TRANSPORT AND INFRASTRUCTURE COUNCIL

Australian Transport Assessment and Planning Guidelines

PV2 Road Parameter Values

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- Vehicle operating cost unit prices are provided for fuel, oil, tyres, repairs & maintenance, depreciation (through new vehicle prices).
- Travel time values are provided for vehicle occupants (passenger and freight) and value of travel time for freight.
- Crash costs: average crash costs by injury severity across jurisdictions are provided.
- Vehicle operating cost models are provided for uninterrupted flow (rural) and interrupted flow (urban) models, in terms of vehicle operating costs and fuel consumption, with applicable coefficients and using an appropriate vehicle classification and with the relationships based on the adaptation and calibration to Australasian conditions of transferrable mechanistic-empirical models.
- Vehicle classifications appropriate to Australia have been reviewed and a 20 vehicle classification has been selected for both unit values and VOC modelling throughout the document. The classification's relationship with the Austroads 12 vehicle classification is explained.
- Guidance is provided for practitioners on the indexation of parameter values until these parameter values are revised.

1.1 Overview

This part of the ATAP Guidelines deals with the updating of parameter (unit) values for use by economic evaluation practitioners in Australia jurisdictions as at June 2013, as well as models to estimate vehicle operating costs (VOC) and, in turn, the calculation of road user costs (RUC) for the purposes of cost-benefit analysis (CBA).

The various methods used to estimate VOC and RUC are reviewed, including their technical bases as reported through various Austroads studies, recognising the need to provide models that possess the following attributes and that can be applied and updated in a clear and consistent manner to:

- Better accommodate changes in vehicle technology and a changing vehicle fleet, including under different loading conditions and regulations
- Be amenable for application across networks subject to uninterrupted and interrupted/stop-start conditions
- Be capable of application to general cost-benefit analysis studies at a network level and for major capital projects, including employing the results of traditional 4–5 stage transport models.

By addressing such issues and using a sufficiently well-defined vehicle fleet classification, and through regular updating of the unit values and models, this update should improve consistency in CBA and other related applications.

Updated parameter values are provided for the following vehicle road user effects (RUE) components:

- Direct road user effects (RUE) components - fuel, oil, tyres, repairs and maintenance, depreciation (through new vehicle prices)
- Travel time – vehicle occupants (passenger and freight) and freight per vehicle type
- Crash costs – average cost of crashes by injury severity across jurisdiction, based on human capital and willingness to pay approaches
- Vehicle operating cost (VOC) models – a review is provided of the state of rural (free/uninterrupted flow speeds) and urban (interrupted flow speeds) VOC models in Australia and updated values for VOC ($/km) and fuel consumption (litres/km). Appropriate models are also specified for uninterrupted and interrupted flow, together with coefficients
- Vehicle classifications appropriate to Australia – an overview is provided of developments in vehicle classifications in Australia, including a 20 vehicle classification used for application of parameter values. This was undertaken as it is broadly consistent with the vehicle classification in Austroads (2005a) and provides a sufficiently broad range of vehicle types from which practitioners can select the vehicles most appropriate to their local vehicle fleets. The vehicle classifications used in Australia, including the Austroads 12 bin classification outlined in Austroads (2013), are presented in Appendix C
- Updating of parameter values - guidance is provided to practitioners on the indexation of parameter values per RUE component until a new set of parameter values is released.

2. Vehicle operating cost (VOC) components

This chapter contains the unit values for the following vehicle operating cost (VOC) components:

- Fuel
- Oil
- Tyres
- Repairs and maintenance
- New vehicles (for estimation of depreciation).

2.1 Fuel prices

Fuel price data were obtained from FuelTrac for urban centres (capital cities and towns) across jurisdictions in Australia for the following fuel types:

- Petrol – unleaded petrol (ULP) and premium (PULP)
- Diesel
- LPG and
- Ethanol fuels.

Retail prices were adjusted in terms of taxes (GST and fuel excise) and applicable subsidies and rebates / tax credits to reflect resource prices for these components. Detailed retail and resource price data across all areas for all fuel types are contained in Appendix A. Retail and resource price data for capital cities are contained in Table 1 while weighted average resource prices for petrol (ULP and PULP) and diesel are presented in Table 2.

2.1.1 Fuel excise

From March 2001 to June 2014, the fuel excise was fixed at 38.143 cents per litre. Changes to fuel excise proposed in the Federal budget for 2014–15, involved a reintroduction of indexation of the fuel excise on a twice-yearly basis. If accepted and eventually introduced, this would be included in future parameter values updates for the ATAP Guidelines.

2.1.2 Fuel tax credits

Changes to fuel tax credit schemes were initiated from 1 July 2013. The fuel tax credit applicable from that date to heavy vehicles with a gross vehicle mass (GVM) greater than 4.5 tonnes travelling on public roads is 12.003 cents per litre for liquid fuels, especially diesel (Australian Taxation Office, 2013). Vehicles used for off road purposes in the agriculture, forestry and fishing sectors are eligible for a fuel tax credit of 38.143 cents per litre (equivalent to the fuel excise). These fuel tax credits are not reflected in the price data in Table 1 as they came into effect from 1 July 2013 and, furthermore, were not applicable to all diesel sold.

2.1.3 Road user charge

The road user charge applicable to fuel used in heavy vehicles from 1 July 2013 (Australian Taxation Office, 2013) was set at 26.14 cents per litre, with the fuel tax credit set at 12.003 cents per litre. This can be incorporated into future parameter values updates for the ATAP Guidelines.

2.1.4 Fuel subsidy schemes

Fuel subsidy schemes were withdrawn from Queensland (8.354 cents per litre) from June 2009, Northern Territory (1.1 cents per litre) from May 2009 and South Australia (3.3 cents per litre) from September 2010. These changes are reflected in the calculation of resource prices in Table 1 and Table 38 in Appendix A.

2.1.5 Fuel price estimates for capital cities

Retail and resource price estimates for all applicable fuel types for each capital city as at 30 June 2013 are set out in Table 1. The resource prices for each fuel type reflect GST and fuel excise (38.143 cents per litre for all fuel types except LPG and 12.5 cents per litre for LPG).

Table 1 Capital city fuel prices – retail and resource prices as at 30 June 2013 (cents per litre)

Capital city	ULP		PULP		Diesel		LPG		Ethanol	
	Retail price(1)	Resource price	Retail price(1)	Resource price	Retail price(1)	Resource price	Retail price(1)	Resource price	Retail price(1)	Resource price
Sydney	145.6	94.2	157.5	105.0	147.6	96.0	64.7	46.3	143.4	117.9
Melbourne	144.8	93.5	156.2	103.9	144.6	93.3	57.9	40.1	138.9	113.8
Brisbane	149.4	97.7	161.8	109.0	148.5	96.9	64.7	46.3	147.6	121.7
Adelaide	144.9	93.6	156.6	104.2	147.8	96.2	68.0	49.3	na	na
Perth	147.0	95.5	159.6	107.0	147.7	96.1	69.3	50.5	na	na
Hobart	151.3	99.4	165.9	112.7	152.5	100.5	88.9	68.3	na	na
Darwin	160.9	108.1	170.5	116.9	161.5	108.7	105.9	83.8	na	na
Canberra	146.4	95.0	159.2	106.6	147.3	95.8	78.7	59.0	144.5	118.9

1 Fueltrac (retail price data generated as at 30 June 2013)

2 Resource prices calculated by ARRB Group Ltd

Source: Fueltrac (data generated as at 30 June 2013)

The prices in Table 1 were then weighted in terms of sales volumes data (especially the case for petrol) to provide weighted average fuel prices per capital city contained in Table 2.

Table 2 Weighted average fuel price by capital city – resource prices at 30 June 2013 (cents per litre)

Capital city	Fuel type (cents/litre)			
	Petrol (weighted average by volume)	Diesel	LPG	Ethanol
Sydney	96.5	96.0	46.3	117.9
Melbourne	94.5	93.3	40.1	113.8
Brisbane	99.4	96.9	46.3	121.7
Adelaide	94.5	96.2	49.3	na
Perth	97.0	96.1	50.5	na
Hobart	101.4	100.5	68.3	na
Darwin	109.5	108.7	83.8	na
Average (Weighted)	96.7	95.7	45.5	118.3

Source: Fueltrac (data generated as at 30 June 2013)

Fuel prices across all jurisdictions and local areas are presented in Table 38 in Appendix A.

2.1.6 Emission conversion factors

The most recent emission conversion factors for all fuel types are provided in Appendix B for appropriate vehicle types and age classifications. The emissions factors have been calculated by BITRE, based on averaging results of various models such as BITRE MVEm (which includes calibrations using NISE1 and NISE2 data, such as reported by FORS and Orbital Australia) and COPERT for Australia (http://www.emisia.com/content/copert-australia). They have been compared with summary results reported in NGGIC 2006 and the National Inventory Report 2012 (Department of the Environment, 2014).

2.2 Oil

A survey was undertaken of retail outlets for small volume sales (1 litre and 4 litre containers) mainly for oil used in petrol engines, as well as oil companies for large containers (209 litres) of engine oil sold in bulk to road freight transport operators for use in diesel engines. The market and resource prices obtained from the surveys across vehicle types are presented in Table 3. The prices for diesel engine oils were therefore lower than might be expected due to the inclusion of larger containers in the sample. This was not the case in previous unit values surveys, which relied primarily on retail outlets for the sample.

Table 3 Oil prices ($ per litre) per vehicle type, as at June $2013

Engine type	Market price ($ per litre)	Resource price ($ per litre)
Petrol	7.66	6.96
Diesel	4.64	4.22

Source: ARRB Group Ltd.

Where a vehicle type, e.g. LCVs, includes petrol and diesel engines, the oil price can be weighted in terms of the vehicle population using the road or in that jurisdiction. Using SMVU data for this vehicle type, a weighted average engine oil price was calculated for LCVs given that this vehicle type includes petrol or diesel engines[1]. Using this methodology, the engine oil price for LCVs was estimated at a market price of $6.15 per litre and resource price of $5.59 per litre.

[1] The proportion of petrol and diesel engine LCVs was based on SMVU (2012) data available at time of calculation.

2.3 Tyres

A survey of tyre prices for all vehicle types[2] was undertaken through a sample of retail outlets and tyre companies and these data are contained in Table 4. Data are presented for market prices and resource prices per vehicle type. Where appropriate, for heavy vehicles, the prices per new tyre are a weighted average between the drive tyres and trailer tyres. The number of tyres per set and the resource price per set of new tyres are also presented in the table, the latter being deducted from the resource price of new vehicles for depreciation purposes.

Table 4 New tyre prices per vehicle type ($ per tyre), as at June $2013

Vehicle type	Market price ($ per new tyre)	Resource price ($ per new tyre)	Number of tyres per set	Resource price ($ per set of new tyres)
Cars				
01. Small Car	98	89	4	356
02. Medium Car	128	116	4	464
03. Large Car	167	151	4	604
Average	136	123	4	492
Utility vehicles				
04. Courier Van-Utility	171	155	4	620
05. 4WD Mid Size Petrol	306	278	4	1,112
Rigid trucks				
06. Light Rigid	247	224	4	897
07. Medium Rigid	507	461	6	2,764
08. Heavy Rigid	728	662	10	6,618
Bus				
09. Heavy Bus	493	448	8	3,584
Articulated				
10. Artic 4 Axle	676	614	14	8,600
11. Artic 5 Axle	690	627	18	11,291
12. Artic 6 Axle	686	624	22	13,720

[2] Using the 20 vehicle classification as developed for use in the harmonisation studies, which employed the Australian adaptation and calibration of the HDM models that have also been adopted for the vehicle operating cost (VOC) modelling chapter of this Part. This is explained further in Appendix C, including how this relates to the Austroads 12 bin classification.

Vehicle type	Market price ($ per new tyre)	Resource price ($ per new tyre)	Number of tyres per set	Resource price ($ per set of new tyres)
Combination vehicles				
13. Rigid + 5 Axle Dog	660	600	30	18,000
14. B-Double	653	594	34	20,196
15. Twin steer + 5 Axle Dog	690	627	32	20,064
16. A-Double	682	620	42	26,040
17. B Triple	689	626	46	28,796
18. A B Combination	653	594	54	32,076
19. A-Triple	688	625	62	38,750
20. Double B-Double	688	625	66	41,250

Source: ARRB Group Ltd.

The resource price per retreaded tyre and resource price per set of retreaded tyres are presented in the table below.

Table 5 Retreaded tyre prices ($ per tyre) per vehicle type, June $2013

Vehicle type	Resource price ($ per retreaded tyre)	Resource price ($ per set of retreaded tyres)
Cars		
01. Small Car	48	194
02. Medium Car	58	232
03. Large Car	68	273
Average	61	245
Utility vehicles		
04. Courier Van-Utility	78	310
05. 4WD Mid Size Petrol	139	556
Rigid trucks		
06. Light Rigid	149	596
07. Medium Rigid	200	1,201
08. Heavy Rigid	222	2,218
Bus		
09. Heavy Bus	161	1,290
Articulated		
10. Artic 4 Axle	222	3,106
11. Artic 5 Axle	214	3,855
12. Artic 6 Axle	220	4,845

Vehicle type	Resource price ($ per retreaded tyre)	Resource price ($ per set of retreaded tyres)
Combination vehicles		
13. Rigid + 5 Axle Dog	227	6,817
14. B-Double	225	7,648
15. Twin steer + 5 Axle Dog	227	7,258
16. A-Double	248	10,416
17. B Triple	249	11,466
18. A B Combination	241	13,006
19. A-Triple	253	15,713
20. Double B-Double	253	16,726

Source: ARRB Group Ltd.

2.4 Repairs and maintenance

For passenger cars and light vehicles, the repairs and maintenance costs used in previous Austroads unit values updates (Austroads, 2012a) were updated using an average of the CPI for vehicle maintenance and repairs and the CPI for motor vehicle spares. For heavy vehicles, repairs and maintenance costs were updated using an average of the PPI for road freight and the PPI for auto parts. This differs from the methodology used in the previous Austroads unit values update (Austroads, 2012a), which used the PPI for road freight only. The repairs and maintenance costs per vehicle type are contained in Table 6. The estimates based on percentage of new vehicle price as used in the adapted HDM-4 models (including estimated time costs for labour) are also presented for comparison purposes. The table shows that there is a reasonable correspondence between the costs based on the PPI update and that based on percentage of new vehicle price with a labour cost component (HDM approach), except for several of the combination vehicle types due to the specification of those vehicles and the new vehicle prices involved.

Table 6 Repairs and maintenance costs per vehicle type, as at June 2013

Vehicle type	Repairs & maintenance costs (cents per km) based on PPI	Repairs & maintenance costs (cents per km) based on % new vehicle price
Cars		
01. Small Car	6.1	7.1
02. Medium Car	7.1	8.1
03. Large Car	5.7	9.3
Average	6.3	8.2
Utility vehicles		
04. Courier Van-Utility	6.7	6.7
05. 4WD Mid Size Petrol	8.2	8.2
Rigid trucks		
06. Light Rigid	6.1	7.5
07. Medium Rigid	13.1	10.7
08. Heavy Rigid	14.0	16.8
Buses		

Vehicle type	Repairs & maintenance costs (cents per km) based on PPI	Repairs & maintenance costs (cents per km) based on % new vehicle price
09. Heavy Bus	13.1	13.1
Articulated trucks		
10. Artic 4 Axle	19.1	18.9
11. Artic 5 Axle	22.2	19.5
12. Artic 6 Axle	22.8	18.0
Combination vehicles		
13. Rigid + 5 Axle Dog	25.2	22.7
14. B-Double	26.5	27.6
15. Twin steer + 5 Axle Dog	27.2	30.5
16. A-Double	28.3	37.7
17. B Triple	35.3	47.1
18. A B Combination	34.7	45.3
19. A-Triple	36.3	46.2
20. Double B-Double	39.2	47.7

Source: ARRB Group Ltd.

Vehicle repair and maintenance costs were also compared to available servicing costs from sources such as the RACV. Summarised data from these sources are contained in Table 7. The servicing costs do not seem to be significantly different to those estimated by the PPI update, and are closer to those values than the HDM approach (% of new vehicle price).

Table 7 Average servicing costs for selected vehicle types as published by RACV, June 2013

Vehicle type	Average vehicle servicing costs (cents per km)
Small car	7.0
Medium car	7.6
Large car	5.5
Average car	6.7
Medium SUV	6.7
Two wheel drive utility vehicle	6.1
Four wheel drive utility	8.2

Source: RACV

2.5 Vehicle prices

Average new vehicle prices for passenger cars and LCVs (utility/delivery vehicles) were obtained from the Automotive Data Services (www.redbook.com.au), while new vehicle prices for heavy commercial vehicles were updated using an average of the PPI for road freight, PPI for motor vehicles and the PPI for vehicle bodies and trailers to give a more representative index for the change in new vehicle prices. These prices were also compared to available sources, namely: http://www.trucksales.com.au and FreightMetrics (www.freightmetrics.com.au). The resource price for each vehicle type in Table8 involved the deduction of a 5% fleet discount, GST and the resource price per set of tyres applicable to that vehicle type, as presented in Table 4.

Table 8 New vehicle prices, as at June $2013

Vehicle type	Market price ($ per vehicle)	Resource price ($ per vehicle)
Cars		
01. Small Car	18,770	15,855
02. Medium Car	29,070	24,645
03. Large Car	41,467	35,204
Average	29,766	25,217
Utility vehicles		
04. Courier Van-Utility	34,203	28,919
05. 4WD Mid Size Petrol	57,280	48,357
Rigid trucks		
06. Light Rigid	56,511	47,913
07. Medium Rigid	139,521	117,726
08. Heavy Rigid	225,004	187,756
Buses		
09. Heavy Bus	322,571	275,000
Articulated		
10. Artic 4 Axle	305,732	255,450
11. Artic 5 Axle	341,347	283,509
12. Artic 6 Axle	373,497	308,840
Combination vehicles		
13. Rigid + 5 Axle Dog	340,037	275,668
14. B-Double	436,881	357,110
15. Twin steer + 5 Axle Dog	410,015	334,040
16. A-Double	552,824	451,399
17. B Triple	707,382	582,125
18. A B Combination	611,048	495,647
19. A-Triple	707,011	571,850
20. Double B-Double	690,398	555,003

Source: ARRB Group Ltd.

3. Travel time

3.1 Value of travel time for vehicle occupants

3.1.1 Travel time values for light vehicle occupants

The value of travel time for the occupants of passenger cars was updated to 30 June 2013 using the change in Average Weekly Earnings (AWE) (Australian Bureau of Statistics, 2013b). The AWE for full-time ordinary adult workers in Australia as per May 2013 ($1,420.90 per week) was updated to June 2013 using the CPI and was calculated at $1,423.67 per week or $37.46 per hour assuming a 38-hour week. As in previous Austroads unit values updates (Austroads, 2012a), private travel time was valued at 40% of seasonally adjusted full time AWE for Australia (Austroads, 1997) or $14.99 per person-hour (i.e. 40% of the AWE).

For business car travel, the value of travel time was assumed to be 129.8% of AWE (135% of full time AWE less 5.2% for payroll tax), assuming a 38-hour week. This methodology was in line with Austroads (1997)[3] and subsequent unit values updates (Austroads, 2012a). On this basis, business car travel was estimated at $48.63 per person-hour. These values are contained in Table 12.

3.1.2 Value of travel time for bus occupants

The value of travel time for bus drivers was estimated at that of a 5 axle articulated vehicle (mid-range of the heavy vehicle drivers) and for bus passengers as the value of travel time for private passenger car trips. These values are contained in Table 12. For future updates of ATAP parameter values, it is recommended that this is based on vehicle occupancy, available trip purpose and value of travel time for bus passengers.

3.1.3 Value of travel for commercial vehicle occupants

The value of travel time for the occupants (crew) of commercial vehicles (business hours) was updated to June 2013 using hourly wage rates based on the Road Transport and Distribution Award (2013, following the methodology recommended in Austroads (1997) and used in Austroads (2010)). The minimum wage per level of transport worker was then annualised and adjusted in terms of leave loading (17.5% of 4 weeks' wages) and on-costs (payroll tax, long service leave, superannuation contribution at 9.25% and training levies). It was then adjusted in terms of assumed available work hours to arrive at a value of travel time per hour.

[3] The payroll tax assumed in Austroads (1997) and used in previous Austroads (2012a) estimates of business car travel time was 7%, but this has subsequently been estimated as 5.2% as presented in Table 3.2.

Road Transport and Distribution Workers Award

The weekly wage rates for each transport worker grade as published in the Road Transport and Distribution Award for the year 2013 (Australian Industrial Relations Commission, 2013), are shown in Table 9. These values formed the basis for the estimation of the value of travel time for commercial vehicle occupants in Table 12.

Table 9 Minimum weekly wage rates per transport worker grade

Transport worker grade	Minimum weekly wage rate ($)
Grade 2	676
Grade 3	684
Grade 4	697
Grade 5	705
Grade 6	713
Grade 7	724
Grade 8	745
Grade 9	757
Grade 10	776

Source: Australian Industrial Relations Commission (2013)

Payroll tax

State payroll taxes in Table 10 were updated using state revenue offices and the Payroll Tax office (www.payrolltax.gov.au). A weighted average payroll tax rate for Australia was calculated using full time equivalent (FTE) employment per state from the Australian Bureau of Statistics (Australian Bureau of Statistics, 2013a). This weighted average payroll tax rate was then applied to the calculation of the value of travel time for commercial vehicle occupants presented in Table 12.

Table 10 Payroll tax rates per state as at June 2013

State	Rate (%)
New South Wales	5.5
Queensland	4.8
Western Australia	5.5
Northern Territory	5.5
South Australia	5.0
ACT	6.9
Tasmania	6.1
Victoria	4.9
Average*	**5.2**

**average weighted in terms of employment.*

Source: State Revenue Offices and www.payrolltax.gov.au (viewed October 2013)

3.1.4 Vehicle occupancy

Vehicle occupancy was included in Table 12 as in previous updates. For comparison purposes, vehicle occupancy data was also obtained from the Austroads indicators, see table below. These data are for comparison purposes only and do not replace the vehicle occupancy data already in use and in Table 12.

Table 11 Car occupancy, Austroads 2011–12

State	AM peak	PM peak	Off peak	All day
NSW	1.21	1.25	1.32	1.26
Victoria	1.12	1.22	1.24	1.21
Queensland	-	1.24	1.28	1.25
Western Australia	-	-	-	-
South Australia	1.0	1.25	1.28	1.26

Source: Austroads (National Performance Indicators 2013) http://algin.net/austroads/site/Index.asp?id=84

3.2 Value of travel time for freight

The value of travel time for freight was updated using the PPI for Road Freight and these values are included in Table 12. For future updates, these values could be based on a more recent and extensive study of the value of travel time for freight taking into account load and vehicle types. Austroads has identified the specific need for such a study in the near future and updates could draw on these results.

3.3 Estimated values of travel time for vehicle occupants and freight

The estimated values of travel time for vehicle occupants and freight are contained in Table 12.

Table 12 Estimated values of travel time (resource costs) – occupant and freight payload values, as at June 2013

Vehicle type	Non-urban		Urban		Freight travel time	
	Occupancy rate (persons/veh)	Value per occupant ($/person-hour)	Occupancy rate (persons/veh)	Value per occupant ($/person-hour)	Non-urban	Urban
					$ values per vehicle-hour	
Cars (all types)						
Private	1.7	14.99	1.6	14.99	na	na
Business	1.3	48.63	1.4	48.63	na	na
Utility vehicles						
04. Courier Van-Utility	1.0	25.41	1.0	25.41	na	na
05. 4WD Mid Size Petrol	1.5	25.41	1.5	25.41	na	na
Rigid trucks						
06. Light Rigid	1.3	25.41	1.3	25.41	0.78	1.53
07. Medium Rigid	1.2	25.72	1.3	25.72	2.11	4.15
08. Heavy Rigid	1.0	26.19	1.0	26.19	7.22	14.20
Buses						
09. Heavy Bus (driver)	1.0	25.72	1.0	25.72	0.00	na
09. Heavy Bus (passenger)	20.0	14.99	20.0	14.99	0.00	na
Articulated trucks						
10. Artic 4 Axle	1.0	26.81	1.0	26.81	15.53	30.59
11. Artic 5 Axle	1.0	26.81	1.0	26.81	19.80	39.01
12. Artic 6 Axle	1.0	26.81	1.0	26.81	21.36	42.06
Combination vehicles						
13. Rigid + 5 Axle Dog	1.0	27.20	1.0	27.20	30.53	62.99
14. B-Double	1.0	27.20	1.0	27.20	31.46	64.91
15. Twin steer + 5 Axle Dog	1.0	27.20	1.0	27.20	29.50	60.89
16. A-Double	1.0	27.98	1.0	27.98	41.31	85.25
17. B Triple	1.0	27.98	1.0	27.98	42.17	87.01
18. A B Combination	1.0	27.98	1.0	27.98	50.79	104.80
19. A-Triple	1.0	28.45	1.0	28.45	60.89	125.64
20. Double B-Double	1.0	28.45	1.0	28.45	61.59	127.09

Note: na denotes not applicable.

Source: ARRB Group Ltd.

3.4 Developments in travel time methodologies

"After decades of study, the value of travel time remains incompletely understood and ripe for further theoretical and empirical investigation" (Small, 2012).

This is indeed the case today with respect to the value of travel time savings, given its significance in economic evaluation. This issue, together with that of travel time reliability, remains an outstanding issue and a key focus area of research internationally, as well as in Australia.

The methodologies used to estimate travel time values were extensively reviewed in Austroads (2011a), which was then followed by studies that examined key aspects and how they are dealt with in project evaluation, namely travel time reliability (Austroads, 2011b) and small travel time savings (Austroads, 2011c). Issues and developments in travel time reliability are also expanded upon in the following section. The conclusion of the Austroads research into the treatment of small travel time savings (Austroads, 2011c) was that there was uncertainty regarding what constitutes 'small' travel time savings and mixed evidence for the use of different values of travel time savings. Estimation difficulties were also identified. Given these factors, the research concluded that there were limited grounds for valuing small travel time savings differently.

More recently, work undertaken internationally (see Wardman et al., 2013) into travel time savings has focused on the issue of trip purpose and the review of the wage rate in estimating values for work trips, as well as for commuting trips (e.g. by public transport). No firm guidance emerged from the review due to the variation in methods identified internationally, although the continued dominance of the wage rate (plus non-wage labour costs, i.e. the cost saving approach) was identified as the basis of work trip travel time values due to its simplicity. There was also a need for values for travel time savings to be updated and to reflect modern (electronic age) work practices and travel patterns, which involve commuters being able to work while using public transport (building on the Hensher approach of 1977). The potential for the use of willingness to pay (WTP) techniques to estimate the value of travel time savings was examined in terms of revealed preference (RP) and stated preference (SP) techniques with some comparison of these methods. An aspect identified in the research was also that of employer valuation versus employee WTP for travel time savings. Developments in this area in Australia must be monitored and adapted for future updates of ATAP parameter values.

3.5 Status of research on travel time reliability

Travel time reliability and its role in project evaluation were addressed in detail in Austroads (2011b). The primary objective of the project was the review of methods and measures of travel time reliability. The project also documented the proceedings and outcomes of an international workshop on travel time and project evaluation held in 2009 in Vancouver, Canada, under the auspices of the State Highway Research Program (SHRP2) and the Joint Transport Research Committee (JTRC). The principal outcome of the workshop was that there has been limited progress in incorporating travel time reliability in project evaluation internationally.

A review of more recent work in this area since the workshop (see Transportation Research Board, 2013) and reviews undertaken in the UK (Small, 2012) reveals that research on travel time reliability has been focused more on issues of variability of travel time and unpredicted variation in trip times arising from incidents as opposed to expected delays (non-recurrent versus recurrent congestion). Evidence also points to the potential of willingness to pay (stated preference) techniques as a means of valuing travel time and value of variability (Small, 2012). However, the consensus remains that travel time variability has potential, but has not yet been implemented in economic evaluation. The standard approach is still centred around the mean and standard deviation (e.g. New Zealand's approach[4]) but also the 95th percentile, which has implications for the values attached to travel time. However, research needs to be based on detailed analysis of network based trip data in terms of origin-destination of trips and trip lengths and delays experienced. In the United States, the State Highways Research Program (SHRP2) component C11 has recently compiled a methodology and spreadsheet tools for 'sketch type' estimation of travel time reliability as part of a suite of resources for the estimation of wider economic benefits in economic evaluation (Transportation Research Board, 2013). Internationally, travel time reliability ratios (i.e. travel time reliability as a percentage of travel time values) have also been used in some countries.

Further research in this area has been identified by Austroads as a priority in the future and it is recommended that the results of this work be incorporated into future updates of ATAP parameter values as they become available.

[4] Approaches to estimating travel time reliability for inclusion in economic appraisal are also set out in detail in the New Zealand Transport Agency's Economic Evaluation Manual (NZTA, 2013).

4. Crash costs

This chapter contains updated average crash costs by crash severity across jurisdictions (i.e. taking into account injury severity), estimated using the hybrid human capital approach and the willingness to pay (WTP) approach.

4.1 Crash data

Crash data by injury type and crash severity were extracted from the Austroads crash data by jurisdiction as at 2010. The 2010 data were the most recent crash data collected from jurisdictions at the time of the update, and were subsequently cleaned and checked for consistency and reconciled as far as possible. The crash data per injury and crash severity were used to estimate the average cost of crashes per crash severity using the latest injury values for both human capital (HC) and willingness to pay (WTP) approaches outlined in this section. The Austroads crash data were obtained from data provided by road agencies across jurisdictions in Australia. Jurisdictions tend to collect data from police reports of crashes, although there is some variability. Police reporting differs between jurisdictions, as does the extent to which police officers attend crashes. Consequently, the crash data in this report refers to reported crashes only.

The steps undertaken in analysing the latest available (2010) crash data and using it to estimate the average cost of crashes by injury severity were:

1. Classifying the jurisdictional crash data road environment (i.e. grouping crashes by rural, urban and urban freeways road environments). The rural road environment refers to mainly built-up undivided roads with speed limits of up to 80 km/h, mainly built-up and divided roads with speed limits of 100 km/h and above and mainly open roads with speed limits from 80 km/h. The urban road environment was defined as mainly built-up and divided roads with speed limits below 100 km/h and all roads with speed limits under 80 km/h. The urban freeway environment was defined as mainly built-up and divided roads with speed limits of 100 km/h and above
2. Grouping by crash severity and road environment (i.e. fatal, serious and minor crashes on the different road environments). Crash severity classifications vary across jurisdictions; for example, New South Wales records fatal, injury, other and tow-away crashes. To standardise the analysis, crashes were classified as fatal, serious and other crashes for all jurisdictions except New South Wales
3. Further classifying jurisdictional data by injury severity, crash severity and road environment. This showed the number of injuries and injury type by crash severity, such as the number of fatalities, medically treated, admitted to hospital, minor injuries and other injuries in fatal crashes
4. Calculating the rate of injury per crash type by road environment (i.e. calculating the rate of fatalities per fatal crash or serious injuries per fatal crash, etc.)
5. Injury rate per crash type was then used, along with the updated human capital and willingness to pay values per injury, to estimate the average cost of crashes by injury severity.

4.2 Casualty costs

Casualty costs across injury types were updated using both the human capital and the WTP approaches. These were then applied to the crash rates and crash severities to calculate an average cost of crashes for crash severity in Australia.

4.2.1 Human capital approach

The updated average casualty costs per person based on the 1996 values (BTE, 2000) and updated to June 2013 using appropriate indices are contained in Table 13. This is the same method used as in previous Austroads unit values updates (Austroads, 2012a). These values for casualty costs were then applied to the crash data per crash severity to estimate the average cost of crashes for Australia in 2013[5].

Table 13 Average casualty costs per person, June 2013

Cost component	Fatal crash	Serious injury crash	Other injury crash	Price index	Fatal crash	Serious injury crash	Other injury crash
	$ per person – June 1996 values				$ per person – June 2013 values		
Human costs							
Ambulance costs	254	254	138	2.0071	510	510	277
Hospital in-patient costs	1,373	5,493	28	2.0071	2,756	11,026	56
Other medical costs	1,018	8,246	40	2.0071	2,043	16,552	80
Long-term care	-	62,395	-	2.0071	0	125,246	0
Labour in the workplace	347,208	16,417	-	2.1092	732,187	34,620	0
Labour in the household	288,832	13,689	-	2.1092	609,085	28,867	0
Quality of life	319,030	34,228	1,819	2.1092	672,766	72,180	3,836
Insurance claims	12,000	21,147	1,264	1.5413	18,495	32,592	1,948
Criminal prosecution	1,548	448	55	1.5413	2,386	690	85
Correctional services	8,511	-	-	1.5413	13,117	0	0
Workplace disruptions	8,077	8,301	538	1.5413	12,449	12,794	829
Funeral	1,700	-	-	1.5413	2,620	0	0
Coroner	558	-	-	1.5413	860	0	0
Total human cost	990,109	170,618	3,882		2,069,274	335,078	7,111
Vehicle costs							
Repairs	8,528	7,126	7,032	1.5934	13,585	11,352	11,202

[5] Also see BTRE (2010) for the Hybrid human capital approach. However, for the ATAP parameter values, the methodology for the update of injury costs was kept the same as for Austroads (2012a), i.e. 1996 base values updated, in line with the human capital approach. This is also explained in Austroads (2011a).

Cost component	Fatal crash	Serious injury crash	Other injury crash	Price index	Fatal crash	Serious injury crash	Other injury crash
	$ per person – June 1996 values				$ per person – June 2013 values		
Unavailability of vehicles	1,082	960	507	1.5934	1,724	1,529	808
Towing	254	226	119	1.5934	405	360	190
Total vehicle costs	9,864	8,312	7,658		15,714	13,241	12,200
General costs							
Travel delays	47,678	57,704	75	1.5413	73,483	88,935	116
Insurance administration	30,553	36,979	48	1.5413	47,089	56,993	74
Police	6,147	2,112	32	1.5413	9,474	3,255	49
Property	990	1,198	2	1.5413	1,526	1,846	3
Fire	323	391	1	1.5413	498	603	2
Total general costs	85,691	98,384	158		132,069	151,632	244
Total combined costs	1,085,664	277,314	11,698		2,217,057	499,951	19,554

1. *Health CPI*
2. *Average weekly earnings include all employees' total earnings (full-time plus part-time) for May 2013 as obtained from the ABS (2013)*
3. *CPI all groups*
4. *CPI motor vehicle repairs and servicing*

Source: Adapted from BTE (2000) by ARRB Group Ltd.

The revised estimate of a property damage only crash based on BTE (2000) data is $9,257 as at June 2013.

4.2.2 Willingness to pay (WTP) approach

Crash costs per injury type derived from WTP values are contained in Table 14. The WTP values estimated by the RTA NSW in 2008 were updated as an interim measure until a national WTP study is undertaken; this was in line with the methodology for interim estimates outlined in Austroads (2015). These values were then applied to the appropriate crash data to estimate crash costs using the WTP values. The WTP average crash cost values estimated by TfNSW in their appraisal guidelines (TfNSW, 2013a)[6] were also updated and included in the WTP average crash costs presented in Table 19. Additional costs as compiled by BITRE for emergency services and

[6] The WTP crash costs estimated for the RTA NSW in 2008 (see Austroads, 2015) were subsequently revised to include weighted averages for cars and pedestrians (RTA, 2008) and used as the basis for the estimate crash costs in TfNSW (2013a), taking account of revised urban and rural crash rates and severities. These values updated to June 2013 have also been published in Table 4.7. It must be noted that the revised values are higher in the case of rural injuries due to the weighting of crash severities applied. This in turn results in higher rural average cost of crashes if the revised injury costs are applied to crash data due to higher rural crash severities.

other costs were then added to the WTP values as the 'inclusive' WTP values and these are presented in Table 15. These injury costs were then applied to the crash data to calculate average crash costs presented in Table 20.

Table 14 Estimated costs by injury type using the willingness to pay (WTP) approach (June $2013)

Injury severity	Urban ($)	Non-urban ($)
Value of statistical life (VSL)	7,425,629	7,342,167
Value of serious injury (VSI)	361,733	226,025
Value of hospitalised injuries (VHI)	87,988	65,210
Value of minor injuries (VMI)	19,296	23,678

Source: ARRB Group Ltd adapted from Austroads (2015).

Table 15 Estimated costs by injury type using the inclusive willingness to pay (WTP) approach (June $2013)

Injury severity	Urban ($)	Non-urban ($)
Value of statistical life (VSL)	7,573,412	7,489,950
Value of serious injury (VSI)	526,606	390,898
Value of hospitalised injuries (VHI)	100,431	77,653
Value of minor injuries (VMI)	31,739	36,121

Includes vehicle and general costs, e.g. vehicle towing, emergency services, administrative, etc, as calculated under the Human Capital approach.

Source: ARRB Group Ltd adapted from Austroads (2015)

4.3 Estimation of average crash costs by injury severity

The updated average costs per crash calculated under the hybrid HC approach for Australia as a whole are set out in Table 16.

Table 16 Updated average crash costs using the human capital approach based on BITRE values, 2013

Crash severity	Fatal	Serious injury	Slight injury	PDO
Value ($2013)	2,463,432	629,484	22,992	9,257

Source: Adapted from BTE (2000)

The estimated average crash cost per crash severity for casualty crashes was also calculated for each jurisdiction using the updated human capital costs per injury severity and 2010 crash data. These values are contained in Table 18.

4.4 Estimation of crash costs by severity and speed zone

Crash costs across jurisdictions were estimated by severity and speed zone for urban freeways, urban roads and rural roads. These data are presented in Tables 21, 22 and 23 respectively. Not all jurisdictions had sufficient data for the estimation of crash costs for all speed zones. Also, the estimates for crash costs for the same crash severity varied across jurisdictions. The estimates were also undertaken using human capital values only for the purposes of this update due to these variations.

The data were also sufficient for the estimation of crash costs for classification of crashes according to DCA codes, although there was significant variation in average crash costs across and within DCA codes. These data are available on request and should be used with appropriate awareness and understanding of this variation.

4.5 Crash rates

The calculation of crash rates was undertaken by Austroads over some years for both Australia and by individual jurisdictions in Jurewicz & Bennett (2008) and Austroads (2010a). The data provide crash rates by mid-block and intersections for both urban and rural situations. It is recommended that practitioners consult these publications for appropriate crash rates for their analyses.

4.6 Crash reduction and mitigation factors

Crash reduction (and mitigation) factors have been published in Austroads (2012b) for a range of treatment types[7]. These were also published as a complement to crash reduction factors for Black Spot Treatments published in Department of Infrastructure, Transport, Regional Development and Local Government (2009) Black Spot Evaluation Notes on Administration. It is recommended that practitioners consult these publications for crash reduction and mitigation factors relevant to their analysis.

[7] Treatment types include: delineation (e.g. pavement or line markings), intersection treatments (e.g. installation of give way signs or roundabouts), railway level crossings (e.g. signage or barriers), road geometry and design (e.g. overtaking lanes), roadside (e.g. installation of guardrails), signage (e.g. variable message or warning signs), pedestrian (e.g. phasing at signals, pedestrian crossing), speed and enforcement (e.g. speed cameras, speed changes) and traffic management (e.g. medians, traffic calming). A level of confidence is also provided for each crash reduction or mitigation factor per treatment type in Austroads (2012b).

4.7 Life-long injury costs

The cost of life-long injuries is also significant but is currently not included in the costs of serious injury. The lifetime costs per incident case estimated in Access Economics (2009) for spinal cord injuries and paraplegia and quadriplegia were updated to $2013 using the CPI for medical and hospital services and the National Accounts Implicit Price Deflator for Health to provide some idea of the extent of these costs. These values are contained in Table 17. It must be noted they have not been included in the estimates compiled for these Guidelines, but there is considerable merit in considering how the costs of long term injury (care costs) might be taken into account in future. Additional data would be required on relevant crash rates and the costs of long term care.

Table 17 Lifetime costs per incident case, Australia ($2013)

Injury type	$2008 values ($m)	$2013 values ($m) using CPI medical & health services	$2013 values ($m) using implicit price deflator for health
Spinal cord injuries (SCI)	4.9	6.8	6.1
Paraplegia and quadriplegia	7.6	10.5	9.4

Source: Adapted from Access Economics (2009)

Table 18 Estimation of crash costs by injury severity, Human Capital (HC) values, June $2013

State	Rural			Urban			Urban freeway			Total		
	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)
New South Wales	2,875,402	588,546		2,538,351	546,231		2,607,771	574,426		2,772,853	537,864	
Victoria	2,843,808	628,914	26,217	2,521,384	562,234	24,550	2,860,449	596,339	25,242	2,715,548	578,847	24,707
Queensland	2,728,617	642,035	25,822	2,456,692	595,803	23,760	2,417,038	602,434	25,760	2,622,924	608,184	24,217
South Australia	2,826,043	610,963	26,080	2,385,285	553,306	23,479	2,569,913	782,048	27,490	2,634,126	578,406	23,963
Western Australia	2,868,662	638,358	28,970	2,447,722	583,884	26,900	2,617,019	646,690	28,149	2,707,518	300,437	26,878
Tasmania	2,568,291	579,621	28,381	2,351,823	533,536	24,696	2,217,057	699,655	28,245	2,502,099	563,854	26,107
Northern Territory	2,803,648	664,275	24,241	2,945,056	620,768	23,343	2,864,360	520,685	31,109	2,847,136	635,163	24,266
Australian Capital Territory				2,857,595	536,679							

Source: ARRB Group Ltd.

Table 19 Estimation of crash costs by injury severity, WTP values, June $2013

State	Rural			Urban		
	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)
New South Wales	7,848,085	216,675		6,476,155	136,505	
Victoria	8,319,000	289,604	31,747	8,217,515	407,930	24,226
Queensland	8,059,080	294,906	31,268	7,741,326	436,471	23,446
South Australia	8,725,853	297,940	31,580	7,625,611	424,018	23,169
Western Australia	8,537,385	294,498	35,079	7,796,363	423,650	26,544
Tasmania	8,087,424	267,428	34,368	7,525,710	386,849	25,831
Northern Territory	8,043,372	302,628	29,353	8,439,525	449,694	23,035
Australian Capital Territory				8,982,223	389,365	

Source: ARRB Group Ltd.

Table 20 Estimation of crash costs by injury severity, inclusive WTP values, June $2013

State	Rural			Urban		
	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)
New South Wales[8]	7,848,085	216,675		6,476,155	136,505	
New South Wales[9]	8,947,869	543,335		8,298,633	659,881	
Victoria	8,611,365	499,138	48,429	8,409,584	594,663	39,848
Queensland	8,331,930	507,261	47,699	7,955,196	633,652	38,566
South Australia	8,905,039	504,427	48,175	7,780,230	611,175	38,110
Western Australia	8,820,027	507,601	53,513	8,001,286	617,588	43,661
Tasmania	8,302,092	460,750	52,429	7,720,934	563,748	42,488
Northern Territory	8,343,480	522,627	44,779	8,780,310	655,048	37,888
Australian Capital Territory				9,233,736	567,583	

Includes vehicle and general costs, e.g. vehicle towing, emergency services, administrative, etc, as calculated under the Human Capital approach.

Source: ARRB Group Ltd.

[8] Note values for NSW are as published in the TfNSW project appraisal guidelines, TfNSW (2013a), where it is assumed that all costs are included in the WTP values. Hence, the Inclusive WTP values for NSW remain the same.

[9] These values for NSW were compiled using RTA NSW (2008) values (incl. additional costs) and NSW crash data as per all other jurisdictions. This approach was accepted as an interim approach in Austroads (2015) until a national WTP study is undertaken for Australia.

Table 21 Average cost of crashes by crash severity and speed zone per jurisdiction (HC values): Urban Freeway, June $2013

Speed zone (km/h)	100 km/h			110 km/h		
Jurisdiction	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)
New South Wales	1,206,207	315,145		955,254	372,809	
Victoria	991,683	242,614	25,242	-	280,195	25,242
Queensland	1,640,750	542,644	16,861	-	-	-
South Australia	-	259,958	54,031	1,118,306	777,702	27,490
Western Australia	1,409,459	646,690	56,298	-	-	56,298
Tasmania	2,217,057	687,433	26,507	-	687,433	27,502
Northern Territory	1,430,225	493,221	22,221	-	519,180	22,221

Source: ARRB Group Ltd.

Table 22 Average cost of crashes by crash severity and speed zone per jurisdiction (HC values): Urban Road, June $2013

Speed zone (km/h)	< 50 km/h			50 km/h			60 km/h			70 km/h			80 km/h		
Jurisdiction	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)
New South Wales	2,330,338	-	-	2,396,664	624,281	-	1,045,673	582,918	-	1,139,960	608,057	-	1,481,236	1,091,367	-
Victoria	811,472	245,184	24,550	1,223,785	279,233	24,550	1,040,310	253,489	25,561	1,252,194	253,929	24,550	1,105,994	223,964	24,550
Queensland	1,761,617	561,080	15,282	-	-	-	1,543,810	537,680	15,282	1,566,233	514,572	15,282	-	-	-
South Australia	-	509,522	23,479	1,576,703	446,454	23,479	1,557,525	447,367	23,479	2,275,401	367,213	23,479	2,275,401	457,774	23,479
Western Australia	1,222,370	579,366	26,900	2,024,751	498,515	26,900	1,807,806	471,782	25,883	1,116,863	480,463	26,900	1,528,694	483,355	26,939
Tasmania	-	530,436	24,696	2,217,057	530,436	24,332	2,217,057	516,100	24,321	2,217,057	530,436	24,412	-	-	-
Northern Territory	-	618,690	18,332	2,401,812	542,951	18,332	1,231,695	565,061	18,332	1,604,584	618,690	18,332	-	-	-

Source: ARRB Group Ltd.

Table 23 Average cost of crashes by crash severity and speed zone per jurisdiction (HC values): Rural Road, June $2013

Speed zone (km/h)	80 km/h			90 km/h			100 km/h			110 km/h		
Jurisdiction	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)
New South Wales	1,432,929	458,899	-	1,337,764	351,451	-	1,386,168	484,664	-	2,010,614	462,809	-
Victoria	894,166	332,792	26,217	1,640,421	295,238	21,017	1,152,344	357,459	26,217	851,010	375,091	26,217
Queensland	1,548,496	590,370	14,677	-	-	-	1,494,690	593,020	14,708	-	-	-
South Australia	2,116,449	464,397	26,080	2,632,756	519,892	26,080	1,557,606	500,275	26,080	1,718,791	513,049	26,080
Western Australia	1,431,823	499,432	28,970	1,624,585	415,669	28,970	1,635,677	526,016	28,970	1,524,414	505,746	26,548
Tasmania	1,543,962	397,174	28,381	815,091	572,525	28,381	536,346	430,068	27,711	921,529	491,750	29,717
Northern Territory	1,457,504	612,205	19,554	2,369,958	567,186	19,554	1,551,542	661,226	19,554	1,521,661	18,138	19,554

Source: ARRB Group Ltd.

5. Vehicle operating cost (VOC) models

5.1 Background

Vehicle operating costs are an important component of cost-benefit analysis and they are required to be estimated for the full vehicle fleet, and for different operating conditions.

Different methods exist and have been developed through various Austroads studies. There has been a stated requirement to provide models that possess the following attributes, and that can be applied and updated in a clear and consistent manner:

- To better accommodate changes in vehicle technology and a changing vehicle fleet, including under different loading conditions and regulations
- To be amenable for application across networks subject to uninterrupted and interrupted/stop-start conditions
- To be capable of application to general cost-benefit analysis studies at a network level and for major capital projects, including employing the results of traditional 4–5 stage transport models.

This chapter describes the background to how models have evolved in the last 20 years and provides a recommended set of models and guidance on their application consistent with the above requirements.

In aiming to meet the first requirement, a number of choices exist, including:

- **'Mechanistic-empirical' model forms**, which estimate resource consumption in terms of the underlying physics and mechanical engineering processes and can be adapted to suit a range of fleet and road operating conditions. The HDM-III (Watanadada et al., 1987) and HDM-4 (Bennett & Greenwood, 2006 and Stannard & Wightman, 2006) models are of this kind and are structured in a mechanistic form, with the coefficients derived by the statistical analysis of observations. The latest models utilise the Australian-developed ARFCOM fuel consumption model (Biggs, 1988). The speed models have been calibrated to driver behaviour and the response of the mechanistic models using results of comprehensive speed studies undertaken in Australia in the late 1990s and early 2000s. The maintenance and spare parts models are also based on field observations in Australia (Thoresen & Roper, 1999). New Zealand studies (OPUS International Consultants, 1999), which form the basis for the NZ economic evaluation manual (NZ Transport Agency, 2013) and further Austroads studies (Austroads, 2012b and Tan et al.. 2012) have also confirmed the suitability of the models. Whereas these models were originally derived for application in non-urban conditions, they have been adapted for use in urban and stop-start environments as a result of Austroads funded studies (Cox & Arup, 1996 and Thoresen, 2004).

- **Regression equation type models**, often described as ‘statistical’ models, where the structure does not seek to emulate the mechanical engineering processes. While these models can provide reasonable results for applications which are close to the original derivation of the models, including the scope and combination of parameters and parameter values tested, this also limits their potential application. These models were amongst the first used for VOC estimation, such as those derived by Hodges et al. (1975), and a number of the original NIMPAC models (Both & Bayley, 1976) were of this kind. The derivation of the NIMPAC models followed the extensive efforts undertaken in Australia to develop methodologies capable of estimating RUCs and their sensitivity to road conditions in both non-urban and urban settings. Work commenced in the late 1960s, largely initiated by the former Commonwealth Bureau of Roads, and proceeded through the 1970s and 1980s under NAASRA.

Either of the above models may be employed to produce more user friendly formats, either as a suite of tables or as a set of derived equations based on specific operating conditions and vehicle related assumptions.

In Australia, achieving consistency between different rural/uninterrupted flow models has previously been the subject of a harmonisation process where algorithms, procedures and values could be used by agencies to benchmark their models to agreed costs and technologies. This culminated in an Austroads Road User Cost Steering Group (RUCSG) program covering the period 1994–2005 (Peters, 2001). The program provided the basis to calibrate models such as NIMPAC and RURAL (Both & Bayley, 1976), which formed the basis of the evaluation procedures of road agencies, to estimate similar values as the ‘mechanistic-empirical’ models. An example of the technical documents that contained parameter values in a set of lookup tables is provided in Thoresen and Roper (1996). These continue to provide the basis for evaluation models in use in Australia at present, with the output of the ‘mechanistic–empirical’ models now used as the benchmark.

However, since the mid-2000s, improvements of rural RUC estimation methodologies in Australia have been *ad hoc* or have been undertaken as part of non-VOC dedicated projects (Michel et al., 2008). As a consequence, practitioners have been challenged in remaining up-to-date with developments. Notably, the parameter values and tables used in current road agency models have benefited from the outputs of the harmonisation process

In meeting the second requirement, Austroads material on urban VOC models extends over a significant period of time, with developments in the specifications of the model. This is reflected in Lloyd and Tsolakis (2000), for example, which provides an overview of urban road user cost (RUC) models, as well as addressing the issue of harmonisation of such models. It describes the Traffic Modelling System (TRAMS) model developed for Western Australia, based mainly on NIMPAC models with the ARRB ARFCOM fuel consumption model. However, the model was never adopted across jurisdictions in Australia, although NIMPAC has been the basis for models in Australia while ARFCOM remains the basis of fuel consumption models in Australia as well.

Austroads (2004) presented an alternative urban stop-start model and a freeway (uninterrupted flow) models on a per trip basis. This drew on the studies by Austroads reported by Cox and Arup (1996). The models initially employed an adaptation of the HDM-III and ARFCOM models for urban conditions, with the final models based on use of Australianised HDM-4 models. The performance estimates for vehicle maintenance and spare parts, tyre consumption, and fuel and oil consumption based on applying multiplicative factors or alternative models to produce estimates for urban conditions. Capital depreciation and interest is accounted for through reduced fleet utilisation because of the lower journey speeds. The free flow version of these models is consistent with the earlier mentioned rural uninterrupted flow models, thus offering the potential for consistency in VOC and RUC estimation across different parts of the network.

In Austroads (2005a) and Austroads (2008), the approach taken was to provide models for 'at grade' and freeway models (Austroads 2008) for all day average speeds, including representative traffic conditions, with model parameters produced on the basis of outputs from the TRAM. This approach has formed the basis of VOC models presented in recent updates (Austroads, 2012) and Austroads (2008). Austroads (2012) involved the aggregation of RUC components (VOC added to travel time), whereas earlier updates had presented coefficients for VOC both excluding travel time and then including travel time (vehicle occupants and freight travel time). This has been identified as an area that required disaggregation of VOC (i.e. excluding travel time).

However, the latter models have proved difficult to calibrate for urban conditions, with some practitioners, such as TfNSW in their VEHOP model (TfNSW, 2013b), preferring to use the models developed in Austroads (2004). The presentation of a set of VOCs excluding travel time has also been a key objective that has directed the review of parameter values for the ATAP Guidelines review, with an objective of obtaining cost data for VOC components (excluding travel time) for urban stop-start conditions and freeway models.

In addressing the third requirement, consideration has been given to the operating conditions and modelling complexity that can be reasonably modelled for cost-benefit analysis purposes. In particular, under interrupted flow conditions performance is highly dependent on factors such as traffic volume and mix, road configuration, geometry and layout (and therefore capacity and speed), intersection types and spacing (including the provision of graded separated or at grade intersections), and signal controlled intersections. A number of these factors are directly accounted for in current CBA oriented modelling. However, the level of complexity that is possible and reasonable for such applications requires consideration.

Bowyer et al. (1985) offered a classification of urban fuel consumption modelling that provides an insight to the complexity of the problem, with the physical estimates drawing on performance models such as the ARRB ARFCOM fuel consumption model (Biggs, 1988), and the modelling framework reflected in software such as aaSIDRA (see Akcelik & Besley, 2003). The classification is as follows:

- Instantaneous models (traffic management schemes, individual road sections, individual intersections, small networks where instantaneous speed data is available)
- Elemental models (incorporating four elements of cruise, idle, acceleration, deceleration). Same application as instantaneous, but used where only speed data are available for elements (modified for non-urban application)

- Running speed models. Travel is split into running and stopped components. Use at a trip level but not for traffic management modelling. Trip length > 1km
- Average travel speed model. Travel speed includes stop time. Used for large scale transport modelling, including traditional 4–5 stage component models. Accurate for average travel speeds < 50 km/h.

The average travel speed model, based on the total time on a link calculated as the sum of the time to traverse a link at the estimated operating speed based on speed–flow considerations and the intersection delay, is considered as a suitable basis for CBA. This method was also employed by Cox and Arup (1996), and in both the preceding and subsequent studies that underpinned the Austroads (2004) urban stop–start model and a freeway (uninterrupted flow) model. These models also adopt the mechanistic-empirical VOC models used to benchmark other model variants and incorporate the ARRB ARFCOM model, which remains the core of fuel consumption models in Australia for both urban and non-urban conditions. Use of this method also provides a consistent approach to incorporating travel time and freight delay costs, including modelling on the basis of different time periods, such as a.m. and p.m. peak periods, and day and night time off-peak periods. This provides a clearly defined and generic basis for general CBA with total RUC calculated using a common average travel speed/total link time.

The following sections describe the scope of both uninterrupted flow and interrupted flow models that use the mechanistic-empirical models and average travel speed approach, with this being consistent with Austroads (2004), TfNSW (2013b) and NZ Transport Agency (2013) for the purposes of general CBA. This provides a preferred model, while noting that other models exist and could justifiably be used.

5.2 Vehicle classification in Australia

The vehicle types included in the analysis follow the 20 vehicle classification (Thoresen & Ronald, 2002) subsequently used in HDM-4 in Australia, as well as the Austroads 12 bin classification (Austroads, 2002 and most recently Austroads, 2013b) as far as possible. The use of this vehicle classification in the ATAP Guidelines aims to provide practitioners with as wide a range of vehicle types as possible from which the appropriate vehicle types can be selected for their analysis. These vehicle types, as well as their assumed vehicle weights, payloads, pavement damage factors in equivalent standard axles (ESA)[10] and passenger car equivalent units (PCUs) are presented in Table 24. An overview of the vehicle classifications used in Australia and their basis over time is described in Appendix C.

[10] Practitioners are therefore able to use the payloads as inputs to the VOC models described in the rest of this section, with corresponding ESAs for their analysis. This provides a link for practitioners between VOCs, which can be estimated using these models, and vehicle loading, which also has an effect on road pavement, especially as loads increase. For sealed granular pavements, the most common type in Australia, this is based on a simple model where the relative damage (in ESA or Standard Axle Repetitions) = (Axle load/Standard load)4, hence the commonly used term '4th power law'. For example, a standard load of 80kN and an actual load of 100kN, the relative damage for an increase in total load of 25% is approximately (100/80)4 or 2.45 times the effect of a standard load. For further guidance, reference should be made to the Guide to Pavement Technology Part 2: Pavement Structural Design

Table 24 Vehicle parameters for vehicle types used in ATAP VOC modelling

Vehicle type	GCM (tonnes)	Maximum payload (tonnes)	ESAs per vehicle at 75% payload	ESAs per vehicle at 100% payload	ESAs per vehicle at 125% payload	Engine power (kw)	Annual km	PCU / PCSE[11]
01. Small Car	1.2	0.4	0.0002	0.0003	0.0004	65	23,000	0.99
02. Medium Car	1.4	0.4	0.0005	0.0006	0.0006	80	23,000	1
03. Large Car	1.6	0.4	0.0008	0.0010	0.0011	110	23,000	1.01
04. Courier Van-Utility	2.15	0.85	0.0024	0.0031	0.0039	60	30,000	1.11
05. 4WD Mid-Size Petrol	2.73	0.93	0.0066	0.0081	0.0097	132	30,000	1.12
06. Light Rigid	3.75	2.15	0.01	0.01	0.02	56	30,000	1.23
07. Medium Rigid	10.4	7.2	0.53	0.69	1.28	130	40,000	1.4
08. Heavy Rigid	22.5	13.5	2.72	3.59	6.17	190	86,000	1.56
09. Heavy Bus	19	7	1.17	2.32	3.51	200	70,000	1.59
10. Artic 4 Axle	31.5	20.5	3.96	5.07	8.95	190	86,000	1.78
11. Artic 5 Axle	39	26	4.4	5.65	10.08	260	86,000	1.84
12. Artic 6 Axle	42.5	27.5	3.89	4.97	8.54	300	86,000	1.89
13. Rigid + 5 Axle Dog	59	40	5.44	7.04	12.65	320	86,000	1.92
14. B-Double	62.5	40.5	4.93	6.35	11.02	350	86,000	2.22
15. Twin steer + 5 Axle Dog	64	43	4.49	7.58	13.66	360	86,000	1.97
16. A-Double	79	48	6.5	8.42	14.34	370	86,000	2.75
17. B Triple	82.5	48.5	5.99	7.73	12.88	380	86,000	2.82
18. A B Combination	99	60	7.54	9.80	16.73	380	86,000	2.9
19. A-Triple	115.5	71.5	9.1	11.86	20.61	390	86,000	3.38
20. Double B-Double	119	72	8.59	11.18	19.13	400	86,000	3.38

Source: ARRB Group Ltd.

(Austroads, 2012d) and specialist advice sought in its application.

[11] Passenger car units (PCUs) and passenger car space equivalents (PCSEs) held to be the same for all traffic conditions.

5.3 Uninterrupted flow VOC models

5.3.1 Basis of the uninterrupted flow VOC models

The development of a suite of models that can be used by a variety of different user types in an uninterrupted flow, typically rural and freeway, environment sought to provide the practitioner with the ability to either:

- Populate a simplified road user cost model with appropriate variables and associated coefficients, or
- Generate a series of tables with appropriate unit cost values that can serve as a 'ready reference' of rural VOC for analysis or a benchmark to calibrate the models used by practitioners.

The simplified model was developed by employing the Australianised HDM-4 VOC models to generate estimates of VOC for a wide range of vehicles and operating conditions, and using this data as input for developing multiple regression equations. These were applied in populating the tables of values.

The underlying VOC component models have been the subject of extensive calibration studies. This has led to the development of an Austroads harmonised version with a vehicle fleet and model configuration specifically created for application in Australia.

A number of simplified, aggregate models, which have been derived using the outputs of a structured analysis, are available from several sources. The resulting models comprise a multi-variate regression equation that includes a number of terms, with parameters and coefficients. The model is generated by first defining and running a series of analysis cases and using the raw outputs to subsequently derive coefficients through regression analysis of multiple HDM-4 outputs.

Several model specifications were considered, specifically the following.

ARRB aggregate model

ARRB developed an aggregate model based on regression of HDM-III, and later HDM-4, outputs for use in the Pavement Life Cycle Costing (PLCC) tool (Linard et al., 1996). This model was later applied in the Freight and Mass Limits Tool (FAMLIT) (Michel & Hassan et al., 2008). Separate sets of coefficients were estimated for each vehicle type. Vehicle speed was not used as an input or output, but is inherent in the model set up where the speed is estimated internally based on a separate free or desired speed model. This model draws on Australian studies and is consistent with design guidance and real life observations, and is structured as follows:

$VOC = a_1*(1 + a_2*NRM + a_3*Rise\&Fall + a_4*Curvature + a_5*Payload)$

where:

VOC = vehicle operating costs in cents per km

NRM = road roughness in NAASRA counts per km

Rise&Fall = the cumulative sum of all rises and falls in m/km

Curvature = the accumulated curvature in degrees/km

Payload = the weight of good carried, i.e. above tare weight, in kg

a_1 to a_5 = model coefficients.

Alternative aggregate model

An alternative aggregate model reported by Phedonos (2006) and applied in international studies by ARRB and by the NZ Transport Agency (2013) produces a base set of VOC's and a set of coefficients that uses speed and roughness as key input parameters, as follows:

$VOC = BaseVOC * [k_1 + k_2/V + k_3*V\ 2 + k_4*IRI + k_5*IRI\ 2]$

where:

BaseVOC = lowest VOC point in curve from raw HDM-4 output

V = Vehicle speed in km/h

IRI = International Roughness Index in m/km

k_1 to k_5 = model coefficients.

In order to generate the models, ranges of various attributes were selected to represent the breadth of operating conditions, including:

- Rise and fall and curvature
- Road roughness
- Road widths
- Vehicle types, weights and payloads parameters.

Typical assumptions for gradient and curvature have not changed since Thoresen and Roper (1996) and the categories typically used together are set out in Table 25 and have also been used in the analysis of uninterrupted flow VOC presented in this report:

Table 25 Gradient and curvature categories assumed for road stereotypes in Australia

Variable	Categories
Gradient (Rise & Fall)	Flat (0%), 4%, 6%, 8% & 10%
Curvature (Terrain type)	Straight (20°/km) Curvy / Hilly / Winding (120°/km) & Very Curvy or Very Winding (300–320°/km)

As one of the most important determinants of VOCs, the relationship between VOC and road roughness was examined in detail in Austroads (2012b) and Tan et al. (2012). The study found that international and local reviews (e.g. Thoresen, 2004) confirmed a varied but positive relationship between VOC-roughness in terms of all VOC components, especially in Australian conditions at levels of 1.2–5.8 IRI[12]:

- Fuel consumption (indeterminate direction, varies with the roughness level)
- Repairs and maintenance costs
- Tyre wear
- Lubricating oil costs.

Ranges of road roughness were tested starting from a value of 2 IRI, with outputs produced at 1 IRI increments up to 11 IRI.

Road widths assumed for the purposes of VOC modelling were identified as the most typical that may result in differences in VOC and are listed below:

- 4.5m
- 5.8m
- 8.5m.

Road widths below 4.5m were deemed to comprise a small portion of the road network and so were not included, while road widths greater than 8.5m did not result in significant increases in speed and changes in VOC.

5.3.2 Recommended model structure and coefficients

Two models were developed, namely for total VOC (including fuel consumption) and for fuel consumption.

Structure and coefficients for uninterrupted flow VOC model

The total VOC model is as follows, with coefficient values for a sample of the relationships shown in Table 26 and a full set of values presented in Appendix D:

$$VOC = BaseVOC * (k_1 + k_2/V + k_3*V^2 + k_4*IRI + k_5*IRI^2 + k_6*GVM)$$

where:

VOC, vehicle operating costs in cents/km

[12] Roughness in Australia is generally held to not exceed IRI of 6, so extreme roughness is held to not be a major issue, hence the focus on 1.2-5.8 IRI for Australia in Austroads (2012b).

BaseVOC = lowest VOC point in curve from raw HDM-4 output

V = Vehicle speed in km/h

IRI = International Roughness Index in m/km

GVM = gross vehicle mass in tonnes

k_1 to k_6 = model coefficients.

Table 26 Example coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

RF = 0

Curvature = 20° / km

Vehicle type	Base VOC (cents/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	21.65553	0.682568	8.926626	1.86E-05	0.029245	0.000812	0.040681
02. Medium Car	28.58679	0.689129	10.27355	1.43E-05	0.027139	0.000945	0.030451
03. Large Car	37.23451	0.714542	10.81935	1.09E-05	0.023979	0.001031	0.020684
04. Courier Van-Utility	32.14678	0.671992	8.085664	1.53E-05	0.039596	0.002492	0.023847
05. 4WD Mid-Size Petrol	35.49258	0.704089	7.16007	1.45E-05	0.034579	0.0021	0.0163
06. Light Rigid	44.70851	0.690409	5.571115	2.38E-05	0.042392	0.001879	0.013114
07. Medium Rigid	51.70626	0.64653	8.310133	2.08E-05	0.037528	0.001762	0.010923
08. Heavy Rigid	64.34463	0.45218	10.40255	3.42E-05	0.082007	0.000232	0.006585
09. Heavy Bus	100.1854	0.599271	9.039805	1.14E-05	0.066026	0.001052	0.004438
10. Artic 4 Axle	86.46287	0.443656	9.169067	3.51E-05	0.087456	0.000257	0.006451
11. Artic 5 Axle	95.65238	0.48678	8.851208	3.03E-05	0.083934	0.000404	0.004411
12. Artic 6 Axle	103.6022	0.491922	8.586421	2.8E-05	0.085237	0.000367	0.004082
13. Rigid + 5 Axle Dog	109.6991	0.507333	7.403231	2.75E-05	0.081194	0.000107	0.003943
14. B-Double	121.4093	0.483655	7.876344	2.41E-05	0.091051	0.000148	0.003567
15. Twin steer + 5 Axle Dog	120.4225	0.501057	7.606813	2.45E-05	0.085776	0.000191	0.003593
16. A-Double	146.9991	0.477559	7.54018	1.95E-05	0.096147	8.86E-05	0.002989
17. B Triple	170.3634	0.488334	7.864302	1.58E-05	0.097835	0.000332	0.00258
18. A B Combination	166.3673	0.475805	7.006039	1.75E-05	0.09811	-5.2E-05	0.002671
19. A-Triple	186.8652	0.480136	6.884288	1.56E-05	0.099253	-2E-05	0.002393
20. Double B-Double	189.7076	0.479935	6.579042	1.57E-05	0.098984	-0.00013	0.002361

Source: ARRB Group Ltd.

Road width is not a required input assumption because it only affects the estimated VOC (or fuel consumption) through the speed of travel, which is a user supplied input.

Structure and coefficients of the uninterrupted fuel consumption model

The fuel consumption model is as follows, with coefficient values for a sample of the relationships shown in Table 27 and a full set of coefficients is presented in Appendix E.

Fuel consumption (litres/km) = BaseFuel * (k_1 + k_2/V + k_3*V^2 + k_4*IRI + k_5*GVM)

BaseFuel = lowest fuel consumption point in curve from raw HDM-4 output

V = Vehicle speed in km/h

IRI = International Roughness Index in m/km

GVM = gross vehicle mass in tonnes

k_1 to k_5 = model coefficients.

The tables of parameters are extensive since they have been defined for different horizontal curvature and rise and fall value.

An example of the coefficients estimated for the model specified above is contained in Table 27.

Table 27 Example coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

RF = 0

Curvature = 20° / km

Vehicle type	Base fuel consumption (litres/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	6.419556	0.441226	12.43718	6.68E-05	0.006151	0.149391
02. Medium Car	7.771756	0.429248	14.42872	5.78E-05	0.005364	0.122652
03. Large Car	9.826507	0.473008	15.01703	4.7E-05	0.004258	0.08713
04. Courier Van-Utility	7.609467	0.284026	19.36752	6.91E-05	0.006175	0.110658
05. 4WD Mid-Size Petrol	10.24522	0.464267	14.11609	5.05E-05	0.005148	0.063315
06. Light Rigid	8.085994	0.239071	13.9732	0.000116	0.012785	0.099828
07. Medium Rigid	12.45859	0.36312	9.564724	9.97E-05	0.014856	0.048677
08. Heavy Rigid	23.22869	0.243735	14.52463	9.95E-05	0.012912	0.019901
09. Heavy Bus	23.33246	0.271022	14.12877	6.85E-05	0.011434	0.01995
10. Artic 4 Axle	27.24712	0.160111	12.59432	0.000116	0.019467	0.021969
11. Artic 5 Axle	30.44964	0.265547	11.51051	0.000103	0.017613	0.014919
12. Artic 6 Axle	33.79927	0.303256	10.38151	9.34E-05	0.017999	0.013406
13. Rigid + 5 Axle Dog	38.14329	0.302384	9.066662	8.58E-05	0.02207	0.011962
14. B-Double	41.48179	0.32033	8.323599	7.96E-05	0.022113	0.010988
15. Twin steer + 5 Axle Dog	40.98332	0.321609	8.44159	8.01E-05	0.022176	0.011101
16. A-Double	47.75104	0.300993	7.10185	7.17E-05	0.024567	0.009609

Vehicle type	Base fuel consumption (litres/100km)	K_1	K_2	K_3	K_4	K_5
17. B Triple	50.31407	0.30429	6.703995	6.89E-05	0.024871	0.009132
18. A B Combination	54.29232	0.287536	6.08939	6.64E-05	0.027662	0.008529
19. A-Triple	58.66595	0.27658	5.547481	6.39E-05	0.029925	0.00794
20. Double B-Double	61.23917	0.280027	5.283165	6.2E-05	0.029966	0.007613

Source: ARRB Group Ltd.

5.3.3 Updated uninterrupted (free flow) speed vehicle operating costs for Australia as at 2013

For practitioners who wish to use tables of values, Tables 26 through 31 contain updated uninterrupted (free flow) speed, VOC (cents per km) and fuel (litres per 100 km) data using the most recent unit values (June 2013) for selected vehicle types based on Austroads (2005a). Applicable speeds were derived from NIMPAC and HDM approaches and VOC and fuel consumption outputs calibrated to those speeds for appropriate vehicle types.

A roughness level of 2 IRI was assumed for the rural VOC modelling analysis, with an assumed 75% payload for freight vehicles. Other VOC estimates can be made applying the model specified and adjusting appropriately for payload.

A full set of values for VOC and fuel consumption for the 20 vehicle classification can be estimated using the appropriate coefficients in Table 26 and Table 27.

Table 28 Free speed (km/h) tables for rural (uninterrupted/free flow speed) roads (NIMPAC model speeds)

Roughness = 2 IRI

Vehicle loading = 75% of vehicle payload

% Gradient	Curvature	Medium car			Rigid trucks													Large bus (3 axles)			Articulated truck (6 axle)			B-Double (9 axles)		
					LCV (2 axle 4 tyre)			Light truck (2 axle 6 tyre)			Medium truck (2 axle 6 tyre)			Heavy truck (3 axles)												
		Road width			Road width			Road width			Road width			Road width				Road width			Road width			Road width		
		4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m		4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m
Flat	Straight	83	105	110	75	92	96	80	89	95	83	95	100	83	95	100		86	100	106	88	100	105	86	100	110
	Curvy	77	90	93	68	78	80	71	77	80	74	81	83	73	80	82		71	75	77	72	75	76	77	85	89
	Very curvy	69	75	76	60	66	67	63	66	67	65	68	70	64	67	68		59	60	60	59	60	60	67	70	72
4	Straight	82	102	106	72	86	88	74	81	86	70	76	79	65	69	71		49	52	53	38	40	41	72	78	82
	Curvy	76	89	90	66	74	76	67	72	74	65	69	70	60	63	64		45	47	47	35	36	36	67	71	73
	Very curvy	68	74	75	59	64	65	60	63	64	59	62	62	55	57	58		41	42	42	32	33	33	61	63	64
6	Straight	76	88	90	65	73	74	64	68	70	57	59	60	50	52	52		39	40	40	27	28	28	57	59	60
	Curvy	72	81	82	61	66	67	60	63	64	54	56	57	49	50	50		38	39	39	27	27	27	55	57	58
	Very curvy	66	71	71	56	60	60	55	57	58	51	53	53	46	47	47		36	36	36	26	26	26	53	54	54
8	Straight	66	72	72	56	59	60	53	55	55	45	46	46	40	40	40		32	32	32	20	20	20	45	46	46
	Curvy	64	68	69	53	56	57	51	53	53	44	45	45	39	39	39		32	32	32	19	19	19	45	45	46
	Very curvy	60	63	63	50	53	53	49	50	50	43	44	44	38	38	38		31	31	31	19	19	19	44	44	44
10	Straight	56	59	59	47	49	49	44	45	45	36	36	36	32	32	32		24	24	24	16	16	16	37	37	37
	Curvy	55	57	58	46	47	48	43	44	44	36	36	36	32	32	32		24	24	24	16	16	16	37	37	37
	Very curvy	53	55	55	44	46	46	42	43	43	36	36	36	32	32	32		24	24	24	16	16	16	36	36	37

Source: ARRB Group Ltd.

Table 29 Vehicle operating cost (cents per km) for rural (uninterrupted/free flow speed) roads, June $2013 (NIMPAC model speeds)

Roughness = 2 IRI

Vehicle loading = 75% of vehicle payload

% Gradient	Curvature	Medium car			Rigid trucks													Large bus (3 axles)			Articulated truck (6 axle)			B-Double (9 axles)		
					LCV (2 axle 4 tyre)			Light truck (2 axle 6 tyre)			Medium truck (2 axle 6 tyre)			Heavy truck (3 axles)												
		Road width			Road width			Road width			Road width			Road width				Road width			Road width			Road width		
		4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m		4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m
Flat	Straight	28.8	29.8	30.1	32.2	33.0	33.2	46.8	48.1	49.1	55.1	56.8	57.6	71.0	74.7	76.5		100.4	101.9	102.8	116.4	121.7	124.3	136.3	142.4	147.6
	Curvy	28.7	29.0	29.2	32.1	32.4	32.5	45.8	46.4	46.8	54.8	55.6	55.8	69.6	71.4	72.0		100.6	100.7	100.8	111.9	112.8	113.1	135.0	138.1	139.9
	Very curvy	28.8	28.8	28.8	32.4	32.5	32.5	45.5	45.8	45.9	56.3	56.8	57.2	71.5	72.5	72.9		103.5	103.5	103.5	113.2	113.5	113.5	140.4	142.2	143.5
4	Straight	29.1	29.8	30.0	33.0	33.3	33.3	47.8	48.4	49.0	59.1	59.2	59.3	85.9	85.7	85.6		120.5	119.4	119.1	151.7	150.7	150.3	186.2	186.1	186.1
	Curvy	29.0	29.3	29.3	33.1	33.1	33.1	47.2	47.4	47.6	59.3	59.2	59.2	86.4	86.1	86.1		122.2	121.4	121.4	154.2	153.6	153.6	187.9	187.7	187.7
	Very curvy	29.2	29.1	29.1	33.4	33.3	33.3	47.1	47.1	47.2	60.2	60.1	60.1	87.8	87.6	87.5		124.4	124.0	124.0	157.0	156.4	156.4	190.6	190.5	190.5
6	Straight	29.5	29.6	29.7	34.8	34.5	34.5	50.0	50.1	50.1	66.3	66.2	66.1	106.7	106.3	106.3		140.6	140.0	140.0	196.6	195.4	195.4	237.3	236.8	236.6
	Curvy	29.5	29.5	29.5	35.0	34.8	34.7	50.0	50.0	50.0	66.7	66.5	66.5	107.1	106.9	106.9		141.2	140.6	140.6	197.0	197.0	197.0	239.6	239.1	238.9
	Very curvy	29.7	29.6	29.6	35.4	35.2	35.2	50.3	50.2	50.2	67.5	67.3	67.3	108.6	108.3	108.3		142.6	142.6	142.6	198.6	198.6	198.6	242.3	242.1	242.1
8	Straight	30.6	30.4	30.4	37.4	37.2	37.2	54.2	54.1	54.1	75.5	75.3	75.3	131.4	131.4	131.4		162.3	162.3	162.3	248.9	248.9	248.9	297.0	296.6	296.6
	Curvy	30.7	30.5	30.5	37.7	37.5	37.4	54.4	54.3	54.3	75.8	75.6	75.6	132.0	132.0	132.0		162.3	162.3	162.3	251.5	251.5	251.5	299.3	299.3	298.9
	Very curvy	31.0	30.8	30.8	38.0	37.8	37.8	54.7	54.6	54.6	76.3	76.1	76.1	133.1	133.1	133.1		163.3	163.3	163.3	251.3	251.3	251.3	302.0	302.0	302.0
10	Straight	32.5	32.3	32.3	40.6	40.4	40.4	59.5	59.4	59.4	85.8	85.8	85.8	159.5	159.5	159.5		189.0	189.0	189.0	307.7	307.7	307.7	364.5	364.5	364.5
	Curvy	32.6	32.5	32.4	40.7	40.6	40.5	59.8	59.7	59.7	85.9	85.9	85.9	159.8	159.8	159.8		189.0	189.0	189.0	307.2	307.2	307.2	367.4	367.4	367.4
	Very curvy	32.9	32.7	32.7	41.0	40.8	40.8	60.2	60.1	60.1	86.1	86.1	86.1	160.4	160.4	160.4		189.0	189.0	189.0	306.4	306.4	306.4	370.6	370.6	370.1

Source: ARRB Group Ltd.

Table 30 Fuel consumption (litres per 100 km) for rural (uninterrupted/free flow speed) roads (NIMPAC model speeds)

Roughness = 2 IRI

Vehicle loading = 75% of vehicle payload

% Gradient	Curvature	Medium car			Rigid trucks													Large bus (3 axles)			Articulated truck (6 axle)			B-Double (9 axles)		
					LCV (2 axle 4 tyre)			Light truck (2 axle 6 tyre)			Medium truck (2 axle 6 tyre)			Heavy truck (3 axles)												
		Road width			Road width			Road width			Road width			Road width				Road width			Road width			Road width		
		4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m
Flat	Straight	9.1	10.7	11.1	8.8	9.9	10.3	12.2	13.5	14.4	20.1	22.6	23.7	35.1	39.5	41.6	30.5	34.2	35.9	56.0	62.7	65.8	67.4	75.5	82.1
	Curvy	8.8	9.6	9.8	8.6	9.1	9.2	11.2	11.9	12.3	19.1	20.6	21.0	33.0	35.5	36.2	28.5	29.3	29.8	50.2	51.6	52.0	65.6	70.3	72.8
	Very curvy	8.7	9.0	9.0	8.7	9.0	9.0	10.8	11.2	11.3	20.0	20.9	21.5	34.5	35.8	36.3	29.3	29.6	29.6	49.7	50.3	50.3	70.3	72.9	74.7
4	Straight	9.2	10.6	10.9	9.3	10.0	10.1	12.2	13.0	13.6	22.5	23.1	23.4	44.6	44.8	45.0	41.6	41.4	41.3	74.2	74.1	74.0	105.3	106.2	106.9
	Curvy	9.0	9.7	9.8	9.2	9.5	9.5	11.5	11.9	12.1	22.2	22.5	22.6	44.5	44.6	44.6	42.0	41.8	41.8	75.1	75.0	75.0	105.4	106.0	106.3
	Very curvy	8.8	9.1	9.1	9.4	9.5	9.5	11.2	11.4	11.5	22.5	22.8	22.8	45.1	45.2	45.2	42.7	42.6	42.6	76.1	76.0	76.0	106.6	107.0	107.3
6	Straight	9.2	9.8	9.9	10.6	10.6	10.6	13.1	13.3	13.4	27.5	27.6	27.6	58.0	57.9	57.9	55.3	55.1	55.1	102.4	102.0	102.0	141.4	141.6	141.7
	Curvy	9.1	9.5	9.5	10.6	10.6	10.6	12.9	13.0	13.1	27.4	27.5	27.6	58.1	58.0	58.0	55.5	55.3	55.3	102.4	102.4	102.4	142.1	142.4	142.5
	Very curvy	9.1	9.3	9.3	10.9	10.8	10.8	12.9	13.0	13.0	27.7	27.8	27.8	58.6	58.6	58.6	55.9	55.9	55.9	102.8	102.8	102.8	143.7	143.9	143.9
8	Straight	9.7	9.8	9.8	12.4	12.3	12.3	15.0	15.0	15.0	33.5	33.5	33.5	72.6	72.6	72.6	69.3	69.3	69.3	132.4	132.4	132.4	180.2	180.2	180.2
	Curvy	9.7	9.7	9.7	12.5	12.4	12.4	15.0	15.0	15.0	33.6	33.6	33.6	72.8	72.8	72.8	69.3	69.3	69.3	133.4	133.4	133.4	180.9	180.9	181.0
	Very curvy	9.7	9.8	9.8	12.7	12.6	12.6	15.2	15.1	15.1	33.7	33.7	33.7	73.1	73.1	73.1	69.6	69.6	69.6	133.6	133.6	133.6	182.0	182.0	182.0
10	Straight	10.7	10.7	10.7	14.5	14.4	14.4	17.5	17.4	17.4	40.0	40.0	40.0	88.0	88.0	88.0	84.7	84.7	84.7	164.1	164.1	164.1	220.9	220.9	220.9
	Curvy	10.8	10.7	10.7	14.5	14.5	14.4	17.5	17.5	17.5	40.0	40.0	40.0	88.0	88.0	88.0	84.7	84.7	84.7	164.3	164.3	164.3	221.5	221.5	221.5
	Very curvy	10.9	10.8	10.8	14.7	14.6	14.6	17.6	17.6	17.6	40.1	40.1	40.1	88.1	88.1	88.1	84.7	84.7	84.7	164.6	164.6	164.6	222.2	222.2	222.4

Source: ARRB Group Ltd.

Table 31 Free speed (km/h) tables for rural (uninterrupted/free flow speed) roads (HDM speeds)

Roughness = 2 IRI

Vehicle loading = 75% of vehicle payload

% Gradient	Curvature	Medium car			Rigid trucks													Large bus (3 axles)			Articulated truck (6 axle)			B-Double (9 axles)		
					LCV (2 axle 4 tyre)			Light truck (2 axle 6 tyre)			Medium truck (2 axle 6 tyre)			Heavy truck (3 axles)												
		Road width			Road width			Road width			Road width			Road width				Road width			Road width			Road width		
		4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m		4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m
Flat	Straight	97	108	112	104	104	104	83	87	87	82	91	100	70	80	89		71	81	92	82	91	97	82	90	96
	Curvy	93	100	102	98	98	98	79	82	82	79	85	91	70	78	84		70	79	86	75	78	79	75	78	79
	Very curvy	80	82	82	81	81	81	71	72	73	72	75	77	66	69	71		66	70	71	62	62	62	62	62	62
4	Straight	95	104	107	93	93	93	73	75	75	72	76	81	58	61	64		63	67	71	56	59	60	49	51	53
	Curvy	91	97	99	89	89	89	70	72	72	71	74	77	57	60	62		63	66	69	55	55	56	48	48	48
	Very curvy	79	81	81	78	78	78	65	66	66	66	68	69	56	57	58		61	62	63	51	51	51	45	45	45
6	Straight	93	100	103	84	84	84	65	67	67	63	66	68	48	50	52		53	56	58	45	47	48	38	40	40
	Curvy	90	95	96	81	81	81	63	64	65	62	64	66	48	50	51		53	55	57	44	45	45	38	38	38
	Very curvy	79	80	81	73	73	73	60	60	60	59	61	61	47	48	48		52	53	53	42	42	42	36	36	36
8	Straight	89	95	98	75	75	75	58	59	59	55	58	60	41	42	44		45	47	49	38	39	40	31	32	33
	Curvy	87	91	92	73	73	73	57	57	57	55	56	58	41	42	43		45	47	48	37	37	37	31	31	31
	Very curvy	77	79	79	67	67	67	54	54	54	53	54	54	40	41	41		44	45	46	35	35	35	30	30	30
10	Straight	85	90	92	67	67	67	54	55	56	49	51	53	35	36	37		40	41	42	32	33	34	27	27	28
	Curvy	83	87	88	66	66	66	52	53	53	48	50	51	35	36	37		39	41	42	32	32	32	26	26	26
	Very curvy	75	76	77	61	61	61	49	50	50	47	47	48	35	35	35		39	39	40	30	30	30	25	25	25

Source: ARRB Group Ltd.

Table 32 Vehicle operating cost (cents per km) for rural (uninterrupted/free flow speed) roads, June $2013 (HDM speeds)

Roughness = 2 IRI

Vehicle loading = 75% of vehicle payload

% Gradient	Curvature	Medium car			Rigid trucks													Large bus (3 axles)			Articulated truck (6 axle)			B-Double (9 axles)		
					LCV (2 axle 4 tyre)			Light truck (2 axle 6 tyre)			Medium truck (2 axle 6 tyre)			Heavy truck (3 axles)												
		Road width			Road width			Road width			Road width			Road width				Road width			Road width			Road width		
		4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m		4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m
Flat	Straight	29.6	30.5	30.9	34.9	34.9	34.9	48.2	48.8	48.9	55.7	57.1	58.9	69.5	71.8	74.9		102.1	102.8	104.4	116.6	120.7	124.0	138.0	141.9	145.0
	Curvy	29.5	30.0	30.2	34.6	34.6	34.6	47.8	48.1	48.2	56.0	57.2	58.5	70.1	72.5	75.0		102.8	103.8	105.2	116.0	117.2	117.7	138.1	139.5	140.0
	Very curvy	29.4	29.4	29.5	34.2	34.2	34.2	47.4	47.6	47.7	58.2	59.2	59.8	73.5	75.4	76.3		106.7	107.9	108.5	117.6	117.8	117.8	141.9	142.1	142.2
4	Straight	29.8	30.4	30.7	34.5	34.5	34.5	48.3	48.7	48.8	59.4	59.1	59.0	88.4	87.4	86.6		119.3	118.1	117.2	148.7	147.7	147.0	193.1	191.8	190.7
	Curvy	29.7	30.1	30.2	34.4	34.4	34.4	48.1	48.3	48.3	59.6	59.4	59.2	88.5	87.6	87.1		119.5	118.5	117.8	149.6	149.2	149.1	194.1	193.7	193.6
	Very curvy	29.6	29.7	29.7	34.5	34.5	34.5	48.1	48.2	48.2	60.7	60.7	60.6	89.5	89.1	88.9		121.1	120.6	120.4	152.0	152.0	152.0	196.5	196.4	196.4
6	Straight	30.0	30.5	30.7	34.9	34.9	34.9	50.3	50.2	50.2	66.6	66.2	65.9	109.1	108.0	106.8		136.6	135.3	134.2	186.8	185.3	184.0	250.0	248.4	246.9
	Curvy	30.0	30.3	30.4	34.9	34.9	34.9	50.5	50.4	50.4	66.8	66.5	66.3	109.2	108.2	107.4		136.7	135.6	134.9	187.9	187.5	187.3	251.1	250.7	250.5
	Very curvy	30.0	30.1	30.1	35.5	35.5	35.5	50.9	50.8	50.8	67.6	67.4	67.3	109.8	109.4	109.2		137.5	137.0	136.8	190.2	190.2	190.2	253.6	253.5	253.5
8	Straight	30.5	30.8	30.9	36.9	36.9	36.9	54.4	54.3	54.2	74.8	74.2	73.6	133.4	132.1	130.7		156.0	154.7	153.5	230.5	228.7	226.9	311.2	309.3	307.5
	Curvy	30.5	30.7	30.7	37.1	37.1	37.1	54.6	54.5	54.5	74.9	74.5	74.2	133.5	132.4	131.5		156.1	155.0	154.2	231.7	231.2	231.0	312.5	312.0	311.8
	Very curvy	30.6	30.7	30.7	37.7	37.7	37.7	55.1	55.0	55.0	75.5	75.3	75.2	134.1	133.6	133.4		156.8	156.3	156.1	234.3	234.2	234.2	315.3	315.2	315.2
10	Straight	31.5	31.3	31.4	39.5	39.5	39.5	58.7	58.2	58.1	83.8	83.2	82.5	160.2	158.7	157.1		177.2	175.8	174.5	277.2	275.1	273.0	380.7	378.5	376.3
	Curvy	31.6	31.5	31.5	39.6	39.6	39.6	59.2	59.0	58.9	83.9	83.5	83.1	160.3	159.0	157.9		177.3	176.1	175.2	278.7	278.1	277.9	382.2	381.7	381.4
	Very curvy	32.0	32.0	32.0	40.1	40.1	40.1	60.0	59.9	59.8	84.5	84.3	84.1	160.9	160.4	160.1		177.9	177.4	177.1	281.5	281.4	281.4	385.2	385.2	385.1

Source: ARRB Group Ltd.

Table 33 Fuel consumption (litres per 100 km) for rural (uninterrupted/free flow speed) roads (HDM speeds)

Roughness = 2 IRI

Vehicle loading = 75% of vehicle payload

% Gradient	Curvature	Medium car			Rigid trucks													Large bus (3 axles)			Articulated truck (6 axle)			B-Double (9 axles)		
					LCV (2 axle 4 tyre)			Light truck (2 axle 6 tyre)			Medium truck (2 axle 6 tyre)			Heavy truck (3 axles)												
		Road width			Road width			Road width			Road width			Road width				Road width			Road width			Road width		
		4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m	4.5m	5.8m	8.5m
Flat	Straight	10.0	10.9	11.4	11.1	11.1	11.1	12.6	13.1	13.2	19.7	21.5	23.7	30.9	33.7	37.2	27.2	29.2	31.9	52.7	57.3	61.0	64.8	69.5	73.1
	Curvy	9.8	10.4	10.6	10.8	10.8	10.8	12.2	12.5	12.6	19.8	21.4	22.9	31.4	34.3	37.2	27.8	30.0	32.2	51.3	52.9	53.4	64.2	65.9	66.6
	Very curvy	9.3	9.4	9.5	10.2	10.2	10.2	11.8	12.0	12.1	21.6	22.8	23.6	34.6	36.8	37.9	31.1	32.9	33.8	51.2	51.5	51.6	65.9	66.2	66.3
4	Straight	10.0	10.7	11.1	10.5	10.5	10.5	11.9	12.3	12.4	22.0	22.0	22.2	44.3	43.9	43.6	41.0	40.7	40.4	73.8	73.5	73.3	103.0	102.7	102.5
	Curvy	9.8	10.3	10.5	10.3	10.3	10.3	11.5	11.8	11.8	22.0	22.1	22.1	44.3	44.0	43.8	41.2	40.9	40.7	74.0	73.9	73.9	103.3	103.2	103.1
	Very curvy	9.4	9.5	9.6	10.1	10.1	10.1	11.4	11.5	11.5	22.8	22.9	23.0	45.1	44.9	44.9	42.3	42.3	42.3	75.1	75.1	75.1	104.1	104.1	104.1
6	Straight	10.0	10.6	10.9	10.4	10.5	10.5	12.6	12.5	12.5	27.5	27.5	27.4	58.0	57.6	57.3	53.5	53.1	52.8	98.9	98.6	98.3	140.7	140.4	140.1
	Curvy	9.9	10.3	10.4	10.4	10.4	10.4	12.6	12.6	12.6	27.6	27.5	27.5	58.0	57.7	57.5	53.5	53.2	53.0	99.1	99.0	99.0	140.9	140.8	140.8
	Very curvy	9.6	9.7	9.8	10.8	10.8	10.8	12.8	12.8	12.8	28.0	28.0	28.0	58.3	58.1	58.1	54.0	53.9	53.8	99.8	99.8	99.8	141.5	141.5	141.5
8	Straight	10.2	10.6	10.8	11.9	11.9	11.9	14.8	14.7	14.7	33.5	33.4	33.3	72.5	72.1	71.8	66.7	66.3	66.0	124.9	124.6	124.3	180.6	180.3	180.0
	Curvy	10.1	10.4	10.5	12.0	12.0	12.0	14.8	14.8	14.8	33.5	33.4	33.4	72.5	72.2	71.9	66.7	66.4	66.1	125.1	125.0	125.0	180.8	180.7	180.7
	Very curvy	9.9	10.0	10.0	12.3	12.3	12.3	15.0	15.0	15.0	33.7	33.7	33.7	72.7	72.5	72.4	66.9	66.8	66.7	125.7	125.7	125.7	181.4	181.4	181.4
10	Straight	10.8	10.8	10.9	13.7	13.7	13.7	17.0	17.0	16.9	39.6	39.5	39.4	87.2	86.8	86.5	80.1	79.7	79.4	152.0	151.7	151.5	222.0	221.7	221.5
	Curvy	10.9	10.9	10.8	13.7	13.7	13.7	17.1	17.1	17.1	39.7	39.6	39.5	87.2	86.9	86.7	80.1	79.8	79.6	152.3	152.2	152.1	222.3	222.2	222.2
	Very curvy	11.0	11.0	11.0	14.0	14.0	14.0	17.3	17.2	17.2	39.8	39.8	39.7	87.4	87.2	87.2	80.3	80.2	80.1	152.9	152.9	152.8	222.9	222.9	222.9

Source: ARRB Group Ltd.

5.4 Interrupted flow VOC models

5.4.1 Basis of interrupted flow VOC models

The approach adopted for interrupted flow VOC models was similar to that used for uninterrupted flow. This involved the development of a suite of models for application to interrupted flow conditions, as experienced on urban and sub-urban arterials and freeways depending on variables such as time of day, traffic capacity and intersection types. However, the scope of operating conditions was considered to be more limited although the underpinning basis and potential were the same.

The model development has involved the reconstruction of the models reported by Cox and Arup (1996) and in Austroads (2004), with a simplified vehicle operating cost model and fuel consumption model produced for typical operating conditions, and for a 20 vehicle fleet.

The development of the models adapted the outputs from the uninterrupted flow analysis by modifying the estimates for the different VOC component, as follows:

- Fuel and lubricating oil consumption, through application of a multiplication factor based on average travel speed
  - Cars and light commercial vehicles
    $F_{F\&LCL} = 1.9*(1 – 0.004*Speed)$
  - Medium and heavy commercial vehicles and buses
    $F_{F\&LHV} = 2.5*(1 – 0.004*Speed)$
- Repairs and maintenance costs, and tyre consumption, through application of a multiplication factor which varies by vehicle type (Table 34), with the full factor applied at 30 km/h and a greater or lesser factor applied at lower and higher speeds with zero additional effect (factor of 1) at a user defined upper value (selected as 100 km/h)
- Capital and interest, by accounting for reduced utilisation in lower journey speed environments and therefore higher per km costs through application of a multiplication factor
  - $F_{C\&I} = 60/Speed$ (in km/h).

Table 34 Multiplication factor for maintenance labour and spare parts and tyre consumption estimates under interrupted flow

Vehicle type	Factor
Cars and light commercial vehicles	1.25
Rigid trucks	1.4
Articulated trucks and buses	1.6

5.4.2 Model structure and coefficients

The form of the interrupted flow VOC models as in Austroads (2004) are as follows:

Stop-start model: c=A+B/V

Free-flow model: $c = C_0 + C_1 V + C_2 V^2$

where:

A, B, C_0, C_1, C_2 = model coefficients

c = Vehicle operating cost (cents/km)

V = Average travel speed in km/h.

As was the case of Austroads (2004), the stop-start model can be used for estimating the VOC on urban and sub-urban arterial roads, or freeways, at average journey speeds of < 60 km/h, while the free-flow model is aimed at estimating VOC where average journey speeds are > 60 km/h. The choice to switch from between models should be based on the judgement of the user, taking account of such factors as the level of vehicle interaction, evidence of significant speed-change cycles, and stop-start operation.

The VOC coefficients for the models have been re-estimated using 2013 unit values by adapting the outputs from the uninterrupted flow models as described earlier. In this case, however. a single set of operating conditions in terms of road geometry, road width and gross vehicle mass were considered and applied for all 20 vehicles[13]. The resulting coefficients are presented in Table 35.

Table 35 VOC model coefficients for stop-start and free-flow models (cents per km), $2013

Vehicle type	Stop-start		Free-flow		
	A	B	C_0	C_1	C_2
01. Small Car	12.5242	838.2969	25.7952	-0.1253	0.0010
02. Medium Car	12.6514	1315.5178	35.0470	-0.1751	0.0012
03. Large Car	14.4297	1838.4754	46.1765	-0.2221	0.0014
04. Courier Van-Utility	15.9354	1357.1233	38.4920	-0.1840	0.0014
05. 4WD Mid-Size Petrol	21.0481	1328.7944	40.5580	-0.1540	0.0013
06. Light Rigid	33.9697	1543.5546	51.5092	-0.2481	0.0025
07. Medium Rigid	35.8038	2259.9048	62.6793	-0.3002	0.0026

[13] The extension of the number of vehicle categories from the limited number in Austroads (2004) to the 20 vehicle classification in the ATAP highlights the importance of what is assumed to be a representative vehicle in a particular category where a limited number of vehicle types is used. These differences are reflected in the coefficients in the model over time.

Vehicle type	Stop-start		Free-flow		
	A	B	C_0	C_1	C_2
08. Heavy Rigid	57.1600	2556.0769	82.2900	-0.5525	0.0053
09. Heavy Bus	64.5569	4632.1535	124.7014	-0.6467	0.0047
10. Artic 4 Axle	84.5711	3323.0102	111.6621	-0.7240	0.0072
11. Artic 5 Axle	91.1303	3688.6095	119.8994	-0.6800	0.0066
12. Artic 6 Axle	98.6903	3991.2764	128.6879	-0.6878	0.0066
13. Rigid + 5 Axle Dog	122.5511	3729.8458	136.1620	-0.6403	0.0065
14. B-Double	122.9920	4592.1836	151.4716	-0.7228	0.0068
15. Twin steer + 5 Axle Dog	127.1973	4379.9716	149.9310	-0.6911	0.0067
16. A-Double	143.9930	5692.0036	183.5354	-0.8330	0.0074
17. B Triple	149.4138	7134.4573	214.1429	-0.9878	0.0081
18. A B Combination	170.3213	6257.8473	208.7075	-0.9017	0.0080
19. A-Triple	190.6482	7134.9278	237.0682	-1.0131	0.0086
20. Double B-Double	199.5704	6976.3148	238.7248	-0.9882	0.0086

The fuel consumption coefficients for the same range of conditions are presented in Table 36.

Table 36 Fuel consumption coefficients for coefficients for stop-start and free-flow models, (litres per 100km) $2013

Vehicle type	Stop-start		Free-flow		
	A	**B**	**C_0**	**C_1**	**C_2**
01. Small Car	7.9302	117.1284	7.9340	-0.0636	0.0007
02. Medium Car	8.8017	179.6890	9.8014	-0.0785	0.0008
03. Large Car	10.4870	255.0092	12.3217	-0.0914	0.0009
04. Courier Van-Utility	8.0758	226.1850	10.8957	-0.1125	0.0011
05. 4WD Mid-Size Petrol	11.5401	246.2530	12.4016	-0.0832	0.0009
06. Light Rigid	16.0634	147.3128	10.8435	-0.1123	0.0016
07. Medium Rigid	28.5369	158.8351	16.3326	-0.1075	0.0018
08. Heavy Rigid	45.5089	535.1584	32.0378	-0.2949	0.0040
09. Heavy Bus	38.3297	661.0688	30.2018	-0.2507	0.0029
10. Artic 4 Axle	63.9608	458.9412	40.1353	-0.3541	0.0053
11. Artic 5 Axle	68.7011	507.3099	42.3944	-0.3260	0.0049
12. Artic 6 Axle	75.4028	547.8857	45.8457	-0.3168	0.0049
13. Rigid + 5 Axle Dog	90.1180	616.4443	53.6148	-0.3176	0.0050
14. B-Double	96.3563	651.9121	56.8966	-0.3128	0.0050
15. TS + 5 Axle Dog	96.5790	659.1193	57.0718	-0.3104	0.0050
16. A-Double	112.0411	723.6597	65.1119	-0.3119	0.0051
17. B Triple	117.0878	745.8925	67.7203	-0.3110	0.0052

Vehicle type	Stop-start		Free-flow		
	A	**B**	**C_0**	**C_1**	**C_2**
18. A B Combination	131.0548	798.2622	74.8085	-0.3105	0.0053
19. A-Triple	145.7190	855.7539	82.2758	-0.3084	0.0055
20. Double B-Double	150.8098	877.3157	84.8826	-0.3070	0.0055

6. Indexation of parameter values

This chapter provides guidance on the indexation of parameter values across all components until a new set of parameter values is released. In all cases, the indices should be applied to the monetary values generated in the document.

This is especially the case with VOCs (cents per km) where the indices should be used to update the total VOC values generated by the models estimated in this report and not applied to the coefficients themselves.

The recommended ABS indices, data series and source databases per component of the parameter values are contained in Table 37.

Table 37 Recommended indices for updating of parameter values

Parameter value component	Recommended ABS index	ABS Series ID, Frequency & ABS Source Database
Fuel	CPI Automotive fuels	A2328636K (monthly) (1)
Oil	CPI Spare parts & accessories	A2328726R (monthly) (1)
Tyres	CPI Spare parts & accessories	A2328726R (monthly) (1)
Repairs & maintenance	CPI Spare parts & accessories CPI Maintenance & repairs of vehicles PPI Road Freight PPI Auto parts	A2328726R (monthly) (1) A2328771A (monthly) (1) A2314058K (monthly) (2)
New vehicles	Passenger vehicles: CPI motor vehicles Commercial vehicles: PPI Road freight PPI Motor vehicles PPI Vehicle body & trailer	 A2328591T (monthly) (1) A2314058K (monthly) (2) A2308487V (monthly) (3) A2305913V (monthly) (3)
Travel time	Average weekly earnings, adjusted by: CPI (all groups) if NA GDP per capita (adjusted by CPI to real terms)	A2772123T (bi-annually: May & Nov) (4) A2325846C (1) A2304887J (5)
Crash costs	CPI (all groups) or GDP per capita[14] CPI Medical, dental & hospital services	A2325846C (monthly) (1) A3604388C (monthly) (1)
VOC models	Passenger cars: CPI private motoring Commercial vehicles: PPI Road freight	A2326656J (monthly) (1) A2314058K (monthly) (2)

Source: ARRB adapted from ABS

Notes:

[14] Methodology as outlined in Austroads (2013a).

1. *ABS Series 6401.0 Consumer Price Index, Australia: Table 7: CPI: Group, Sub-group and Expenditure Class, Weighted Average of Eight Capital Cities.*
2. *ABS Series 6427.0 Producer Price Indexes, Australia: Table 21: Output of the Transport, postal and warehousing industries, group and class index numbers.*
3. *ABS Series 6427.0 Producer Price Indexes, Australia. Table 12: Output of the Manufacturing industries, division, subdivision, group and class index numbers.*
4. *ABS Series 6302.0 Average Weekly Earnings, Australia: Table 2: Average Weekly Earnings, Australia (Dollars) - Seasonally Adjusted.*
5. *5206.0 Australian National Accounts: National Income, Expenditure and Product. . Table 30: Key Aggregates and analytical series, Annual.*

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Appendix A Fuel price data by jurisdiction and local area

Table 38 Regional variations in petrol and diesel prices – market and resource prices at 30 June 2013

State/regional centre	Automotive fuel type									
	ULP		PULP		Diesel		LPG		Ethanol	
	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)
ACT										
Canberra	146.40	94.9	159.20	106.6	147.30	95.8	78.7	59.0	144.5	93.2
New South Wales										
Sydney Metro	145.6	94.2	157.5	105.0	147.6	96.0	64.7	46.3	143.4	92.2
Albury	143.5	92.3	159.0	106.4	148.1	96.5	69.6	50.8	141.4	90.4
Armidale	154.2	102.0	168.1	114.7	154.0	101.9	84.5	64.3	153.9	101.8
Batemans Bay	na	na	168.9	115.4	159.6	106.9	81.9	62.0	155.9	103.6
Bathurst	147.0	95.5	159.3	106.7	149.4	97.7	74.5	55.2	145.1	93.8
Bega	155.0	102.8	168.1	114.7	156.6	104.2	88.3	67.8	152.6	100.6
Broken Hill	150.2	98.4	164.3	111.2	153.5	101.4	83.5	63.4	na	na
Canberra	146.4	94.9	159.2	106.6	147.3	95.8	78.7	59.0	144.5	93.2
Casino	148.3	96.7	160.2	107.5	148.7	97.0	81.0	61.1	146.0	94.6
Coffs Harbour	151.7	99.8	164.2	111.1	153.3	101.2	82.0	62.0	150.1	98.3
Cooma	153.1	101.0	163.4	110.4	159.2	106.6	89.1	68.5	149.5	97.8
Coonabarabran	155.9	103.6	165.9	112.7	160.8	108.0	88.9	68.3	153.9	101.8
Cowra	143.9	92.7	156.2	103.9	150.7	98.9	89.9	69.2	142.9	91.8
Dubbo	149.0	97.3	161.4	108.6	150.2	98.4	80.1	60.3	147.5	95.9
Forbes	149.6	97.9	160.9	108.1	148.2	96.6	90.4	69.7	145.5	94.1
Forster	150.9	99.0	163.6	110.6	155.9	103.6	79.8	60.0	148.9	97.2
Glen Innes	150.1	98.3	161.4	108.6	150.9	99.0	81.3	61.4	146.9	95.4
Goulburn	147.4	95.9	158.9	106.3	151.9	99.9	79.6	59.9	145.5	94.1
Grafton	149.7	97.9	159.9	107.2	151.4	99.5	84.8	64.6	147.5	95.9
Griffith	148.7	97.0	161.4	108.6	149.6	97.9	86.9	66.5	146.5	95.0
Hay	149.0	97.3	160.3	107.6	149.1	97.4	78.9	59.2	na	na
Inverell	150.0	98.2	160.9	108.1	151.6	99.7	89.9	69.2	147.9	96.3

State/regional centre	Automotive fuel type									
	ULP		PULP		Diesel		LPG		Ethanol	
	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)
Kempsey	148.4	96.8	159.5	106.9	148.7	97.0	80.1	60.3	144.4	93.1
Lismore	145.9	94.5	158.1	105.6	150.5	98.7	81.9	62.0	144.6	93.3
Maitland	147.5	95.9	159.7	107.0	147.9	96.3	77.9	58.3	146.1	94.7
Moree	153.9	101.8	164.4	111.3	151.3	99.4	97.4	76.0	149.0	97.3
Narrabri	153.6	101.5	163.7	110.7	154.9	102.7	89.4	68.8	150.5	98.7
Newcastle	148.0	96.4	158.5	105.9	148.4	96.8	78.0	58.4	143.5	92.3
Oberon	152.3	100.3	na	na	154.3	102.1	na	na	na	na
Orange	149.5	97.8	159.2	106.6	150.1	98.3	87.7	67.2	141.2	90.2
Parkes	149.9	98.1	160.9	108.1	150.1	98.3	89.4	68.8	147.9	96.3
Port Macquarie	153.6	101.5	166.2	112.9	156.5	104.1	85.8	65.5	151.9	99.9
Tamworth	152.9	100.9	163.6	110.6	155.7	103.4	82.4	62.4	149.1	97.4
Taree	154.6	102.4	166.2	112.9	148.9	97.2	77.2	57.7	151.6	99.7
Ulladulla	152.4	100.4	163.9	110.9	153.4	101.3	85.9	65.6	149.9	98.1
Wagga Wagga	152.9	100.9	165.4	112.2	149.7	97.9	79.3	59.6	150.9	99.0
Wollongong	148.2	96.6	160.3	107.6	148.2	96.6	73.9	54.7	146.8	95.3
Yass	152.2	100.2	161.5	108.7	148.5	96.9	69.7	50.9	147.1	95.6
Victoria										
Melbourne Metro	144.8	93.5	156.2	103.9	144.6	93.3	57.9	40.1	138.9	88.1
Ararat	139.3	88.5	152.9	100.9	146.1	94.7	61.9	43.8	na	na
Bairnsdale	141.8	90.8	151.4	99.5	142.6	91.5	70.5	51.6	na	na
Ballarat	138.1	87.4	147.8	96.2	147.6	96.0	60.1	42.1	136.3	85.8
Benalla	150.0	98.2	161.9	109.0	151.7	99.8	78.9	59.2	na	na
Bendigo	139.6	88.8	156.8	104.4	148.8	97.1	63.9	45.6	na	na
Colac	146.5	95.0	156.6	104.2	149.5	97.8	72.9	53.8	na	na
Echuca	142.6	91.5	156.5	104.1	144.4	93.1	68.8	50.0	na	na
Geelong	144.3	93.0	158.5	105.9	146.6	95.1	58.9	41.0	na	na
Horsham	146.2	94.8	159.2	106.6	147.7	96.1	75.5	56.1	na	na
Lakes Entrance	151.0	99.1	159.8	107.1	147.5	95.9	79.7	60.0	na	na
Mansfield	150.3	98.5	163.3	110.3	151.2	99.3	82.9	62.9	na	na
Mildura	147.9	96.3	162.6	109.7	148.9	97.2	76.8	57.3	na	na

State/regional centre	Automotive fuel type									
	ULP		PULP		Diesel		LPG		Ethanol	
	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)
Orbost	152.8	100.8	159.1	na	152.4	100.4	na	na	na	na
Portland	147.5	95.9	154.7	102.5	147.1	95.6	75.8	56.4	na	na
Sale	148.9	97.2	161.5	108.7	149.8	98.0	77.4	57.9	na	na
Shepparton	146.6	95.1	159.3	106.7	145.8	94.4	67.2	48.6	na	na
Sunbury	144.6	93.3	155.9	103.6	143.0	91.9	57.5	39.8	na	na
Swan Hill	150.4	98.6	164.4	111.3	150.5	98.7	75.9	56.5	na	na
Traralgon	150.4	98.6	161.0	108.2	148.3	96.7	77.8	58.2	na	na
Wangaratta	149.0	97.3	162.5	109.6	147.6	96.0	69.8	51.0	na	na
Warrnambool	145.4	94.0	156.8	104.4	147.3	95.8	68.3	49.6	na	na
Wodonga	145.2	93.9	159.9	107.2	148.0	96.4	71.3	52.3	na	na
Wonthaggi	149.8	98.0	163.2	110.2	149.9	98.1	74.4	55.1	na	na
Yarrawonga	153.7	101.6	166.6	113.3	148.6	96.9	82.4	62.4	na	na
Queensland										
Brisbane Metro	149.4	97.7	161.8	108.9	148.5	96.9	64.7	46.3	147.6	96.0
Bowen	151.5	99.6	164.2	111.1	148.2	96.6	89.9	69.2	148.0	96.4
Bundaberg	150.3	98.5	162.0	109.1	150.4	98.6	85.1	64.9	148.0	96.4
Caboolture	150.9	99.0	163.2	110.2	148.6	96.9	na	na	150.1	98.3
Cairns	154.9	102.7	167.2	113.9	156.1	103.8	na	na	152.9	100.9
Caloundra	147.6	96.0	159.7	107.0	147.4	95.9	63.2	45.0	141.4	90.4
Charleville	154.0	101.9	163.9	110.9	153.9	101.8	na	na	na	na
Charters Towers	152.1	100.1	166.0	112.8	149.5	97.8	87.9	67.4	149.1	97.4
Cloncurry	170.1	116.5	180.4	125.9	170.7	117.0	99.9	78.3	na	na
Cunnamulla	156.1	103.8	170.8	117.1	159.3	106.7	na	na	na	na
Dalby	149.1	97.4	160.9	108.1	147.1	95.6	86.9	66.5	146.4	94.9
Emerald	150.6	98.8	162.6	109.7	152.6	100.6	91.1	70.3	148.0	96.4
Gladstone	148.9	97.2	160.8	108.0	150.6	98.8	89.9	69.2	148.7	97.0
Gold Coast	147.9	96.3	159.8	107.1	148.8	97.1	66.2	47.7	145.8	94.4
Goondiwindi	151.6	99.7	165.0	111.9	148.8	97.1	83.9	63.8	na	na
Gympie	148.7	97.0	158.0	105.5	146.4	94.9	na	na	147.0	95.5
Hervey Bay	148.1	96.5	158.9	106.3	150.2	98.4	85.7	65.4	144.7	93.4

State/regional centre	Automotive fuel type									
	ULP		PULP		Diesel		LPG		Ethanol	
	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)
Ipswich	146.9	95.4	159.4	106.8	149.0	97.3	na	na	146.7	95.2
Kingaroy	148.0	96.4	160.8	108.0	148.4	96.8	82.0	62.0	145.4	94.0
Longreach	157.0	104.6	166.8	113.5	156.3	103.9	89.6	69.0	na	na
Mackay	148.4	96.8	161.9	109.0	151.7	99.8	109.9	87.4	146.1	94.7
Maryborough	148.1	96.5	159.6	106.9	147.8	96.2	79.9	60.1	147.3	95.8
Mt Isa	157.6	105.1	167.2	113.9	158.0	105.5	na	na	na	na
Normanton	171.4	117.7	Na	na	173.2	119.3	99.9	78.3	na	na
North Coast	147.1	95.6	158.9	106.3	148.4	96.8	73.7	54.5	145.7	94.3
Rockhampton	150.5	98.7	161.5	108.7	150.3	98.5	97.1	75.8	150.9	99.0
Roma	151.6	99.7	163.9	110.9	150.2	98.4	98.3	76.9	150.2	98.4
Toowoomba	140.7	89.8	152.8	100.8	148.1	96.5	69.2	50.4	137.6	86.9
Townsville	148.3	96.7	161.1	108.3	146.9	95.4	92.9	72.0	145.9	94.5
Warwick	143.1	91.9	156.1	103.8	147.0	95.5	76.7	57.2	134.2	83.9
South Australia										
Adelaide Metro	144.9	93.6	156.6	104.2	147.8	96.2	68.0	49.3	148.0	96.4
Ceduna	153.7	101.6	169.6	116.0	153.6	101.5	84.6	64.4	148.0	96.4
Coober Pedy	166.1	112.9	179.3	124.9	167.6	114.2	108.8	86.4	150.1	98.3
Mt Gambier	147.7	96.1	160.1	107.4	150.8	98.9	75.7	56.3	152.9	100.9
Murray Bridge	145.1	93.8	156.3	103.9	149.1	97.4	70.0	51.1	141.4	90.4
Port Augusta	145.8	94.4	158.6	106.0	147.2	95.7	83.9	63.8	na	na
Port Lincoln	149.1	97.4	161.5	108.7	150.9	99.0	80.9	61.0	149.1	97.4
Port Pirie	146.7	95.2	159.9	107.2	148.9	97.2	77.2	57.7	na	na
Renmark	145.2	93.9	157.7	105.2	144.2	92.9	80.5	60.7	na	na
Victor Harbour	143.3	92.1	156.8	104.4	147.5	95.9	66.9	48.3	146.4	94.9
Whyalla	150.1	98.3	162.2	109.3	152.6	100.6	78.7	59.0	148.0	96.4
Western Australia										
Perth Metro	147.0	95.5	159.6	106.9	147.7	96.1	69.3	50.5	na	na
Albany	149.7	97.9	160.2	107.5	150.4	98.6	91.6	70.8	na	na
Bunbury	149.0	97.3	161.1	108.3	150.9	99.0	74.7	55.4	na	na

State/regional centre	Automotive fuel type									
	ULP		PULP		Diesel		LPG		Ethanol	
	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)	Market price (c/l)	Resource price (c/l)
Carnarvon	163.3	110.3	174.3	120.3	165.3	112.1	104.9	82.9	na	na
Eucla	172.6	118.8	177.4	123.1	159.3	106.7	na	na	na	na
Kalgoorlie	151.2	99.3	162.5	109.6	153.0	100.9	102.8	81.0	na	na
Mandurah	147.1	95.6	159.2	106.6	148.0	96.4	67.3	48.7	142.7	91.6
Tasmania										
Hobart	151.3	99.4	165.9	112.7	152.5	100.5	88.9	68.3	na	na
Burnie	152.2	100.2	163.0	110.0	152.7	100.7	90.2	69.5	na	na
Campbelltown	155.8	103.5	168.0	114.6	157.7	105.2	na	na	na	na
Devonport	152.7	100.7	165.3	112.1	153.8	101.7	91.9	71.0	na	na
Launceston	153.4	101.3	166.0	112.8	153.6	101.5	89.9	69.2	na	na
New Norfolk	153.2	101.1	167.1	113.8	154.8	102.6	89.9	69.2	na	na
Ulverstone	152.4	100.4	162.6	109.7	153.3	101.2	89.9	69.2	na	na
Wynyard	156.6	104.2	164.1	111.0	155.7	103.4	89.9	69.2	na	na
Northern Territory										
Darwin	160.90	108.1	170.50	116.9	161.50	108.7	105.9	83.8	na	na
Alice Springs	170.80	117.1	183.40	128.6	172.40	118.6	na	na	na	na
Katherine	156.90	104.5	166.80	113.5	160.20	107.5	109.9	87.4	na	na
Tennant Creek	167.20	113.9	Na	na	169.50	115.9	na	na	na	na

Appendix B Emission conversion factors

This Appendix provides representative emission factors for the Australian vehicle fleet for average driving conditions. It shows a series of conversion factors from fuel (litres) to emissions (g/l)) across on-road vehicles for a range of vehicle types and age classifications from pre-1976 to the portion of the vehicle fleet manufactured from 2008 to 2014.

These figures have been calculated by BITRE and are based on averaging results of various models (with varying input parameter settings, such as for congestion effects or annual vehicle deterioration rates) across BITRE MVEm (which includes calibrations using NISE1 and NISE2 data, such as reported by FORS and Orbital Australia) and COPERT for Australia (www.emisia.com/content/copert-australia), and have been compared with summary results reported in NGGIC 2006 and the National Inventory Report 2012 (Department of the Environment, 2014).

Table 39 Conversion ratios fuel (l) to emissions (g/l)

Vehicle type		CO_2 Carbon dioxide	CH_4 Methane	N_20 Nitrous oxide	NO_X Nitrogen oxide	CO Carbon monoxide	NMVOC Non–methane volatile organic compounds	SO_X Sulphur oxide	PM_{10} Particulate matter
Passenger cars									
Petrol	Post-08	2282.0	0.33	0.069	0.77	9.3	3.28	0.172	0.012
	06-08	2282.0	0.43	0.081	1.14	23.5	3.72	0.172	0.018
	04-05	2282.0	0.50	0.112	1.98	38.8	4.72	0.172	0.025
	98-03	2282.0	0.90	0.273	6.42	57.3	6.76	0.172	0.048
	86-97	2282.0	1.29	0.284	15.33	109.0	12.94	0.172	0.131
	76-85	2282.0	1.48	0.097	25.12	164.5	27.91	0.172	0.175
	Pre-76	2282.0	1.78	0.070	26.10	259.9	64.91	0.172	0.258

Vehicle type		CO_2 Carbon dioxide	CH_4 Methane	N_20 Nitrous oxide	NO_X Nitrogen oxide	CO Carbon monoxide	NMVOC Non–methane volatile organic compounds	SO_X Sulphur oxide	PM_{10} Particulate matter
LPG	Post-08	1561.5	0.29	0.050	0.96	8.3	0.95	0.016	0.008
	06-08	1561.5	0.45	0.065	1.64	26.8	2.05	0.016	0.010
	04-05	1561.5	0.59	0.162	3.84	30.0	6.42	0.016	0.018
	98-03	1561.5	0.67	0.287	6.07	36.9	10.62	0.016	0.023
	86-97	1561.5	0.59	0.050	8.32	49.9	11.51	0.016	0.233
	76-85	1561.5	0.62	0.040	14.63	97.5	16.20	0.016	0.370
	Pre-76	1561.5	0.71	0.020	16.50	158.0	22.11	0.016	0.414
Diesel	Post-08	2671.2	0.01	0.116	2.99	1.6	0.18	0.017	0.201
	06-08	2671.2	0.01	0.116	5.35	2.3	0.18	0.017	0.383
	04-05	2671.2	0.02	0.058	7.43	2.6	0.54	0.017	0.422
	98-03	2671.2	0.05	0.027	11.31	7.1	1.39	0.017	0.643
	86-97	2671.2	0.06	0.027	14.88	10.7	1.40	0.017	0.808
	76-85	2671.2	0.07	0.027	16.22	11.5	1.41	0.017	1.282
	Pre-76	2671.2	0.14	0.010	18.09	14.2	2.30	0.017	2.660
Light commercial vehicles									
Petrol	Post-08	2282.0	0.53	0.104	1.46	10.2	6.55	0.194	0.024
	06-08	2282.0	0.69	0.122	2.16	27.1	7.43	0.194	0.037
	04-05	2282.0	0.80	0.167	3.77	46.5	9.45	0.194	0.049
	98-03	2282.0	1.43	0.409	12.20	103.1	13.52	0.194	0.095
	86-97	2282.0	2.06	0.426	29.13	196.2	25.88	0.194	0.262
	76-85	2282.0	2.37	0.145	37.68	230.3	55.82	0.194	0.349
	Pre-76	2282.0	2.85	0.105	39.15	337.9	129.81	0.194	0.516

Vehicle type		CO_2 Carbon dioxide	CH_4 Methane	N_20 Nitrous oxide	NO_X Nitrogen oxide	CO Carbon monoxide	NMVOC Non–methane volatile organic compounds	SO_X Sulphur oxide	PM_{10} Particulate matter
LPG	Post-08	1561.5	0.35	0.075	1.05	9.2	1.04	0.016	0.009
	06-08	1561.5	0.54	0.097	1.81	29.5	2.26	0.016	0.011
	04-05	1561.5	0.71	0.243	4.22	33.0	7.06	0.016	0.019
	98-03	1561.5	0.81	0.431	6.68	40.6	11.68	0.016	0.026
	86-97	1561.5	0.70	0.075	9.15	54.9	12.66	0.016	0.256
	76-85	1561.5	0.74	0.060	16.09	107.3	17.82	0.016	0.407
	Pre-76	1561.5	0.85	0.030	18.15	173.8	24.32	0.016	0.456
Diesel	Post-08	2671.2	0.01	0.116	3.28	2.3	0.35	0.017	0.261
	06-08	2671.2	0.01	0.116	5.88	3.5	0.35	0.017	0.498
	04-05	2671.2	0.04	0.058	8.17	3.9	1.07	0.017	0.549
	98-03	2671.2	0.10	0.027	16.96	10.6	2.79	0.017	0.836
	86-97	2671.2	0.11	0.027	22.32	16.1	2.80	0.017	1.051
	76-85	2671.2	0.12	0.027	24.32	17.2	2.11	0.017	1.666
	Pre-76	2671.2	0.25	0.010	27.14	21.4	3.45	0.017	3.458
Medium trucks									
		2282.0	0.61	0.032	17.09	43.4	12.48	0.194	0.185
Diesel	post 08	2671.2	0.01	0.036	9.00	2.2	0.30	0.017	0.139
	03-08	2671.2	0.06	0.036	16.44	5.4	0.84	0.017	0.348
	96-02	2671.2	0.10	0.036	20.54	11.3	1.47	0.017	1.570
	pre 96	2671.2	0.20	0.036	25.69	20.7	3.98	0.017	3.059
Heavy trucks									
Diesel	post 08	2671.2	0.01	0.033	9.41	2.7	0.21	0.017	0.107
	03-08	2671.2	0.02	0.033	16.70	6.6	0.62	0.017	0.294
	96-02	2671.2	0.04	0.033	22.19	10.8	0.94	0.017	0.898
	pre 96	2671.2	0.08	0.033	27.71	21.6	2.07	0.017	1.626

Vehicle type		CO_2 Carbon dioxide	CH_4 Methane	N_20 Nitrous oxide	NO_X Nitrogen oxide	CO Carbon monoxide	NMVOC Non–methane volatile organic compounds	SO_X Sulphur oxide	PM_{10} Particulate matter
Buses									
	CNG	1974.1	1.50	0.003	10.00	2.5	0.10	0.020	0.030
Diesel	post 08	2671.2	0.01	0.054	11.66	2.9	0.26	0.017	0.131
	03-08	2671.2	0.03	0.054	19.55	7.0	0.87	0.017	0.378
	96-02	2671.2	0.04	0.054	24.92	11.6	1.10	0.017	1.153
	pre 96	2671.2	0.14	0.054	34.89	23.5	3.45	0.017	1.757

Note:

Post 2008– represents current averages across on-road estimates for all new vehicles manufactured after 2006, from 2008 to 2014. It is acknowledged that each year from 2014, new vehicle sales will be added to this topmost age category, typically with slightly better noxious emission performance than these current group averages. Therefore, the actual 'post-2008' levels will tend to gradually decline over time, although these present values (for the newer portion of the fleet) should be sufficiently applicable in the short term, since it is predicted to be several years before any such declines in the averages become noticeable.

For some of the fuel types, no date is reported. This is because there are insufficient background data to accurately derive different emission rates by age of vehicle. Therefore, average values are given across that portion of the current fleet (i.e. for all on-road vehicles of that vehicle and fuel type).

Source: Email communication BITRE, November 2014; COPERT Australia (EMISIA 2014); Department of the Environment (2014)

B.1 Notes to emission conversion factors

As advised by BITRE (Email communication, November 2014), the above emission factors relate to emissions directly from vehicles and do not include any 'upstream' emissions due to vehicle or fuel provision, such as motor vehicle manufacturing, petrol refining or power generation for electric vehicle use.

The CO_2 values have had standard 'oxidation factors' applied to them, assumed by the Department of the Environment to be approximately 99% for liquid fuels (approximately 1% of fuel carbon is not released as CO_2, but ends up as residual ash). These values otherwise follow the standard convention of assuming complete combustion to CO_2. It is assumed that all the fuel carbon not ending up as residual ash is fully oxidised by the engine and is released as CO_2. However, in actual real world conditions, a portion of the fuel carbon is not directly emitted as CO_2, but as CO, CH_4 and other volatile organics, with most of this portion later oxidising to CO_2 in the atmosphere.

The NMVOC results include allowances for evaporative emissions. For the current passenger car fleet, approximately 30% of NMVOC emissions from vehicles are due to exhaust emissions, with the remainder being evaporative releases, while the vehicles are either driven or parked. Average daily evaporative emissions have been prorated over average distance travelled, at average operating fuel consumption rates.

PM_{10} values (for particulate matter emissions smaller than 10 microns in diameter) relate to exhaust emissions (i.e. do not include wear particulates from abrasion of tyres, brakes and the road surface; or secondary particulates, such as sulphates and nitrates, formed later in the atmosphere from other vehicle emissions). For the current passenger car fleet, exhaust particulate emissions comprise approximately 20% of total PM_{10} from vehicle use (from exhaust, wear including the fine component of re-suspended road dust and secondary sulphate/nitrate). Of the PM_{10} exhaust releases, typically around 30-40% is in the form of black carbon, one of the most significant greenhouse emission species.

Estimation of emissions from E10 usage can be roughly approximated by using the petrol values for equivalently sized vehicles. This is because, for low percentage ethanol blends, output of most emission species should not typically differ extensively.

Values for natural gas (NG) buses are provided in terms of 'grams emitted per litre of diesel equivalent'. This represents the unit emissions from the consumption of an amount of natural gas with the same energy content as a litre of ADO.

Due to limited in-service testing data, especially for some vehicle/fuel types, many emission factors are quite approximate. Some factors (such as for CO_2 and SO_x) are directly related to average fuel properties and will typically not alter under different driving/vehicle conditions. For others such as CO and VOC emissions, these are more dependent on the particular engine operating characteristics, and will typically alter depending on driving or ambient conditions. For example, with travel under purely congested driving conditions, several such emission factors will generally be higher than these median level values; and conversely, for purely highway driving, such emission factors will tend to be lower than these provided averages.

Appendix C Development of vehicle classification in Australia

This Appendix provides an overview of vehicle classifications in Australia, including the 20 vehicle classification (Thoresen & Ronald, 2002) used in HDM, the Austroads 12 bin classification (Austroads, 2002 and more recently Austroads, 2013b) and the vehicle classifications used in Austroads (2005a).

The Austroads 12 bin classification was developed in 1994 (Austroads, 2002) and then Austroads (2006), with the most recent description of the vehicles in terms of mass and length appearing in Austroads (2013) (column (a) in Table 40), which also contains references to other vehicle classifications used by the Australian Bureau of Statistics and by State and Territory road agencies. The changes in classification of combination vehicles has changed the most, with extensions of these vehicle types also put forward in Austroads (2002). The 20 vehicle classification used in the ATAP parameter values was based on Thoresen and Ronald (2002) and is also used in HDM-4 in Australia (column (b) in Table 40). Previous updates of unit values for Austroads (Austroads, 2012a) have used the 18 vehicle classification in Austroads (2005a) (column (c) in Table 40). Designations based on axle numbers have also been used (Austroads, 2005a) (column (e) in Table 40), while selected vehicle types (8 vehicle classification) have been used in NIMPAC models (Austroads, 2005a)(column (g) in Table 40).

Table 40 Vehicle classifications in Australia

From Austroads vehicle classification scheme (circa 1990's) (Austroads 1994, 2002 & 2013b)	From ARRB report RC2062 (Thoresen & Ronald 2002) for Austroads. Consistent vehicle types adopted for use in HDM-4 in Australia	From Austroads report AP-R264-05 (Austroads 2005a)				HDM-4 vehicles (8) adopted for 2014 update to AP-R264-05 Tables 6 & 7 (Austroads 2005a)
		From Appendix A – Vehicle nomenclature			NIMPAC vehicle types (8) from Austroads AP-R264-05 Tables 6 & 7 (Austroads 2005a)	
Vehicle class (a)	Vehicle name (b)	Vehicle category (also Austroads 2012a) (c)	Code (d)	Designation (e)	Vehicle category (f)	Vehicle name (g)
1	01. Small Car	Small Car	C	C1.1	Cars	
	02. Medium Car	Medium Car	C	C1.2		Medium car
	03. Large Car	Large Car	C	C1.3		
	04. Courier Van-Utility	Light commercial (2 axle 4 tyre)	V1.1	V1.1	Light commercial (2 axle 4 tyre)	Light commercial (2 axle 4 tyre)
	05. 4WD Mid-Size Petrol	4WD Mid-Size SUV Petrol				
3	06. Light Rigid	Light truck (2 axle 6 tyre) petrol	11	L11p	Light truck (2 axle 6 tyre)	Light diesel truck (2 axle 6 tyre)
		Light truck (2 axle 6 tyre) diesel	11	L11d		
	07. Medium Rigid	Medium truck (2 axle 6 tyre)	11	11	Medium truck (2 axle 6 tyre)	Medium truck (2 axle 6 tyre)
		Small bus	Bu	Bu1		
		Route bus (includes school bus)	Bu	Bu2		
4	09. Heavy Bus	Large bus (coach)	Bu	Bu3	Large bus	Large bus (3 axle)
	08. Heavy Rigid	Large truck (3 axle)	12	12	Heavy truck (3 axle)	Heavy truck (3 axle)
6		Articulated truck (3 axle)	A	11S1	Articulated trucks (3,4,5 & 6 axle)	
7	10. Artic 4 Axle	Articulated truck (4 axle)	A	11S2		
8	11. Artic 5 Axle	Articulated truck (5 axle)	A	12S2		
9	12. Artic 6 Axle	Articulated truck (6 axle)	A	12S3		Articulated truck (6 axle)

From Austroads vehicle classification scheme (circa 1990's) (Austroads 1994, 2002 & 2013b)	From ARRB report RC2062 (Thoresen & Ronald 2002) for Austroads. Consistent vehicle types adopted for use in HDM-4 in Australia	From Austroads report AP-R264-05 (Austroads 2005a)				HDM-4 vehicles (8) adopted for 2014 update to AP-R264-05 Tables 6 & 7 (Austroads 2005a)
		From Appendix A – Vehicle nomenclature			NIMPAC vehicle types (8) from Austroads AP-R264-05 Tables 6 & 7 (Austroads 2005a)	
10	13. Rigid + 5 Axle Dog	Large truck (rigid 3 axle) + 5 axle dog trailer	RT	12-2S3	Combination vehicles	
	14. B-Double	B-Double (tri-tandem)	B2	12S3S2		B-Double (9 axle)
		B-Double (tri-tri)	B2	12(S3)2		
		Twin steer truck + 4 axle dog trailer	RT	22-2S2		
	15. Twin steer + 5 Axle Dog	Twin steer truck + 5 axle dog trailer	RT	22-2S3		
11	16. A-Double	Road train (double)	A2	12S3-2S3		
	17. B Triple	B Triple	B3	12(S3)3		
	18. A B Combination	A B Combination	AB2	12S3-2(S3)2		
12	19. A-Triple	Road train (triple)	A3	12s3(-2s3)2		
	20. Double B-Double	Double B-Double	2b2	12(s3)2-2(s3)2		

Source: ARRB Group Ltd adapted from Austroads

Appendix D Detailed VOC coefficients (uninterrupted flow)

Table 41 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 0

Curvature = 20° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	21.65553	0.682568	8.926626	1.86E-05	0.029245	0.000812	0.040681
02. Medium Car	28.58679	0.689129	10.27355	1.43E-05	0.027139	0.000945	0.030451
03. Large Car	37.23451	0.714542	10.81935	1.09E-05	0.023979	0.001031	0.020684
04. Courier Van-Utility	32.14678	0.671992	8.085664	1.53E-05	0.039596	0.002492	0.023847
05. 4WD Mid-Size Petrol	35.49258	0.704089	7.16007	1.45E-05	0.034579	0.0021	0.0163
06. Light Rigid	44.70851	0.690409	5.571115	2.38E-05	0.042392	0.001879	0.013114
07. Medium Rigid	51.70626	0.64653	8.310133	2.08E-05	0.037528	0.001762	0.010923
08. Heavy Rigid	64.34463	0.45218	10.40255	3.42E-05	0.082007	0.000232	0.006585
09. Heavy Bus	100.1854	0.599271	9.039805	1.14E-05	0.066026	0.001052	0.004438
10. Artic 4 Axle	86.46287	0.443656	9.169067	3.51E-05	0.087456	0.000257	0.006451
11. Artic 5 Axle	95.65238	0.48678	8.851208	3.03E-05	0.083934	0.000404	0.004411
12. Artic 6 Axle	103.6022	0.491922	8.586421	2.8E-05	0.085237	0.000367	0.004082
13. Rigid + 5 Axle Dog	109.6991	0.507333	7.403231	2.75E-05	0.081194	0.000107	0.003943
14. B-Double	121.4093	0.483655	7.876344	2.41E-05	0.091051	0.000148	0.003567
15. Twin steer + 5 Axle Dog	120.4225	0.501057	7.606813	2.45E-05	0.085776	0.000191	0.003593
16. A-Double	146.9991	0.477559	7.54018	1.95E-05	0.096147	8.86E-05	0.002989
17. B Triple	170.3634	0.488334	7.864302	1.58E-05	0.097835	0.000332	0.00258
18. A B Combination	166.3673	0.475805	7.006039	1.75E-05	0.09811	-5.2E-05	0.002671
19. A-Triple	186.8652	0.480136	6.884288	1.56E-05	0.099253	-2E-05	0.002393
20. Double B-Double	189.7076	0.479935	6.579042	1.57E-05	0.098984	-0.00013	0.002361

Source: ARRB Group Ltd.

Table 42 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 0

Curvature = 120° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	21.66246	0.684502	8.768415	1.8E-05	0.0298	0.000759	0.043477
02. Medium Car	28.60306	0.691181	10.09801	1.36E-05	0.027718	0.000888	0.033003
03. Large Car	37.27617	0.716756	10.61812	1.02E-05	0.024594	0.000968	0.022989
04. Courier Van-Utility	32.16708	0.664829	8.087403	1.6E-05	0.039782	0.002468	0.026789
05. 4WD Mid-Size Petrol	35.52194	0.698627	7.155194	1.51E-05	0.03476	0.002075	0.017918
06. Light Rigid	44.70767	0.690012	5.494819	2.35E-05	0.042572	0.001863	0.014156
07. Medium Rigid	51.73376	0.627128	8.480745	2.37E-05	0.037502	0.001748	0.012201
08. Heavy Rigid	64.40828	0.424878	10.71108	3.87E-05	0.081776	0.000231	0.007219
09. Heavy Bus	100.4786	0.580512	9.200564	1.41E-05	0.065886	0.001041	0.004881
10. Artic 4 Axle	86.53048	0.425281	9.182197	3.8E-05	0.087723	0.000201	0.007054
11. Artic 5 Axle	95.73909	0.476725	8.757648	3.15E-05	0.085014	0.000297	0.004718
12. Artic 6 Axle	103.705	0.482078	8.490884	2.91E-05	0.086408	0.000254	0.004347
13. Rigid + 5 Axle Dog	109.8207	0.488207	7.50567	3.09E-05	0.081612	4.8E-05	0.004173
14. B-Double	121.5633	0.465999	7.944521	2.71E-05	0.091667	7.45E-05	0.003769
15. Twin steer + 5 Axle Dog	120.5663	0.481958	7.696449	2.79E-05	0.086353	0.000121	0.003803
16. A-Double	147.2284	0.456474	7.683767	2.33E-05	0.096413	3.98E-05	0.003152
17. B Triple	170.9616	0.469714	7.934173	1.88E-05	0.098067	0.000272	0.002716
18. A B Combination	166.669	0.453332	7.19835	2.21E-05	0.097883	-7E-05	0.002803
19. A-Triple	187.6023	0.459523	7.026224	2E-05	0.098623	-3E-05	0.002496
20. Double B-Double	190.2648	0.458884	6.752736	2.04E-05	0.098383	-0.00013	0.002462

Source: ARRB Group Ltd.

Table 43 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 0

Curvature = 300° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	21.71945	0.683456	8.407408	1.71E-05	0.030865	0.000661	0.052795
02. Medium Car	28.72457	0.690163	9.662748	1.25E-05	0.028907	0.000775	0.041417
03. Large Car	37.54378	0.714285	10.12023	8.86E-06	0.02584	0.000841	0.030385
04. Courier Van-Utility	32.32619	0.633967	8.075438	1.94E-05	0.04055	0.002375	0.038047
05. 4WD Mid-Size Petrol	35.75135	0.673498	7.158748	1.88E-05	0.03548	0.00198	0.023408
06. Light Rigid	44.76709	0.674658	5.507015	2.61E-05	0.04269	0.001842	0.017887
07. Medium Rigid	51.97566	0.536519	9.219307	4.04E-05	0.038001	0.00166	0.017562
08. Heavy Rigid	65.10272	0.315792	11.51216	6.06E-05	0.082456	8.04E-05	0.009849
09. Heavy Bus	102.6137	0.507817	9.463476	2.61E-05	0.065828	0.000909	0.006612
10. Artic 4 Axle	87.24572	0.307459	9.952775	6.38E-05	0.088664	5.16E-05	0.009361
11. Artic 5 Axle	96.62218	0.410379	9.087996	4.74E-05	0.086043	0.000147	0.005655
12. Artic 6 Axle	104.7388	0.417303	8.814774	4.47E-05	0.087314	0.000108	0.005151
13. Rigid + 5 Axle Dog	111.0581	0.393219	8.234647	5.47E-05	0.082283	-9E-05	0.004926
14. B-Double	123.0926	0.377369	8.57147	4.9E-05	0.092193	-6.7E-05	0.004422
15. Twin steer + 5 Axle Dog	122.0029	0.387692	8.401896	5.13E-05	0.086992	-2.2E-05	0.004488
16. A-Double	149.4775	0.356311	8.437562	4.78E-05	0.096563	-9.6E-05	0.003699
17. B Triple	174.0196	0.380161	8.518252	4E-05	0.097964	0.000135	0.003171
18. A B Combination	169.4884	0.337568	8.153897	5.05E-05	0.097681	-0.0002	0.003287
19. A-Triple	190.8301	0.338299	8.043317	4.98E-05	0.098255	-0.00015	0.002936
20. Double B-Double	193.6681	0.335128	7.809177	5.09E-05	0.097887	-0.00024	0.002889

Source: ARRB Group Ltd.

Table 44 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 40m/km

Curvature = 20° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	21.77701	0.676646	8.84071	1.78E-05	0.029251	0.00078	0.055107
02. Medium Car	28.77737	0.684136	10.14324	1.34E-05	0.027084	0.000915	0.042771
03. Large Car	37.48681	0.709327	10.69816	1.01E-05	0.023856	0.001009	0.030947
04. Courier Van-Utility	32.54266	0.656055	8.087261	1.16E-05	0.038363	0.002476	0.051734
05. 4WD Mid-Size Petrol	35.89298	0.699215	7.008638	1.28E-05	0.034033	0.002077	0.025696
06. Light Rigid	45.38901	0.666827	6.029789	1.99E-05	0.040338	0.00193	0.033109
07. Medium Rigid	52.2994	0.615392	8.454842	1.31E-05	0.035675	0.001824	0.029213
08. Heavy Rigid	70.52667	0.40264	9.203288	1.02E-05	0.072624	0.000369	0.025286
09. Heavy Bus	107.7354	0.583615	7.384707	-5E-06	0.062057	0.000904	0.01559
10. Artic 4 Axle	93.7909	0.324703	9.439323	2.06E-05	0.081556	0.000253	0.021187
11. Artic 5 Axle	103.9641	0.362538	8.677248	1.59E-05	0.079564	0.000287	0.017641
12. Artic 6 Axle	113.1935	0.372582	8.09736	1.25E-05	0.080523	0.000215	0.016133
13. Rigid + 5 Axle Dog	122.7591	0.364701	6.979721	1.2E-05	0.074484	-4E-05	0.015089
14. B-Double	135.7933	0.356468	7.08738	7.06E-06	0.083405	8.51E-06	0.013615
15. Twin steer + 5 Axle Dog	135.0691	0.35734	7.031495	9.86E-06	0.078876	3.72E-05	0.013819
16. A-Double	170.3588	0.36611	6.362374	-4.2E-08	0.084517	-5.3E-05	0.010825
17. B Triple	197.0098	0.393853	6.489415	-4.1E-06	0.085982	0.00017	0.009303
18. A B Combination	199.4189	0.368899	5.874719	-3.1E-06	0.082276	-0.00014	0.008982
19. A-Triple	227.1595	0.372549	5.871347	-4.1E-06	0.081963	-0.00012	0.007827
20. Double B-Double	233.9273	0.359344	5.642749	-2.8E-06	0.080346	-0.00019	0.007639

Source: ARRB Group Ltd.

Table 45 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 40m/km

Curvature = 120° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	21.78375	0.678144	8.701279	1.73E-05	0.029765	0.000732	0.057671
02. Medium Car	28.79335	0.685639	9.990258	1.28E-05	0.027607	0.000865	0.045124
03. Large Car	37.52777	0.710864	10.52145	9.44E-06	0.024393	0.000955	0.033158
04. Courier Van-Utility	32.56191	0.654997	7.993459	1.13E-05	0.03886	0.002429	0.053305
05. 4WD Mid-Size Petrol	35.92078	0.695503	6.97774	1.32E-05	0.034346	0.002043	0.026956
06. Light Rigid	45.38908	0.676261	5.763052	1.78E-05	0.040911	0.001884	0.033457
07. Medium Rigid	52.33585	0.626162	8.130709	1.16E-05	0.035909	0.001778	0.029486
08. Heavy Rigid	70.6196	0.406985	9.073364	9.76E-06	0.072419	0.000362	0.025295
09. Heavy Bus	108.45	0.577681	7.362434	-4.5E-06	0.061632	0.000899	0.015528
10. Artic 4 Axle	93.67407	0.356962	8.785326	1.52E-05	0.081088	0.000245	0.021264
11. Artic 5 Axle	104.0333	0.391645	8.065266	1.17E-05	0.078761	0.000286	0.017668
12. Artic 6 Axle	113.4547	0.397737	7.535838	9E-06	0.079532	0.00022	0.016145
13. Rigid + 5 Axle Dog	123.4886	0.37206	6.711033	1.19E-05	0.072961	5E-06	0.015069
14. B-Double	137.3535	0.354016	6.924007	8.54E-06	0.081304	6.52E-05	0.013544
15. Twin steer + 5 Axle Dog	135.9043	0.361419	6.825939	1.05E-05	0.077204	9.1E-05	0.013803
16. A-Double	173.2381	0.358887	6.203839	2.04E-06	0.082041	5.2E-06	0.010723
17. B Triple	200.406	0.388494	6.280163	-2.9E-06	0.083661	0.000211	0.009211
18. A B Combination	202.3999	0.368241	5.622275	-2.6E-06	0.080238	-9.8E-05	0.008904
19. A-Triple	230.3998	0.374513	5.577195	-4.4E-06	0.080046	-8.3E-05	0.007765
20. Double B-Double	237.0755	0.360484	5.377519	-2.7E-06	0.078522	-0.00015	0.007585

Source: ARRB Group Ltd.

Table 46 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 40m/km

Curvature = 300° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	21.83955	0.67651	8.368516	1.65E-05	0.030691	0.000646	0.066877
02. Medium Car	28.91282	0.684208	9.581405	1.16E-05	0.028669	0.000763	0.053384
03. Large Car	37.79151	0.708847	10.03177	7.99E-06	0.025576	0.000834	0.040302
04. Courier Van-Utility	32.71224	0.636675	7.853893	1.29E-05	0.039885	0.002318	0.06108
05. 4WD Mid-Size Petrol	36.13688	0.67246	6.971711	1.64E-05	0.034999	0.001958	0.032129
06. Light Rigid	45.44968	0.681482	5.43677	1.65E-05	0.041368	0.001832	0.035492
07. Medium Rigid	52.66385	0.627908	7.642323	1.23E-05	0.036157	0.001693	0.030682
08. Heavy Rigid	71.34569	0.41848	8.511501	9.6E-06	0.07181	0.000302	0.025287
09. Heavy Bus	111.128	0.554634	7.216613	-1.3E-06	0.060151	0.000872	0.015511
10. Artic 4 Axle	94.85839	0.374609	8.127238	1.38E-05	0.079939	0.000191	0.021131
11. Artic 5 Axle	105.0509	0.418287	7.29351	8.38E-06	0.078038	0.000219	0.017553
12. Artic 6 Axle	114.611	0.418395	6.868454	6.86E-06	0.078712	0.000162	0.016059
13. Rigid + 5 Axle Dog	125.3302	0.368537	6.482005	1.56E-05	0.071479	-8.6E-06	0.014917
14. B-Double	140.0574	0.348429	6.675514	1.21E-05	0.079379	5.03E-05	0.013344
15. Twin steer + 5 Axle Dog	138.0403	0.361274	6.530508	1.34E-05	0.075656	7.15E-05	0.01364
16. A-Double	177.2015	0.345133	6.049153	6.78E-06	0.079958	-4.5E-06	0.010557
17. B Triple	204.9486	0.378299	6.051701	3E-07	0.08165	0.000194	0.00907
18. A B Combination	206.2298	0.36378	5.34831	-5.4E-07	0.078622	-0.00011	0.008795
19. A-Triple	234.3808	0.37476	5.235795	-3.9E-06	0.078593	-9.6E-05	0.007685
20. Double B-Double	240.9149	0.359891	5.070919	-1.9E-06	0.07717	-0.00016	0.007515

Source: ARRB Group Ltd.

Table 47 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 60m/km

Curvature = 20° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	21.99904	0.664673	8.686131	1.62E-05	0.028962	0.000757	0.081558
02. Medium Car	29.08416	0.670193	9.996327	1.17E-05	0.02705	0.000868	0.06638
03. Large Car	37.9282	0.701291	10.40397	8.85E-06	0.024018	0.000957	0.045478
04. Courier Van-Utility	33.27911	0.662872	7.026945	3.19E-06	0.038163	0.002393	0.090493
05. 4WD Mid-Size Petrol	36.53044	0.668795	7.005041	9.45E-06	0.032973	0.002043	0.051212
06. Light Rigid	46.50147	0.649475	5.640557	1.25E-05	0.039829	0.001897	0.062145
07. Medium Rigid	53.46788	0.570361	8.304298	1.15E-05	0.035231	0.001781	0.047612
08. Heavy Rigid	77.71982	0.36783	8.316237	3.25E-06	0.066142	0.000361	0.036443
09. Heavy Bus	118.4576	0.557995	6.246492	-1.2E-05	0.056932	0.000828	0.021452
10. Artic 4 Axle	101.9191	0.334515	8.384086	4.46E-06	0.080324	-6.5E-05	0.029109
11. Artic 5 Axle	113.2533	0.337257	7.804495	6.74E-06	0.077856	-5.1E-06	0.025067
12. Artic 6 Axle	124.4025	0.332789	7.325255	5.54E-06	0.077725	-3.9E-05	0.022928
13. Rigid + 5 Axle Dog	138.2292	0.31611	6.504697	6.97E-06	0.07062	-0.00027	0.02037
14. B-Double	155.0313	0.304834	6.545506	3.08E-06	0.076877	-0.00016	0.018098
15. Twin steer + 5 Axle Dog	152.528	0.303685	6.548808	5.98E-06	0.074454	-0.00018	0.01871
16. A-Double	201.5084	0.292156	6.046875	-1.1E-06	0.075173	-0.0002	0.013817
17. B Triple	232.772	0.323409	6.176226	-5.3E-06	0.07617	-3.3E-06	0.01175
18. A B Combination	240.1296	0.235502	6.146186	9.96E-06	0.072352	-0.00029	0.011499
19. A-Triple	274.9925	0.208613	6.337793	1.99E-05	0.071946	-0.00028	0.010137
20. Double B-Double	284.9464	0.192351	6.099853	2.32E-05	0.070245	-0.00033	0.009862

Source: ARRB Group Ltd.

Table 48 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 60m/km

Curvature = 120° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	22.00601	0.666305	8.541353	1.56E-05	0.029559	0.000705	0.083996
02. Medium Car	29.10209	0.671336	9.848264	1.11E-05	0.027616	0.000817	0.068691
03. Large Car	37.96987	0.701303	10.25833	8.29E-06	0.024517	0.000908	0.04786
04. Courier Van-Utility	33.30684	0.663352	6.909507	2.58E-06	0.038483	0.002361	0.091965
05. 4WD Mid-Size Petrol	36.55789	0.667906	6.9267	9.35E-06	0.0334	0.002001	0.052086
06. Light Rigid	46.5146	0.659024	5.36819	1.04E-05	0.040041	0.001867	0.062845
07. Medium Rigid	53.50391	0.582655	8.00768	9.82E-06	0.035175	0.001759	0.047656
08. Heavy Rigid	78.21084	0.363399	8.274425	4.36E-06	0.065315	0.000376	0.036344
09. Heavy Bus	119.0811	0.553513	6.223668	-1.2E-05	0.056618	0.000824	0.021397
10. Artic 4 Axle	103.6091	0.339222	7.937484	5.84E-06	0.076856	4.32E-05	0.028979
11. Artic 5 Axle	115.3691	0.332103	7.560967	9.77E-06	0.074311	0.000107	0.024853
12. Artic 6 Axle	126.8047	0.324508	7.148264	8.93E-06	0.074217	7.21E-05	0.022713
13. Rigid + 5 Axle Dog	140.6703	0.314987	6.218685	9.23E-06	0.06761	-0.00017	0.020169
14. B-Double	157.8807	0.303911	6.250501	4.91E-06	0.073914	-8E-05	0.017903
15. Twin steer + 5 Axle Dog	155.3684	0.301915	6.271591	8.27E-06	0.071336	-8.4E-05	0.018502
16. A-Double	205.2756	0.293294	5.708607	-7.3E-08	0.072554	-0.00013	0.013669
17. B Triple	237.1165	0.324911	5.821274	-5E-06	0.073702	5.15E-05	0.011629
18. A B Combination	244.1029	0.233969	5.873942	1.25E-05	0.070056	-0.00022	0.01141
19. A-Triple	279.3868	0.206103	6.07951	2.35E-05	0.069718	-0.00021	0.010072
20. Double B-Double	289.2979	0.189086	5.865461	2.74E-05	0.068116	-0.00026	0.009805

Source: ARRB Group Ltd.

Table 49 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 60m/km

Curvature = 300° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	22.06228	0.661241	8.268551	1.5E-05	0.030286	0.000636	0.094462
02. Medium Car	29.23015	0.666432	9.514375	1.03E-05	0.028396	0.000738	0.077433
03. Large Car	38.22448	0.695569	9.881117	7.47E-06	0.02534	0.000819	0.055124
04. Courier Van-Utility	33.48581	0.652607	6.723518	2.77E-06	0.038603	0.002315	0.098023
05. 4WD Mid-Size Petrol	36.77218	0.653111	6.848594	1.13E-05	0.034137	0.001909	0.055317
06. Light Rigid	46.58444	0.669546	4.985933	8.23E-06	0.040114	0.001832	0.064465
07. Medium Rigid	53.82781	0.5979	7.455479	8.33E-06	0.035094	0.001703	0.047741
08. Heavy Rigid	79.98585	0.349089	8.094219	8.75E-06	0.063419	0.000359	0.035842
09. Heavy Bus	121.3877	0.539979	6.108798	-1E-05	0.055529	0.000807	0.021104
10. Artic 4 Axle	106.1258	0.336365	7.431609	8.82E-06	0.074663	1.16E-05	0.028651
11. Artic 5 Axle	117.8632	0.325309	7.239637	1.38E-05	0.072274	8.71E-05	0.024536
12. Artic 6 Axle	129.4914	0.316251	6.885916	1.32E-05	0.072215	5.61E-05	0.022418
13. Rigid + 5 Axle Dog	143.5687	0.306699	5.961026	1.38E-05	0.06588	-0.00019	0.019911
14. B-Double	161.2538	0.297547	5.959541	8.6E-06	0.072075	-9.4E-05	0.017656
15. Twin steer + 5 Axle Dog	158.6605	0.294216	6.007304	1.26E-05	0.069504	-9.8E-05	0.018247
16. A-Double	208.9125	0.293723	5.348433	1.23E-06	0.071116	-0.00015	0.013535
17. B Triple	241.2634	0.327452	5.422062	-5E-06	0.072303	3.46E-05	0.011523
18. A B Combination	247.7097	0.231323	5.600193	1.57E-05	0.068853	-0.00023	0.011343
19. A-Triple	283.297	0.201802	5.833249	2.81E-05	0.068569	-0.00022	0.010028
20. Double B-Double	293.1199	0.183905	5.645777	3.28E-05	0.067041	-0.00027	0.009769

Source: ARRB Group Ltd.

Table 50 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 80m/km

Curvature = 20° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	22.32029	0.638351	8.457562	1.23E-05	0.027831	0.000778	0.143898
02. Medium Car	29.54708	0.647921	9.606611	7.5E-06	0.025998	0.000885	0.118559
03. Large Car	38.5286	0.668705	10.23459	6.15E-06	0.02321	0.00095	0.086986
04. Courier Van-Utility	34.39707	0.665203	6.168753	-2.5E-06	0.037322	0.002296	0.122428
05. 4WD Mid-Size Petrol	37.44664	0.653816	6.274919	3.18E-06	0.032933	0.001947	0.083961
06. Light Rigid	48.32419	0.633581	5.205566	6.13E-06	0.038719	0.001833	0.089417
07. Medium Rigid	55.73066	0.556715	7.647288	6.76E-06	0.033555	0.001731	0.062744
08. Heavy Rigid	87.04416	0.326628	7.840715	-8.2E-08	0.058713	0.000373	0.045384
09. Heavy Bus	130.9259	0.517569	5.374209	-1.9E-05	0.05248	0.000721	0.027006
10. Artic 4 Axle	114.7653	0.271576	8.329702	2.75E-06	0.076418	-0.0003	0.035503
11. Artic 5 Axle	126.5033	0.284345	7.573163	4.62E-06	0.074211	-0.00022	0.030814
12. Artic 6 Axle	139.8735	0.279081	7.045395	3.54E-06	0.073406	-0.00024	0.0281
13. Rigid + 5 Axle Dog	157.9544	0.222609	6.596106	1.08E-05	0.066897	-0.00048	0.024937
14. B-Double	178.6784	0.215884	6.565731	6.81E-06	0.071298	-0.00033	0.021873
15. Twin steer + 5 Axle Dog	174.9632	0.214012	6.557188	9.13E-06	0.070041	-0.00037	0.022825
16. A-Double	238.4183	0.160724	6.371468	1.62E-05	0.068295	-0.00037	0.016513
17. B Triple	274.7751	0.190647	6.511399	1.44E-05	0.068886	-0.00019	0.014052
18. A B Combination	287.2938	0.093365	6.269776	4.18E-05	0.065126	-0.00043	0.01373
19. A-Triple	330.0979	0.057983	6.350494	6.3E-05	0.06472	-0.00043	0.012193
20. Double B-Double	342.8597	0.044589	6.063738	6.58E-05	0.063091	-0.00046	0.011863

Source: ARRB Group Ltd.

Table 51 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 80m/km

Curvature = 120° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	22.32697	0.641807	8.269515	1.13E-05	0.028512	0.000719	0.146273
02. Medium Car	29.56498	0.650962	9.419935	6.49E-06	0.026658	0.000828	0.120565
03. Large Car	38.56945	0.67069	10.0717	5.39E-06	0.023698	0.000903	0.08863
04. Courier Van-Utility	34.41717	0.665134	6.114566	-2.7E-06	0.037424	0.002283	0.123191
05. 4WD Mid-Size Petrol	37.48462	0.652532	6.188863	2.87E-06	0.03319	0.001918	0.085227
06. Light Rigid	48.35548	0.642527	4.953744	4.27E-06	0.038699	0.001816	0.090075
07. Medium Rigid	55.83282	0.566727	7.391364	5.24E-06	0.033408	0.001716	0.062659
08. Heavy Rigid	87.6042	0.324329	7.742817	9.34E-07	0.057892	0.000386	0.045266
09. Heavy Bus	131.5805	0.513865	5.338644	-1.9E-05	0.052177	0.000718	0.026959
10. Artic 4 Axle	116.7518	0.289501	7.602208	1.77E-06	0.072561	-0.00017	0.035395
11. Artic 5 Axle	129.0754	0.29081	7.073729	5.9E-06	0.070458	-0.0001	0.030501
12. Artic 6 Axle	142.7644	0.281918	6.629753	5.41E-06	0.069767	-0.00013	0.027789
13. Rigid + 5 Axle Dog	161.3933	0.225096	6.184062	1.34E-05	0.063437	-0.00037	0.024627
14. B-Double	182.5335	0.218687	6.157842	8.82E-06	0.067992	-0.00023	0.0216
15. Twin steer + 5 Axle Dog	178.7906	0.217036	6.146929	1.13E-05	0.066579	-0.00026	0.022525
16. A-Double	242.9603	0.160989	6.030128	1.96E-05	0.065524	-0.00029	0.016369
17. B Triple	279.914	0.189731	6.180801	1.78E-05	0.066279	-0.00011	0.013947
18. A B Combination	292.0358	0.091031	5.9934	4.78E-05	0.062755	-0.00036	0.013654
19. A-Triple	335.3136	0.055492	6.077929	7.03E-05	0.062449	-0.00035	0.012142
20. Double B-Double	348.0381	0.042062	5.805791	7.33E-05	0.060937	-0.00039	0.011818

Source: ARRB Group Ltd.

Table 52 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 80m/km

Curvature = 300° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	22.38143	0.641919	7.879913	9.44E-06	0.029429	0.000635	0.156696
02. Medium Car	29.69182	0.648861	9.001802	4.56E-06	0.027539	0.000742	0.130199
03. Large Car	38.8192	0.670697	9.608563	3.45E-06	0.024681	0.000803	0.094646
04. Courier Van-Utility	34.81281	0.651523	6.034396	-1.8E-06	0.036948	0.002255	0.12507
05. 4WD Mid-Size Petrol	37.73343	0.638046	6.079566	3.84E-06	0.033271	0.001873	0.089452
06. Light Rigid	48.44158	0.653145	4.597237	2.11E-06	0.038742	0.001782	0.091215
07. Medium Rigid	56.27631	0.57908	6.930505	3.53E-06	0.033252	0.001667	0.062272
08. Heavy Rigid	89.50594	0.312607	7.486763	5.24E-06	0.056257	0.00036	0.044757
09. Heavy Bus	133.6075	0.503993	5.218436	-1.8E-05	0.051394	0.0007	0.026739
10. Artic 4 Axle	119.5508	0.297748	6.87023	2.13E-06	0.070533	-0.0002	0.035065
11. Artic 5 Axle	132.0805	0.290389	6.585823	8.6E-06	0.068486	-0.00012	0.030096
12. Artic 6 Axle	145.978	0.278896	6.227653	8.68E-06	0.067864	-0.00015	0.027418
13. Rigid + 5 Axle Dog	164.4562	0.222897	5.824035	1.73E-05	0.061913	-0.00038	0.024372
14. B-Double	185.9548	0.218824	5.77149	1.16E-05	0.06646	-0.00025	0.021377
15. Twin steer + 5 Axle Dog	182.2284	0.216209	5.770886	1.47E-05	0.065008	-0.00027	0.022275
16. A-Double	246.7058	0.159216	5.718427	2.36E-05	0.06429	-0.00029	0.016273
17. B Triple	284.2144	0.18755	5.868173	2.16E-05	0.065062	-0.00012	0.013882
18. A B Combination	295.88	0.085138	5.766814	5.58E-05	0.061711	-0.00036	0.013615
19. A-Triple	339.5336	0.048769	5.861335	8.05E-05	0.061447	-0.00036	0.012121
20. Double B-Double	352.1919	0.035376	5.601985	8.38E-05	0.060003	-0.00039	0.011802

Source: ARRB Group Ltd.

Table 53 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 100m/km

Curvature = 20° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	22.81627	0.627319	7.643341	6.92E-06	0.028055	0.000705	0.20589
02. Medium Car	30.20063	0.644851	8.719775	2.43E-06	0.026478	0.000794	0.163829
03. Large Car	39.24362	0.660818	9.473121	1.82E-06	0.023633	0.000871	0.126488
04. Courier Van-Utility	35.57831	0.665382	5.605125	-7E-06	0.036163	0.002225	0.150318
05. 4WD Mid-Size Petrol	38.80404	0.648079	5.5489	-1.7E-06	0.032353	0.001845	0.109026
06. Light Rigid	50.1137	0.620951	4.946638	-5.3E-07	0.038724	0.001726	0.115411
07. Medium Rigid	57.99632	0.538815	7.220077	3.67E-06	0.032788	0.001639	0.077111
08. Heavy Rigid	98.67556	0.291459	7.481891	-2.8E-06	0.051638	0.000357	0.051733
09. Heavy Bus	144.9163	0.487704	4.678601	-2.7E-05	0.048637	0.000598	0.031136
10. Artic 4 Axle	128.0443	0.171373	8.807071	1.02E-05	0.074862	-0.00058	0.042077
11. Artic 5 Axle	141.1906	0.20947	7.63609	6.6E-06	0.071933	-0.00046	0.036247
12. Artic 6 Axle	157.2348	0.208761	7.029486	4.85E-06	0.070435	-0.00046	0.032804
13. Rigid + 5 Axle Dog	181.2452	0.109501	6.823851	2.38E-05	0.064108	-0.0007	0.028924
14. B-Double	206.289	0.104754	6.767036	2.07E-05	0.066995	-0.00051	0.025187
15. Twin steer + 5 Axle Dog	201.3527	0.100599	6.782692	2.16E-05	0.066797	-0.00057	0.026432
16. A-Double	280.1225	0.043377	6.393418	4.28E-05	0.063198	-0.00053	0.018866
17. B Triple	321.998	0.072114	6.514677	4.5E-05	0.063405	-0.00035	0.016119
18. A B Combination	338.0546	-0.02639	6.083074	8.04E-05	0.060235	-0.00058	0.015826
19. A-Triple	387.5931	-0.06585	6.067933	0.000111	0.060247	-0.00058	0.014208
20. Double B-Double	404.5929	-0.07896	5.770779	0.000116	0.058498	-0.00059	0.013767

Source: ARRB Group Ltd.

Table 54 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 100m/km

Curvature = 120° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	22.81554	0.627435	7.49654	6.1E-06	0.028571	0.00066	0.210537
02. Medium Car	30.20508	0.643619	8.605099	1.81E-06	0.026854	0.000761	0.167811
03. Large Car	39.28052	0.659219	9.341566	1.17E-06	0.024045	0.000833	0.129886
04. Courier Van-Utility	35.77219	0.659108	5.599225	-6.6E-06	0.035854	0.002219	0.15043
05. 4WD Mid-Size Petrol	38.89505	0.6453	5.499904	-1.7E-06	0.032331	0.001833	0.109869
06. Light Rigid	50.1144	0.621236	4.843372	-1.3E-07	0.038263	0.001738	0.117116
07. Medium Rigid	58.34971	0.537036	7.115011	4.16E-06	0.032143	0.001645	0.076914
08. Heavy Rigid	99.12405	0.29389	7.315553	-2.6E-06	0.050961	0.000368	0.051688
09. Heavy Bus	145.6107	0.484786	4.630706	-2.7E-05	0.048332	0.000596	0.031092
10. Artic 4 Axle	132.1239	0.185519	7.930512	1.17E-05	0.069352	-0.0004	0.04155
11. Artic 5 Axle	145.1345	0.21772	6.998913	8.39E-06	0.067354	-0.00031	0.035692
12. Artic 6 Axle	161.4171	0.214724	6.477981	6.9E-06	0.066183	-0.00033	0.032304
13. Rigid + 5 Axle Dog	185.416	0.114045	6.356816	2.76E-05	0.060424	-0.00057	0.028577
14. B-Double	210.8751	0.108771	6.325143	2.42E-05	0.063541	-0.00039	0.024898
15. Twin steer + 5 Axle Dog	205.9388	0.105651	6.324165	2.5E-05	0.063156	-0.00044	0.026101
16. A-Double	285.4486	0.044214	6.032881	4.86E-05	0.060379	-0.00043	0.018736
17. B Triple	327.9357	0.071027	6.176734	5.14E-05	0.060765	-0.00026	0.016034
18. A B Combination	343.5652	-0.02654	5.772979	8.84E-05	0.057879	-0.00049	0.015762
19. A-Triple	393.6301	-0.06558	5.76171	0.00012	0.058006	-0.0005	0.014167
20. Double B-Double	410.5981	-0.07881	5.481441	0.000126	0.056377	-0.00052	0.013732

Source: ARRB Group Ltd.

Table 55 Coefficients for rural (uninterrupted/free flow speed) VOC model (cents per km)

Road width = 8.5m

RF = 100m/km

Curvature = 300° / km

Vehicle type	Base VOC (c/km)	K_1	K_2	K_3	K_4	K_5	K_6
01. Small Car	22.83076	0.618246	7.30516	5.54E-06	0.028755	0.000632	0.225616
02. Medium Car	30.35869	0.632992	8.37936	1.15E-06	0.02695	0.000731	0.178449
03. Large Car	39.54573	0.648595	9.047941	1.89E-07	0.024288	0.000789	0.13924
04. Courier Van-Utility	36.31417	0.643701	5.521223	-5.6E-06	0.035194	0.002189	0.150954
05. 4WD Mid-Size Petrol	39.30201	0.629316	5.474172	-3E-07	0.031918	0.001813	0.111811
06. Light Rigid	50.51551	0.615503	4.671897	1.04E-06	0.037672	0.001715	0.118443
07. Medium Rigid	59.11182	0.534888	6.854957	4.96E-06	0.03151	0.001613	0.076259
08. Heavy Rigid	100.8667	0.293957	6.877132	-6.2E-07	0.049736	0.000336	0.051313
09. Heavy Bus	147.5751	0.478312	4.46454	-2.6E-05	0.047698	0.000577	0.030939
10. Artic 4 Axle	135.4435	0.193477	7.168291	1.37E-05	0.067231	-0.00042	0.041229
11. Artic 5 Axle	148.4371	0.221801	6.426378	1.06E-05	0.065482	-0.00033	0.035283
12. Artic 6 Axle	164.8885	0.217463	5.974856	9.29E-06	0.064436	-0.00034	0.031935
13. Rigid + 5 Axle Dog	188.665	0.112824	5.989117	3.29E-05	0.059023	-0.00058	0.028349
14. B-Double	214.4745	0.108823	5.951336	2.86E-05	0.06216	-0.0004	0.02471
15. Twin steer + 5 Axle Dog	209.5405	0.105984	5.942593	2.95E-05	0.061733	-0.00045	0.02588
16. A-Double	289.4952	0.040729	5.745942	5.62E-05	0.059265	-0.00044	0.018672
17. B Triple	332.5626	0.06612	5.901342	5.98E-05	0.059667	-0.00027	0.016001
18. A B Combination	347.7601	-0.03191	5.538538	1E-04	0.056944	-0.00049	0.015743
19. A-Triple	398.2401	-0.07095	5.531043	0.000134	0.05711	-0.0005	0.014162
20. Double B-Double	415.1446	-0.08417	5.263537	0.00014	0.055545	-0.00052	0.013732

Source: ARRB Group Ltd.

Appendix E Detailed fuel consumption coefficients (uninterrupted flow)

Table 56 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 0

Curvature = 20° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	6.419556	0.441226	12.43718	6.68E-05	0.006151	0.149391
02. Medium Car	7.771756	0.429248	14.42872	5.78E-05	0.005364	0.122652
03. Large Car	9.826507	0.473008	15.01703	4.7E-05	0.004258	0.08713
04. Courier Van-Utility	7.609467	0.284026	19.36752	6.91E-05	0.006175	0.110658
05. 4WD Mid-Size Petrol	10.24522	0.464267	14.11609	5.05E-05	0.005148	0.063315
06. Light Rigid	8.085994	0.239071	13.9732	0.000116	0.012785	0.099828
07. Medium Rigid	12.45859	0.36312	9.564724	9.97E-05	0.014856	0.048677
08. Heavy Rigid	23.22869	0.243735	14.52463	9.95E-05	0.012912	0.019901
09. Heavy Bus	23.33246	0.271022	14.12877	6.85E-05	0.011434	0.01995
10. Artic 4 Axle	27.24712	0.160111	12.59432	0.000116	0.019467	0.021969
11. Artic 5 Axle	30.44964	0.265547	11.51051	0.000103	0.017613	0.014919
12. Artic 6 Axle	33.79927	0.303256	10.38151	9.34E-05	0.017999	0.013406
13. Rigid + 5 Axle Dog	38.14329	0.302384	9.066662	8.58E-05	0.02207	0.011962
14. B-Double	41.48179	0.32033	8.323599	7.96E-05	0.022113	0.010988
15. Twin steer + 5 Axle Dog	40.98332	0.321609	8.44159	8.01E-05	0.022176	0.011101
16. A-Double	47.75104	0.300993	7.10185	7.17E-05	0.024567	0.009609
17. B Triple	50.31407	0.30429	6.703995	6.89E-05	0.024871	0.009132
18. A B Combination	54.29232	0.287536	6.08939	6.64E-05	0.027662	0.008529
19. A-Triple	58.66595	0.27658	5.547481	6.39E-05	0.029925	0.00794
20. Double B-Double	61.23917	0.280027	5.283165	6.2E-05	0.029966	0.007613

Source: ARRB Group Ltd.

Table 57 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 0

Curvature = 120° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	6.420102	0.439234	12.28431	6.7E-05	0.005893	0.157521
02. Medium Car	7.775476	0.42409	14.30184	5.84E-05	0.005073	0.130745
03. Large Car	9.832691	0.466236	14.90356	4.78E-05	0.003936	0.094725
04. Courier Van-Utility	7.616445	0.249977	19.61225	7.34E-05	0.005816	0.122244
05. 4WD Mid-Size Petrol	10.25566	0.438984	14.39811	5.46E-05	0.00485	0.068036
06. Light Rigid	8.086364	0.225894	14.05784	0.000119	0.012559	0.102707
07. Medium Rigid	12.46055	0.261205	10.88355	0.000116	0.014085	0.053823
08. Heavy Rigid	23.2391	0.161191	15.62442	0.000114	0.012347	0.021583
09. Heavy Bus	23.37863	0.184935	15.22807	8.3E-05	0.010906	0.02188
10. Artic 4 Axle	27.25844	0.078697	13.41707	0.000132	0.018432	0.023635
11. Artic 5 Axle	30.46289	0.215002	12.05477	0.000114	0.016873	0.015683
12. Artic 6 Axle	33.81456	0.254183	10.9273	0.000105	0.017296	0.014056
13. Rigid + 5 Axle Dog	38.16272	0.23046	9.992665	0.000102	0.021312	0.012538
14. B-Double	41.50446	0.248591	9.264501	9.55E-05	0.021412	0.011506
15. Twin steer + 5 Axle Dog	41.00494	0.245251	9.44317	9.69E-05	0.02144	0.011646
16. A-Double	47.78389	0.213792	8.297749	9.06E-05	0.023832	0.010063
17. B Triple	50.35022	0.217325	7.908359	8.77E-05	0.024161	0.009554
18. A B Combination	54.33392	0.196344	7.363974	8.68E-05	0.026772	0.008899
19. A-Triple	58.71299	0.188315	6.781563	8.47E-05	0.028839	0.008253
20. Double B-Double	61.28954	0.192702	6.513579	8.25E-05	0.028915	0.007907

Source: ARRB Group Ltd.

Table 58 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 0

Curvature = 300° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	6.430818	0.413296	12.05829	7.13E-05	0.005493	0.186733
02. Medium Car	7.817367	0.389915	14.03742	6.35E-05	0.004599	0.159215
03. Large Car	9.898382	0.428103	14.63301	5.33E-05	0.003436	0.120841
04. Courier Van-Utility	7.692486	0.125209	20.04833	9.27E-05	0.004954	0.16706
05. 4WD Mid-Size Petrol	10.36996	0.357685	14.85765	7.11E-05	0.004083	0.084988
06. Light Rigid	8.114709	0.126441	14.91988	0.000142	0.011942	0.11842
07. Medium Rigid	12.5064	-0.14671	15.26244	0.000198	0.012141	0.076241
08. Heavy Rigid	23.48931	-0.1457	18.70081	0.000183	0.010893	0.028691
09. Heavy Bus	23.75106	-0.10871	17.93336	0.000147	0.009469	0.029562
10. Artic 4 Axle	27.54483	-0.31256	16.98501	0.000227	0.017068	0.030663
11. Artic 5 Axle	30.79391	-0.00859	14.17715	0.000178	0.015795	0.018493
12. Artic 6 Axle	34.19471	0.041147	12.98095	0.000165	0.016237	0.016427
13. Rigid + 5 Axle Dog	38.64359	-0.04963	12.91794	0.00018	0.020026	0.014665
14. B-Double	42.06335	-0.02236	12.10437	0.000172	0.020135	0.013392
15. Twin steer + 5 Axle Dog	41.53801	-0.04102	12.45213	0.000177	0.020122	0.013629
16. A-Double	48.29061	-0.10604	11.80937	0.00018	0.022492	0.0118
17. B Triple	50.82917	-0.09977	11.42352	0.000176	0.022859	0.011189
18. A B Combination	54.74679	-0.16904	11.51535	0.000188	0.025386	0.010482
19. A-Triple	59.06178	-0.21146	11.36175	0.000196	0.027322	0.009765
20. Double B-Double	61.60803	-0.20134	11.04583	0.000192	0.027435	0.009347

Source: ARRB Group Ltd.

Table 59 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 40 m/km

Curvature = 20° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	6.491702	0.421436	12.37906	6.51E-05	0.005492	0.186578
02. Medium Car	7.868947	0.410501	14.29675	5.58E-05	0.004706	0.155039
03. Large Car	9.963608	0.45366	14.87534	4.5E-05	0.003707	0.112982
04. Courier Van-Utility	7.832269	0.213757	19.69587	5.62E-05	0.003273	0.209737
05. 4WD Mid-Size Petrol	10.41163	0.449003	13.97532	4.69E-05	0.004451	0.081451
06. Light Rigid	8.194043	0.12436	17.12533	0.000105	0.008075	0.169038
07. Medium Rigid	12.99676	0.21809	10.39679	6.96E-05	0.011354	0.115936
08. Heavy Rigid	28.30358	0.154471	11.0119	3.42E-05	0.00796	0.057013
09. Heavy Bus	32.60248	0.228565	7.548896	7.54E-06	0.005175	0.050176
10. Artic 4 Axle	33.39936	-0.027	11.85291	6.2E-05	0.011762	0.051206
11. Artic 5 Axle	37.52704	0.045769	9.932212	5.12E-05	0.01116	0.043394
12. Artic 6 Axle	41.89155	0.08751	8.372325	4.27E-05	0.010967	0.038763
13. Rigid + 5 Axle Dog	49.68329	0.089869	6.958297	3.38E-05	0.011206	0.03299
14. B-Double	55.50393	0.123463	5.655572	2.53E-05	0.010672	0.029441
15. Twin steer + 5 Axle Dog	53.77065	0.107184	6.134378	2.99E-05	0.011087	0.030439
16. A-Double	70.87782	0.090232	4.637931	1.99E-05	0.010249	0.023259
17. B Triple	76.101	0.086012	4.363395	1.9E-05	0.010076	0.021702
18. A B Combination	84.65477	0.012202	4.870402	2.85E-05	0.010692	0.019903
19. A-Triple	93.68756	-0.04522	5.128339	3.82E-05	0.011146	0.018281
20. Double B-Double	99.14634	-0.04822	4.938515	3.86E-05	0.010979	0.017311

Source: ARRB Group Ltd.

Table 60 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 40 m/km

Curvature = 120° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	6.493322	0.420576	12.22087	6.51E-05	0.005274	0.193604
02. Medium Car	7.872492	0.407349	14.15426	5.61E-05	0.004455	0.162052
03. Large Car	9.969471	0.448725	14.74419	4.55E-05	0.003412	0.119872
04. Courier Van-Utility	7.838735	0.213127	19.44389	5.63E-05	0.002959	0.215253
05. 4WD Mid-Size Petrol	10.42136	0.437022	14.03395	4.93E-05	0.004167	0.084735
06. Light Rigid	8.195025	0.16858	16.15015	9.71E-05	0.008117	0.168629
07. Medium Rigid	12.99869	0.246486	9.633341	6.75E-05	0.010245	0.116933
08. Heavy Rigid	28.33669	0.163915	10.80028	3.37E-05	0.007627	0.056952
09. Heavy Bus	32.65292	0.219811	7.703291	1.01E-05	0.005089	0.050121
10. Artic 4 Axle	33.40959	0.05646	10.2964	4.65E-05	0.010702	0.050966
11. Artic 5 Axle	37.53559	0.11535	8.606099	4.06E-05	0.00982	0.043285
12. Artic 6 Axle	41.90111	0.1461	7.240625	3.43E-05	0.009678	0.038709
13. Rigid + 5 Axle Dog	49.69475	0.102705	6.665637	3.35E-05	0.010667	0.033009
14. B-Double	55.51692	0.115608	5.726222	2.91E-05	0.010274	0.029512
15. Twin steer + 5 Axle Dog	53.78323	0.110606	6.010958	3.16E-05	0.010577	0.030479
16. A-Double	71.56002	0.067406	4.892933	2.66E-05	0.009926	0.02313
17. B Triple	76.78857	0.064714	4.597889	2.54E-05	0.009782	0.021592
18. A B Combination	85.29855	-0.00897	5.104891	3.6E-05	0.01042	0.019823
19. A-Triple	94.30344	-0.06631	5.364557	4.66E-05	0.010892	0.018218
20. Double B-Double	99.74974	-0.06869	5.167497	4.68E-05	0.010745	0.017259

Source: ARRB Group Ltd.

Table 61 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 40 m/km

Curvature = 300° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	6.50887	0.395606	11.99303	6.9E-05	0.004896	0.22141
02. Medium Car	7.911688	0.376754	13.86783	6.04E-05	0.004018	0.189019
03. Large Car	10.03082	0.417092	14.4	4.99E-05	0.002941	0.14439
04. Courier Van-Utility	7.908757	0.153452	19.18577	6.59E-05	0.002259	0.243295
05. 4WD Mid-Size Petrol	10.52677	0.369651	14.3127	6.31E-05	0.00353	0.099866
06. Light Rigid	8.221647	0.188198	15.12783	9.68E-05	0.007588	0.174732
07. Medium Rigid	13.06227	0.232187	8.89884	8.02E-05	0.00832	0.121418
08. Heavy Rigid	28.70234	0.185064	10.01106	3.69E-05	0.006607	0.056523
09. Heavy Bus	33.20975	0.175593	8.061245	2.46E-05	0.004641	0.050075
10. Artic 4 Axle	33.57317	0.090655	9.511494	4.72E-05	0.009588	0.050723
11. Artic 5 Axle	37.72303	0.158172	7.640554	4.03E-05	0.008516	0.043088
12. Artic 6 Axle	42.11388	0.1725	6.561832	3.74E-05	0.008475	0.038596
13. Rigid + 5 Axle Dog	49.9594	0.081453	6.917595	4.69E-05	0.009926	0.032908
14. B-Double	55.82178	0.091411	6.044326	4.29E-05	0.009603	0.029416
15. Twin steer + 5 Axle Dog	54.07515	0.094774	6.179251	4.38E-05	0.00982	0.030361
16. A-Double	71.97696	0.02199	5.549003	4.49E-05	0.009529	0.0231
17. B Triple	77.60805	0.020778	5.199092	4.29E-05	0.00938	0.021462
18. A B Combination	86.70535	-0.05037	5.607509	5.36E-05	0.009974	0.01959
19. A-Triple	95.55213	-0.10394	5.814082	6.43E-05	0.010483	0.018051
20. Double B-Double	100.9416	-0.10482	5.599205	6.41E-05	0.010368	0.017122

Source: ARRB Group Ltd.

Table 62 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 60 m/km

Curvature = 20° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	6.660659	0.383441	12.05435	6.02E-05	0.004748	0.259216
02. Medium Car	8.088164	0.362947	14.05313	5.09E-05	0.003776	0.223792
03. Large Car	10.21493	0.433193	14.14124	4.13E-05	0.003358	0.151311
04. Courier Van-Utility	8.628304	0.254692	14.78987	2.37E-05	0.003761	0.328462
05. 4WD Mid-Size Petrol	10.67786	0.354199	14.35104	3.76E-05	0.002676	0.152982
06. Light Rigid	8.868398	0.100342	14.27262	6.79E-05	0.008529	0.266148
07. Medium Rigid	14.41519	0.085917	9.278373	5.93E-05	0.010135	0.167807
08. Heavy Rigid	34.54665	0.154153	8.303831	1.67E-05	0.006399	0.06815
09. Heavy Bus	40.43583	0.222189	5.431081	-4.1E-06	0.004267	0.058178
10. Artic 4 Axle	39.85896	0.063163	8.47945	2.72E-05	0.009022	0.060658
11. Artic 5 Axle	46.52422	0.092265	7.003547	2.51E-05	0.008172	0.050401
12. Artic 6 Axle	52.45046	0.110276	5.950767	2.17E-05	0.008045	0.04461
13. Rigid + 5 Axle Dog	62.31096	0.024451	6.170531	2.97E-05	0.008903	0.038382
14. B-Double	70.10879	0.031785	5.430211	2.68E-05	0.008552	0.034093
15. Twin steer + 5 Axle Dog	68.10427	0.03025	5.611995	2.78E-05	0.008778	0.035072
16. A-Double	91.3902	-0.04766	5.033767	3.52E-05	0.008133	0.026777
17. B Triple	98.94077	-0.05406	4.770973	3.6E-05	0.007935	0.024833
18. A B Combination	111.5167	-0.12552	4.913514	5.28E-05	0.008334	0.022614
19. A-Triple	124.3793	-0.18484	4.947623	7.04E-05	0.008709	0.020733
20. Double B-Double	132.0606	-0.18468	4.721459	7.1E-05	0.00854	0.019594

Source: ARRB Group Ltd.

Table 63 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 60 m/km

Curvature = 120° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	6.66118	0.38597	11.83227	5.97E-05	0.00459	0.26565
02. Medium Car	8.09162	0.36214	13.8632	5.07E-05	0.003596	0.230401
03. Large Car	10.2207	0.426125	14.04099	4.18E-05	0.003159	0.158539
04. Courier Van-Utility	8.638611	0.260974	14.41565	2.2E-05	0.003549	0.333078
05. 4WD Mid-Size Petrol	10.68749	0.356644	14.16712	3.79E-05	0.002397	0.154782
06. Light Rigid	8.870616	0.142956	13.25778	6.01E-05	0.007989	0.267849
07. Medium Rigid	14.41721	0.115409	8.640166	5.65E-05	0.009299	0.167948
08. Heavy Rigid	34.75485	0.146114	8.362031	1.87E-05	0.00625	0.067837
09. Heavy Bus	40.65993	0.21837	5.446216	-3.2E-06	0.004214	0.057873
10. Artic 4 Axle	40.35225	0.045768	8.556549	3.34E-05	0.00858	0.060166
11. Artic 5 Axle	46.69599	0.067883	7.304556	3.28E-05	0.007798	0.050442
12. Artic 6 Axle	52.45946	0.086464	6.280863	2.9E-05	0.007727	0.044801
13. Rigid + 5 Axle Dog	62.93881	0.000857	6.419083	3.76E-05	0.008552	0.038134
14. B-Double	70.7471	0.009179	5.676765	3.42E-05	0.008242	0.033907
15. Twin steer + 5 Axle Dog	68.70264	0.005631	5.895285	3.58E-05	0.00845	0.034892
16. A-Double	92.05697	-0.0697	5.279134	4.39E-05	0.007901	0.026669
17. B Triple	99.60275	-0.0752	5.004972	4.46E-05	0.007727	0.024746
18. A B Combination	112.175	-0.14565	5.125811	6.29E-05	0.008141	0.02254
19. A-Triple	125.0379	-0.20479	5.151179	8.22E-05	0.008525	0.02067
20. Double B-Double	132.7192	-0.20394	4.91556	8.27E-05	0.00837	0.01954

Source: ARRB Group Ltd.

Table 64 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 60 m/km

Curvature = 300° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	6.671103	0.353384	11.72121	6.38E-05	0.004305	0.296659
02. Medium Car	8.130261	0.32417	13.73434	5.55E-05	0.003274	0.257727
03. Large Car	10.28149	0.383253	13.98039	4.77E-05	0.002791	0.182381
04. Courier Van-Utility	8.721555	0.234586	13.88386	2.46E-05	0.00295	0.351359
05. 4WD Mid-Size Petrol	10.79231	0.325967	14.0717	4.63E-05	0.001819	0.162062
06. Light Rigid	8.90674	0.186791	11.96899	5.39E-05	0.007028	0.271206
07. Medium Rigid	14.45852	0.142413	7.796252	6.03E-05	0.008031	0.168549
08. Heavy Rigid	35.19441	0.121799	8.614031	2.87E-05	0.005787	0.067161
09. Heavy Bus	41.78446	0.203008	5.479375	3.23E-06	0.004008	0.056234
10. Artic 4 Axle	41.2539	0.011604	8.785071	4.81E-05	0.007892	0.059194
11. Artic 5 Axle	46.88105	0.034322	7.738604	4.78E-05	0.007212	0.050475
12. Artic 6 Axle	52.66982	0.055954	6.683765	4.29E-05	0.007168	0.044802
13. Rigid + 5 Axle Dog	63.47482	-0.04254	6.977474	5.58E-05	0.00808	0.037988
14. B-Double	71.50701	-0.03299	6.213738	5.15E-05	0.007801	0.033703
15. Twin steer + 5 Axle Dog	68.98461	-0.03963	6.525944	5.44E-05	0.008028	0.03491
16. A-Double	93.09581	-0.10354	5.671144	5.99E-05	0.007552	0.026476
17. B Triple	100.5787	-0.10689	5.368857	6.01E-05	0.007414	0.024601
18. A B Combination	113.0233	-0.1732	5.423315	7.92E-05	0.007862	0.022439
19. A-Triple	125.8265	-0.23133	5.429643	0.0001	0.008266	0.020593
20. Double B-Double	133.4894	-0.22954	5.180474	0.0001	0.008132	0.019477

Source: ARRB Group Ltd.

Table 65 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 80 m/km

Curvature = 20° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	6.843005	0.29989	11.63124	4.83E-05	0.003534	0.445097
02. Medium Car	8.396108	0.283436	13.04597	3.72E-05	0.002766	0.386246
03. Large Car	10.49274	0.319691	14.08242	3.31E-05	0.002064	0.284781
04. Courier Van-Utility	9.721387	0.285821	11.20472	6.62E-06	0.003463	0.393865
05. 4WD Mid-Size Petrol	11.32372	0.317651	12.00848	1.92E-05	0.002788	0.237287
06. Light Rigid	10.01749	0.140161	10.84775	3.94E-05	0.006965	0.320465
07. Medium Rigid	16.6881	0.124102	6.617649	3.7E-05	0.007796	0.191137
08. Heavy Rigid	40.17012	0.105414	7.650529	1.55E-05	0.00545	0.07714
09. Heavy Bus	48.93764	0.187502	4.435923	-1E-05	0.003527	0.06338
10. Artic 4 Axle	47.03696	-0.00698	8.044601	3.33E-05	0.007539	0.067528
11. Artic 5 Axle	54.51961	0.016157	6.88415	2.98E-05	0.006959	0.056987
12. Artic 6 Axle	61.83468	0.028879	5.993544	2.67E-05	0.006874	0.050191
13. Rigid + 5 Axle Dog	74.67714	-0.07871	6.254406	4.26E-05	0.007567	0.042834
14. B-Double	84.67729	-0.0718	5.581742	4.01E-05	0.007201	0.037799
15. Twin steer + 5 Axle Dog	81.75482	-0.07521	5.818556	4.06E-05	0.007474	0.039091
16. A-Double	113.0883	-0.1502	4.93549	5.74E-05	0.006704	0.02922
17. B Triple	122.907	-0.15491	4.642439	5.92E-05	0.006523	0.027043
18. A B Combination	139.354	-0.24207	4.733977	9.1E-05	0.006924	0.024691
19. A-Triple	155.9806	-0.3161	4.768328	0.000125	0.007322	0.0227
20. Double B-Double	166.0829	-0.31384	4.532479	0.000127	0.00718	0.021415

Source: ARRB Group Ltd.

Table 66 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 80 m/km

Curvature = 120° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	6.843503	0.311187	11.22108	4.63E-05	0.003355	0.45123
02. Medium Car	8.399035	0.293159	12.65611	3.54E-05	0.002597	0.39161
03. Large Car	10.49838	0.323944	13.82907	3.24E-05	0.001838	0.289059
04. Courier Van-Utility	9.735065	0.28858	11.04339	5.94E-06	0.003357	0.395156
05. 4WD Mid-Size Petrol	11.33932	0.320586	11.74431	1.83E-05	0.002574	0.240142
06. Light Rigid	10.02026	0.184425	9.926024	3.1E-05	0.006572	0.320354
07. Medium Rigid	16.68998	0.147204	6.155281	3.41E-05	0.007409	0.190969
08. Heavy Rigid	40.3425	0.100147	7.673981	1.71E-05	0.005338	0.076906
09. Heavy Bus	49.12072	0.1868	4.406284	-9.9E-06	0.003486	0.063176
10. Artic 4 Axle	47.46922	-0.01739	8.052259	3.82E-05	0.007233	0.067105
11. Artic 5 Axle	55.0735	-0.0028	7.041924	3.66E-05	0.006627	0.056602
12. Artic 6 Axle	62.41772	0.008696	6.188781	3.35E-05	0.006567	0.049896
13. Rigid + 5 Axle Dog	75.34548	-0.10247	6.508512	5.23E-05	0.007281	0.042577
14. B-Double	85.34317	-0.09473	5.8343	4.95E-05	0.006951	0.037616
15. Twin steer + 5 Axle Dog	82.42721	-0.09982	6.098776	5.02E-05	0.0072	0.038887
16. A-Double	113.7469	-0.17015	5.141846	6.81E-05	0.006525	0.029122
17. B Triple	123.5657	-0.17389	4.835259	6.99E-05	0.006364	0.026964
18. A B Combination	140.0128	-0.2608	4.909581	0.000104	0.006772	0.024625
19. A-Triple	156.6395	-0.33523	4.936094	0.000141	0.007174	0.022648
20. Double B-Double	166.7418	-0.33246	4.692249	0.000144	0.007043	0.021373

Source: ARRB Group Ltd.

Table 67 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 80 m/km

Curvature = 300° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	6.850633	0.302709	10.62808	4.54E-05	0.003047	0.481118
02. Medium Car	8.427881	0.274598	12.09516	3.51E-05	0.002293	0.420888
03. Large Car	10.55836	0.312025	13.28676	3.3E-05	0.001502	0.306944
04. Courier Van-Utility	9.895639	0.266583	10.91513	9.99E-06	0.003018	0.396213
05. 4WD Mid-Size Petrol	11.46182	0.295474	11.4256	2.2E-05	0.002062	0.249415
06. Light Rigid	10.05607	0.232052	8.829506	2.28E-05	0.006105	0.319835
07. Medium Rigid	16.73087	0.166147	5.68081	3.56E-05	0.006833	0.190571
08. Heavy Rigid	41.13544	0.076169	7.827707	2.57E-05	0.004968	0.075699
09. Heavy Bus	49.88076	0.181793	4.366817	-7.2E-06	0.003367	0.062194
10. Artic 4 Axle	48.28824	-0.0413	8.163107	5.08E-05	0.006745	0.066272
11. Artic 5 Axle	56.02333	-0.03787	7.3792	5.19E-05	0.006114	0.055904
12. Artic 6 Axle	63.40329	-0.02787	6.584284	4.87E-05	0.006092	0.049354
13. Rigid + 5 Axle Dog	76.32008	-0.13647	6.878878	6.93E-05	0.006862	0.042179
14. B-Double	86.30705	-0.12782	6.20732	6.58E-05	0.006582	0.037328
15. Twin steer + 5 Axle Dog	83.45961	-0.13599	6.519241	6.76E-05	0.006793	0.038541
16. A-Double	114.5364	-0.19693	5.424729	8.47E-05	0.006269	0.029005
17. B Triple	124.3283	-0.19932	5.09837	8.63E-05	0.006136	0.026876
18. A B Combination	140.7353	-0.28565	5.149728	0.000124	0.006564	0.024557
19. A-Triple	157.3492	-0.36082	5.169334	0.000165	0.006974	0.022594
20. Double B-Double	167.452	-0.3575	4.914559	0.000168	0.006857	0.021329

Source: ARRB Group Ltd.

Table 68 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 100 m/km

Curvature = 20° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	7.400402	0.27435	9.057882	3.11E-05	0.003508	0.59533
02. Medium Car	9.244845	0.276724	9.985246	2.09E-05	0.002794	0.487639
03. Large Car	11.34047	0.292851	11.41155	1.9E-05	0.00204	0.38506
04. Courier Van-Utility	10.62315	0.30124	9.424766	-2.1E-06	0.003237	0.442821
05. 4WD Mid-Size Petrol	12.48065	0.316942	9.63952	7.31E-06	0.002581	0.27934
06. Light Rigid	11.07491	0.195597	8.391925	1.67E-05	0.006231	0.356572
07. Medium Rigid	18.98699	0.134422	5.340234	2.51E-05	0.006723	0.206634
08. Heavy Rigid	46.38865	0.054034	7.277578	1.84E-05	0.004642	0.08303
09. Heavy Bus	57.90962	0.140971	4.139998	-1E-05	0.003004	0.066641
10. Artic 4 Axle	54.40387	-0.08188	7.741008	4.51E-05	0.00659	0.073154
11. Artic 5 Axle	62.98867	-0.05919	6.782378	3.88E-05	0.006073	0.062015
12. Artic 6 Axle	71.67603	-0.04859	6.01876	3.57E-05	0.005983	0.054472
13. Rigid + 5 Axle Dog	87.78566	-0.17518	6.231594	6.36E-05	0.006571	0.046213
14. B-Double	99.97769	-0.16196	5.54257	6.01E-05	0.00621	0.04062
15. Twin steer + 5 Axle Dog	96.17379	-0.16775	5.824172	5.98E-05	0.006477	0.042124
16. A-Double	135.2839	-0.24581	4.800226	9.03E-05	0.005779	0.031275
17. B Triple	147.3281	-0.24789	4.47458	9.27E-05	0.005616	0.028939
18. A B Combination	168.1839	-0.35595	4.602786	0.000152	0.00607	0.026431
19. A-Triple	189.3478	-0.4478	4.685001	0.000217	0.006449	0.024286
20. Double B-Double	201.9437	-0.44355	4.456079	0.000222	0.006314	0.022891

Source: ARRB Group Ltd.

Table 69 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 100 m/km

Curvature = 120° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	7.401802	0.273919	8.756665	2.97E-05	0.003342	0.60797
02. Medium Car	9.249476	0.270127	9.798424	2.02E-05	0.002659	0.498825
03. Large Car	11.3496	0.285801	11.21226	1.84E-05	0.001901	0.39505
04. Courier Van-Utility	10.70718	0.295149	9.394596	-1.4E-06	0.003163	0.440236
05. 4WD Mid-Size Petrol	12.52925	0.317388	9.460006	6.78E-06	0.002444	0.280232
06. Light Rigid	11.08096	0.204522	8.157152	1.52E-05	0.00606	0.356948
07. Medium Rigid	18.9887	0.124664	5.475966	2.8E-05	0.006523	0.206998
08. Heavy Rigid	46.50087	0.051624	7.272455	1.95E-05	0.004563	0.082902
09. Heavy Bus	58.08002	0.140767	4.108501	-1E-05	0.00297	0.066484
10. Artic 4 Axle	55.06011	-0.09882	7.829649	5.37E-05	0.006305	0.072499
11. Artic 5 Axle	63.65135	-0.08057	6.975969	4.77E-05	0.005788	0.061556
12. Artic 6 Axle	72.34027	-0.07061	6.242102	4.44E-05	0.005724	0.054141
13. Rigid + 5 Axle Dog	88.44452	-0.19801	6.468989	7.54E-05	0.006328	0.045976
14. B-Double	100.6361	-0.18374	5.771909	7.13E-05	0.006001	0.040451
15. Twin steer + 5 Axle Dog	96.8333	-0.19113	6.080694	7.13E-05	0.006244	0.041935
16. A-Double	135.9427	-0.26482	4.978743	0.000104	0.00563	0.031189
17. B Triple	147.9869	-0.26574	4.63718	0.000106	0.005485	0.028869
18. A B Combination	168.8427	-0.37489	4.755026	0.00017	0.005936	0.026382
19. A-Triple	190.0067	-0.46752	4.828272	0.00024	0.00631	0.024252
20. Double B-Double	202.6026	-0.4628	4.593326	0.000245	0.006186	0.022864

Source: ARRB Group Ltd.

Table 70 Coefficients for rural (uninterrupted/free flow speed) fuel consumption model (litres per 100 km)

Road width = 8.5m

RF = 100 m/km

Curvature = 300° / km

Vehicle type	Base fuel (l/100km)	K_1	K_2	K_3	K_4	K_5
01. Small Car	7.41718	0.232865	8.65607	3.2E-05	0.002823	0.648334
02. Medium Car	9.289185	0.227191	9.780091	2.31E-05	0.002282	0.528603
03. Large Car	11.42163	0.240324	11.12027	2.12E-05	0.001563	0.422469
04. Courier Van-Utility	10.95924	0.279912	9.188647	1.28E-06	0.002897	0.433984
05. 4WD Mid-Size Petrol	12.66393	0.298769	9.392347	1.06E-05	0.00218	0.282367
06. Light Rigid	11.19492	0.197906	8.062212	1.82E-05	0.005709	0.354644
07. Medium Rigid	19.02887	0.107885	5.694181	3.56E-05	0.006133	0.207032
08. Heavy Rigid	47.0826	0.036959	7.32971	2.59E-05	0.004297	0.082131
09. Heavy Bus	58.67713	0.137035	4.062768	-8.5E-06	0.002869	0.065908
10. Artic 4 Axle	55.83263	-0.12107	7.948376	6.76E-05	0.005915	0.071778
11. Artic 5 Axle	64.52	-0.11032	7.251788	6.29E-05	0.005378	0.060958
12. Artic 6 Axle	73.23695	-0.10205	6.569634	5.96E-05	0.005342	0.053687
13. Rigid + 5 Axle Dog	89.26285	-0.22815	6.790303	9.38E-05	0.005987	0.045672
14. B-Double	101.439	-0.21272	6.084114	8.89E-05	0.005704	0.040241
15. Twin steer + 5 Axle Dog	97.67962	-0.22234	6.430972	8.96E-05	0.005912	0.04168
16. A-Double	136.6621	-0.29009	5.222857	0.000124	0.005423	0.031099
17. B Triple	148.698	-0.28963	4.860205	0.000126	0.005303	0.0288
18. A B Combination	169.5518	-0.40054	4.967801	0.000197	0.005754	0.026332
19. A-Triple	190.7166	-0.49442	5.030725	0.000274	0.006125	0.024217
20. Double B-Double	203.313	-0.48916	4.787312	0.000279	0.006014	0.022838

Source: ARRB Group Ltd.

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