 2 Impact of improvement in crashworthiness on road fatalities, 2000 to 2010**



Source: Budd et al 2016

Road trauma reductions due to fleet regeneration are expected to continue into the future. Figure 3 shows the estimated proportionate reduction in expected fatalities over a 10 year period due to fleet regeneration under two scenarios. The first, labelled 'Business as Usual' (the lower line in Figure 3), is based on the trend of improving crashworthiness of new vehicles continuing at the same rate as observed in Figure 1. The second presents a worst case scenario, assuming there is no further improvement in the crashworthiness of new vehicles in future years. This scenario still shows significant benefits from removing older, less safe vehicles from the fleet, although these improvements would slow over time. Estimated future fatality reductions across the two scenarios varied from 25 per cent (stalled crashworthiness) to 38 per cent (business as usual) over 10 years.

**Figure 3 Projected impact of continued improvement in new vehicle crashworthiness**

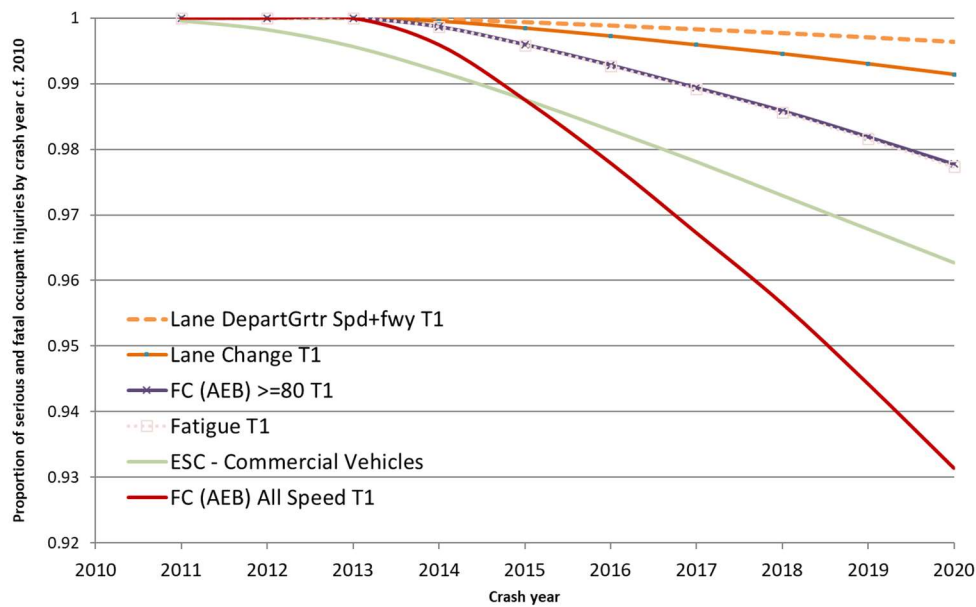


Source: Budd et al 2016

Whilst clear reductions in serious road trauma are expected from vehicle secondary safety improvement, a number of vehicle technologies designed to improve crash avoidance (primary safety) have emerged over the last 10 years which are expected to provide further trauma reductions. Technologies which have shown proven benefits through evaluation include electronic stability control (ESC) and autonomous emergency braking (AEB), the latter often including a Forward Collision warning system. Other technologies which have estimated theoretical benefits but have not yet been subject to in-service evaluation include lane departure warning systems, fatigue warning systems and blind spot/lane change warning systems.

Budd et al (2016) have estimated the likely future trauma savings associated with gradual uptake of a range of crash avoidance technologies in new vehicles. Estimated proportionate crash savings over a 10 year period are shown in Figure 4 for the technologies considered. The vertical scale represents the proportion of the original crash population remaining at each time point. As evident from the figure, after 10 years, each of these technologies is estimated to reduce the number of crashes occurring by between one per cent and four per cent. These benefits will accrue from fleet regeneration and are in addition to those estimated from secondary safety improvements.

**Figure 4 Projected impact of vehicle crash avoidance technologies**



Source: Budd et al 2016

This combined body of research evidence highlights the estimated safety benefits of regeneration of the light vehicle fleet through the ongoing introduction of safer new vehicles to the fleet and the retirement of less safe older vehicles. Data from the Australian Motor Vehicle Census (ABS 2016) shows that the rate of regeneration of the Australian light vehicle fleet has been in equilibrium for some years as demonstrated by the average age of the fleet being static for the last five years at around 9.8 years for passenger vehicles and 10.4 years for light commercial vehicles. Increasing the number of new vehicles entering the fleet and the number of older vehicles retired would have the effect of lowering the average age of the fleet. Based on the research evidence presented, it would also be anticipated to produce additional safety benefits above those expected at the current rate of regeneration.

### 2.1.3 The cost of road trauma

The cost of road trauma in Australia has been estimated at \$22.2 billion in 2015 (ECON 2017).<sup>10</sup> This cost encompasses valuation of the loss of life, in cases of fatalities and valuation of loss of functional wellbeing in cases of disability following injury, as well as other costs including health and emergency services and vehicle damage. Despite the long term decline in road fatalities, Australia ranks only fourteenth out of 32 OECD nations, when measured by the number of road fatalities per 100,000 inhabitants. Australia sits behind countries such as the United Kingdom, Norway, Israel, Japan and Germany (OECD/ITF 2016, p. 19). There is, accordingly, both need and opportunity for improvement in road trauma outcomes.

<sup>10</sup> \$29.7 billion on the basis of an alternative valuation of statistical life that is included in the report as a sensitivity test.

## **2.2 The transport emissions case**

### **2.2.1 Pollutants and human health**

Through their effect on air quality, transport emissions impact human health in both the short and long terms, increasing the risk of death, particularly due to heart and lung diseases, increasing the risk of hospitalisation for these diseases and increasing the risk of asthma attacks (Australian Senate 2013).

Light petrol vehicles are the main transport contributors to these emissions, while diesel vehicles tend to produce oxides of nitrogen at a higher rate per vehicle relative to petrol vehicles (Department of Infrastructure and Regional Development 2016a). Vehicle exhausts are a major source of particle emissions, which are particularly damaging to human health, as they often contain metals and sulfates. In addition, the urbanised character of Australia means that a high proportion of the population are co-located with major transport corridors and hence highly exposed to transport related emissions (Centre for Air Quality and Health Research and Evaluation 2013).

Motor vehicle-related ambient pollution has been estimated to account for between 900 and 4,500 morbidity cases per year and between 900 and 2,000 early deaths (Bureau of Transport and Regional Economics 2005). The economic cost of morbidity was estimated at between \$0.4 billion and \$1.2 billion, while that of premature mortality ranged from \$1.1 billion to \$2.6 billion.

Recent introduction of Euro 5 emissions standards is both working to reduce passenger vehicle emissions of oxides of nitrogen and other pollutants and creating an opportunity for further reductions. This would bring increased health benefits, if the introduction of new vehicles into the vehicle fleet were to be accelerated. In the event that Euro 6 standards are introduced in future, more rapid fleet changeover would augment their impact. These standards provide for: further reductions in emission limits for oxides of nitrogen for light diesel vehicles; a particle number limit to reduce fine particle emissions from petrol direct injection vehicles; and tighter thresholds and monitoring requirements for on-board diagnostic systems that monitor the performance of emission control systems (DIRD 2016c, p. 12).

### **2.2.2 Carbon dioxide and climate change**

Greenhouse gas emissions from burning of fossil fuels contribute to global warming, with attendant risk of severe and irreversible impacts on all aspects of the climate system (Intergovernmental Panel on Climate Change 2014). The transport sector accounts for around 17 per cent of Australia's greenhouse gas emissions and 60 per cent of transport sector emissions are from light vehicles (DIRD 2016b, p. 4).

In contrast to both road crash fatalities and overall pollution emissions, carbon dioxide emitted by the total road transport fleet continues to increase, at about two thirds of the rate of increase in total distance travelled. Carbon dioxide emissions from road transport are projected to grow by around one per cent per year between 2015 and 2030 (Department of the Environment and Energy 2016). Light vehicles contribute two thirds of all transport emissions (Climate Change Authority 2014).

Notwithstanding this situation, new vehicles are mostly more fuel efficient than their older counterparts, with the long term trend improvement rate for new light vehicles estimated at slightly greater than one per cent per year (BITRE 2014, p. 11).

This trend improvement creates a limited opportunity to lower greenhouse gas emissions and assist the effort to mitigate harmful climate change, through introduction of a younger vehicle fleet. Future adoption of mandatory fuel efficiency standards, as in North America, the European Union and several countries in Asia (DIRD 2016a), were this to eventuate, would augment the opportunity provided by accelerated introduction of newer vehicles. Options explored in a recent draft regulation impact statement involve reducing carbon dioxide emitted by new light vehicles by between 57 per cent and 73 per cent compared with new light vehicles sold in Australia in 2015 (DIRD 2016a, p. 5).<sup>11</sup>

### **2.3 This study**

Against the background of the ‘in principle’ benefits of the introduction a younger passenger vehicle fleet, this study seeks to quantify and value the road safety-related and emissions-related impacts of such a course of action.

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<sup>11</sup> Options of 105 grams per kilometre, 119 grams per kilometre and 135 grams per kilometre of carbon dioxide were investigated. The average efficiency of new light vehicles sold in Australia in 2015 was 184 grams per kilometre (175 grams per kilometre for passenger vehicles and 229 grams per kilometre for light commercial vehicles).

## 3. Future light vehicle fleet

This section sets out: key assumptions for the business as usual case and the reduced vehicle fleet age scenarios: the size of the business as usual light vehicle fleet, i.e. both passenger vehicles and LCVs, over the 20 year analysis period; distance travelled estimates; and the scenario fleet age adjustment process.

The modelling process which underpins information in this section is described in detail in Appendix A.

### 3.1 Key assumptions

The study base year is 2014. This was selected due to data constraints affecting the road safety impact analysis (see Section 4.1).

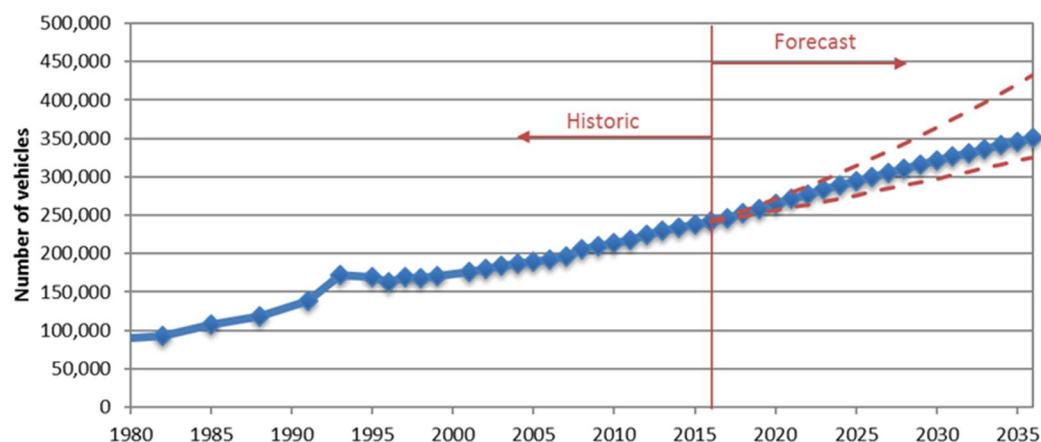
The scenarios to implement a light vehicle fleet with an average age reduced by one year from the current one are based on two take up periods, a shorter (four year) one and a longer (eight year) one. The further assumption is that, once achieved, the younger vehicle fleet age remain in place for the balance of the project period. This totals 20 years (2015 to 2034), a period that is long enough to incorporate a complete 'lifetime' for early year vehicles.

Estimates of the number of vehicles in the fleet and of total distance travelled are held at the same levels as those projected under the business as usual case. New vehicles are driven substantially greater distances than older vehicles. Accordingly, with more new vehicles in the scenario vehicle fleet, compared to business as usual, the usual distance travelled differential between new vehicles and other vehicles was moderated, in order to allow consistency in distance travelled between the business as usual case and the scenarios.

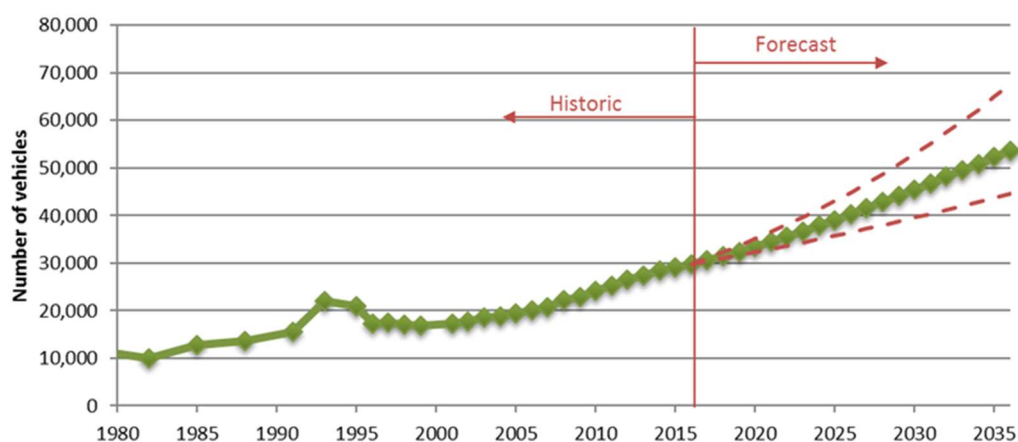
### 3.2 Business as usual scenario

The business as usual modelling process generated the number of registered vehicles for each vehicle type and for each state and territory, as at 31 December for each year. The jurisdiction-based estimates were combined to estimate the growth in the national vehicle fleet. Figure 5 and Figure 6 show the expected growth in the national passenger and LCV fleets respectively, together with the 80th and 20th percentile upper and lower (respective) growth rates observed over the last 37 years.

**Figure 5 Growth in passenger vehicles, Australia**



**Figure 6 Growth in LCVs, Australia**



In addition to the annual totals, this process forecast the number of vehicles by vintage, under a business as usual scenario.

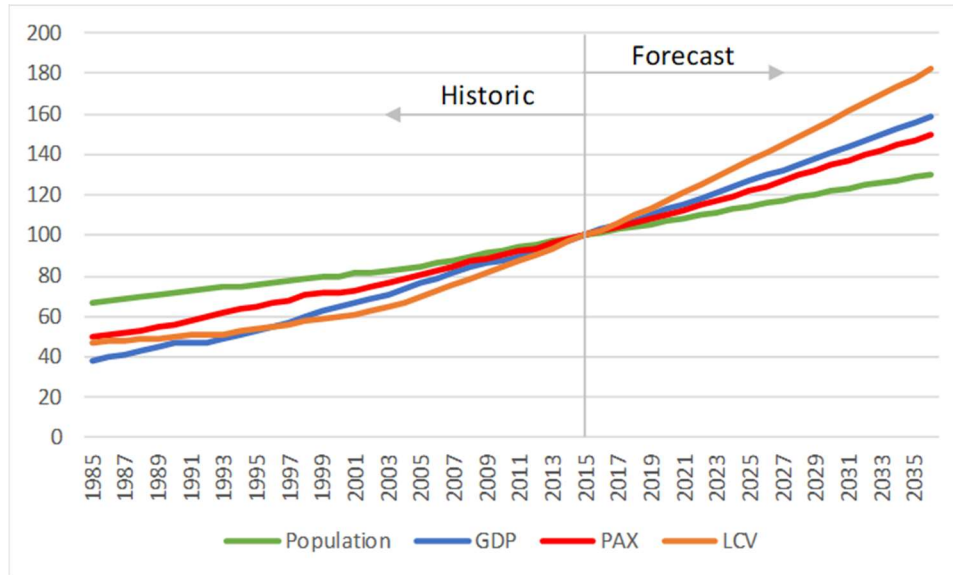
The resulting forecasts are considered reasonable given that they lie between the upper and lower bounds of historic growth rates and reflect expected changes in key economic and demographic variables (i.e. growth in income and population) for the 20 year period of analysis (i.e. 2015 to 2034 inclusive). The passenger vehicle fleet is forecast to growth by 47 per cent over the 20 years from 2014, compared to a 53 per cent increase in the number of light commercial vehicles (Table 1). Over this period, Australia's population is expected to grow by 28 per cent while gross domestic product (GDP) is expected to grow by 54 per cent (Figure 7).

**Table 1 2014 and projected 2034 passenger vehicle fleet**

Year	Passenger vehcies	Average annual growth	LCVs	Average annual growth	Total	Average annual growth
2014	13,607,737	2.0%	2,909,596	2.9%	16,517,333	2.1%
2034	20,037,502		5,171,769		25,209,271	



**Figure 7 Relative growth in light vehicle stock, population and GDP**



### 3.3 Vehicle kilometres travelled forecasts

The output from the vehicle kilometres travelled (VKT) models for both passenger vehicles and LCVs are shown in Figure 8 and Figure 9 respectively. These forecasts equate to a 36 per cent increase in total passenger vehicle VKT (involving an average annual growth rate of 1.6 per cent) and a 54 per cent increase in total LCV VKT (average annual growth of 2.2 per cent) over the 20 years (Table 2).

**Table 2 Growth in distance travelled, passenger cars and LCVs, billion VKT**

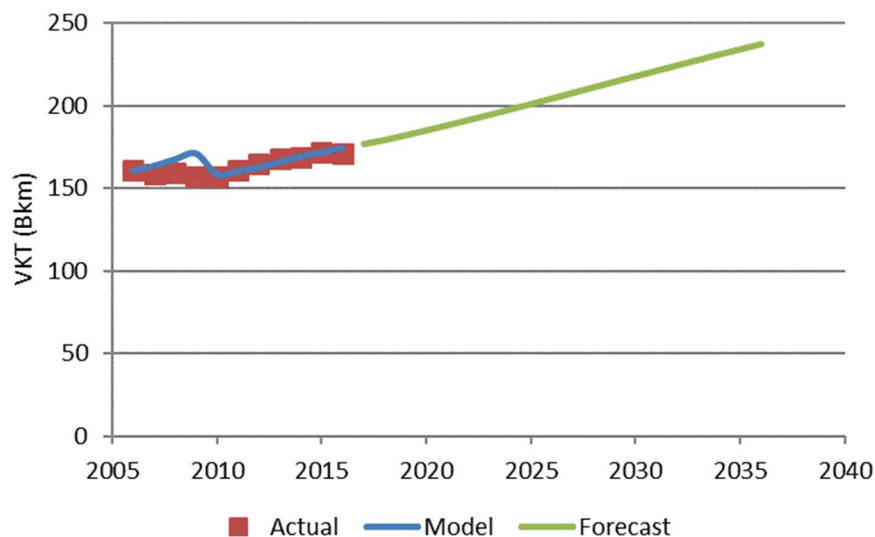
Year	Passenger vehicles	Average annual growth	LCVs	Average annual growth	Total	Average annual growth	% Car	% LCV
2014	171,532	1.6%	46,550	2.2%	218,083	1.7%	78.7%	21.3%
2034	233,855		71,617		305,472		76.6%	23.4%

Average distance travelled per vehicle is projected to fall slightly over the 20 years, by 7.4 per cent in total for passenger vehicles and by 13.4 per cent for LCVs (Table 3).

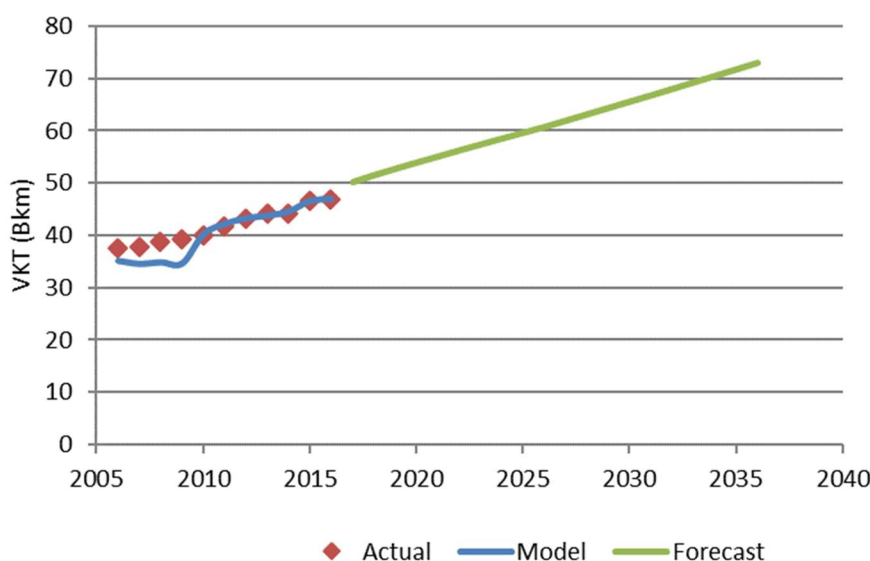
**Table 3 Change in distance travelled per passenger vehicle**

	Distance travelled cars (billion vkt)	VKT per passenger vehicle	Distance travelled LCVs (billion vkt)	VKT per LCV
2014	171,532	12,606	46,550	15,999
2034	233,855	11,671	71,617	13,848
Total % change		-7.4%		-13.4%
% change per year		-0.4%		-0.7%

**Figure 8 Projected passenger vehicle kilometres travelled**



**Figure 9 Projected LCV vehicle kilometres travelled**



### 3.4 Light vehicle fleet age adjustment

An age adjustment process was developed to reduce the average age of the light vehicle fleet by 10 per cent. This was undertaken for both the short (i.e. four year) take up period and the long (i.e. eight year) take up period. No adjustment was applied to vehicles aged 30 years or older, as these were considered 'classic and vintage cars' and unlikely to be targeted by any possible policy intervention to accelerate fleet turnover rate.

The age adjustment process considered the current average age of approximately 9.8 years for passenger cars and 10.4 years for LCVs and applied a 10 per cent reduction. The proportion of vehicles older than 10 years was reduced, whereas the proportion of newer vehicles was

increased, as shown in Figure 10. This adjustment process was used to ensure no discontinuities were introduced into the adjusted fleet profile.

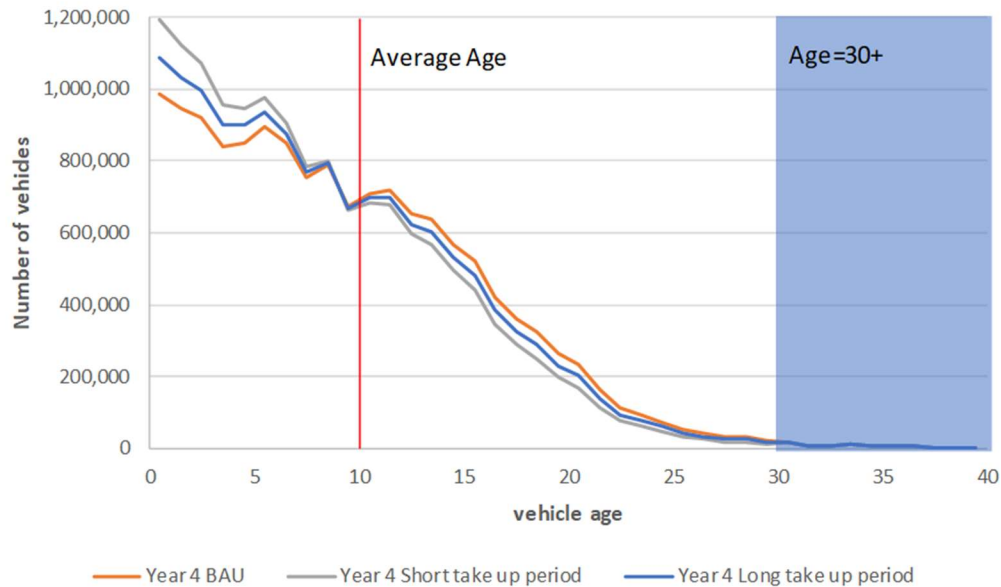
The percentage change was applied proportionately during each year of the take up period. For example, in year one of the four year take up period, the average fleet age was reduced by 2.5 per cent, relative to the business as usual scenario, while in year two the average fleet age was reduced by five per cent. These percentage adjustment factors were applied to the business as usual fleet profiles discussed above to generate the age adjusted fleet profiles.

**Figure 10 Light vehicle fleet age adjustment factors**

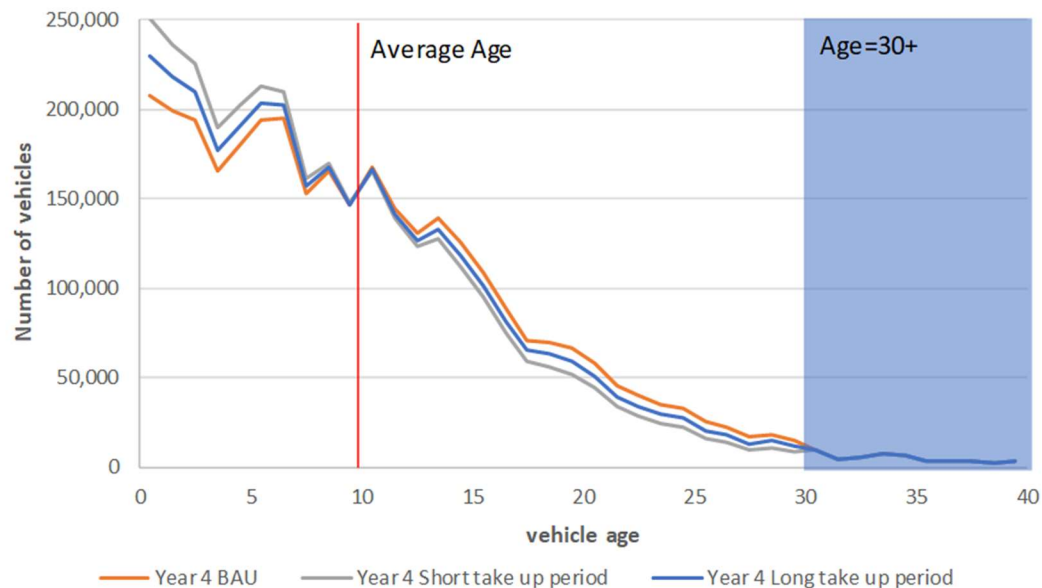


The output from the age adjustment process was the number of vehicles by vintage for each forecast year, for both the four year and eight year take up periods. Figure 11 shows the difference in the year four profiles for the two different take up periods and the business as usual scenario for the passenger car fleet. Figure 12 shows the same data for the light commercial vehicle fleet.

**Figure 11 Passenger vehicle fleet age profile (Year 4)**



**Figure 12 LCV fleet age profile (Year 4)**



The age adjusted profiles derived from this process are considered reasonable given that they:

- Allow for classic and vintage vehicles to be unaffected by the proposed policy
- Do not incorporate any discontinuities as a consequence of the adjustment process
- Apply larger increases to the percentage of newer vehicles and larger decreases to the proportion of older vehicles.

For the short take up scenario, an average of an additional 233,000 passenger cars, amounting to an increase in annual new cars of 29 per cent and 1.7 per cent of the 2014 fleet size and an additional 53,000 LCVs were added for each of the first four years, with a similar number of

older vehicles withdrawn (Table 4). For the long take up scenario, some 146,000 cars were added and withdrawn for each of the first eight years (33,000 LCVs). New vehicle fleet additions (and older vehicle scrappages) continue at slightly above normal rates for the balance of the analysis period,<sup>12</sup> thereby preserving an average light vehicle fleet age of nine years throughout the period.

**Table 4 Additional new and scrapped vehicles, scenarios**

Additional vehicles per year (take up)	Short (4 year) take up		Long (8 year) take up	
	Passenger vehicles	LCVs	Passenger vehicles	LCVs
New	232,913	53,282	145,572	33,302
Scrapped	232,913	53,282	145,572	33,302

---

<sup>12</sup> An additional 15,000 to 20,000 vehicles per year.

## 4. Road trauma impacts

This section: describes the modelling framework for estimating road trauma impacts; outlines key modelling inputs and parameter values; and details estimated reductions in road crashes of different types in the two change scenarios.

### 4.1 Introduction

Estimation of the road trauma impacts from reducing the average age of the light vehicle fleet is based broadly on applying information from previous MUARC studies that measure the primary (crash avoidance) and secondary (casualty risk reduction) safety performance of the Australian light vehicle fleet by year of vehicle manufacture and market group to the business as usual case and to the two scenarios. Under each, the expected number of road crashes and injuries resulting from these crashes was estimated for the base year of 2014<sup>13</sup> and every following year until 2034. The net road trauma impacts of reducing the age of the light vehicle fleet under each change scenario were measured by comparing the crashes and injuries expected under each change scenario with those predicted under the business as usual case.

Primary measures of road trauma impacts derived from the analysis were the number of fatal, serious (i.e. resulting in hospitalisation) and minor/other injuries (i.e. those with no hospitalisation consequence) saved under each change scenario. Since non-injury crashes also have an economic burden to the community, the analysis also considered the number of crashes prevented under each change scenario compared to the business as usual (BAU) scenario.

### 4.2 Estimating road trauma impacts

The process for estimating the expected number of injuries and crashes under the business as usual and change scenarios was the same, being based on considering the chain of events from exposure to outcome and measured quantities in each link of the chain as depicted in Figure 13.

**Figure 13 Event chain for estimating road trauma impacts**



Multiplying the first two event change measures gives the number of crashes expected for the exposed vehicle fleet being considered. Multiplying all three event chain measures gives the number of injuries expected from the exposed vehicle fleet. The final link in the chain was varied to measure the three different severities of injury outcome of interest in the study, i.e. fatal, hospitalised and non-hospitalised injuries.

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<sup>13</sup> 2014 was selected as the study base year, as the most recent year for which a database of road crashes and vehicles involved by year of manufacture was available.

#### 4.2.1 Exposure

For the business as usual and each change scenario, the number of registered vehicles by year of manufacture observed in 2014 and expected in each year from 2015 to 2034 was used as the base exposure measure (Section 3.2).

#### 4.2.2 Crash risk per exposed vehicle

Ideally, crash risk per registered vehicle would have been calculated from all crashes occurring Australia-wide, including both property damage only crashes as well as those resulting in injury. Whilst police forces in all Australian jurisdictions record crashes involving injury reasonably reliably, not all jurisdictions record crashes involving property damage only with no injury. Notably, both Victoria and Queensland do not record crashes that only involve property damage. Complete crash data including property only damage crashes was available for the 2014 base year from New South Wales, South Australia and Western Australia. Data from these three jurisdictions were assumed to be representative of the national crash population. Crashes involving light vehicles during 2014 were identified in each jurisdiction and tabulated by year of manufacture. They were then divided by the corresponding number of registered vehicles by year of manufacture in 2014. Since the absolute crash numbers used were not those for Australia as a whole, the crash risk estimates were converted to relative risks by vehicle year of manufacture by dividing the estimated risk for each year of manufacture by the aggregate risk across all years of manufacture. Estimates were obtained for passenger vehicles and light commercial vehicles separately.

The estimated relative crash risk from the base year 2014 was applied to subsequent years by assuming that the risk estimates by age of vehicle, rather than year of manufacture, in 2014 also applied in subsequent years (e.g. the crash risk for a three year old vehicle was the same in all years). ECON 2017 estimated total road crash numbers for Australia in 2015 by severity of crash and these estimates were adopted for the study (Table 5). So that these numbers matched those predicted in the study road trauma model, a scaling factor was estimated to ensure the required consistency. The estimated scaling factor for 2015 was then applied to all crash years in the model giving the final crash risk per exposure estimates used over the 20 year period.

**Table 5 Estimated number of road crashes by type, Australia 2015**

Crash type	No of crashes
Fatal crashes	1,101
Hospitalised injury crashes	31,637
Non-hospitalised injury crashes	189,643
Property damage crashes	456,978
TOTAL	679,359

Source: ECON 2017

#### 4.2.3 Adjusting crash risk for changes in travel exposure

Projections of the light vehicle fleet numbers and total travel suggest that the average exposure of the fleet is expected to reduce slightly over time on a per vehicle basis (Section 3.3). Furthermore, under the proposed age change scenarios, the distribution of travel between different age vehicles is also predicted to change. Impacts of the changes in travel exposure

predicted were accommodated in the road trauma outcome models by estimating the proportionate net change in expected travel exposure between the BAU scenario and each age change scenario in each crash year and vehicle year of manufacture and adjusting the estimated crash risk in each accordingly.

#### **4.2.4 Future total crash numbers**

Vehicle safety improvement is not the only factor influencing future expected crash numbers. A range of other factors also influence observed crash numbers including the range of other road safety programs in place and their level of output as well as economic and socio-demographic factors (Scuffham et al 2002). Predicting future annual crash numbers based on all these varying factors was considered peripheral to the objectives of this study. Accordingly, to isolate the effects of vehicle fleet changes on crash and injury outcomes from the range of other possible influencing factors, the modelling approach fixed annual crash numbers at the 2015 observed level (Table 5) for all future years.<sup>14</sup> Whilst the absolute number of crashes and injuries saved under each change scenario relative to BAU varies according to the absolute number of crashes assumed, the impact of any assumption about absolute future crash numbers is diminished somewhat by the analysis estimating relative number of crashes between scenarios rather than using total predicted crashes.

Assuming a fixed number of crashes in future years also changes the purpose of the initial stages of the modelling estimating crash risk per vehicle and changes in travel exposure. Instead of providing absolute measures, these measures become reflective only of changes in the distribution of exposure and risk between vehicles of different year of manufacture from year to year during the analysis period. As such, this approach also minimises the sensitivity of the analysis to assumptions about future growth in fleet size, since the distribution of vehicles by year of manufacture becomes the more important attribute.

#### **4.2.5 Reductions in crash risk due to primary safety technologies**

Two primary safety technologies were considered: Electronic Stability Control (ESC) and Autonomous Emergency Braking (AEB). The study chose these technologies for two main reasons, the first being that they are the most prevalent in the fleet and are likely to remain so at least in the short term. The second is that they are the only two of the emerging crash avoidance technologies whose crash reduction effectiveness is supported by robust real world evaluation. As yet, the remaining technologies are unproven in terms of their measured crash reduction performance. This is not to say that they will not be proven effective. Indeed, if this is the case, the crash reduction benefits estimated for the age change scenarios considered in this study will be conservative.

Data from RedBook (Automotive Data Services Pty Ltd) was used to identify those vehicles fitted standard with either AEB or ESC. For vehicles where the technology was optional, it was assumed that the feature was not fitted, reflecting the typically low take-up rate of optional safety features in Australia.<sup>15</sup>

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<sup>14</sup> On the available evidence, this may not be greatly different from trends of the recent past. ECON 2017 estimated growth in the total number of road crashes at 0.4 per cent per year between 2006 and 2015.

<sup>15</sup> There has, however, been a change in consumer attitudes in their car purchasing decisions. In 1993, only 3 percent of consumers ranked safety as their main priority in buying a new car; in 2012, 25 percent of consumers ranked safety as their first priority (McIntosh 2012).



Estimates of the proportion of the light vehicle fleet fitted with each technology in each year of manufacture were tabulated. Crash reductions expected in each calendar year related to fitment of the technologies were estimated by calculating the total proportion of the fleet fitted with each technology and multiplying this by the overall crash reduction expected from the technology. For ESC, crash reduction benefits were taken from the Australasian evaluation of Scully et al (2008) whilst crash reduction estimates for AEB were taken from the multi-national study of Fildes et al (2015), the more recent of the two studies to date.

#### **4.2.6 Rate of Injuries per crash**

Estimates of vehicle secondary safety taken from Newstead et al (2016) were used to estimate the number of injuries at various levels of severity resulting from light vehicle crashes. Of the available secondary safety measures calculated by Newstead et al (2016), the total secondary safety index (TSSI) was chosen as the most appropriate for use in the analysis. The TSSI represents the average risk of death or serious injury to all people involved in a crash, with the vehicle being rated. In addition to vehicle occupants, it reflects injury outcomes to those colliding with the light vehicle including pedestrians, cyclists and motorcyclists. Interrogation of the data showed that over 95 per cent of reported crashes involve a light vehicle, highlighting the relevance of the TSSI to the study objective.

The TSSI estimates the relative rate of death or serious injury between vehicles given crash involvement. Estimates are available by make and model of vehicle and by year of manufacture and year of manufacture by market group. Reflecting the stratification used in the analysis model for this study, estimates of the TSSI based on market group and year of manufacture were used for the analysis. The overall TSSI was used to estimate the number of deaths and serious injuries expected from the estimated number of crash involvements by year of vehicle manufacture within each crash year. Estimation of the TSSI assumes the relative risk between years of manufacture is the same for deaths as for serious injuries, an assumption carried through to the analysis here.

The TSSI is calculated as a product of two risk components: the risk of any injury given crash involvement (risk component) and the risk of a fatal or serious injury given some level of injury was sustained (severity component). To estimate the number of minor/other injuries sustained, the injury risk component was applied to the observed number of crashes to estimate the total number of injuries expected. The number of estimated fatal and serious injuries was then subtracted to give an estimate of the number of minor/other injuries by year of vehicle manufacture within each crash year.

Estimates of TSSI by year of manufacture and market group were obtained for vehicles manufactured after 2014, the last year of available estimates, by projecting the estimates assuming past trends of improvement by year of manufacture continued in the future. Given the long term trend of improving TSSI by year of manufacture (Figure 1), this was considered a reasonable assumption.

The average TSSI used to scale the published ratings is calculated based on a standardised set of crash circumstances and demographics. To ensure consistency between the injuries predicted by the TSSI and those observed, the estimates were scaled to the observed number

of injuries at each severity level for the 2015 crash year for which injury counts at each severity level were available from ECON 2017. Different scaling factors were calculated for the three severity levels considered based on the 2015 data and then applied to all other years.

#### 4.2.7 Model outputs

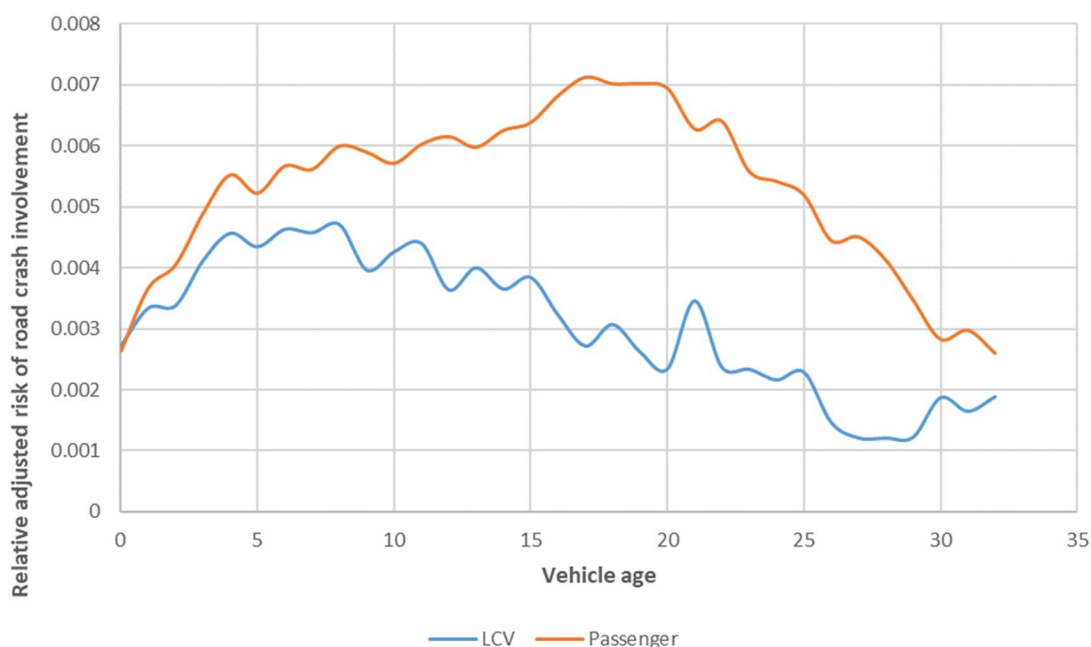
For the business as usual case and each change scenario, the safety model produced estimates of the expected number of crashes and injuries by year of vehicle manufacture and year of crash. The net impacts of each change scenario were calculated by subtracting the estimated total crashes and injuries for business as usual from each of the age change scenarios to give the net savings in crashes and injuries. Estimates were summed across each year of vehicle manufacture within a crash year to give total annual savings. These estimates formed the basis of the crash and trauma savings used in the economic valuation.

### 4.3 Key modelling inputs

#### 4.3.1 Relative crash risk per registered vehicle by vehicle age

Relative risk estimates for light passenger and commercial vehicles are given in Figure 14, presented by vehicle age in 2014, noting that the estimates were applied by age subsequently in the model for future crash years.

**Figure 14 Relative adjusted risk of road crash involvement by vehicle age**



Note: Crash risk is estimated at the time of crash, from 2014 base year data

The trends in relative crash risk by age of vehicle show significant differences between passenger vehicles and LCVs. Over the first five years, the trends are similar, with risk rising slightly with vehicle age. Beyond this, LCV crash risk reduces gradually as vehicle age increases in line with observed reductions in travel exposure as vehicles age. In contrast, the passenger vehicle segment crash risk continues to increase until vehicles are 20 years old, after which risk decreases sharply. An increase in risk for older passenger vehicles is consistent with

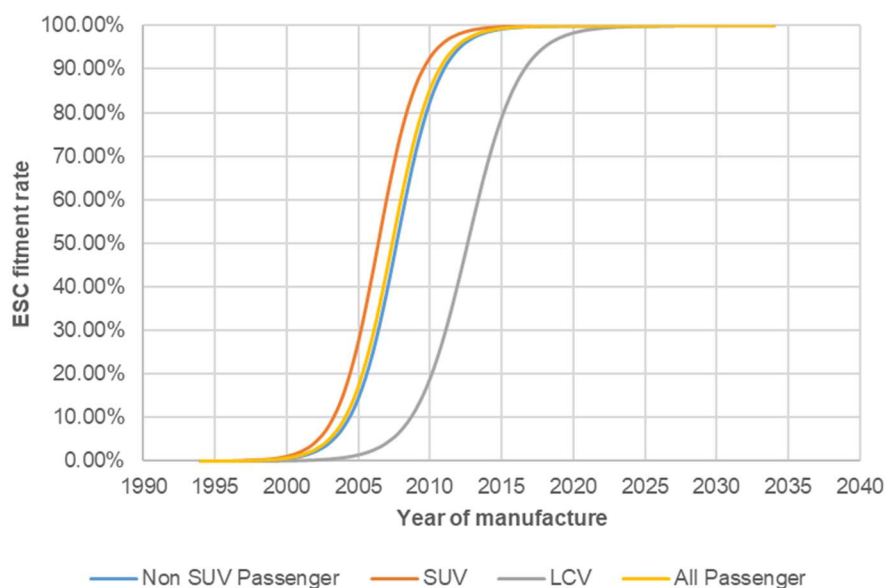
research knowledge that older vehicles, as they age, are increasingly driven by high crash risk novice drivers (Whelan et al 2009).

In applying these relative crash risk curves to future crash years, it is assumed that there is no change in the ownership profiles or purpose of use of vehicles by age. Furthermore, in applying these crash risk curves to the average age change scenarios, it has been assumed that having a greater number of newer vehicles in the fleet will not change the risk distribution through changing the way in which the vehicle fleet is driven by different age groups of drivers. This assumption seems reasonable given that the relationship between driver age and vehicle age is primarily driven by vehicle cost. This is unlikely to be changed significantly by the shift in vehicle age profile.

#### 4.3.2 Proportion of vehicles fitted with crash avoidance technologies

Estimates of the proportion of new vehicles fitted with ESC and AEB for future years of manufacture were derived by fitting a logistic regression model to the observed data and extrapolating this to 2034. The future increase in uptake of AEB was assumed to be the same as observed for ESC albeit starting much later. The resulting estimates of fitment rate by year of vehicle manufacture are shown in Figure 15 (ESC) and Figure 16 (AEB). Results are given for LCVs and passenger vehicles separately, as well as for SUVs and all other passenger vehicle sub-groups.

**Figure 15 ESC fitment rate by year of manufacture and market group**



**Figure 16 AEB fitment rate by year of manufacture and market group**

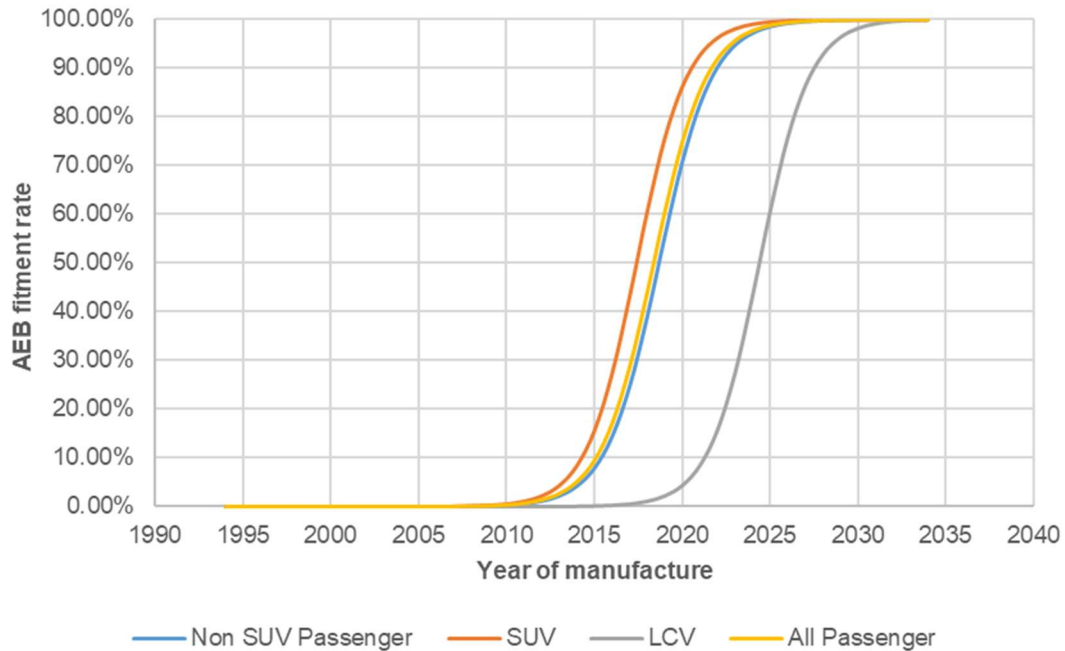


Figure 16 shows that the fitment rate of ESC for passenger vehicles is almost 100 per cent in the 2014 base year, reflecting the mandate for ESC to be fitted to all passenger vehicles in Australia from 2012. In contrast, the LCV ESC fitment rate is only projected to reach 100 per cent by 2020, reflecting a later timing of mandated ESC fitment to this vehicle class. In contrast, 100 per cent AEB fitment rate for new passenger vehicles is not anticipated until around 2025 and for LCVs around five to seven years later. It is possible AEB fitment rates might be impacted by an earlier mandate for compulsory fitment, should this eventuate.

#### **4.3.3 Average reduction in crash risk associated with each primary safety technology**

Estimates of the overall crash reduction effect of each of these technologies were taken from the evaluation literature. For ESC, a 9.8 per cent overall reduction across all crash types was taken from Scully et al (2008). For AEB, a 12 per cent overall reduction across all crash types was taken from Fildes et al (2015). Estimated AEB effectiveness from Fildes et al (2015) is based on the analysis of real world effects in vehicles largely fitted with AEB operational at lower speed, generally less than 50 kilometres per hour. As AEB systems operational at higher speeds become more prevalent in the market, estimated effectiveness may increase. However, at this stage there is no research evidence to quantify this.

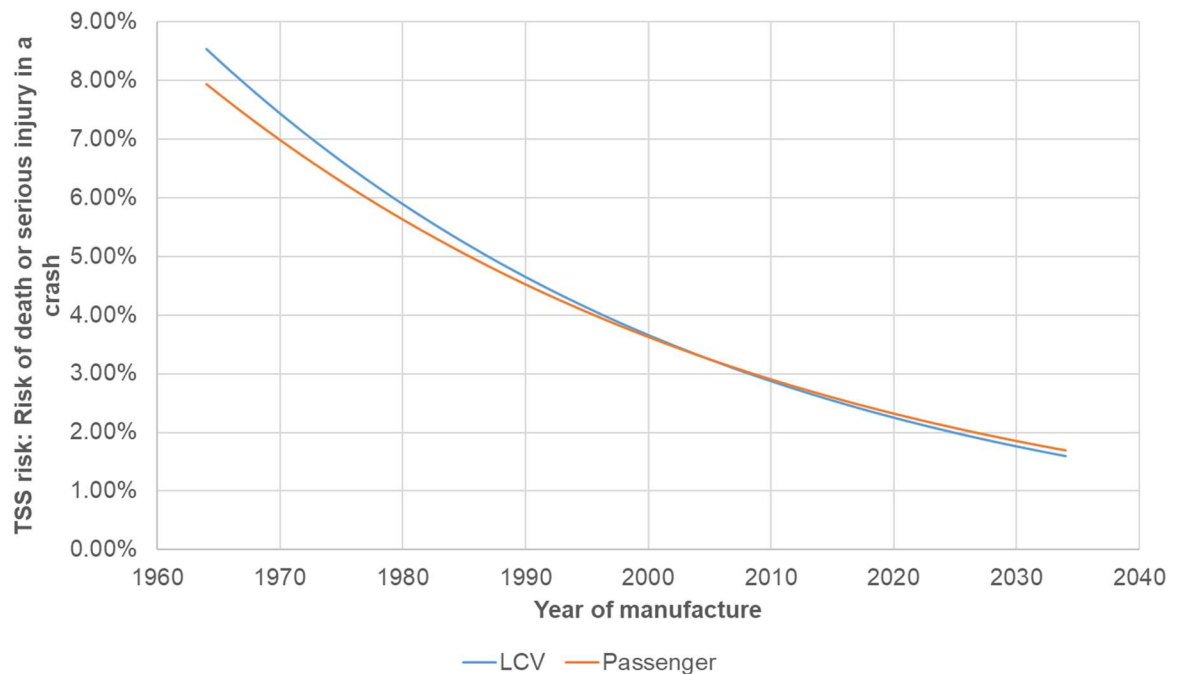
#### **4.3.4 Secondary safety index by year of vehicle manufacture and vehicle market group**

Total secondary safety estimates by vehicle market group and year of manufacture have been produced by MUARC for the Used Car Safety Ratings project (Newstead et al, 2016) for the years 1982 to 2014. These estimates were extrapolated forwards to 2034 and backwards to 1963 years of vehicle manufacture, using a logistic regression model. The TSS injury severity risk model and projections are shown in Figure 17 for passenger vehicles and LCVs. These estimates were used to derive the number of fatal and serious injuries (hospitalisations) resulting from crash-involved light vehicles.

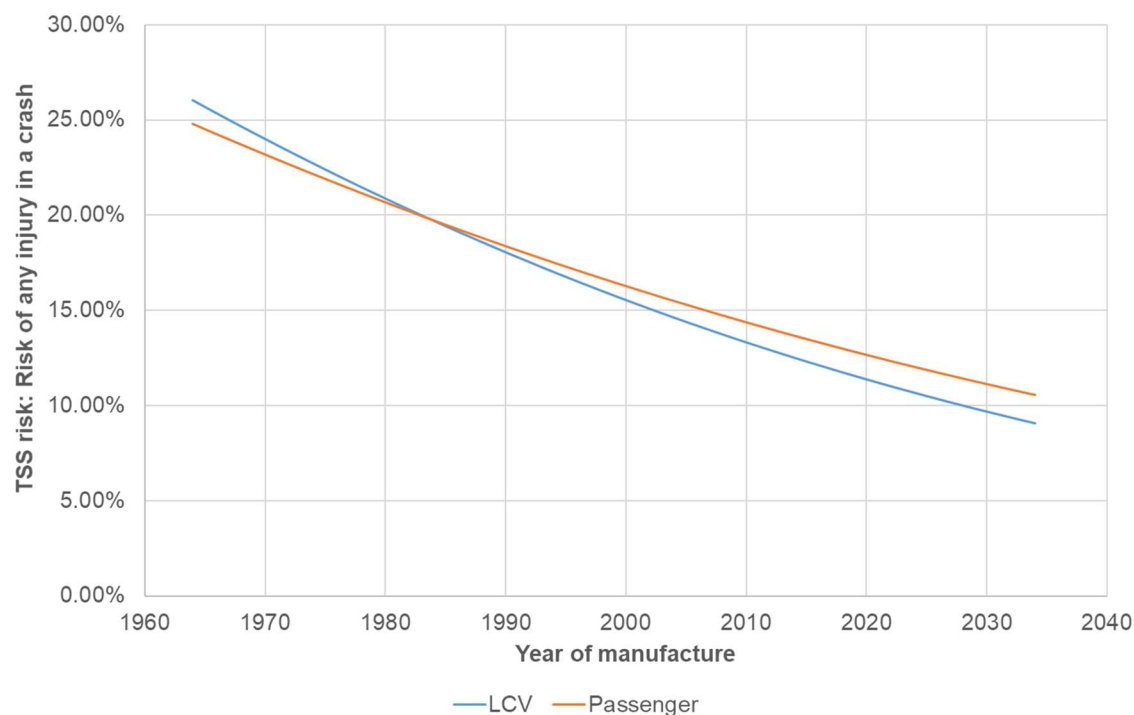
Figure 17 shows that the secondary safety of LCVs has improved faster than that of passenger cars. After being some way behind in total secondary safety in early years, the average secondary safety of LCVs has converged to that of regular light passenger vehicles. Safety improvements, such as airbag fitment and structural improvements, are generally applied to LCVs after passenger cars, both as manufacturer provided features as well as through the ADR mandating process.

The same process was followed for the TSS risk component measure, which was used to estimate the total number of injured road users in the safety analysis, including fatal and serious injuries. Fatal and serious injuries estimated using the overall Total Secondary Safety Index were then subtracted from the total number of injuries estimated from the risk component to derive the number of other injuries (i.e. not fatal or serious) expected. Figure 18 shows the Total Secondary Safety risk estimates and projections for passenger vehicles and LCVs.

**Figure 17 Total vehicle secondary safety by year of manufacture – injury severity component**



**Figure 18 Total vehicle secondary safety by year of manufacture – risk of any injury component**



## 4.4 Estimated crash and injury savings

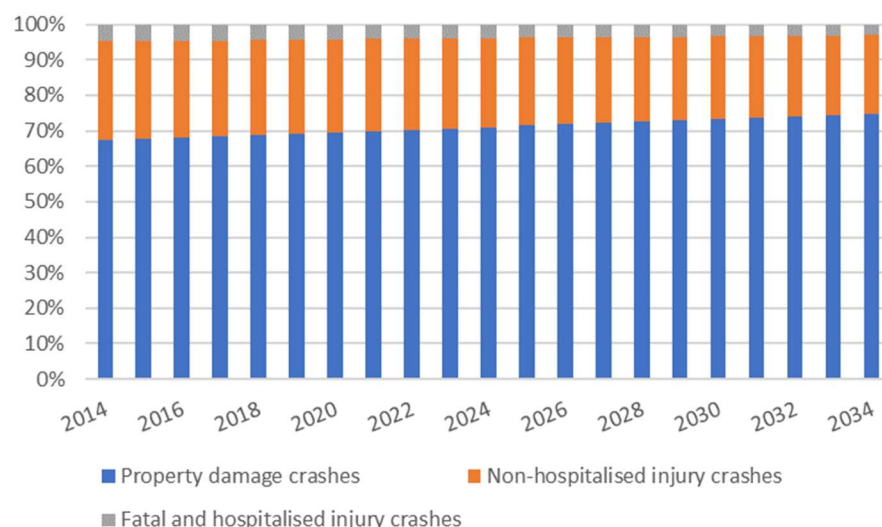
### 4.4.1 Crash savings

Using the key inputs presented in Section 4.3, the analysis model was applied to derive annual net savings in road crashes expected from implementation of each of the fleet age change scenarios over the years 2014 to 2034 for passenger cars and LCVs.

In the business as usual case, the total number of crashes is held constant, but with their severity reducing. Fatal and injury crashes decline by 36 per cent over the 20 year period, from 4.8 per cent of all crashes in 2014 to 3.2 per cent of all crashes in 2034 (Figure 19). Non-hospitalised injury crashes also fall, from 27.9 per cent to 22.8 per cent. Property damage crashes increase from 67.3 per cent in 2014 to 74 per cent in 2034, in an improved overall outcome for road safety users, increase notwithstanding.<sup>16</sup>

<sup>16</sup> Alternative 'crash increase' and 'crash reduction' business as usual cases were also modelled, prior to selection of the 'fixed crashes' (intermediate) case. While absolute numbers differ (larger with a crash increase business as usual and smaller with a lower one), percentage crash reductions under the two scenarios are not affected.

**Figure 19 Change in distribution of crash severity, business as usual case, 2014 to 2034**



In terms of absolute numbers, in the short take up scenario (Table 6), total fatal crashes reduce by 1,263 and hospitalised injury crashes by 36,298 (each 7.2 per cent). Total crashes (all types) fall by 5.4 per cent. In the long take up scenario, crash reductions are approximately a percentage point lower (Table 7).

There is differentiation in outcomes for passenger vehicles and LCVs, with passenger vehicle fatal and hospitalised crashes reducing in the short take up (long take up) scenario by 7.5 per cent (6.5 per cent), while comparable LCV crash numbers reduce by 5.2 per cent (4.6 per cent).

**Table 6 Reduction in passenger vehicle and LCV road crashes, short take up**

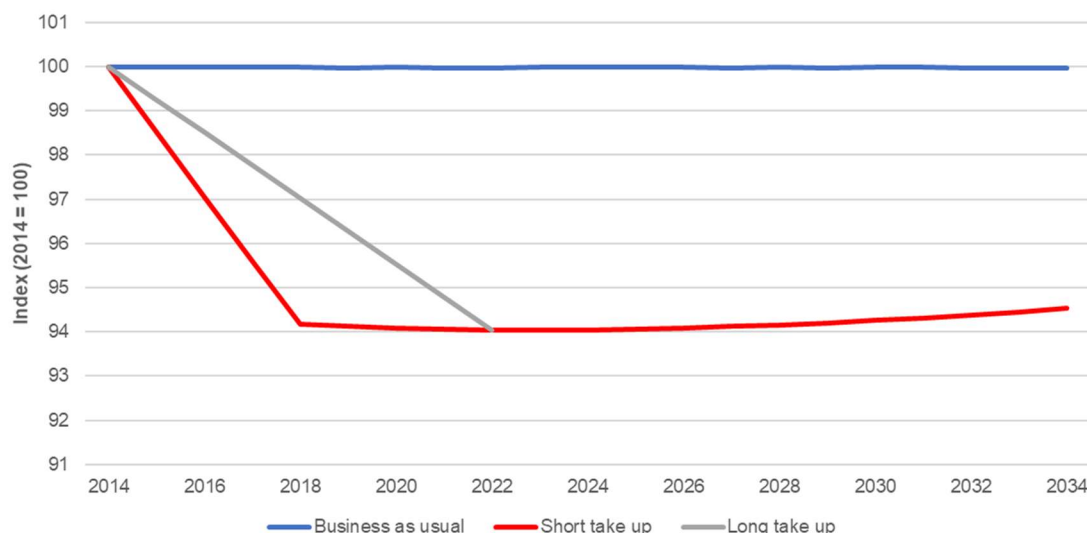
Crash type	Passenger vehicles			LCVs			Total vehicles		
	Business as usual 20 year total crashes	20 year scenario reduction	% change	Business as usual 20 year total crashes	20 year reduction	% change	Business as usual 20 year total crashes	20 year scenario reduction	% change
Fatal	15,155	-1,134	-7.5%	2,498	-129	-5.2%	17,653	-1,263	-7.2%
Hospitalised injury	435,467	-32,592	-7.5%	71,769	-3,706	-5.2%	507,236	-36,298	-7.2%
Non-hospitalised injury	2,913,318	-192,478	-6.6%	471,355	-20,654	-4.4%	3,384,673	-213,131	-6.3%
Property damage	8,287,843	-442,397	-5.3%	1,389,775	-38,561	-2.8%	9,677,619	-480,958	-5.0%
TOTAL	11,651,783	-668,601	-5.7%	1,937,895	-63,050	-3.3%	13,589,678	-731,651	-5.4%

**Table 7 Reduction in passenger vehicle and LCV road crashes, long take up**

Crash type	Passenger vehicles			LCVs			Total vehicles		
	Business as usual 20 year total crashes	20 year scenario reduction	% change	Business as usual 20 year total crashes	20 year scenario reduction	% change	Business as usual 20 year total crashes	20 year scenario reduction	% change
Fatal	15,155	-992	-6.5%	2,498	-115	-4.6%	17,653	-1,107	-6.3%
Hospitalised injury	435,467	-28,513	-6.5%	71,769	-3,290	-4.6%	507,236	-31,804	-6.3%
Non-hospitalised injury	2,913,318	-170,131	-5.8%	471,355	-18,479	-3.9%	3,384,673	-188,610	-5.6%
Property damage	8,287,843	-396,590	-4.8%	1,389,775	-35,007	-2.5%	9,677,619	-431,597	-4.5%
TOTAL	11,651,783	-668,601	-5.7%	1,935,397	-63,050	-3.3%	13,587,180	-653,117	-4.8%

Estimated savings for each group peak at the point where the full maximum age reduction is delivered (after 4 years and 8 years respectively) and diminish slowly from this point (Figure 20). This trend reflects that the general crash base to which the age change savings apply diminishes slowly over time as the general trend in improving safety of the vehicle fleet continues and hence the absolute crash and injury savings, which are proportionate to the change in safety level, diminish also after the age change is fully implemented.

**Figure 20 Total road crashes, business as usual and scenarios**



Note: Long take up is identical to the short take up from year 8 (2022) onwards and so is not shown.

#### 4.4.2 Injury reductions

Reduction in crashes is converted into injury reductions using the average values for crashes of differing severity shown in Table 8. Table 9 provides estimates of total 20 year reduction in injuries. For the short take up scenario, they amount to a reduction in fatalities of 1,377, together with 44,467 fewer hospitalised injuries and 262,995 fewer non-hospitalised injuries. Injury reduction outcomes for the long take up scenario are 12 per cent lower.



**Table 8 Estimated injuries per crash, by crash type**

Injuries per crash	Fatal crash	Hospitalised injury crash	Non-hospitalised injury crash	Total injuries
Fatality	1.09	na	na	1.09
Hospitalised	0.72	1.20	na	1.92
Non-hospitalised	0.27	0.19	1.20	1.66

Source: ECON 2017 based on BITRE 2009

**Table 9 Reduction in injuries, short and long take up scenarios**

Injury type	Fatal crash	Hospitalised injury crash	Non-hospitalised injury crash	Total 20 year injury reduction
<b>Short take up</b>				
Fatality	1,377	na	na	1,377
Hospitalised	910	43,558	na	44,467
Non-hospitalised	341	6,897	255,758	262,995
<b>Long take up</b>				
Fatality	1,206	na	na	1,206
Hospitalised	797	38,164	na	38,961
Non-hospitalised	299	6,043	226,332	232,673

## 4.5 Passenger vehicle market sub-groups

Analysis was undertaken of the road safety impacts of vehicle fleet age reduction by passenger car market sub-group: light-small; medium-large-people mover; and sports utility vehicle (SUV). Data deficiencies relating to the risk of crash involvement across these vehicle types and number of future vehicles in each category precluded reliable application of the three-step event chain modelling framework (Section 4.2), on which the results depend. See Appendix B for further information.

## 5. Emissions impacts

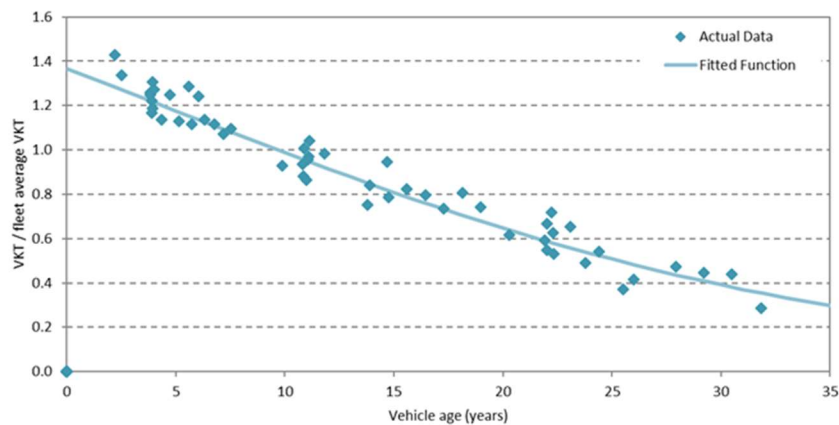
This section outlines the passenger vehicle emissions modelling framework and details pollutant emission reductions and greenhouse gas emissions reductions under the business as usual case and under the two change scenarios.

### 5.1 Emissions modelling

Historical and forecast motor vehicle emissions are estimated by combining published emissions rates (in terms of grams per kilometre or grams per litre) to the estimated distance travelled and fuel consumed. Appendix C provides charts for each pollutant and greenhouse gas under consideration. The emissions model used is characterised by the following features.

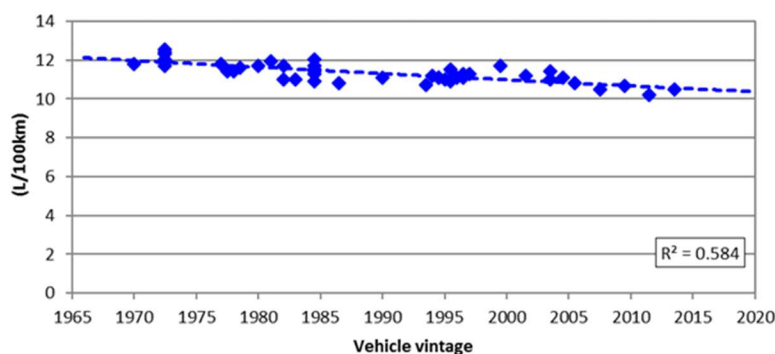
1. The distance travelled by vintage and vehicle type is converted to a ratio of the fleet average distance travelled for each state and territory. This reflects the observation that newer vehicles are driven more than older vehicles. Functions are fitted to the observed data from the ABS Survey of Motor Vehicle Use (SMVU), as shown in Figure 21 for New South Wales passenger cars.

**Figure 21 Annual VKT ratio, New South Wales passenger cars**



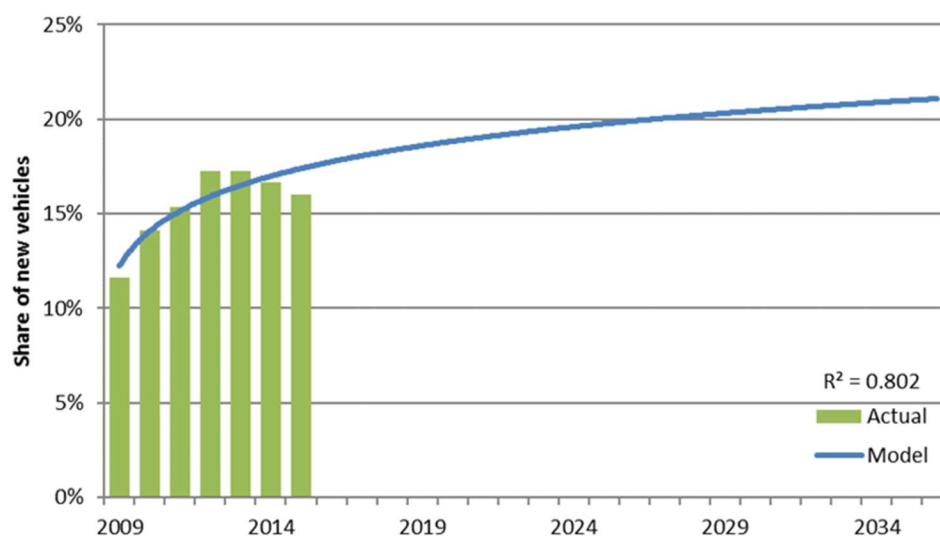
2. ABS SMVU data are used to identify the variation in the fleet average fuel consumption rates by jurisdiction, vehicle type, fuel type and vintage. The fuel types considered include unleaded petrol (ULP), diesel, liquefied petroleum gas (LPG), compressed natural gas (CNG), hybrid, electric, ethanol and biodiesel. Reflecting the change in engine technology, newer vehicles tend to have a lower fuel consumption rate than older vehicles. This relationship for passenger cars in NSW fuelled by unleaded petrol is shown in Figure 22.

**Figure 22 Fuel consumption rate by vehicle vintage, NSW ULP passenger cars**



3. The total amount of fuel consumed by vehicle type, vintage and fuel type is then estimated by applying the fuel consumption rate to the annual VKT and adjusting for average distance travelled by vintage.
4. Speed dependent emission factors by vehicle type, vintage, area of operation (urban and rural), road type (residential, arterial and freeway) and fuel type are derived from a combination of Australian and European data. Future emission factors reflect the likely impact of recently introduced Australian Design Rules (see also Section 5.2.1).
5. Emission factors are adjusted to account for:
  - a. *Mileage*: a correction to CO, NOx and VOC emissions is based upon expected catalytic converter deterioration and estimated vehicle odometer values
  - b. *Cold start*: multipliers reflecting the climatic conditions and average trip lengths in the capital cities
  - c. *Fuel specification*: emission factors are adjusted according to the specific fuel chemical properties and composition in each state and territory.
  - d. *Vehicle speed*: emission factors are velocity-dependent; accordingly, the model apportions distance travelled by area (capital city, provincial urban and non-urban), road (local and arterial with arterial incorporating freeway travel) and vehicle type in each state/territory.
6. Future changes in the share of traditional and alternative fuel technologies for new vehicles are estimated by vehicle type and jurisdiction, by fitting a logarithmic trend to the recent time series data. For example, Figure 23 shows the expected increase in the share of diesel vehicles for new passenger cars in New South Wales.

**Figure 23 Share of new passenger cars using diesel, New South Wales**



## 5.2 Pollutant emission reductions

### 5.2.1 Business as usual reductions

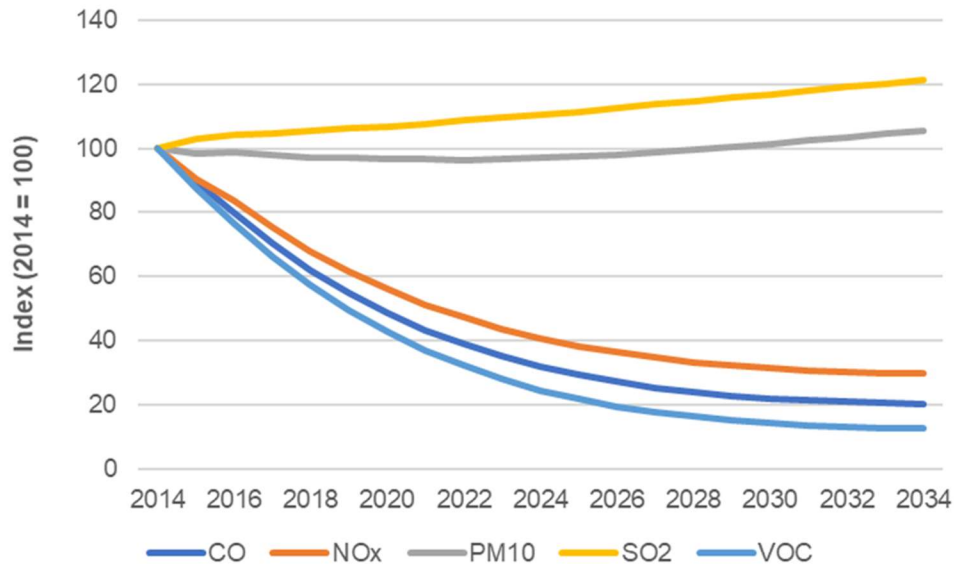
Under business as usual conditions, significant further reductions are expected in carbon monoxide (CO), hydrocarbons/volatile organic compounds (HC/VOC) and oxides of nitrogen (NO<sub>x</sub>) (Table 10). Reduction rates are projected to diminish by the mid 2020s, with very low levels having been achieved by that time (Figure 24).<sup>17</sup> These reductions are as a consequence of the continuing impact of Euro 5 noxious emissions standards (through ADR 79/04 – Emission Control for Light Vehicles) for newly approved models first manufactured from November 2013 and for all light vehicles manufactured from November 2016 (DIRD 2016c, p. 12).

**Table 10 Pollutants, business as usual annual per cent change, 2014 to 2034**

Pollutant	Passenger vehicles	LCVs	Total
CO	-8.4%	-6.3%	-7.6%
HC/VOC	-11.2%	-7.2%	-9.8%
NO <sub>x</sub>	-7.4%	-3.8%	-5.9%
PM <sub>2.5</sub>	0.2%	-1.8%	-0.5%
PM <sub>10</sub>	0.7%	-0.6%	0.3%
SO <sub>2</sub>	1.2%	-0.6%	1.0%

<sup>17</sup> See also Appendix C for past trends and future projections for each individual pollutant.

**Figure 24 Pollutant emissions, business as usual, 2014 to 2034**



The more rigorous Euro 6 standards, now in force in many overseas countries, are currently under policy consideration. If introduced, these standards would further reduce emissions limits for oxides of nitrogen (NO<sub>x</sub>) for diesel vehicles and would also introduce a particle number limit to reduce fine particle emissions from petrol direct injection vehicles. This would lower the future particulate matter (PM) trajectory. Euro 6 standards are not included in the business as usual case, or in the scenarios.

### 5.2.2 Scenario reductions

Compared to the business as usual case, pollutant reductions, under the short take up (four year phase-in) scenario, range from 0.7 per cent (sulfur dioxide, SO<sub>2</sub>) to 11.6 per cent (HC/VOC). Under the long take up (eight year phase-in), the corresponding range is from 0.6 per cent (SO<sub>2</sub>) to 8.6 per cent (HC/VOC).

**Table 11 20 year reduction in pollutant emissions, tonnes, short take up**

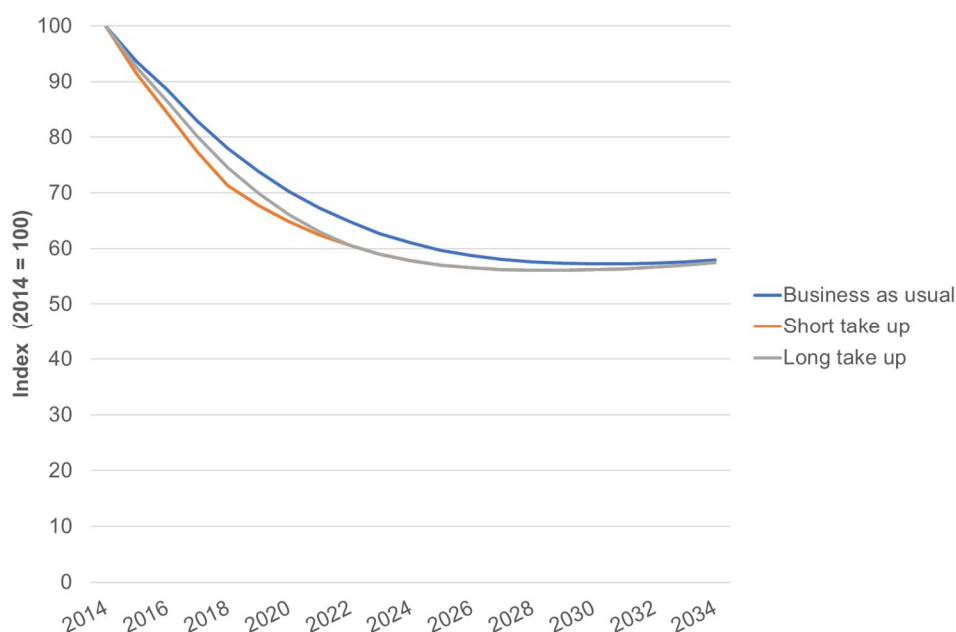
Pollutant	Passenger vehicles			LCVs			Total vehicles		
	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change
CO	2,581,452	-244,320	-9.5%	1,655,726	-172,169	-10.4%	4,237,178	-416,489	-9.8%
HC/VOC	263,145	-30,646	-11.6%	128,754	-14,688	-11.4%	391,900	-45,333	-11.6%
NO <sub>x</sub>	826,564	-70,219	-8.5%	662,576	-41,602	-6.3%	1,489,140	-111,820	-7.5%
PM <sub>2.5</sub>	58,192	-590	-1.0%	32,275	-1,343	-4.2%	90,467	-1,933	-2.1%
PM <sub>10</sub>	100,199	-621	-0.6%	49,554	-1,413	-2.9%	149,754	-2,035	-1.4%
SO <sub>2</sub>	27,415	-94	-0.3%	3,993	-119	-3.0%	31,408	-213	-0.7%

**Table 12 Reduction in pollutant emissions, tonnes, long take up**

Pollutant	Passenger vehicles			LCVs			Total vehicles		
	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change
CO	2,581,452	-182,056	-7.1%	1,655,726	-135,322	-8.2%	4,237,178	-317,377	-7.5%
HC/VOC	263,145	-22,746	-8.6%	128,754	-11,088	-8.6%	391,900	-33,834	-8.6%
NO <sub>x</sub>	826,564	-52,955	-6.4%	662,576	-34,214	-5.2%	1,489,140	-87,169	-5.9%
PM <sub>2.5</sub>	58,192	-490	-0.8%	32,275	-1,140	-3.5%	90,467	-1,630	-1.8%
PM <sub>10</sub>	100,199	-516	-0.5%	49,554	-1,200	-2.4%	149,754	-1,716	-1.1%
SO <sub>2</sub>	27,415	-84	-0.3%	3,993	-103	-2.6%	31,408	-187	-0.6%

The time path of emission reductions peaks in 2019 (year 4) in the short take up scenario (year 8 in the long take up scenario) and declines thereafter as the business as usual scenario 'catches up', with continuing reductions in total emissions.

**Figure 25 Pollutant emissions, business as usual and scenarios**



Note: The index is constructed by equally weighting the volumes of each pollutant in 2014, rather than by totalling across pollutants. This mitigates what would otherwise be the high impact of the preponderant volumes of carbon monoxide, a less harmful pollutant and, conversely, the low impact of the small volumes of particulate matter, the most harmful pollutant.

## 5.3 Greenhouse gas emission reductions

### 5.3.2 Business as usual case

Greenhouse gas emissions are expected to increase over the 20 year period, by 1.4 per cent per year for passenger vehicles and 2.3 per cent per year for LCVs, in carbon dioxide equivalent (CO<sub>2</sub>-e) terms,<sup>18</sup> as shown in Table 13. This is broadly consistent with Australian Government projections, where road transport emissions are projected to increase from 79 million tonnes carbon dioxide equivalent in 2015 to 92 million tonnes in 2030 (Department of the Environment and Energy 2016, p. 15).

Comprising less than half of one per cent of total carbon dioxide equivalent tonnes emitted by the passenger vehicle fleet, methane (CH<sub>4</sub>) and, for passenger cars, nitrous oxide (N<sub>2</sub>O) emissions are expected to continue to decline.

Other factors that potentially impact vehicle emissions, such as driver behaviour, congestion, travel speed, and vehicle loading are held constant for all future year scenarios.

**Table 13 Greenhouse gas emissions, business as usual, annual % change, 2014 to 2034**

Greenhouse gas	Passenger vehicles	LCVs	Total
CO <sub>2</sub>	1.4%	2.3%	1.6%
CH <sub>4</sub>	-8.9%	-9.8%	-9.1%
N <sub>2</sub> O	-3.3%	0.7%	-1.8%
TOTAL (1)	1.4%	2.3%	1.6%

(1) Total is measured in carbon dioxide equivalent (CO<sub>2</sub>-e) terms. See footnote 18.

### 5.3.3 Scenario impacts

A small net reduction in carbon dioxide emissions (0.1 per cent) over the 20 year period, under both short and long take up scenarios (Table 14 and Table 15), includes a partially offsetting, increase in LCV emissions. While the fuel consumption rate for new petrol LCVs is expected to continue to decline, the fuel consumption rate for the growing share of new diesel LCVs is expected to remain flat or decrease.

**Table 14 Reduction in greenhouse emissions, 000 CO<sub>2</sub>-e tonnes, short take up**

Greenhouse gas	Passenger vehicles			LCVs			Total vehicles		
	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change
CO <sub>2</sub>	1,034,558	-1,713	-0.2%	385,236	175	0.05%	1,419,794	-1,538	-0.1%
CH <sub>4</sub>	469	-48	-10.3%	108	-15	-13.9%	577	-63	-8.0%
N <sub>2</sub> O	2,852	-139	-4.9%	2,022	-41	-2.0%	4,874	-180	-2.8%
TOTAL	1,037,879	-1,901	-0.2%	387,365	120	0.03%	1,425,244	-1,781	-0.1%

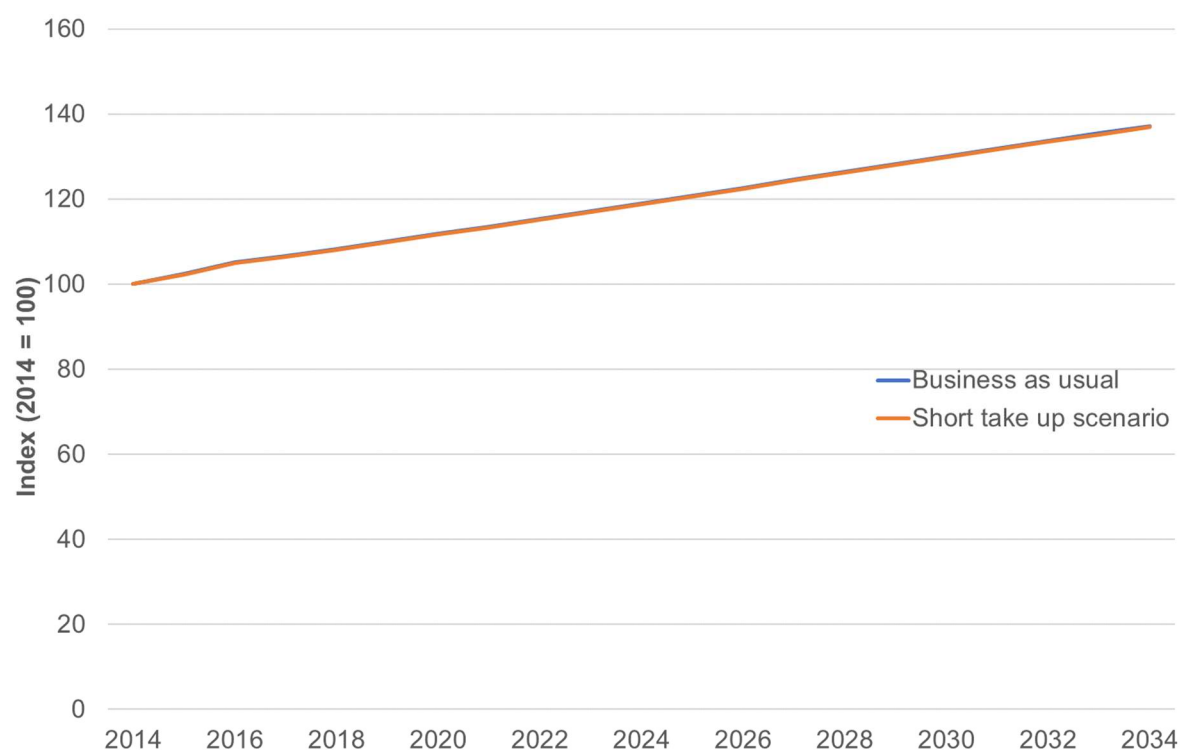
<sup>18</sup> The carbon dioxide equivalent measure adjusts for the global warming potential of different gases: 25 times carbon dioxide for methane and 298 times for nitrous oxide (Department of the Environment 2015).

**Table 15 Reduction in greenhouse emissions, 000 CO<sub>2</sub>e tonnes, long take up**

Greenhouse gas	Passenger vehicles			LCVs			Total vehicles		
	Business as usual 20 year total emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change	Business as usual - total 20 year emissions	20 year scenario reduction	% change
CO <sub>2</sub>	1,034,558	-1,395	-0.1%	385,236	167	0.04%	1,419,794	-1,229	-0.1%
CH <sub>4</sub>	469	-34	-7.3%	108	-12	-10.8%	577	-46	-8.0%
N <sub>2</sub> O	2,852	-103	-3.6%	2,022	-33	-1.6%	4,874	-136	-2.8%
TOTAL	1,037,879	-1,533	-0.1%	387,365	122	0.03%	1,425,244	-1,411	-0.1%

Scenario reductions are almost too small to be visually discernible in Figure 26.

**Figure 26 Greenhouse gas emissions, business as usual and short take up scenario**



Note: The index is constructed by totalling emissions of the three greenhouse gases in 2014 in carbon dioxide equivalent terms. The long take up scenario is distinguishable from the short take up only from the second decimal onwards and is accordingly not shown separately here.



## 6. Benefits analysis

This section: sets out the economic valuation approach to road trauma impacts, pollutant emissions impacts and greenhouse gas emissions impacts; outlines parameter values used for both the central results and for sensitivity testing ; and details estimated scenario benefits and sensitivity test results.

### 6.1. Benefits valuation approach

Economic valuation of the benefits of a younger vehicle fleet centre on estimates of:

- Reduced road trauma, i.e. loss of life and functional wellbeing, from improved vehicle safety
- Avoided health costs, i.e. reduced mortality and reduced morbidity from lower vehicle pollutant emissions and
- Avoided global climate damage from reduced greenhouse gas emissions.

Economic values reflect both 'technical' quantification of impacts (quantities) and valuation assumptions (dollar values). Because impacts stretch into the future, discounting of future benefits is required and, as Abelson (2008) notes, the choice of a discount rate and decisions on values can be inter-related. This study follows ECON 2017 and BITRE 2009 in use of a three per cent (real) discount rate, as outlined further below. A sensitivity test using a seven per cent (real) discount rate is also undertaken.

As the analysis does not consider costs associated with implementation of the scenarios, discounted benefits are 'gross' rather than 'net' benefits and expressed as a 'present value' rather than 'net present value'. The price year is 2015.

#### 6.1.1 Road trauma impacts valuation

Valuation of reductions in road trauma is based on Economic Connections' update (ECON 2017), using 2015 data, of BITRE's estimates of the cost of road trauma in 2006 (BITRE 2009). At \$4,339,000 (based on an average loss of life expectancy of 40 years, in 2015 prices), the estimated cost per fatality in ECON 2017 is more than 30 per cent higher than the BITRE 2009 estimate (\$3,260,000, also in 2015 prices). ECON 2017 adopts the 'willingness to pay' based valuation of statistical life recommended by the Australian Government Office of Best Practice Regulation (Department of Prime Minister and Cabinet 2014), in preference to BITRE's 'hybrid human capital' valuation. The valuation is, however, lower than a valuation, based on willingness to pay for road safety (Hensher et al 2009), that was included as a sensitivity test in BITRE 2009 (\$7.94m in 2015 prices). While there can be variability in empirical estimates, willingness to pay valuations acknowledge consumer preferences, consistent with economic theory.

In some contrast, the estimated cost per hospitalised injury in ECON 2017 is 18 per cent lower than in the BITRE study, reducing from \$292,000 to \$239,000. While the higher valuation of statistical life applies here also, changes to the BITRE study costing approach, which reduce the cost of disability care and insurance administration, have a more significant impact.

The estimated unit costs per crash of different types are shown in Table 16.

**Table 16 Casualties and costs by crash type, Australia 2015**

Crash type	No crashes	Fatalities per crash	Hospitalised injuries per crash	Non-hospitalised injuries per crash	Cost per crash \$m
Fatal	1,101	1.09	0.45	0.27	4.749
Hospitalised injury	31,637	na	1.20	0.19	0.287
Non-hospitalised injury	189,643	na		1.20	0.015
Property damage	456,978	na			0.011
TOTAL	679,359				0.030

na Not applicable

Source: ECON 2017

The study follows BITRE 2009 in using a discount rate of three per cent real in valuing future costs. This discount rate is 'embedded' in the estimates in the sense that a higher (lower) discount rate would entail a lower (higher) value of statistical life, or alternatively a higher (lower) value of statistical life year, than the ones used.<sup>19</sup>

### 6.1.2 Pollution emission valuation

With regard to pollutant emission valuation, this study follows the Australian Government's draft regulation impact on introduction of Euro 6 light vehicle emission standards (DIRD 2016c). Values for carbon monoxide (CO), hydrocarbons and volatile organic compounds (HC/VOC) and oxides of nitrogen (NO<sub>x</sub>) are as adopted for that study (Table 17).

With PM<sub>2.5</sub> comprising the bulk of vehicle exhaust particle emissions (and much of the estimated volume of PM<sub>10</sub> emission reductions), PM<sub>2.5</sub> is valued in the analysis, rather than PM<sub>10</sub>.<sup>20</sup> A value for PM<sub>2.5</sub> is sourced from a study undertaken for the New South Wales Environment Protection Authority (PAE Holmes 2013). PM<sub>2.5</sub> comprises the bulk of vehicle exhaust particle emissions.

Lower values for non-capital city Australia reflect differences in exposure, due to differences in population density, geographic spread, traffic congestion and other factors. With these various factors internalised in the valuations, the values were applied in the analysis on a simple population-weighted basis (i.e. with two thirds of the Australian population located in capital cities and one third outside them).

<sup>19</sup> See ECON 2017, p. 10 for a more detailed discussion.

<sup>20</sup> Larger particles are emitted through vehicle braking and tyre action, as well as through exhaust. PM<sub>10</sub>, i.e. particles of up to 10 micrometres in diameter, by definition includes PM<sub>2.5</sub>, i.e. particles of less than 2.5 micrometres in diameter (Grigoratos and Martini 2014).

**Table 17 Value of pollutants, 2015 \$ per tonne**

Pollutant	Capital cities	Rest of Australia
Carbon monoxide (CO)	5	0.5
Hydrocarbons/Volatile organic compounds (HC/VOC)	2,000	200
Nitrogen oxides (NOx)	3,500	1,167
Particulate matter (PM <sub>2.5</sub> )	303,427	67,968
Particulate matter (PM <sub>10</sub> )	250,000	56,000
Sulfur dioxide (SO <sub>2</sub> )	23,694	TBA

Source: DIRD 2016c, PAE Holmes 2013; Shadbegian et al 2005 and ECON analysis

### 6.1.3 Carbon dioxide valuation

Valuation of carbon dioxide emissions is based on values used by the United States Environmental Protection Agency (USEPA) in relation to environmental rulemaking. USEPA values are also a valuation source in DIRD 2016 (p. 58). USEPA 2016 provides values for a range of discount rates, enabling alignment with the discount rate of three per cent per year used in this study. At three per cent, values increase from \$US36 in 2015 to \$US55 in 2035 and \$US69 in 2050 (all in 2007 US dollars). This price path captures a projected intensification over time of the adverse impacts of global warming. For this study, a single 2015 value that reflects the USEPA's projected cost increase trajectory between 2014 and 2034 and conversion to Australian dollars (at a rate of \$US1 = \$A0.75) is used of \$A68 (Table 18).<sup>21</sup>

This valuation is also applied to the two other greenhouse gases, for which emissions are measured, methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O), through the metric of 'carbon dioxide equivalent' tonnes. These two gases have global warming potential, respectively, of 25 times and 298 times that of carbon dioxide (Department of the Environment 2015, p. 56).

**Table 18 Social cost of carbon and greenhouse gas global warming potential**

	2015 \$ (Australian)	Global warming potential
Social cost of carbon (CO <sub>2</sub> equivalent)	68	
Carbon dioxide (CO <sub>2</sub> )		1 times CO <sub>2</sub>
Methane (CH <sub>4</sub> )		25 times CO <sub>2</sub>
Nitrous oxide (N <sub>2</sub> O)		298 times CO <sub>2</sub>

Source: DoE 2015, USEPA 2016 and ECON analysis

### 6.1.4 Sensitivity analysis

Sensitivity analysis can address uncertainties in both the quantification of impacts and in economic valuation. Quantification uncertainties are prominent in emissions analysis. They include: differences between on road versus laboratory or test emissions; dose-response or 'medical' uncertainties; applicability of overseas health impact studies in the Australian context in view of differences of climate, population density and other factors; and the range, severity and timing of adverse climate change impacts. Impact quantification issues also arise in relation

<sup>21</sup> See Appendix D for full details of the calculation.

to road trauma, for example with regard to the range, severity and duration of disabilities resulting from road crashes (Gabbé et al 2016). However, valuation uncertainties are more prominent, notably with regard to the valuation of statistical life. Alternative values of life and life years are also a source of differences in valuation of the health impact of vehicle emissions.

For the road trauma analysis, this study provides sensitivity tests based, firstly, on the BITRE 2009 hybrid human capital valuation approach and, secondly, on a 'willingness to pay for road safety' valuation (Hensher et al 2009) that was included in BITRE 2009.<sup>22</sup> These values give a cost per fatal (hospitalised injury) crash that are respectively 21 per cent (11 per cent) lower and 121 per cent (55 per cent) higher than the central ECON estimate (Table 19).

**Table 19 Road trauma sensitivity test values, 2015 \$m**

Crash type	BITRE 2009 Hybrid human capital approach (ECON proxy estimate)	ECON 2017 Willingness to pay approach (OBPR)	BITRE 2009 Willingness to pay for road safety in Australia sensitivity test
Fatal	3.765	4.749	8.338
Hospitalised injury	0.257	0.287	0.397
Non-hospitalised injury	0.015	0.015	0.015
Property damage	0.011	0.011	0.011
TOTAL	0.030	0.033	0.044

For the emissions analysis, this study follows DIRD 2016c in varying the central values by plus and minus 50 per cent in each case. The wide range of values acknowledges the significant uncertainty regarding actual health cost effects (DIRD 2016c, p. 45). In contrast to DIRD 2016c, this approach is extended to carbon dioxide emissions (Table 20).<sup>23</sup>

<sup>22</sup> These two approaches also provide the sensitivity tests for the total cost of road trauma in ECON 2017.

<sup>23</sup> DIRD 2016b provides a total of two values, rather than three as in this study. One value is based on USEPA data and the second (lower) value is based on estimates of the cost of greenhouse abatement in Australia, as measured through auctions of the Emissions Reduction Fund.

**Table 20 Emission sensitivity test values, 2015 \$ per tonne**

Emission	Capital cities	Rest of Australia
Carbon monoxide (CO)	5	0.5
<i>Upper bound</i>	8	0.8
<i>Lower bound</i>	3	0.3
Hydrocarbons/Volatile organic compounds (HC/VOC)	2,000	200
<i>Upper bound</i>	3,000	300
<i>Lower bound</i>	1,000	100
Nitrogen oxides (NOx)	3,500	1,167
<i>Upper bound</i>	5,250	1,751
<i>Lower bound</i>	1,750	584
Particulate matter (PM <sub>2.5</sub> )	303,427	67,968
<i>Upper bound</i>	455,141	101,952
<i>Lower bound</i>	151,714	33,984
Particulate matter (PM <sub>10</sub> )	250,000	56,000
<i>Upper bound</i>	375,000	84,000
<i>Lower bound</i>	125,000	28,000
Sulfur dioxide (SO <sub>2</sub> )	23,694	7,819
<i>Upper bound</i>	35,541	11,729
<i>Lower bound</i>	11,847	3,910
Carbon dioxide equivalent (CO <sub>2</sub> -e)	68	
<i>Upper bound</i>	101	
<i>Lower bound</i>	34	

Finally, to provide comparability with higher discount rates that are widely used in project evaluation contexts, the 'lower' and 'higher' sensitivity analyses are repeated at a discount rate of seven per cent real.

## 6.2. Scenario benefits

### 6.2.1 Road trauma reduction benefits

The present value of road trauma benefits over the 20 year analysis period total \$18,957.8m in the short take up scenario (Table 21) and \$16,251.9m under the long take up one (Table 22).

**Table 21 Road trauma reduction benefits present value, short take up, 3% discount rate, 2015 \$m**

Road crash type	Passenger vehicles	LCVs	Total	% road trauma benefits
Fatal	4,120.0	463.1	4,583.2	24.2%
Hospitalised injury	7,148.5	803.6	7,952.1	41.9%
Non-hospitalised injury	2,177.1	231.4	2,408.5	12.7%
Property damage	3,695.4	318.6	4,014.0	21.2%
TOTAL	17,141.0	1,816.7	18,957.8	100.0%

**Table 22 Road trauma reduction benefits present value, long take up, 3% discount rate, 2015 \$m**

Road crash type	Passenger vehicles	LCVs	Total	% road trauma benefits
Fatal	3,501.1	400.2	3,901.2	24.0%
Hospitalised injury	6,074.6	694.3	6,768.9	41.6%
Non-hospitalised injury	1,871.1	201.7	2,072.8	12.8%
Property damage	3,226.7	282.3	3,509.0	21.6%
TOTAL	14,673.4	1,578.5	16,251.9	100.0%

Passenger vehicles account for 92 per cent and 90 per cent of the benefits in the short and long take up scenarios respectively.

### 6.2.2 Emissions reduction benefits

The present value of 20 year emission reduction benefits total \$746.9m in the short take up scenario (Table 23) and \$593.9m (Table 24).

**Table 23 Emission reduction benefits present value, short take up, 3% discount rate, 2015 \$m**

Pollutant, greenhouse gas	Passenger vehicles	LCVs	Total	% emission reduction benefits
CO	0.7	0.5	1.2	0.2%
HC/VOC	36.7	17.5	54.3	7.3%
NO <sub>x</sub>	161.9	91.4	253.3	33.9%
PM <sub>2.5</sub> (1)	106.7	238.3	345.0	46.2%
SO <sub>2</sub>	1.3	1.7	3.0	0.4%
CO <sub>2</sub>	84.7	-8.6	76.1	10.2%
CH <sub>4</sub>	2.8	0.9	3.7	0.5%
N <sub>2</sub> O	8.1	2.3	10.3	1.4%
TOTAL	402.9	344.0	746.9	100.0%

(1) Reduction in PM<sub>10</sub> is excluded from the net present value, due to substantial overlap with the PM<sub>2.5</sub> reduction (see Table 24).

**Table 24 Emission reduction benefits present value, long take up, 3% discount rate, 2015 \$m**

Pollutant, greenhouse gas	Passenger vehicles	LCVs	Total	% emission reduction benefits
CO	0.4	0.4	0.8	0.1%
HC/VOC	26.5	12.9	39.4	6.6%
NO <sub>x</sub>	118.4	72.9	191.3	32.2%
PM <sub>2.5</sub> (1)	85.9	196.5	282.4	47.5%
SO <sub>2</sub>	1.1	1.4	2.6	0.4%
CO <sub>2</sub>	75.3	-8.1	67.2	11.3%
CH <sub>4</sub>	2.0	0.6	2.6	0.4%
N <sub>2</sub> O	5.9	1.8	7.6	1.3%
TOTAL	315.4	278.5	593.9	100.0%

(1) Reduction in PM<sub>10</sub> is excluded from the net present value, due to substantial overlap with the PM<sub>2.5</sub> reduction (see Table 24).

Passenger vehicles account for 78 per cent and 77 per cent of the benefits in the short and long take up scenarios respectively.

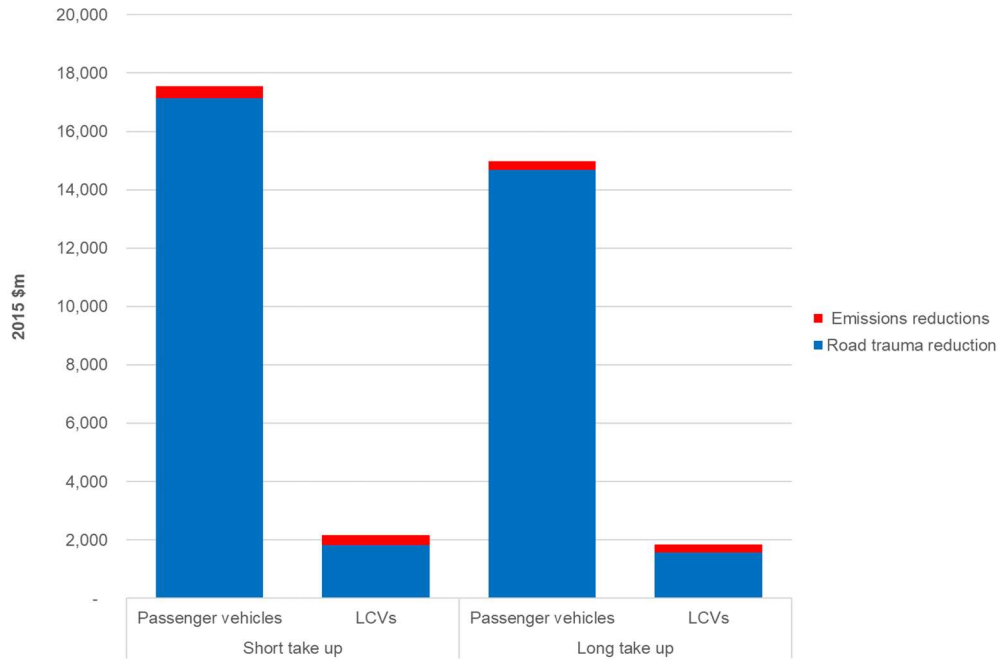
### 6.2.3 Total benefits

The present value of total benefits is \$19,704.7m in the short take up scenario and \$16,845.8m under the long take up one (Table 25 and Figure 27).

**Table 25 Total benefits present value, short and long take up, 3% discount rate, 2015 \$m**

Scenario	Passenger vehicles	LCVs	Total	% total benefits
Short take up	17,544.0	2,160.7	19,704.7	100.0%
Safety	17,141.0	1,816.7	18,957.8	96.2%
Emissions	402.9	344.0	746.9	3.8%
Long take up	14,988.8	1,857.0	16,845.8	100.0%
Safety	14,673.4	1,578.5	16,251.9	96.5%
Emissions	315.4	278.5	593.9	3.5%

**Figure 27 Total benefits present value, short and long take up, 3% discount rate**



### 6.3. Sensitivity tests

Sensitivity tests are undertaken using, in relation to safety benefits, the BITRE 2009 hybrid human capital valuation of statistical life (ECON proxy) approach, Sensitivity 1 in Table 26 and also the BITRE 2009 willingness to pay for road safety approach (Sensitivity 2).

With regard to emissions benefits, all values are varied by plus and minus 50 per cent, as with the Australian Government draft regulation impact statement (in respect of pollutant emissions).

Under the first approach, the net present value of benefits for the short and long take ups total \$17,542.9m and \$15,026.7m, respectively). Corresponding benefits are \$26,598.2m and \$22,692.9m, respectively, under the second approach.

**Table 26 Sensitivity tests, alternative parameter valuations, 2015 \$m**

Scenario	SENSITIVITY 1 (1)			STUDY ESTIMATES			SENSITIVITY 2 (2)		
	Passenger vehicle	LCV	Total	Passenger vehicle	LCV	Total	Passenger vehicle	LCV	Total
Short take up	15,734.9	1,808.0	17,542.9	17,544.0	2,160.7	19,704.7	23,606.6	2,991.6	26,598.2
Safety	15,533.4	1,636.0	17,169.5	17,141.0	1,816.7	18,957.8	23,002.2	2,475.6	25,477.8
Emissions	201.5	172.0	373.5	402.9	344.0	746.9	604.4	516.0	1,120.4
Long take up	13,465.1	1,561.6	15,026.7	14,988.8	1,857.0	16,845.8	20,127.4	2,565.5	22,692.9
Safety	13,307.4	1,422.4	14,729.7	14,673.4	1,578.5	16,251.9	19,654.1	2,147.8	21,801.9
Emissions	157.8	139.2	297.0	315.4	278.5	593.9	473.3	417.7	891.0

- (3) This involves, for road safety, an ECON proxy of the BITRE hybrid human capital approach and, for emissions, a 50 per cent reduction of all study values.
- (4) This involves use of the BITRE 2009 willingness to pay for road safety sensitivity approach and, for emissions, an increase in study values of 50 per cent.



Sensitivity tests were also conducted at an alternative higher discount rate (seven per cent). Total benefits are approximately 30 per cent below the results at a three per cent discount rate: \$12,763.8m and \$10,504.4 for the short and long take ups respectively, under the first approach and \$19,429.3m and \$15,921.2m under the second approach.

**Table 27 Sensitivity tests, 7% discount rate, 2015 \$m**

Scenario	SENSITIVITY 1 (1)	STUDY ESTIMATES	SENSITIVITY 2 (2)
Short take up	12,763.8	14,364.0	19,429.3
Safety	12,473.2	13,782.7	18,557.4
Emissions	290.6	581.3	871.9
Long take up	10,504.4	11,796.5	15,921.2
Safety	10,282.8	11,353.3	15,256.3
Emissions	221.6	443.3	664.9

(1) See note 1 to Table 26.

(2) See note 2 to Table 26.

## 7 Financial savings to government

Government finances are not exempt from the impact of both road trauma and pollution-induced mortality and morbidity, particularly through the lasting effects they have on workforce participation and earnings and, in consequence, on government taxation revenues and income support expenditure outlays. Other costs to government include emergency services costs and health and disability care costs not covered by private insurance arrangements.

This section considers financial savings to government resulting from the benefits of the two passenger vehicle fleet age change scenarios. The section: explains difference in scope from the economic benefits analysis; outlines the estimates of the cost to government of road trauma 2015 on which the road trauma-related savings estimates are based; provides estimates of those savings; and also discusses estimation of savings to government from reduced vehicle pollutant and greenhouse gas emissions.

### 7.1 Distinguishing financial and economic costs

In an economic analysis, 'costs' comprise either resource costs – for example, in the road trauma context, hospital, medical and emergency services costs – or opportunity costs, in the sense of forgone opportunities, for example, opportunities for injured persons, fatally and otherwise, to live and maintain health and wellbeing. Economic costs may or may not have a financial counterpart, wholly or in part. In contrast, in a financial or cost to government analysis, 'costs' (or savings) are calculated as the net sum of all financial flows, i.e. the negative flows less any positive flows or savings, that are known to affect government budgets.

The principal area of difference between the two types of analysis, in the road trauma context, relates to taxation revenue impacts and government income support payment impacts. These are excluded from economic analysis of the costs of road trauma, on the grounds that these represent transfers between agents in the economy, i.e. from taxpayers to eligible individuals, rather than resource costs.<sup>24</sup> However, these financial flows are appropriately part of a financial analysis.

### 7.2 Estimated cost to government of road trauma

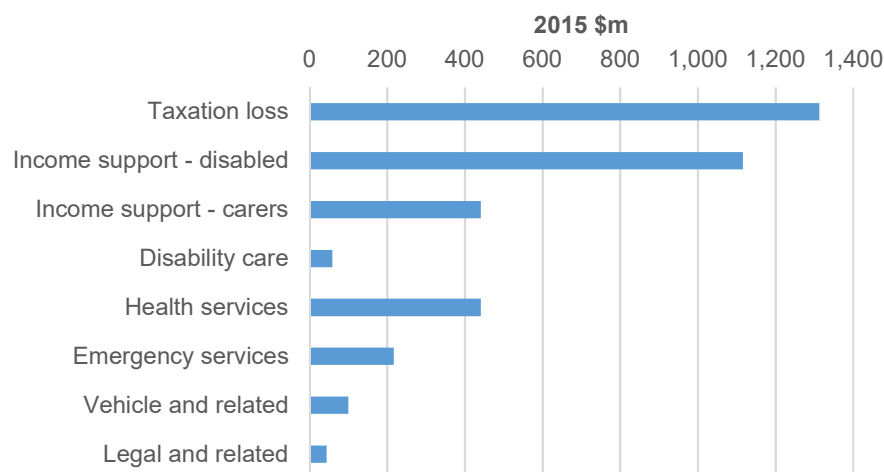
Savings to government from reduced road trauma over the 20 year period were calculated using the 'cost to government' estimates included in ECON 2017 (p. 39ff and Figure 28). The cost to government arising from the (estimated) 679,359 road crashes that occurred in 2015 is estimated at \$3,731.6m (present value, discounted at three per cent real). More than three quarters of this cost comprises the present value of many future years of forgone taxation revenue and additional income support payments, arising directly from road crash fatalities and disabilities and including the cost of disability carer income support. An estimated 87.1 per cent of these costs (\$3,250.7m) are borne by the Commonwealth Government, 11.8 per cent (\$413.2m) by state and territory governments and the remaining 1.8 per cent (\$67.7m) by local governments.

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<sup>24</sup> The valuation of loss of life, health and wellbeing in

About one third of the cost to government from 2015 road trauma was estimated to accrue immediately, i.e. within twelve months of the crash. These costs include health system and emergency services costs, as well as initial taxation revenue losses and income support expenditure. The balance, predominantly forgone taxation and additional income support and disability care costs, accrue over a lengthy future period of more than 90 years, by which time the youngest person killed or disabled in a road crash within the twenty year analysis period would otherwise, on actuarial assumptions and absent the road crash, have ceased either paid work or reliance on disability-related income support.

**Figure 28 Cost to government of road trauma occurring in 2015**



Source: ECON 2017

### 7.3 Financial savings to government – reduced road trauma

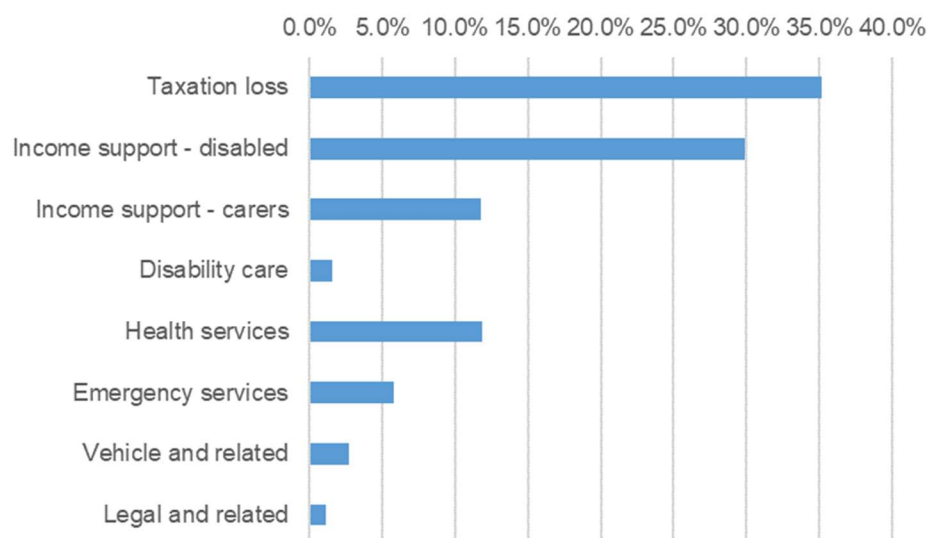
Using data on the estimated number and severity of crashes in 2015 and the number and type of casualties per crash (Table 16) a cost to government per crash of each type was estimated, as shown in Table 28. These costs were applied to the crash reduction estimates for each year under the short take up and long take up scenarios.

**Table 28 Cost to government per crash, 2015 \$m**

Crash type	Cost to government per crash
Fatal	\$342,458
Hospitalised injury	\$90,162
Non-hospitalised injury	\$2,209
Property damage	\$337

Expressed as a present value, discounted at three per cent real, savings to government, across the areas of government outlined in Figure 28, are estimated at \$3,308.3m (short take up) and \$2,822.2m (long take up), both in 2015 prices. Percentage distributions across cost categories, applicable to each scenario, are shown in Figure 29.

**Figure 29 Savings to government from reduced road trauma, by cost category, per cent**



## 7.4 Financial savings to government – reduced light vehicle emissions

Savings to government associated with the health impact benefits of a reduced light vehicle fleet age were not estimated, due to source literature data limitations. While the estimated benefits would include health service savings, disaggregation of those benefits, along lines of the BITRE road trauma study, is not available. Similarly, the age group profile of persons affected is insufficiently delineated to estimate the impacts on taxation revenue losses and income support expenditure associated with the reduction in mortality and morbidity.

The problem of insufficiently detailed delineation of impacts constrains, to an even greater extent, the attempt to estimate the savings to government from reduced future climate damage.

## 8 References

- Abelson, P 2008, *Establishing a Monetary Value for Lives Saved: Issues and Controversies*, Office of Best Practice Regulation, Department of Finance and Deregulation WP 2008-02  
[https://www.dpmc.gov.au/sites/default/files/publications/Working\\_paper\\_2\\_Peter\\_Abelson.pdf](https://www.dpmc.gov.au/sites/default/files/publications/Working_paper_2_Peter_Abelson.pdf)
- ABS 2016, *Motor Vehicle Census, Australia, 31 Jan 2016*, 9309.0  
<http://www.abs.gov.au/ausstats/abs@.nsf/mf/9309.0>
- Australian Senate Community Affairs References Committee 2013, *Impacts on health of air quality in Australia*, Parliament House, Canberra.  
[www.aph.gov.au/.../Senate/.../Affairs/.../airquality/.../senate/.../air\\_quality/.../report.ash...](http://www.aph.gov.au/.../Senate/.../Affairs/.../airquality/.../senate/.../air_quality/.../report.ash...)
- Australian Transport Council 2011, *National Road Safety Strategy 2011-2020*, Canberra, Australia <http://roadsafety.gov.au/nrss/>
- Australian Transport Safety Bureau 2007, *Road crash casualties and rates, Australia, 1925 to 2005* <http://www.cycle-helmets.com/1925-05-casualties.pdf>
- Budd, L, Keall, M and Newstead, S 2015, *Retrospective and Prospective Changes in Secondary Safety of the Australian and New Zealand Vehicle Fleets and the Potential Influence of New Vehicle Safety Technologies*, Report No. 329, May  
[https://www.monash.edu/\\_data/assets/pdf\\_file/0008/633554/VSRG-Prospective-and-Retrospective-Vehicle-Safety-Effects-Report-329.pdf](https://www.monash.edu/_data/assets/pdf_file/0008/633554/VSRG-Prospective-and-Retrospective-Vehicle-Safety-Effects-Report-329.pdf)
- Bureau of Infrastructure, Transport and Regional Economics (BITRE) 2009, *Cost of road crashes in Australia 2006*, Report 118 [https://bitre.gov.au/publications/2010/report\\_118.aspx](https://bitre.gov.au/publications/2010/report_118.aspx)
- BITRE 2014, *New passenger vehicle fuel consumption trends, 1979 to 2013*,  
[https://bitre.gov.au/publications/2014/files/is\\_066.pdf](https://bitre.gov.au/publications/2014/files/is_066.pdf)
- BITRE 2016, *Road trauma Australia 2015 statistical summary*,  
[https://bitre.gov.au/publications/ongoing/files/Road\\_trauma\\_Australia\\_2015.pdf](https://bitre.gov.au/publications/ongoing/files/Road_trauma_Australia_2015.pdf)
- Bureau of Transport and Regional Economics 2005, *Health impacts of transport emissions in Australia: Economic costs*, Working Paper 63,  
[https://bitre.gov.au/publications/2005/files/wp\\_063.pdf](https://bitre.gov.au/publications/2005/files/wp_063.pdf)
- Castalia 2015, *Reduced Vehicle Import Restrictions: Cost Benefit Analysis Final Report*, Report to the Department of Infrastructure and Regional Development, March  
[https://infrastructure.gov.au/vehicles/mv\\_standards\\_act/files/Reduced\\_vehicle\\_import\\_restrictions\\_CBA.pdf](https://infrastructure.gov.au/vehicles/mv_standards_act/files/Reduced_vehicle_import_restrictions_CBA.pdf)
- Climate Change Authority 2014, *Light vehicle emissions standards for Australia*, Research Report, June 2014, CCA Canberra.  
<http://climatechangeauthority.gov.au/files/files/Light%20Vehicle%20Report/Lightvehiclesreport.pdf>
- Department of the Environment (DoE) 2015, *National Greenhouse Accounts Factors*, August  
<http://www.environment.gov.au/system/files/resources/3ef30d52-d447-4911-b85c-1ad53e55dc39/files/national-greenhouse-accounts-factors-august-2015.pdf>

Department of the Environment and Energy 2016, *Australia's Emissions Projections*, December  
<http://www.environment.gov.au/system/files/resources/9437fe27-64f4-4d16-b3f1-4e03c2f7b0d7/files/aust-emissions-projections-2016.pdf>

Department of Infrastructure and Regional Development (DIRD) 2016a, *Improving the efficiency of new light vehicles*, Draft Regulation Impact Statement, December  
[https://infrastructure.gov.au/roads/environment/forum/files/Vehicle\\_Fuel\\_Efficiency\\_RIS.pdf](https://infrastructure.gov.au/roads/environment/forum/files/Vehicle_Fuel_Efficiency_RIS.pdf)

DIRD 2016b, *Vehicle emissions discussion paper*, Commonwealth of Australia.  
[https://infrastructure.gov.au/roads/environment/forum/files/Vehicle\\_Emissions\\_Discussion\\_Paper.pdf](https://infrastructure.gov.au/roads/environment/forum/files/Vehicle_Emissions_Discussion_Paper.pdf)

DIRD 2016c, *Vehicle emissions standards for cleaner air*, Draft Regulation Impact Statement, Ministerial Forum on Vehicle Emissions, December  
[https://infrastructure.gov.au/roads/environment/forum/files/Vehicle\\_Noxious\\_Emissions\\_RIS.pdf](https://infrastructure.gov.au/roads/environment/forum/files/Vehicle_Noxious_Emissions_RIS.pdf)

Department of Prime Minister and Cabinet 2014, *Best Practice Regulation Guidance Note Value of statistical life*, Office of Best Practice Regulation, December  
[https://www.dpmc.gov.au/sites/default/files/publications/Value\\_of\\_Statistical\\_Life\\_guidance\\_note.pdf](https://www.dpmc.gov.au/sites/default/files/publications/Value_of_Statistical_Life_guidance_note.pdf)

Department for Transport 2015, *TAG Unit A3 Environmental Impact Appraisal*, December  
[https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/487684/TAG\\_unit\\_a3\\_envir\\_imp\\_app\\_dec\\_15.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/487684/TAG_unit_a3_envir_imp_app_dec_15.pdf)

Department for Transport 2016, *TAG Data Book*, July  
<https://www.gov.uk/government/publications/webtag-tag-data-book-july-2016>

Economic Connections (ECON) 2017, *Cost of road trauma in Australia 2015*, Report for the Australian Automobile Association

Environmental Protection Agency (USEPA) 2016, *EPA Fact Sheet: Social Cost of Carbon*, December  
[https://www.epa.gov/sites/production/files/2016-12/documents/social\\_cost\\_of\\_carbon\\_fact\\_sheet.pdf](https://www.epa.gov/sites/production/files/2016-12/documents/social_cost_of_carbon_fact_sheet.pdf)

Federal Chamber of Automotive Industries, Segmentation criteria  
<https://www.fcai.com.au/sales/segmentation-criteria> Accessed 7 June 2017

Federal Reserve Bank of St Louis 2017, FRED Economic Data, *Consumer Price Index for All Urban Consumers: All Items*, updated May 12, 2017  
<https://fred.stlouisfed.org/series/CPIAUCSL>

Fildes, B, Keall, M, Bos, N, Lie, A, Page, E, Pastor, C, Pennisi, L, Rizzi, M, Thomas, P and Tingvall, C 2015, "Effectiveness of low speed autonomous emergency braking in real-world rear-end crashes", *Accident Analysis & Prevention* vol 81, pp. 24–29

Grgoratos, T and Martini, G 2014, *Non-exhaust traffic related emissions. Brake and tyre wear PM Literature Review* JRC Science and Policy Reports European Joint Research Centre Institute of Energy and Transport  
<http://publications.jrc.ec.europa.eu/repository/bitstream/JRC89231/jrc89231-online%20final%20version%202.pdf>

Hensher, D, Rose, J, de Dios Ortuzar, J and Rizzi, L 2009, *Estimating the willingness-to-pay and value of risk reduction for car occupants in the road environment*, February, Institute of

Transport and Logistics Studies, University of Sydney

[http://sydney.edu.au/business/\\_data/assets/pdf\\_file/0007/25675/itls\\_wp\\_09\\_03.pdf](http://sydney.edu.au/business/_data/assets/pdf_file/0007/25675/itls_wp_09_03.pdf)

Intergovernmental Panel on Climate Change 2014, *Climate Change 2014 Synthesis Report* edited by Core Writing Team, Pachauri, R and Meyer, L [http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR\\_AR5\\_FINAL\\_full\\_wcover.pdf](http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf)

McIntosh, L 2012, "Changing Attitudes to Vehicle Safety in Australia", Australasian College of Road Safety Conference, August

Newstead, S, Mulvihill, C, Budd, L, Andrea, C, Fridman, M, Nheu, N, Koppel, S 2015, *Research on the Safety Implications of Taxi and Hire Car Age Limits*

Newstead, S, Watson, L and Cameron, M 2016, *Vehicle Safety Ratings Estimated from Police Reported Crash Data: 2016 Update Australian and New Zealand Crashes During 1987-2014*, Report No. 328, Monash University Accident Research Centre, Melbourne  
[https://www.monash.edu/\\_data/assets/pdf\\_file/0004/632533/UCSR-2016-Update-MUARC-Report-328.pdf](https://www.monash.edu/_data/assets/pdf_file/0004/632533/UCSR-2016-Update-MUARC-Report-328.pdf)

NZ Transport Agency 2016, *Economic Evaluation Manual*, January  
<https://www.nzta.govt.nz/resources/economic-evaluation-manual>

OECD/ITF 2016, *Road Safety Annual Report 2016*, OECD Publishing, Paris.  
<http://dx.doi.org/10.1787/irtad-2016-en>

PAE Holmes 2013, *Methodology for Valuing the Health Impacts of Changes in Particle Emissions – Final Report*, NSW Environment Protection Authority, February  
<http://www.epa.nsw.gov.au/resources/air/healthpartemiss.pdf>

Reserve Bank of Australia 2017, Statistical Tables <http://www.rba.gov.au/statistics/tables/>  
Accessed 1 June 2017

Scuffham, P and Langley, J 2002, "A model of traffic crashes in New Zealand", *Accident Analysis & Prevention* vol 34, pp. 673-687

Scully, J and Newstead, S 2008, "Evaluation of electronic stability control effectiveness in Australasia" *Accident Analysis and Prevention*, vol 40, pp. 2050–2057

Shadbegian, R, Gray, W and Morgan C 2005, *Benefits and Costs from Sulfur Dioxide Trading: A Distributional Analysis*, US Environmental Protection Agency, Working Paper #05-09, December 2005 [https://www.epa.gov/sites/production/files/2014-12/documents/benefits\\_and\\_costs\\_from\\_sulfur\\_dioxide.pdf](https://www.epa.gov/sites/production/files/2014-12/documents/benefits_and_costs_from_sulfur_dioxide.pdf)

Truck Industry Council 2013, *The Ageing of the Australian Truck Fleet: Implications and Opportunities*, 30 July <http://www.the-linc.com.au/article/view/509>

Whelan, M, Scully, J & Newstead, S 2009, *Vehicle safety and young drivers Stages 2 and 3: Analysis of young driver crash types and vehicle choice optimisation*, Monash University Accident Research Centre, Report No. 292  
[https://www.monash.edu/\\_data/assets/pdf\\_file/0006/216915/muarc292.pdf](https://www.monash.edu/_data/assets/pdf_file/0006/216915/muarc292.pdf)





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# Appendices

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# Appendix A – Vehicle fleet modelling methodology

This appendix details the vehicle fleet modelling methodology for the business as usual case. The vehicle fleet age adjustment process, used to construct the two scenarios, is outlined in Section 3.4.

The inputs used during this phase of the work included ABS Motor Vehicle Census (Cat 9309.0) 1971 to 2016 data, ABS Sales of New Motor Vehicles (Cat 9314.0) 1994 to 2016 data and selected economic and demographic forecasts for the next 20 years (e.g. gross state product, population and fuel price).

## A.1 Process

The basic process for estimating the growth in the passenger and light commercial vehicle fleet (under 4.5 tons GVM) is described by the following formula, where “t” is the year:

$$\text{Stock}_{t+1} = \text{Stock}_t + \text{NewSales}_t - \text{ScrappedVehicles}_t \quad [1]$$

Forecasts of the vehicle stock were initially made at a state level and the results aggregated to derive national level estimates.

New sales data were obtained from the ABS Sales of New Motor Vehicle (Cat 9314.0) data. A series of auto regressive distributed lag models were developed to estimate new vehicle sales, based on 20-25 years of historic data. The generic model form for each state is given below:

$$\begin{aligned} \ln(\text{SalesPerCapita}_t) = & \beta_0 + \beta_1 \times \ln(\text{GSPPerCapita}_{t-1}) + \beta_2 \times \ln(\text{ULPPrice}_t) \\ & + \beta_3 \times \ln(\text{SalesPerCapita}_{t-1}) + \beta_4 \times (\text{GFCDummy}_t) \end{aligned} \quad [2]$$

Where:

GSP: Gross State Product (Per Capita)

ULP: Unleaded Petrol Price

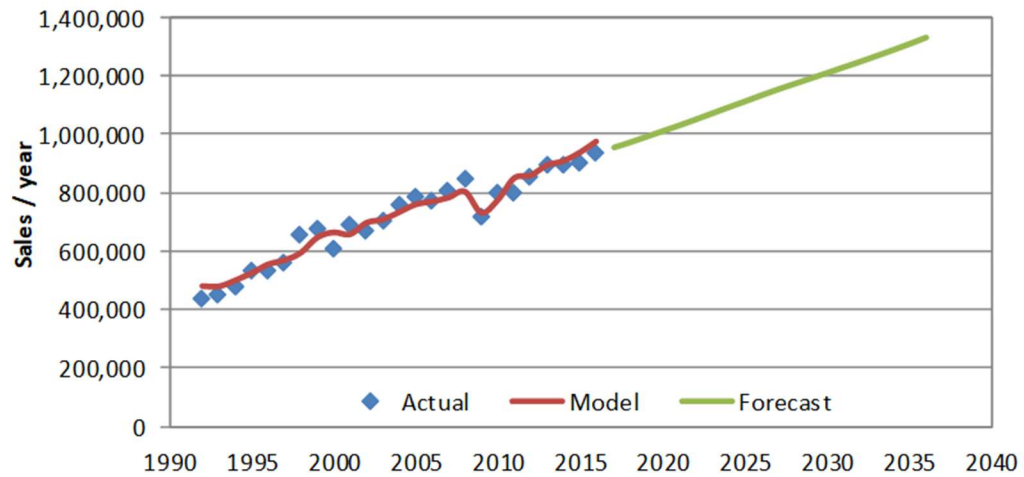
GFC: Global Financial Crisis (dummy variable to account for exogenous shock to the economic system arising from the GFC (=1 for 2009 and 0 otherwise)

Figures A1 and A2 plot the performance of these models for national passenger and light commercial vehicles (LCV) vehicle sales' respectively, against the actual data. The model parameters and performance are summarised in Tables 1 and 2 for passenger and LCV, respectively. The national figures are the aggregation of the state models.

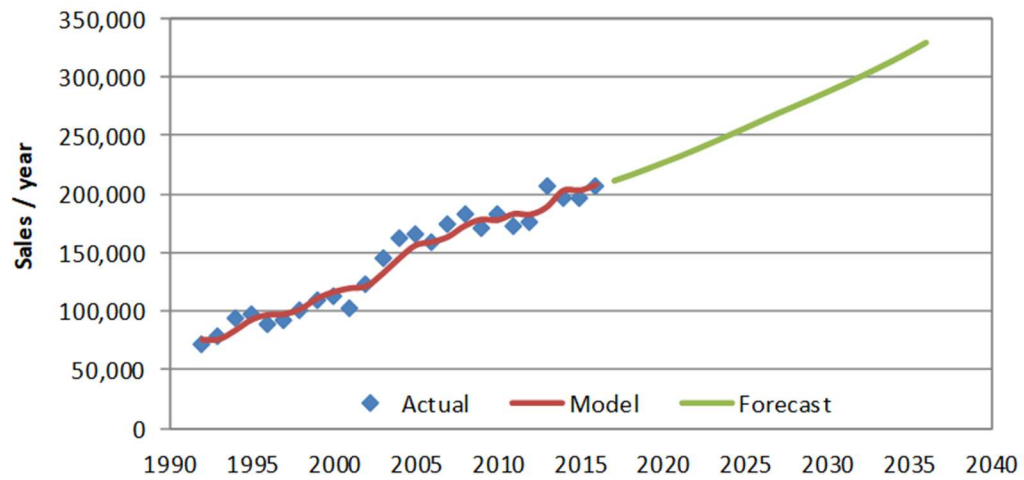
Where no beta value is presented in Tables A1 and A2, that variable is insignificant for that state and hence not used. For SA, passenger vehicle sales appear to be highly responsive to GSP which could be attributable, in part, to that state's lower economic performance with their strong dependence on major players such as mining, GM-H and Arrium Steel.

The LCV modelling results for QLD, WA and NT performed better than the comparable modelling results for passenger vehicles. This could be related to the relatively higher proportion of LCVs in the light vehicle fleets in those states. For example, according to the ABS, the proportions of LCVs in the QLD, WA and NT light vehicle fleets represented around 20 percent, 17 percent and 28 percent, respectively, in 2016 (ABS 2016).

**Figure A1 National passenger vehicle sales**



**Figure A2 National LCV sales**



**Table A1 Passenger vehicle sales functions**

State	n	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	F Statistic	Adjusted R <sup>2</sup>
NSW	25	0.912 2.469	0.806 4.129	-0.300 -2.696	0.230 1.499	-0.150 -3.811	33.8	0.845
VIC	25	-0.130 -0.249	1.275 3.263	-0.429 -2.321	0.206 0.920	-0.155 -2.680	64.8	0.914
QLD	25	0.277 0.799	0.360 2.054		0.519 2.749	-0.143 -2.142	29.5	0.781
SA	25	-0.350 -0.993	0.954 10.532			-0.127 -1.999	55.6	0.820
WA	20	0.420 0.548		0.647 4.092			16.7	0.453
TAS	25	-0.260 -0.535	0.633 2.750		0.353 1.832	-0.121 -2.267	21.3	0.717
NT	25	1.131 2.795			0.667 5.528		30.6	0.552
ACT	25	1.791 2.745			0.510 2.840	-0.091 -1.392	4.48	0.225

Note: (1) Figures in blue below coefficients represent t-statistics.

(2) Blank cells highlight those parameters that were not statistically significant (at the 5% level) for the subject state

**Table A2 LCV sales functions**

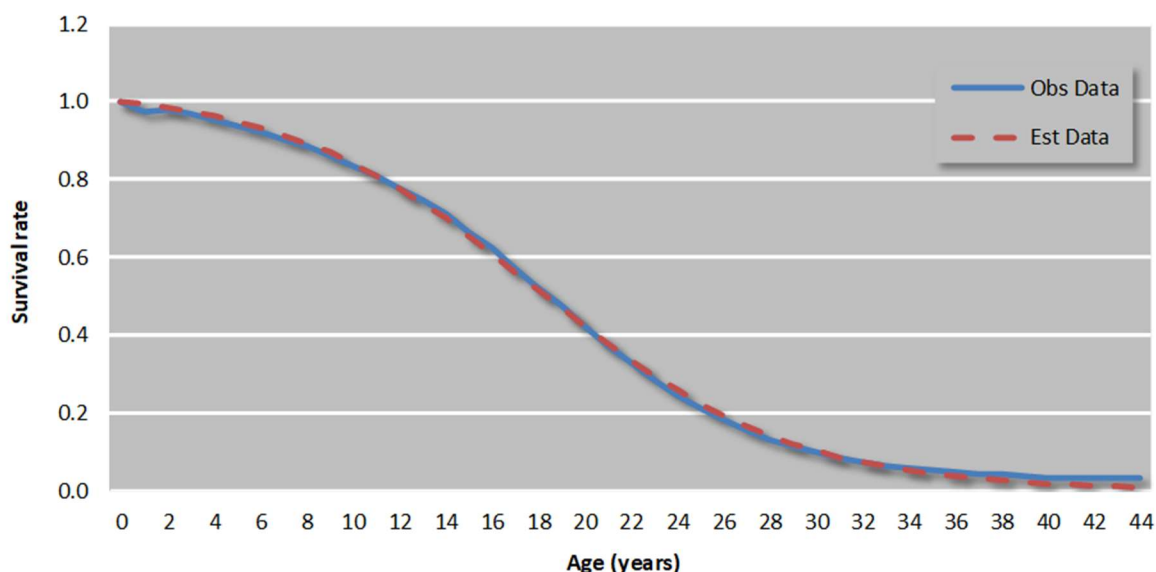
State	n	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	F Statistic	Adjusted R <sup>2</sup>
NSW	25	-3.590 -3.391	1.595 5.530	-0.309 -1.480	0.214 1.272	-0.087 -1.018	31.7	0.837
VIC	25	-2.140 -3.249	1.385 5.871	-2.798	0.306 4.327	-0.039 -0.707	147	0.961
QLD	25	-0.954 -1.308	0.451 1.664		0.625 3.413		74.3	0.859
SA	25	-3.107 -2.310	1.058 2.439		0.405 1.845		120	0.908
WA	25	-1.425 -1.224		0.423 <sup>(1)</sup> 1.539	0.708 6.485		72.4	0.856
TAS	25	-4.441 -6.390	1.672 9.051				81.9	0.771
NT	25	-3.440 -4.323	0.692 4.134	0.589 2.533			38.2	0.756
ACT	25	-4.705 -5.534	1.436 7.359				54.2	0.689

Note: Figures in blue below coefficients represent t-statistics

(1) For WA, ULPPrice<sub>t-1</sub> was used instead, because the non-lagged version of this variable was not significant at the 5% level.

Vehicle scrappage functions (or survival functions) for each vehicle type and state/territory were derived from ABS Motor Vehicle Census data. A typical scrappage function is shown in Figure A3.

**Figure A3 Typical scrappage function**



## A.2 Vehicle kilometres travelled forecasts

### A.2.1 Inputs

The inputs used during this phase of the work included ABS Survey of Motor Vehicle Use 2016 data and selected economic and demographic forecasts (e.g. gross state product, population and fuel price).

### A.2.2 Passenger vehicle VKT

The process for estimating the growth in light vehicle VKT uses a series of distributed lag models developed to estimate annual VKT per vehicle, based on 21 years of historic data. The generic model form for each state is given below:

$$\ln(\text{VKT}_t/\text{Veh}_t) = \beta_0 + \beta_1 \times \ln(\text{GSPPerCapita}_t) + \beta_2 \times \text{PostGFCDDummy}_t \times \ln(\text{ULPPPrice}_{t-1}) \quad [3]$$

Where:

GSP: Gross state product (per capita)

ULPPPrice: Unleaded petrol price

PostGFCDDummy: Global Financial Crisis (dummy variable to account for exogenous shock to the economic system arising from the GFC (=1 for 2009 onwards and 0 otherwise).

The performance of these models aggregated to a national level is plotted in Section 3.3. The model parameters and performance are summarised in Table A3.

**Table A3 Passenger vehicle VKT functions**

State	n	$\beta_0$	$\beta_1$	$\beta_2$	F Statistic	Adjusted R <sup>2</sup>
NSW	21	-5.987 -24.256	-0.615 -7.104	-0.016 -3.910	71.5	0.876
VIC	21	-5.470 -20.060	-0.433 -4.678	-0.031 -5.807	55.4	0.845
QLD	21	-4.649 -27.835	-0.176 3.142	-0.016 -3.996	31.8	0.755
SA	21	-5.327 -16.517	-0.342 -3.220	-0.014 -2.336	21.4	0.671
WA	21	-5.368 -41.054	-0.431 -8.947	-0.007 -1.639	113.2	0.918
TAS	21	-5.407 -26.578	-0.344 -5.351	-0.012 -3.518	44.9	0.815
NT	21	-3.524 -11.868	0.172 1.547	-0.030 -3.902	8.6	0.433
ACT	21	-6.112 -19.326	-0.750 -6.101	-0.019 -3.237	65.45	0.866

Note: Figures in blue below coefficients represent t-statistics

### A.2.3 LCV VKT

The total VKT is derived from the following equation:

$$VKT_t = (\text{Tonnes}_t \times \text{AverageLadenTripLength}_t) / (\text{AverageLoad}_t \times \text{ProportionLadenVKT}_t) \quad [4]$$

The derivation of these variables is described below:

1. *Tonnes*: The process for estimating the growth in LCV VKT starts with a series of econometric models to estimate tonnes carried by LCV, based on 18-23 years of historic data.

$$\ln(\text{Tonnes}_t) = \beta_0 + \beta_1 \times \ln(\text{PrvCons}_t) + \beta_2 \times \text{PostGFCDDummy}_t \times \ln(\text{PrvCons}_t) \quad [5]$$

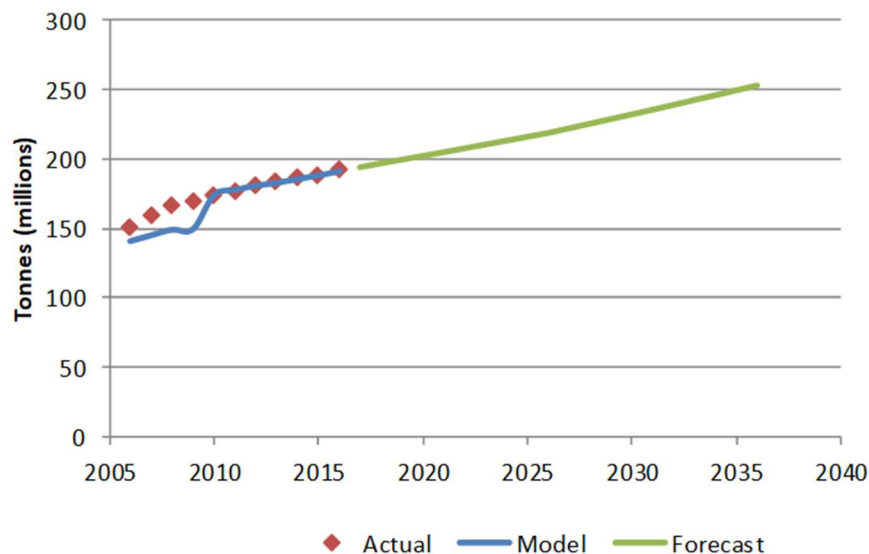
Where:

PrvCons: Private Consumption

PostGFCDDummy: Global Financial Crisis (dummy variable to account for exogenous shock to the economic system arising from the GFC, (=1 for 2009 onwards and 0 otherwise)

Figure 5 plots the model performance at the national level and the model parameters and performance are summarised in Table A4.

**Figure A4 National LCV tonnes**



**Table A4 LCV tonnes functions**

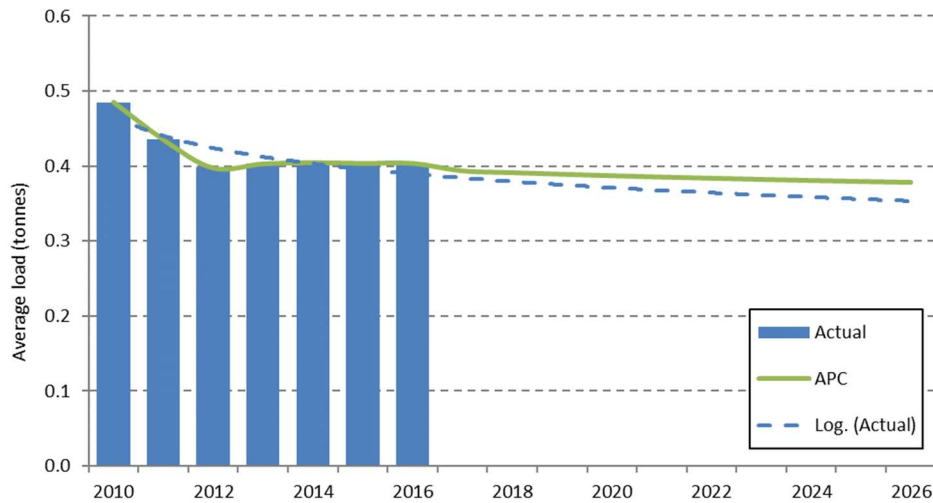
State	n	$\beta_0$	$\beta_1$	$\beta_2$	F Statistic	Adjusted R <sup>2</sup>
NSW	23	-4.008 -3.269	0.617 6.149	0.007 1.544	50.7	0.819
VIC	23	-1.607 -0.844	0.425 2.652	0.012 1.462	13.2	0.527
QLD	23	-3.453 -3.374	0.587 6.618	0.017 2.884	66.9	0.857
SA	23	-1.054 -1.175	0.310 3.681	0.027 6.868	84.3	0.883
WA	23	-6.089 -5.377	0.806 7.777	0.009 1.343	79.1	0.877
TAS	23	-4.443 -2.573	0.590 3.222	0.001 0.087	9.7	0.443
NT	18	-9.980 -4.530	1.169 0.912	0.001 0.119	32.9	0.815
ACT	23	-8.018 -8.406	8.859	0.002 0.356	70.6	0.864

Note: Figures in blue below coefficients represent t-statistics

2. **Average Load:** The change in the average load LCV for each state and territory was estimated, by fitting a logarithmic trend to the last few years of observed data. An example of this is shown in Figure A6 which plots this trend for LCV operating in NSW.

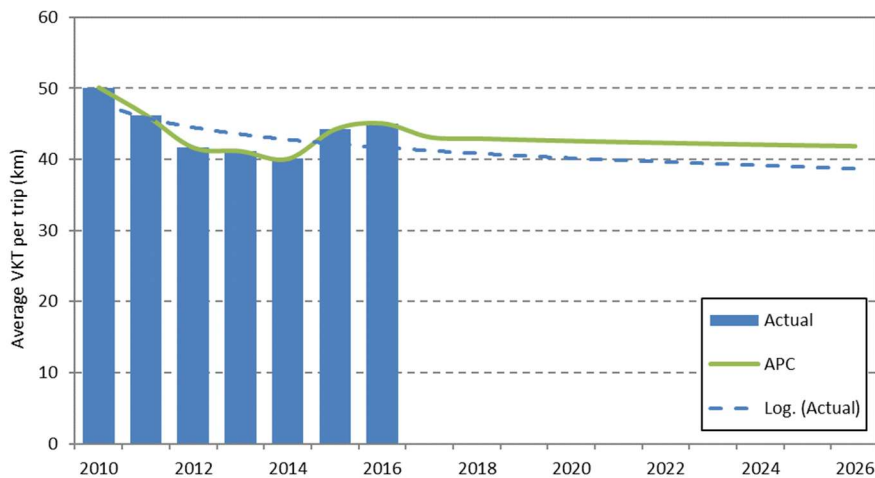


**Figure A5 Average load New South Wales LCV**



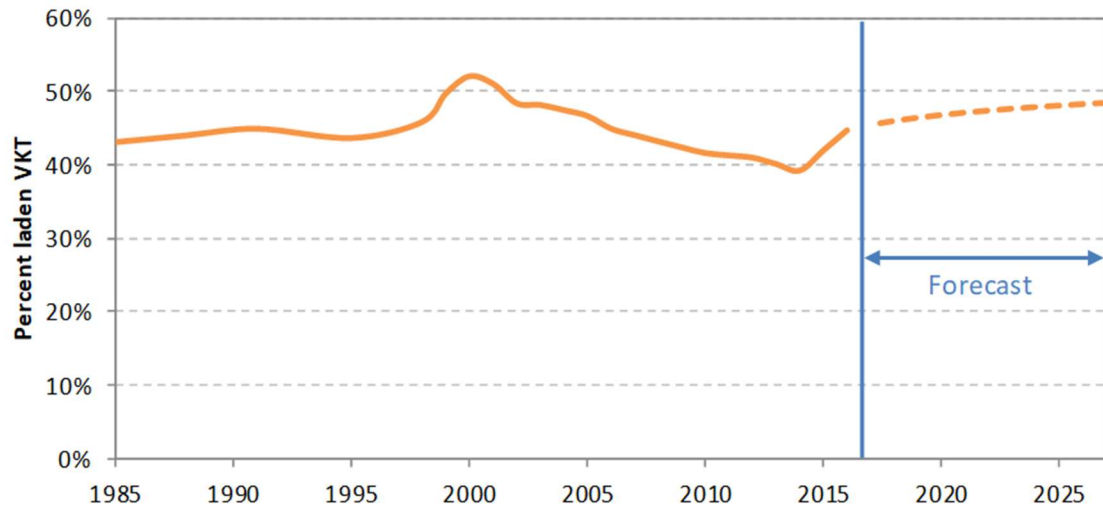
3. *Average laden trip length*: The change in the average laden trip length (in kilometres) for LCVs for each state/territory was estimated, by fitting a logarithmic trend to the last few years of observed data. Figure A7 plots this trend for LCVs operating in NSW.

**Figure A6 Average laden VKT, New South Wales LCV**



4. *Proportion of laden VKT*: The change in the proportion laden VKT LCV for each state/territory, was estimated by fitting a logarithmic trend to the last few years of observed data. Figure A8 plots this trend for LCVs operating in NSW.

**Figure A7 Proportion of laden VKT, New South Wales**



## Appendix B – Road safety impacts by passenger car market sub-group

This appendix outlines analysis undertaken of road safety impacts of the passenger vehicle fleet age reduction scenarios by passenger car market sub-group: i.e. light and small vehicles, medium, large and people mover vehicles and sport utility vehicles (SUV). Definition of these passenger vehicle sub groups followed broadly those defined by the Federal Chamber of Automotive Industries in classifying vehicle sales by market group (FCAI 2017).

Due to data gaps, it was not possible to fully apply the three-step road safety impact event chain modelling framework (Section 4.2) which underpins the primary passenger car and LCV analysis. In view of the compromises required to compensate for the data gaps, the results obtained are provided primarily for completeness of reporting and cannot be considered reliable.

### B.1 Application of the event chain modelling framework

As set out in Section 4.2, estimation of road safety impacts involves estimation of:

- Travel exposure, based on the number of registered vehicles of a particular type and average distance travelled per vehicle
- The risk of a road crash, based on estimates of the number of crashes of each vehicle type and exposure
- The rate of injuries per road crash, based on reported crash data.

In analysing the road trauma impacts of reducing the age of the vehicle fleet in each specific passenger vehicle sub-category, projections of the number of vehicles by year of manufacture in future years within these sub categories were not available. Consequently, specific estimates of both travel exposure and relative crash risk within the passenger vehicle sub-groups could not be calculated.

In order to generate estimates of road trauma savings in these circumstances, a number of assumptions were made. Since estimates of crash involvement were available by passenger sub-group, it was assumed that the total number of registered vehicles was comprised of the sub-groups in the same proportions as represented in the crash data. This resulted in relative crash risk estimates by age of vehicle that were assumed to be the same for each passenger sub-group.

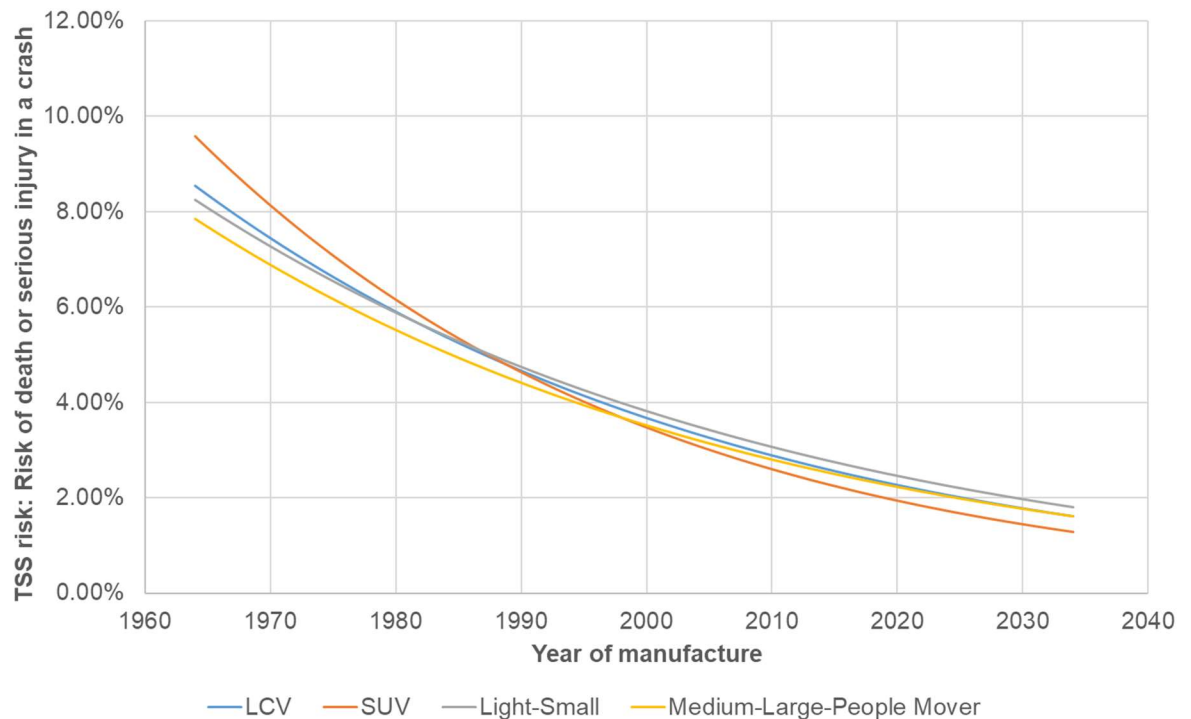
While an unavoidable assumption in the circumstances, this is implausible given the known differences in crash risk between passenger vehicles and LCVs. These differences are associated with contrasting vehicle sizes and weights and purposes of use over the vehicle lifetime, as are also characteristic of the passenger vehicle market sub-groups. To illustrate, Figure 14 (Section 4.3.1) details the difference in relative adjusted risk of road crash involvement by vehicle age for passenger vehicles and LCVs. Crash risk patterns between the two groups are very different, reflecting different purpose of use for the vehicles and ownership characteristics over time as is also likely to be the case between passenger vehicle sub groups.

With regard to the third element in the model, risk of injury, estimates of the Total Secondary Safety Index (Section 4.3.4) were available for each passenger sub-group considered and so were used directly in the analysis, including sub-group specific projections of the index for future

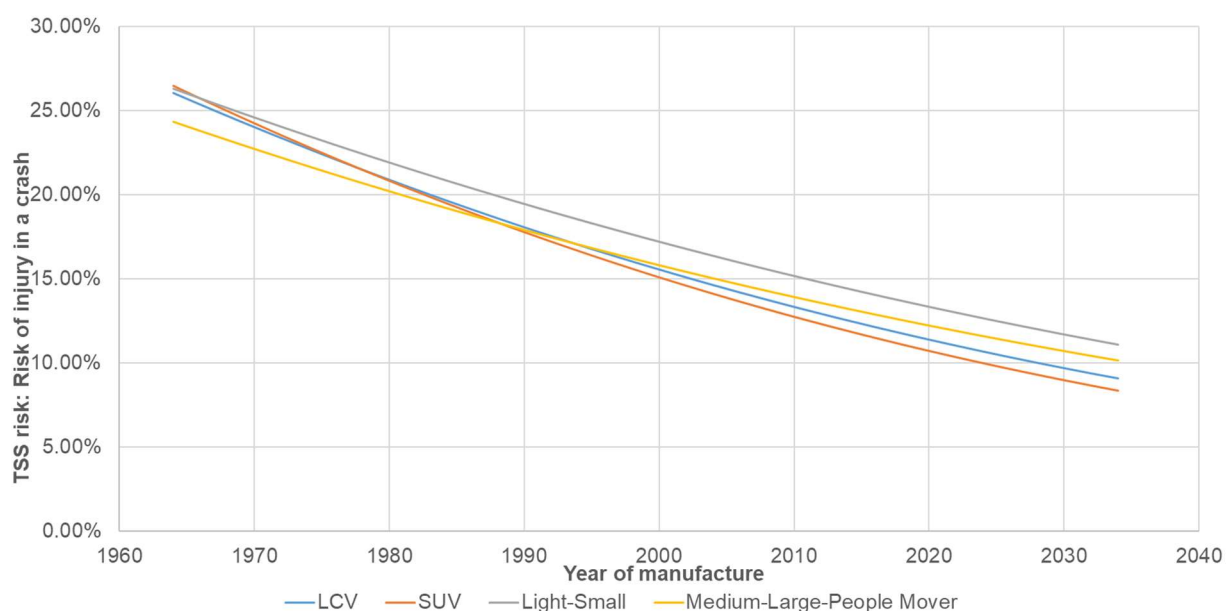
vehicle years of manufacture. Primary safety technology fitment rates were also available for SUVs as distinct from other passenger vehicles and so were used.

For 2015, as shown in Figure B1, risk of death or hospitalised injury, given involvement in a crash, is estimated in a range from 2.24 per cent (SUV) to 2.74 per cent (light-small passenger vehicles). LCV risk by comparison was 2.55 per cent. Risk of injury of any severity ranged from 18.74 per cent for SUVs to 19.04 per cent for light-small vehicles (20.45 per cent LCVs).

**Figure B1 Estimated total vehicle secondary safety by year of manufacture and market sub-group – risk of death or hospitalised injury**



**Figure B2 Estimated total vehicle secondary safety by year of manufacture and market sub-group – risk of injury of any severity**



## B.2 Market group analysis results

The results obtained from the analysis are shown in tables B1, B2 and B3. Percentage reductions in road crashes are almost identical across the market sub-groups, which is not considered plausible

**Table B1 Reduction in road crashes in the light and small sub-group, both scenarios**

Road crash type	Business as usual 20 year total road crashes	Short take up	% reduction	Long take up	% reduction
Fatal	6,553	-489	-7.5%	-428	-6.5%
Hospitalised injury	188,287	-14,043	-7.5%	-12,289	-6.5%
Non-hospitalised injury	1,252,528	-82,999	-6.6%	-73,347	-5.9%
Property damage	3,574,358	-190,626	-5.3%	-170,900	-4.8%
TOTAL	5,021,726	-288,156	-5.7%	-256,964	-5.1%

**Table B2 Reduction in road crashes in the medium-large-people mover sub-group, both scenarios**

Road crash type	Business as usual 20 year total road crashes	Short take up	% reduction	Long take up	% reduction
Fatal	5,877	-442	-7.5%	-387	-6.6%
Hospitalised injury	168,861	-12,710	-7.5%	-11,114	-6.6%
Non-hospitalised injury	1,132,884	-75,062	-6.6%	-66,334	-5.9%
Property damage	3,233,977	-172,391	-5.3%	-154,561	-4.8%
TOTAL	4,541,598	-260,605	-5.7%	-232,396	-5.1%

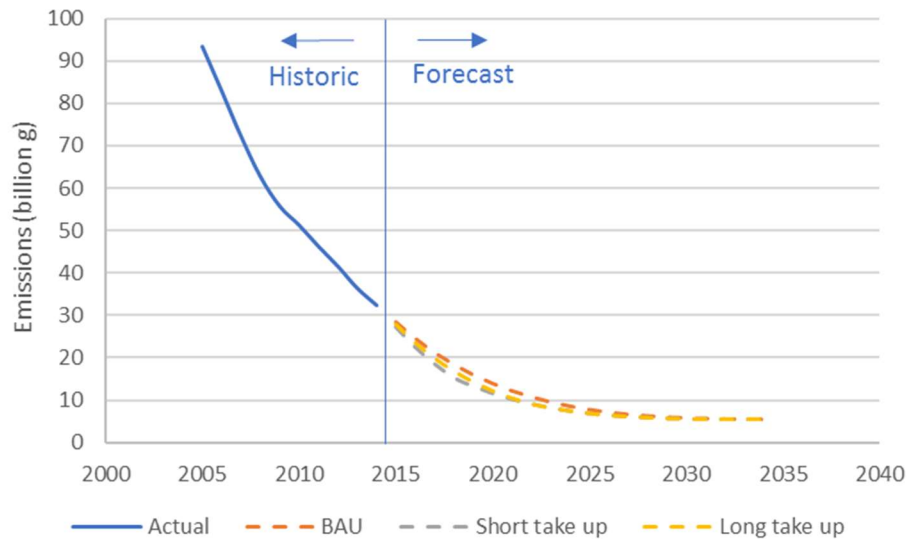
**Table B3 Reduction in road crashes in the SUV, both scenarios**

Road crash type	Business as usual 20 year total road crashes	Short take up	% reduction	Long take up	% reduction
Fatal	2,548	-204	-8.0%	-178	-7.0%
Hospitalised injury	73,223	-5,869	-8.0%	-5,103	-7.0%
Non-hospitalised injury	501,491	-34,785	-6.9%	-30,642	-6.1%
Property damage	1,511,196	-78,981	-5.2%	-70,945	-4.7%
TOTAL	2,088,459	-119,840	-5.7%	-106,867	-5.1%

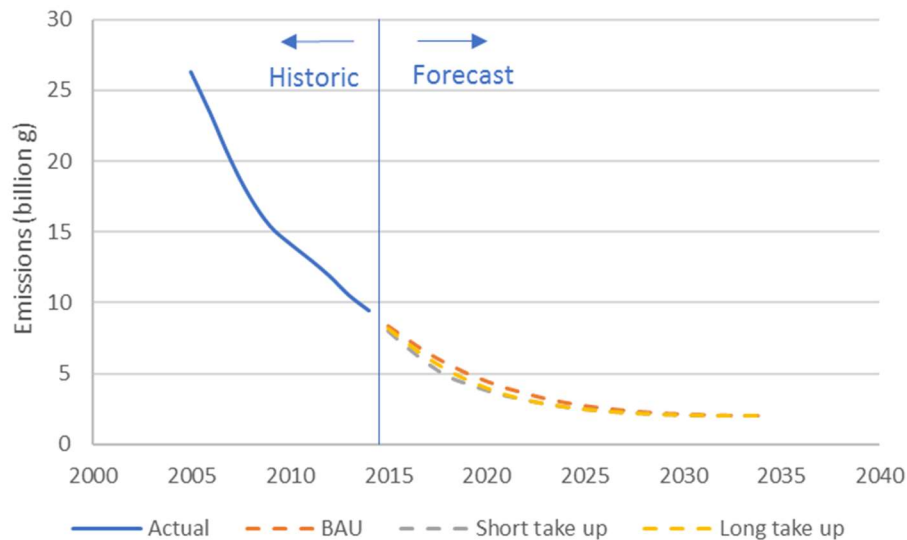
## Appendix C – Emissions trends and projections

This appendix details emissions projections, in the context of past trends, for the business as usual case and each of the two scenarios, for passenger vehicles and LCVs.

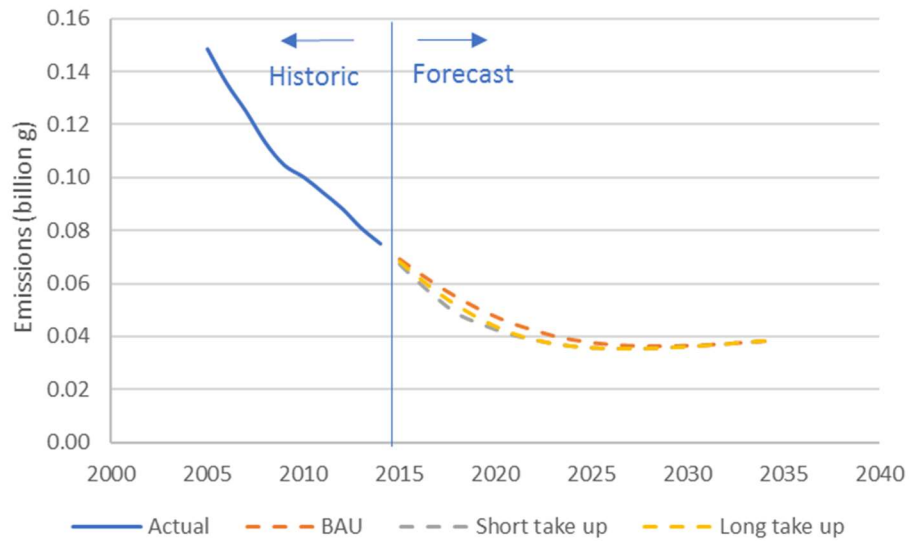
**Figure C1 Passenger vehicle CO emissions forecasts**



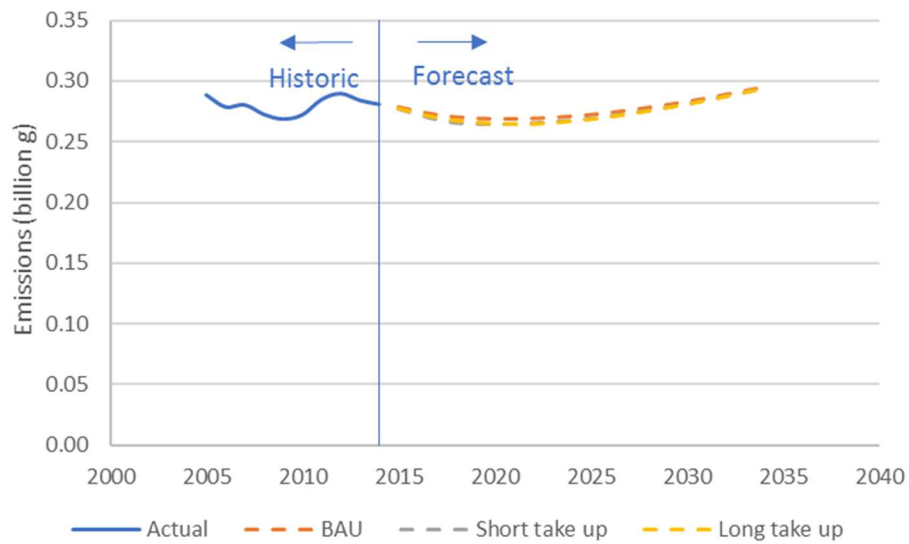
**Figure C2 Passenger vehicle NOx emissions forecasts**



**Figure C3 Passenger vehicle N<sub>2</sub>O emissions forecasts**

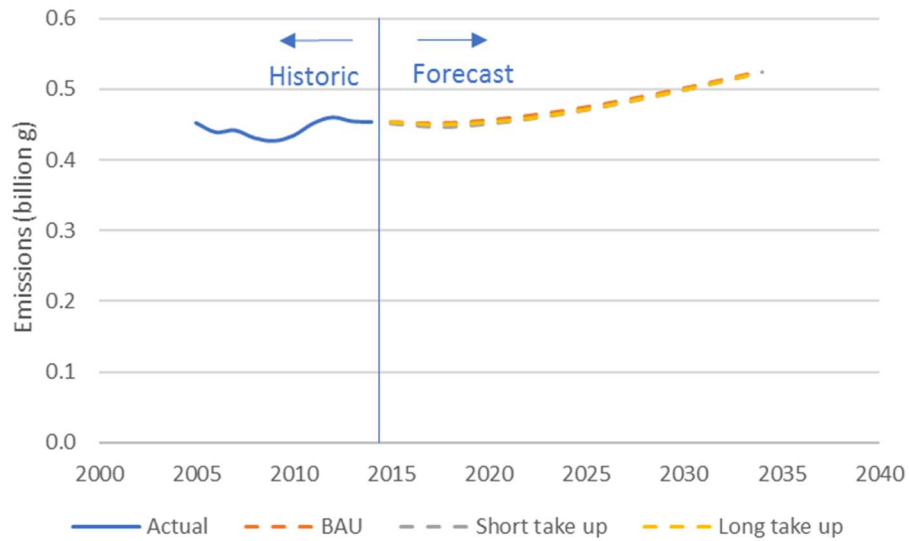


**Figure C4 Passenger vehicle PM<sub>2.5</sub> emissions forecasts**

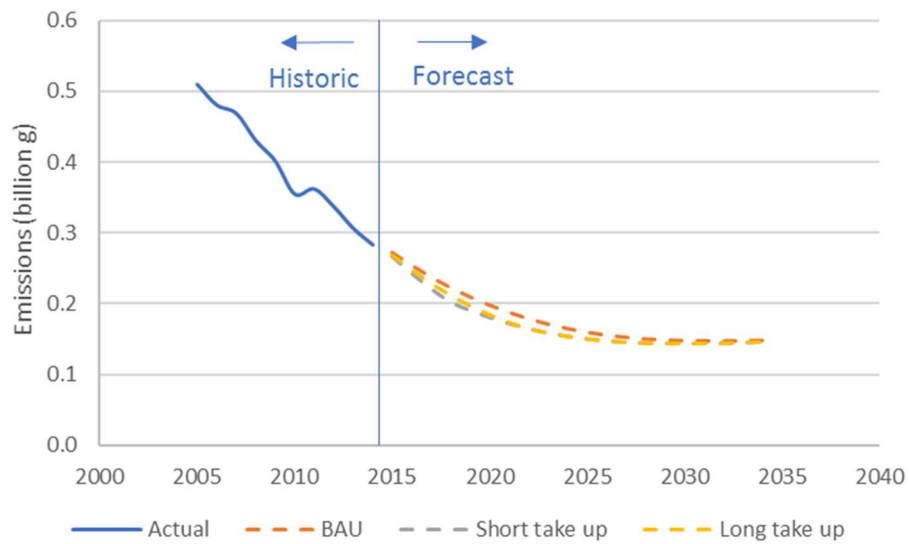




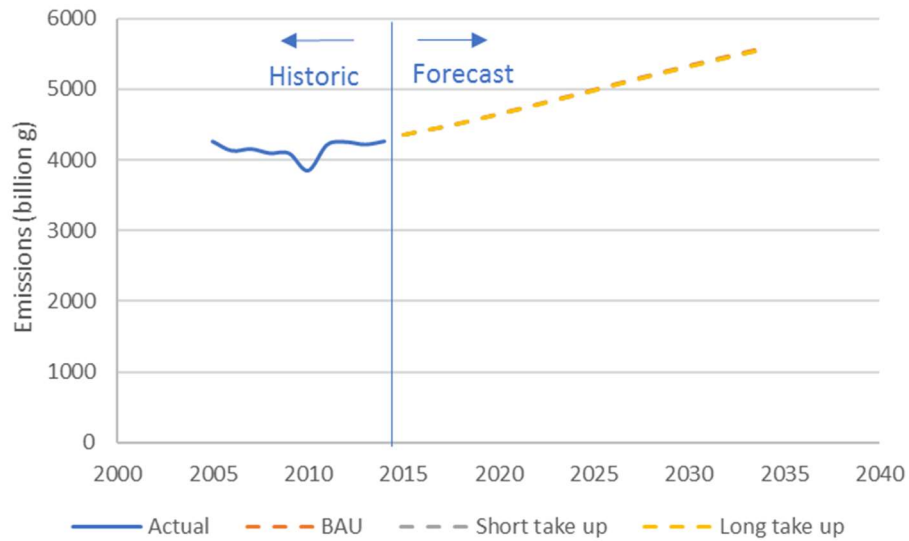
**Figure C5 Passenger vehicle PM<sub>10</sub> emissions forecasts**



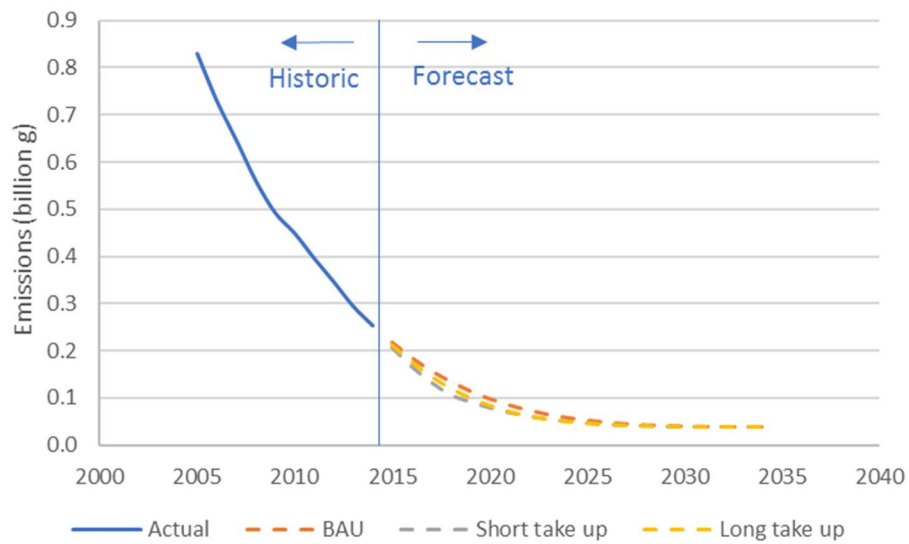
**Figure C6 Passenger vehicle SO<sub>2</sub> emissions forecasts**



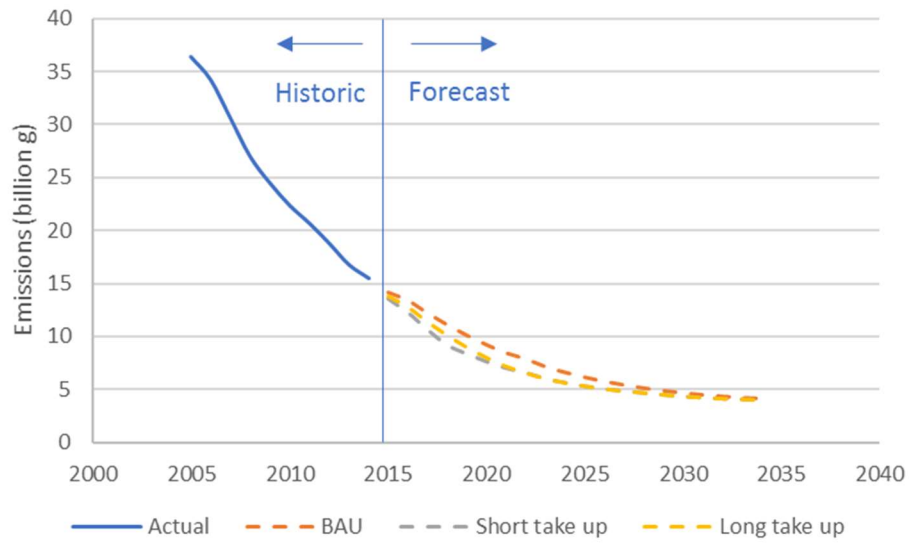
**Figure C7 Passenger vehicle CO<sub>2</sub> emissions forecasts**



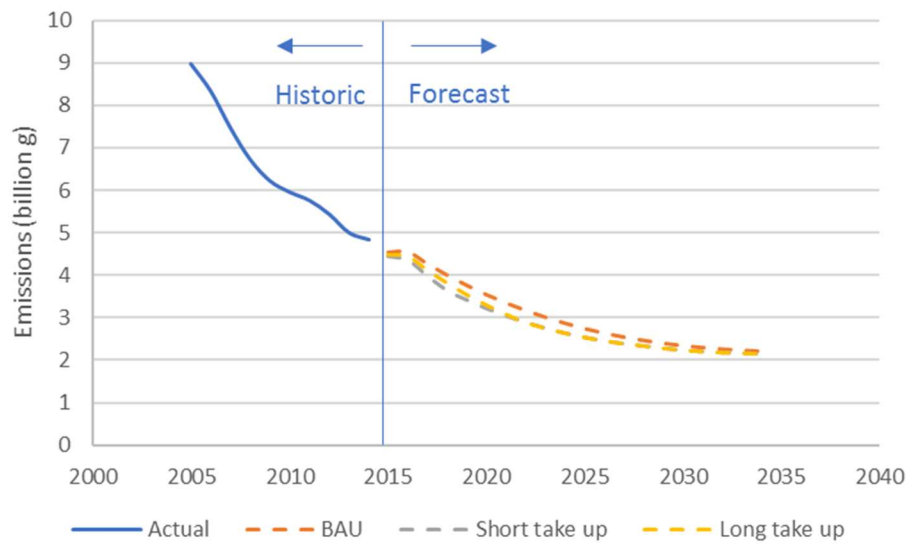
**Figure C8 Passenger vehicle CH<sub>4</sub> emissions forecasts**



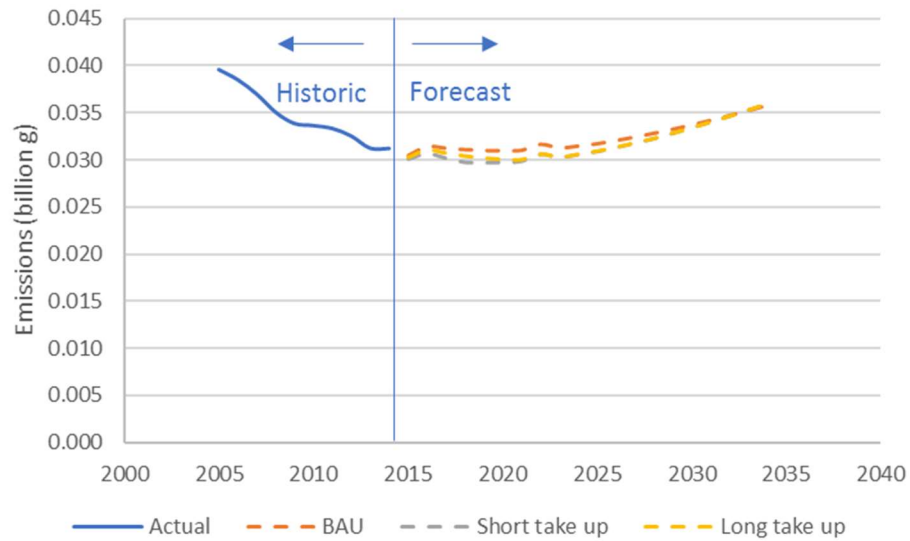
**Figure C9 LCV CO emissions forecasts**



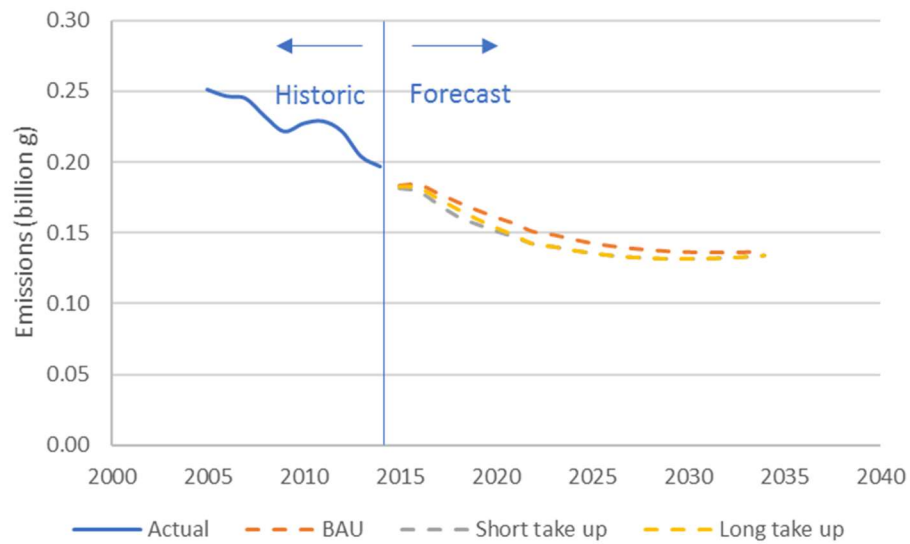
**Figure C10 LCV NOx emissions forecasts**



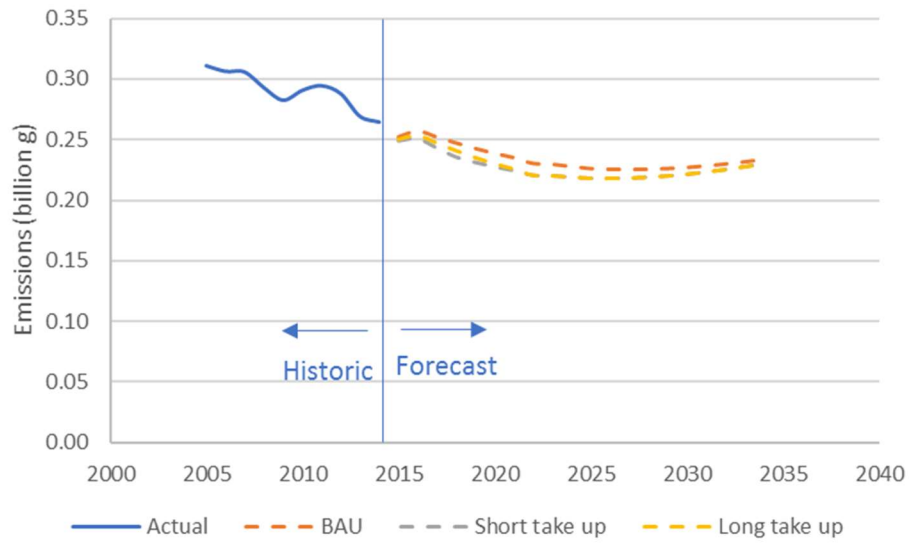
**Figure C11 LCV N<sub>2</sub>O emissions forecasts**



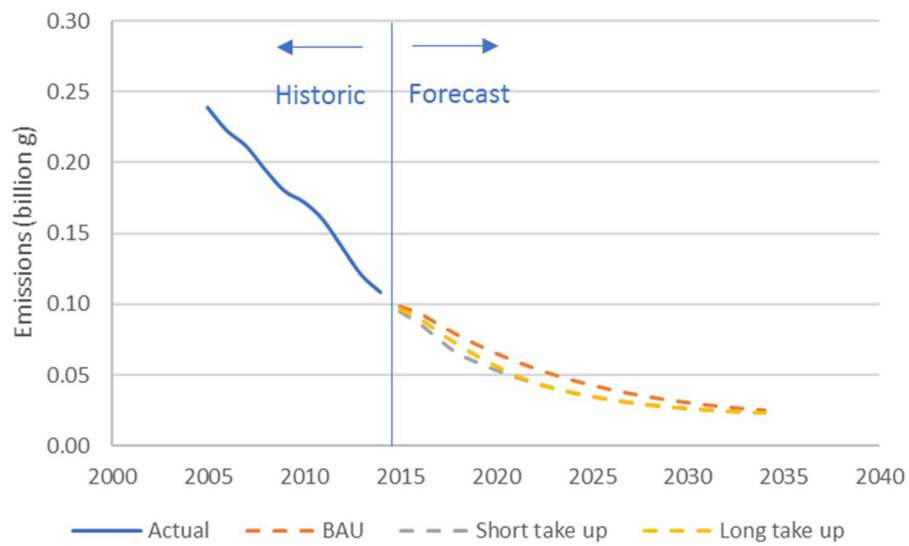
**Figure C12 LCV PM<sub>2.5</sub> emissions forecasts**



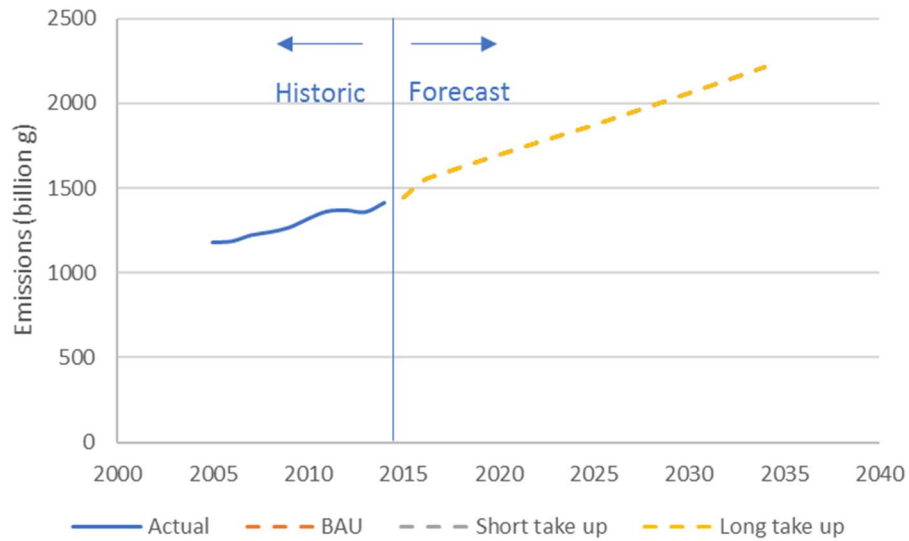
**Figure C13 LCV  $PM_{10}$  emissions forecasts**



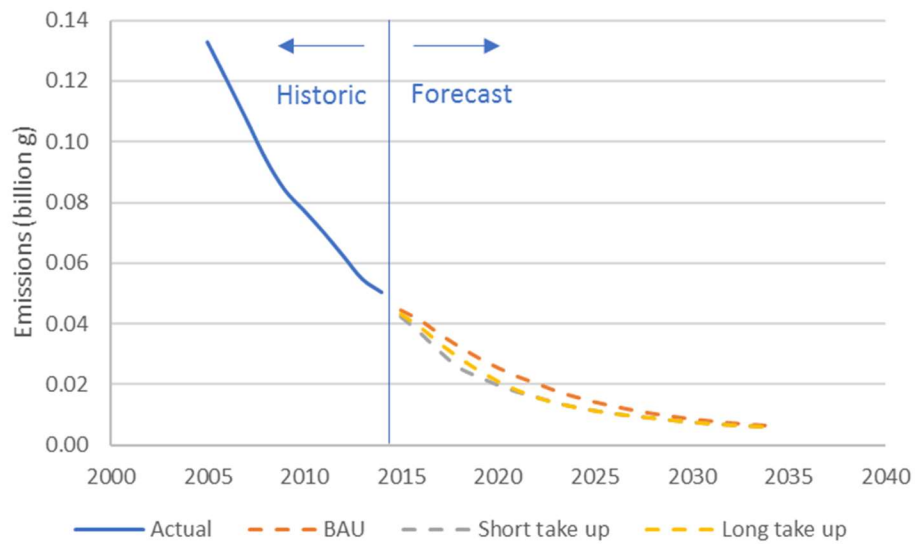
**Figure C14 LCV  $SO_2$  emissions forecasts**



**Figure C15 LCV CO<sub>2</sub> emissions forecasts**



**Figure C16 LCV CH<sub>4</sub> emissions forecasts**



## Appendix D – Estimating the social cost of carbon

United States Environmental Protection Agency values of the social cost of carbon (USEPA 2016) underpin the estimate of an Australian social cost of carbon for the purposes of this study, i.e. covering a 20 year forward period and aligning with the study discount rate of three per cent.<sup>25</sup>

The estimation approach involves: calculation of a single annualised value that is exactly equivalent to the USEPA projected future price path; indexing the USEPA 2007 annualised price to 2015 US prices; and conversion to Australian dollars (at a rate of \$US0.75), also in 2015 prices. The choice of exchange rate took account of both recent year trends and forecasts.

**Table D1 Estimation of an Australian social cost of carbon (20 year forward period)**

Year	USEPA Social cost of carbon, 3% discount rate, 2007 \$US prices	
	Price path, 5 year intervals	Annualised value
2015	36.00	44.28
2020	42.00	44.28
2025	46.00	44.28
2030	50.00	44.28
2034 (1)	54.00	44.28
2015 prices, \$US		50.72
2015 prices, \$A (2)		67.62

(1) The source document shows five year intervals: \$US54.00 is an interpolated value.

(2) Exchange rate \$A1 = \$US0.75.

Source: Federal Reserve Bank of St Louis 2017 (price inflation data), RBA 2017 (exchange rate data), USEPA 2016 and ECON analysis

<sup>25</sup> USEPA values for the social cost of carbon are also shown at discount rates of 2.5 per cent and five per cent. In contrast, United Kingdom transport project appraisal values, with central values increasing from 58 pounds in 2015 to 100 pounds in 2034, do not specifically indicate a discount rate (Department for Transport 2015). However, the UK Government's recommended discount rate is 3.5 per cent (Department for Transport 2016). Similarly, New Zealand transport project appraisal values (\$NZ40 in 2004 prices) do not indicate a preferred discount rate (NZTA 2016, p. 5-375), while discount rate values of six per cent (base case) and four and eight per cent (sensitivity values) are indicated (p. 5-139ff). No official appraisal values for the social cost of carbon are available for Australia.





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