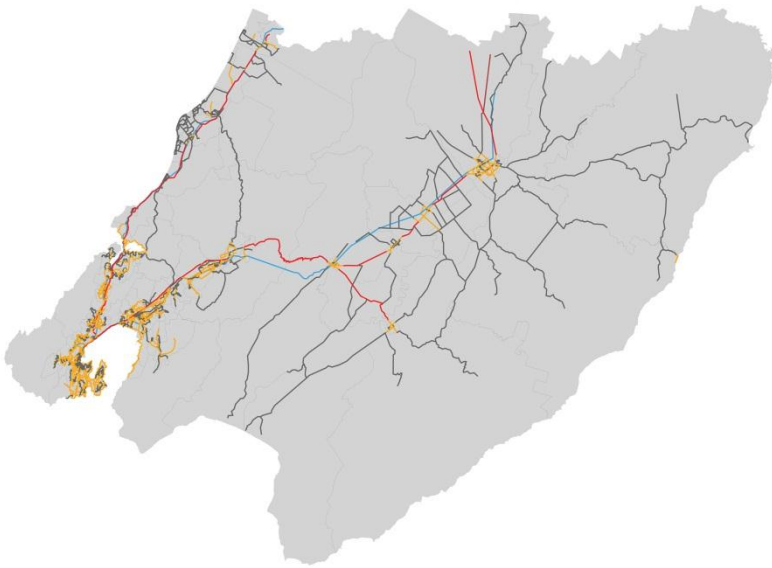


OPUS INTERNATIONAL CONSULTANTS AND ARUP

WELLINGTON TRANSPORT MODELS

Contract No C3079



TN15 Input Parameters

Date: December 2012

ARUP



Wellington Transport Models

TN15: Input Parameters

prepared for

Greater Wellington Regional Council



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1 Introduction

Opus International Consultants Limited (Opus) and Arup Australia (Arup) were commissioned by Greater Wellington Regional Council (GWRC) to rebase the existing 2006 Wellington Transport Strategy Model (WTSM) to a new base year of 2011. Opus updated the WTSM while Arup developed a Wellington Public Transport Model (WPTM) based on figures from WTSM and detailed public transport surveys. The whole process of model updates and development is complex and involves several steps which have each been individually reported in a series of technical notes.







This note documents the process used to update the Wellington Transport Strategic Model (WTSM) input parameters from 2006 to 2011 and the approach to forecasting these parameters to 2021, 2031 and 2041. The approach differs significantly from the 2006 update in both the calculation of the base 2011 parameters and the forecast year parameters:

- Firstly, the 2006 update used nominal 2006 values whereas during this update it was decided to adjust nominal 2011 prices back to 2001 dollars using the Consumer Price Index (CPI). The reason for this was that trip distribution and mode choice models had been calibrated in 2001 prices so the model would respond to prices at these levels i.e. using inflated nominal prices “supercharged” model responses;
- Secondly, substantial investigations were conducted into adjusting input parameters for forecast scenarios. This included reviews of the approaches in Auckland, Christchurch, Waikato and Melbourne. The work was initially guided by the work of David Young who produced a memo for GWRC which has been included in Appendix D. The memo contrasted the approaches of Auckland and Wellington (given the similarities of the models). Also contacted were the New Zealand Transport Agency (NZTA) and developers / users of the Canterbury, Waikato and Melbourne Travel Demand Forecasting Models for additional perspective. Teleconference meetings were held with representatives of some interested parties while others were contacted for their views and experience directly; and
- Thirdly, in calibrating the 2011 model it became clear that there was excess Public Transport (PT) demand in the mode choice model. The reasons for this have been summarised in TN18 but the outcomes have also been reported in this technical note due to the fact the manipulation was applied directly to the input parameters. The result of the investigations was that a factor of 1.2 was applied to the PT generalised cost matrices.

1.1 Base 2011 Approach

All the input parameters in the 2006 version of WTSM were expressed in 2006 prices. The approach taken in the 2011 update is to first adjust all inputs to nominal values in 2011 before making an inflation adjustment to 2001. Table 1-1 below summarises the approach taken.

Table 1-1: Summary of Input Sources and Adjustment Process

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Value of Time (VoT)	 VoT taken from Economic Evaluation Manual (EEM) and adjusted to 2011 nominal value using growth in nominal GDP per capita from 2001 to 2011.										
Vehicle Operating Cost (VoC) - Fuel	 VoC – fuel taken from EEM in 2008 values and adjusted to 2011 nominal values using fuel inflation.										
VoC – Non Fuel	 VoC – non fuel taken from EEM in 2008 and adjusted to 2011 nominal values using CPI.										
Parking Charges	 Parking charges taken from WCC and Wilsons Parking websites in 2011.										
Public Transport (PT)Fares	 PT Fares extracted from metlink website in 2011.										
All Input Values	 All inputs then inflation adjusted to 2001 using CPI.										

The inflation adjustment is not to reproduce costs as they were in 2001 but to scale them in a way that the trip distribution and mode split models can respond properly - due to the fact the demand model was calibrated using responses in 2001 prices. The nominal 2011 prices include an inflationary element which the demand model would interpret as a real effect and respond accordingly. The figure below shows how key nominal economic indicators used in the model have changed compared to an index year of 2001 (data included in Appendix A).

It can be seen from Figure 1-1 that Gross Domestic Product (GDP) per capita has been increasing but with a levelling off period between 2008 and 2009 reflecting the impacts of the Global Financial Crisis. CPI is also growing but at a slower rate than GDP. Perhaps most remarkable is the volatility of the household petrol index which climbed rapidly to peaks in 2005, 2008 and 2011.

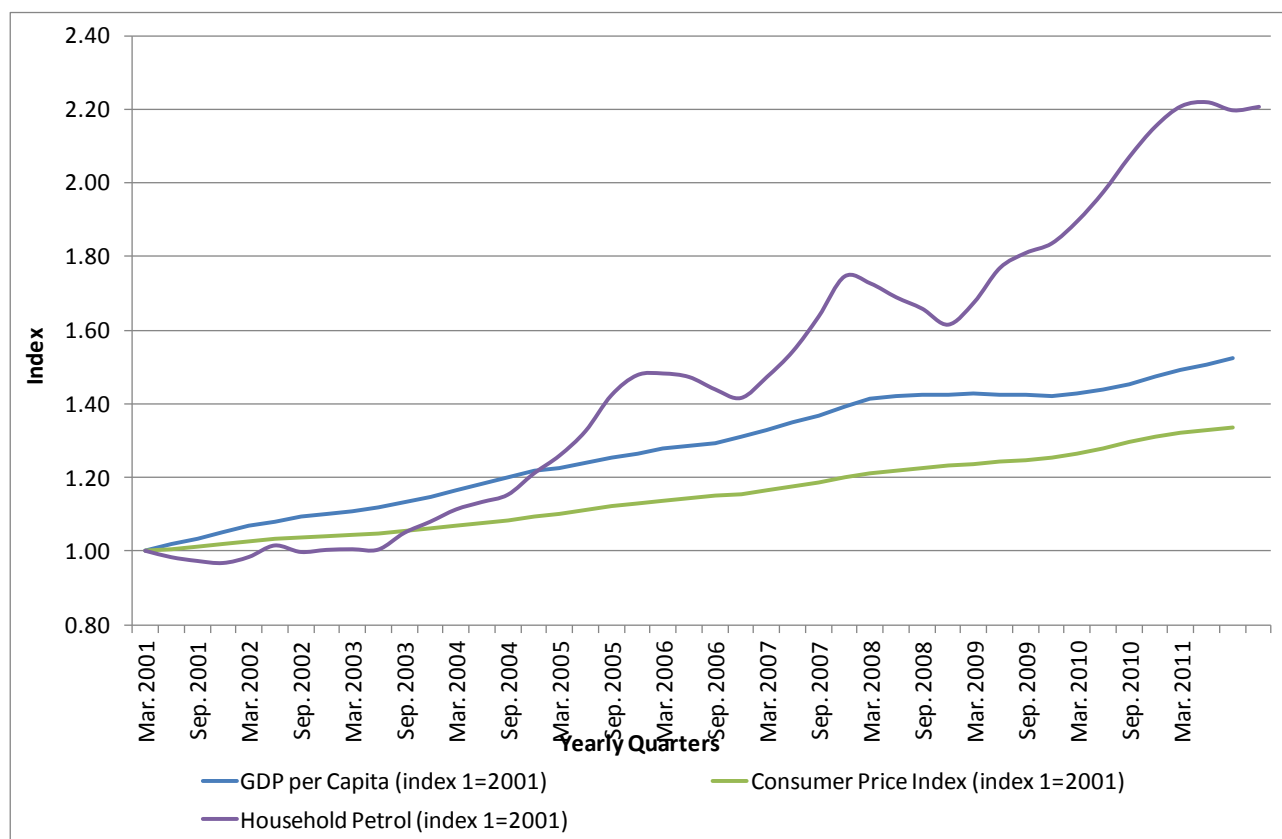


Figure 1-1: Nominal Economic Indicators Indexing 2001-2011¹

Finally input parameters must distinguish between the price year required for the operation of the 4 stage model and the price year required for reporting. To clarify:

- As mentioned above the price year required for the operation of the model is 2001 - the year the demand model was calibrated; and
- Model outputs, such as estimated Public Transport (PT) revenues, are reported in 2011 prices.

The approach of using 2001 prices rather than 2011 prices was confirmed during the validation process. The balance of car and PT trips aligned much more closely with observed values using 2001 prices rather than 2011 prices. In addition, the sensitivity testing undertaken as part of the validation process also confirmed sensible responses using 2001 prices. The results of the testing have been documented in Appendix F.

1.2 Forecast Approach

Wide consultation was undertaken on the approach to forecast parameters in other major centres. It was found that, at the time of writing this note, the only model where input parameters had been adjusted in the future scenarios was Auckland. The Christchurch, Waikato and Melbourne models kept parameters unchanged in future scenarios. Auckland modellers, in large part, were driven by public pressures regarding planning for peak oil

¹Source: \\wbsv01\wb_gen_g\Z_Drive\WTSM_2011\Economic Parameters\Updated 2011 VoT, VOC & Parking.xlsx

whereas developers of the Canterbury, Waikato and Melbourne models had maintained the convention of keeping input parameters unchanged due to the magnitude of the uncertainties involved.

On balance, the favoured approach was to make some changes as the overwhelming weight of evidence pointed to changes, particularly with regards to fuel prices. Ultimately, it was decided that it would be very useful to understand the impacts these were having under different assumption scenarios. This view was supported by NZTA who favoured the Auckland based approach to input parameter forecasting as it helped provide consistency in appraising economic benefits of projects in the two regions. NZTA, however, were also cautious as it was likely that the findings from the Wellington investigations (being the most recent) would warrant circulation for further discussion.

2 Values of Time

2.1 Methodology

Values of time parameters in WTSM are based on values from the NZTA's Economic Evaluation Manual (EEM) expressed by different modes and trip purposes, and by proportions for these trips modes and purposes from the 2001 Wellington Household Travel Survey (HTS).

These values of time were adjusted for the WTSM 2006 update using GDP growth, and the same procedure has been applied to update these values to 2011.

2.2 Values of Time Calculation

The values of time given by the EEM (Vol1, Table A4.1) are for 2002 and are shown in Table 2-1.

Table 2-1: EEM Base Values of Time 2002

Values for Vehicle Occupant Transport User Time in \$/hr (all road categories; all time periods - July 2002)

Vehicle occupant	Work travel purpose	Commuting to/from work	Other non-work travel purposes
Base values of time for uncongested traffic (\$/h)			
Car / motorcycle driver	23.85	7.8	6.9
Car / motorcycle passenger	21.7	5.85	5.2
Light commercial driver	23.45	7.8	6.9
Light commercial passenger	21.7	5.85	5.2
Medium/heavy commercial driver	20.1	7.8	6.9
Medium/heavy commercial passenger	20.1	5.85	5.2
Seated bus and train passenger	21.7	4.7	3.05
Standing bus and train passenger	21.7	6.6	4.25

These costs were adjusted to 2011 using *nominal* GDP per capita from Statistics NZ between 2001 and 2011, which led to a growth factor of **1.49**. These values (converted to cents/minute) were allocated to the different trip modes and purposes used in the model, and the proportions from the 2001 HTS and were used to calculate the values of time per trip purpose and car availability. The resulting values of time are detailed in the Table 2-2.

Table 2-2: Value of Time per Purpose (All road categories, all time periods – July 2011)

Purpose	Car Availability	2011 VoT (c/min)				
		Car Driver	Car Pax	PT	CV ¹	
HBW ²	Captive	19.39	14.54	11.68		
	Competition & Choice	19.39	14.54	11.68		
HBEd ³	Captive	17.15	12.93	7.58		
	Competition & Choice	17.15	12.93	7.58		
EB ⁴	All	59.29	53.94	53.94	58.29	
Other	Captive	17.15	12.93	7.58		
	Competition & Choice	17.15	12.93	7.58		
Purpose	Car Availability	Trips (from 2001 HTS)				2011 VoT (c/min) ⁵
		Car Driver	Car Pax	PT	CV ¹	
HBW ²	Captive	423	717	3,048		13.0
	Competition & Choice	141,940	26,803	37,245		17.4
HBEd ³	Captive	64	626	3,615		8.5
	Competition & Choice	37,596	48,967	30,268		12.9
EB ⁴	All	79,792	9,007	4,291	32,765	58.5
Other	Captive	1,876	18,043	13,395		11.0
	Competition & Choice	569,006	213,199	32,759		15.7

Notes:

1. CV = commercial vehicle
2. HBW = home based work
3. HBEd = home based education
4. EB = employers business
5. Average weighted by number of trips

Table 2-3 below shows the final 2001 values of time as well as the values used in the 2006 update and intermediate 2011 values for comparison.

Table 2-3: 2006 and 2011 Values of Time (All road categories, all time periods – July 2011)

Purpose	Car Availability	Nominal values used in WTSM 2006 (c/min) ¹	Estimated Nominal 2011 (c/min) ¹	CPI adjusted to 2001 (c/min) ¹
HBW	Captive	9.6	13.0	9.8
	Competition & Choice	12.9	17.4	13.2
	All	12.9	17.3	13.1
HBEEd	Captive	6.3	8.5	6.4
	Competition & Choice	9.6	12.9	9.8
	All	9.5	12.7	9.7
EB	All	43.5	58.5	44.3
Other	Captive	8.2	11.0	8.3
	Competition & Choice	11.7	15.7	11.9
	All	11.5	15.5	11.7

Notes:

1. Average weighted by number of trips

2.3 Values of Time Forecast

The forecast approach for values of time has been based on the recommendations of both David Young and a group of industry representatives mentioned in Section 1. The recommendation was to use the Auckland approach which included adjustment to real VoT using the real GDP per capita growth with an elasticity of 0.8 applied to non-work travel purposes.

Figure 2-1 shows how the work and non-work values of time increase with respect to 2006 values in the Auckland model resulting in increases of 87% and 65% respectively by 2041.

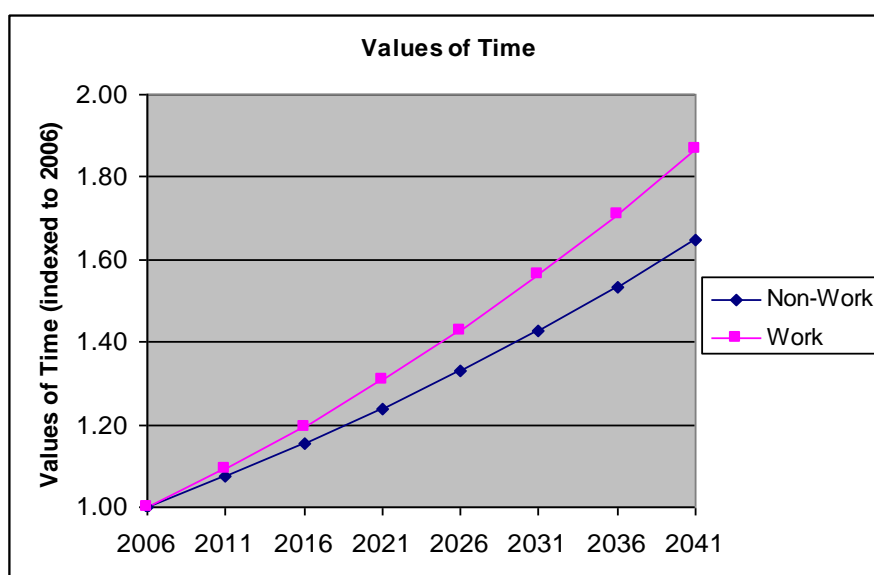


Figure 2-1: Auckland Values of Time (Indexed to 2006 values)

Table 2-4 shows the values of time in each model year (2011, 2021, 2031 and 2041) for each trip purpose plus how the adjustment factors were calculated. The use of NZ Treasury forecasts made it possible to improve the accuracy of the VoT forecast by using the labour force instead of total population. The approach was chosen because the purpose of the using GDP per capita was that it would reflect the fact that peoples incomes were increasing and a large proportion of the VoT explanatory variables related to income i.e. the more a person earned the higher their value of time. By using “Forecast Labour Force” it was possible to determine a more accurate link between VoT and income.

Table 2-4: Wellington Forecast Values of Time (in 2001 Prices)

Adjustment Factor Source		2011	2021	2031	2041	2011	2021	2031	2041
Real GDP (Base = 1995/96)		-	-	-	-	135.12	180.48	215.44	262.50
Labour Force (millions)		-	-	-	-	2.23	2.52	2.64	2.72
GDP/Labour_force		-	-	-	-	60.69	71.60	81.56	96.44
DDP/Labour_force Index		-	-	-	-	1.00	1.18	1.34	1.59
Purpose	Car Availability	Values of Time				Adjustment Factors (Index 1=2011)			
HBW	Captive	9.82	11.58	13.44	15.60	1.00	1.18	1.37	1.59
	Competition & Choice	13.16	15.53	18.02	20.91	1.00	1.18	1.37	1.59
	Combined	13.09	15.45	17.93	20.81	1.00	1.18	1.37	1.59
HBE d	Captive	6.44	7.37	8.35	9.48	1.00	1.14	1.30	1.47
	Competition & Choice	9.78	11.18	12.67	14.39	1.00	1.14	1.30	1.47
	Combined	9.66	11.05	12.51	14.21	1.00	1.14	1.30	1.47
EB	Competition & Choice	44.31	52.28	60.67	70.41	1.00	1.18	1.37	1.59
	Captive	40.88	48.23	55.98	64.96	1.00	1.18	1.37	1.59
Other	Captive	8.35	9.55	10.81	12.28	1.00	1.14	1.30	1.47
	Competition & Choice	11.87	13.58	15.38	17.46	1.00	1.14	1.30	1.47
	Combined	11.73	13.42	15.20	17.26	1.00	1.14	1.30	1.47

3 Vehicle Operating Costs

3.1 Methodology

The vehicle operating costs (VoC) used in WTSM are based on values from Appendix A5 of the EEM (all costs in July 2008 dollars) and include the following components:

- Base costs: fuel and oil, tyres, maintenance and repairs (M&R), depreciation;
- Road surface condition / roughness;
- Congestion;
- Stoppages (VoC due to bottleneck delay); and
- Changes in speed.

Although some of these components are defined in the EEM as a function of road category, gradient or speed (and therefore congestion), they are implemented in WTSM as fixed parameters and do not vary with changes in infrastructure or travel conditions. For this purpose, and in order to calculate network-wide values, a number of assumptions had to be made regarding average speed, gradient and other parameters, which were all based on the 2006 model update.

VoC are, however, calculated separately for the following vehicle categories:

- Private Car (PC);
- Light Commercial Vehicle (LCV);
- Medium Commercial Vehicle (MCV);
- Heavy Commercial Vehicle Category I (HCVI);
- Heavy Commercial Vehicle Category II (HCVII); and
- Bus.

In addition to this, the Road User Charges for diesel vehicles have also been included. The costs are calculated in units of cents per kilometre.

3.2 Base 2008 Costs from the EEM

Base VoC includes fuel, tyres, maintenance and repairs (M&R), and vehicle depreciation. The total base VoC for each vehicle category is given in Tables A5.1 to A5.6 of the EEM and are a function of speed and gradient (see Appendix E). The 2006 model assumed a network-wide value with an average speed of 45km/h and an average gradient of 1%. The 2011 model used the same assumptions to maintain consistency.

These total costs are then disaggregated into fuel, tyre, M&R and depreciation with the proportions for each components obtained from Table A5.0(a) of the EEM (also included in Appendix E). The total base costs, proportions and resulting components costs are detailed in Table 3-1.

Table 3-1: Base Costs (2008)

Class	Base Cost	Component Proportions and Costs							
		Fuel/Oil		Tyres		R&M		Depreciation	
	c/km	%	c/km	%	c/km	%	c/km	%	c/km
PC	25.3	49.5	12.5	5.1	1.3	24.9	6.3	20.5	5.2
LCV	27.5	54.9	15.1	7.1	2.0	20.6	5.7	17.4	4.8
MCV	49.4	53.3	26.3	5.2	2.6	32.7	16.2	8.8	4.3
HCVI	97.2	58.2	56.6	6.9	6.7	29.7	28.9	5.2	5.1
HCVII	157.3	55.3	87.0	9.4	14.8	29.1	45.8	6.2	9.8
Bus	78.8	61.9	48.8	4.4	3.5	26.0	20.5	7.7	6.1

3.3 Road Surface Condition Costs

The road surface condition (or road roughness) costs are an estimation of a vehicles natural wear and tear caused by the condition of the road. It is given for each vehicle category in Table A5.12 of the EEM (Appendix E) and is a function of the International Roughness Index (IRI) of the road. The 2006 model assumed a network-wide cost with an average value of 4.5 m/km for urban road. The 2011 model used the same assumptions to maintain consistency

The resulting road surface condition costs are shown in Table 3-2.

Table 3-2: Road Surface Condition Costs (2008)

Class	Costs (c/km)
PC	2.4
LCV	2.3
MCV	5.8
HCVI	8.4
HCVII	12.3
Bus	8

3.4 Congestion Costs

Congestion costs account for additional fuel use caused by vehicle acceleration and deceleration in a congested environment and are a function of the vehicle to capacity ratio (V/C). The 2006 model assumed values for urban roads category with an average V/C of 0.7, as shown in Table A5.16 of the EEM. The 2011 model used the same assumptions to maintain consistency

The resulting congestion costs are shown in Table 3-3.

Table 3-3: Congestion Costs (2008)

Class	Costs (c/km)
PC	1.2
LCV	2.2
MCV	3.5
HCVI	13.1
HCVII	37.2
Bus	7.3

3.5 Stoppage Costs

Stoppage costs represent the fuel consumption of idle vehicles experiencing bottleneck delays (when $V/C > 1$) and are shown in Table A5.22 of the EEM (Appendix E). Stoppage costs assumed in the 2006 model were expressed in c/min and the following assumptions were made to convert them to c/km:

- 1 stop per kilometre travelled; and
- 4 minutes per stop.

Again, the same has been assumed for the 2011 update. The resulting stoppage costs are shown in Table 3-4, both in c/min and c/km.

Table 3-4: Stoppage Costs (2008)

Class	Costs (c/min)	Costs (c/km)
PC	2.9	1.2
LCV	3.7	1.5
MCV	4.5	1.8
HCVI	6.7	2.7
HCVII	6.7	2.7
Bus	5.2	2.1

3.6 Changes in Speed Costs

Changes in speed costs account for additional costs incurred by vehicles having their speed interrupted due to road features (change in geometry, intersection, etc), causing speed cycles: the vehicle decelerates to a minimum speed and then accelerates back to its original cruise speed.

Changes in speed costs are given in EEM Tables A5.25 to A5.35 and are expressed in cents/cycle. The following assumptions were made in the 2006 model to convert them to c/km:

- 1 intersection stop per kilometre (as opposed to bottleneck stops in stoppages);
- Lower speed is 0kph; and
- Upper speed is 65kph.

The assumptions have been carried forward into the 2011 model. The resulting change in speed costs are shown in Table 3-5.

Table 3-5: Changes in Speed Costs (2008)

Class	Costs (c/cycle)	Costs (c/km)
PC	2.4	2.4
LCV	3.6	3.6
MCV	9.7	9.7
HCVI	26.9	26.9
HCVII	23.4	23.4
Bus	18.0	18.0

3.7 Total Costs

Table 3-6 below shows the calculated VoC for each vehicle category. The components are separated into fuel, M&R and 'other'.

Table 3-6: Total Vehicle Operating Costs (2008)

Financial Costs (c/km)		PC	LCV	MCV	HCVI	HCVII	Bus
Fuel	Base Costs: Fuel/Oil	12.5	15.1	26.3	56.6	87.0	48.8
	Congestion	1.2	2.2	3.5	13.1	37.2	7.3
	Stoppages	1.2	1.5	1.8	2.7	2.7	2.1
	Changes in Speed	2.4	3.6	9.7	26.9	23.4	18
	Total	17.3	22.4	41.3	99.2	150.3	76.2
R&M	Base Costs: R&M	6.3	5.7	16.2	28.9	45.8	20.5
	Road Surface Condition	2.4	2.3	5.8	8.4	12.3	8
	Total	8.7	8.0	22.0	37.3	58.1	28.5
Other*	Base Costs: Tyres	1.3	2.0	2.6	6.7	14.8	3.5
	Base Costs: Depreciation	5.2	4.8	4.3	5.1	9.8	6.1
	Total	6.5	6.7	6.9	11.8	24.5	9.5
Total (excl GST)		32.5	37.1	70.2	148.3	232.9	114.2

* Extracted directly from Base Costs (EEM Tables A5.7 to A5.6, July 2008)

VoC values in WTSM are input for Cars – Employers Business (fuel and non-fuel), Cars – Other (fuel only, including 12.5% GST) and Trucks (fuel and non-fuel). The above values were therefore aggregated using the following vehicle proportions from the 2001 Wellington HTS:

- Cars – Employers Business: 93.2% cars, 6.8% LCV;
- Cars – Other: 93.2% cars, 6.8% LCV; and
- Trucks: 39% MCV, 26% HCVI, 35% HCVII.

The resulting VoC parameters are shown in Table 3-7 below.

Table 3-7: Vehicle Operating Costs (2008)

Class	(c/km)
Car-EB fuel	17.63
Car-EB non-fuel	15.14
Car - EB Total	32.77
Car - Other (inc GST)	19.83
Trucks - fuel	94.51
Trucks -non-fuel	52.92
Trucks - total	147.43

3.8 Total VoC Adjustment to 2011

WTSM fuel costs were calculated in two steps:

- First, the 2008 VoCs were adjusted to 2011 using:
 - Nominal fuel price index from Statistics NZ to adjust fuel component of VoC (factor of **1.28**); and
 - CPI to adjust non-fuel costs (factor of **1.09**).
- Second, the 2011 nominal costs were then adjusted to 2001 levels using Statistics New Zealand's CPI (factor of **0.76**).

The final 2011 VoC inputs to WTSM are shown in Table 3-8 below, along with the 2006 VoC for comparison.

Table 3-8: Vehicle Operating Costs

Class	Nominal values used in WTSM 2006 (c/km)	Estimated Nominal 2011 (c/km)	CPI used to adjust VoC to 2001 (c/km)
Car-EB fuel	7.62	20.89	15.83
Car-EB non-fuel	12.41	16.62	12.60
Car - EB Total	20.03	37.51	28.43
Car - Other (inc GST)	8.58	23.50	17.81
Trucks - fuel	36.69	111.99	84.87
Trucks -non-fuel	42.66	58.09	44.03
Trucks - total	79.34	170.08	128.90

3.9 VoC & VoT Assignment Weightings

VoC is incorporated into the WTSM assignment through the @fcost extra attribute. The assignment also required a weighting to be applied and 2006 values were carried forward and used in the 2011 update:

- 6.3 weighting on fixed costs for light vehicles; and

- 2.7 weighting on fixed costs for heavy commercial vehicles.

These weightings are only applied in the final assignments. Assignments conducted during looping of the trip distribution and mode split models used single class highway assignment. These assignments used:

- Vehicle operating costs of 7.5 cents per km; and
- A weighting of 6.3 for all vehicles.

Again, the above parameters were used in 2006 (and 2001) and carried forward in the 2011 update.

3.10 Vehicle Operating Cost Forecast

The approach to forecast VoC was split in to two elements – non-fuel related, and fuel related VoC. Forecast non-fuel related VoC was assumed to increase at the CPI and given this element was represented in the model in 2001 prices, the values used in the final forecasts remained at 2011 levels.

Forecast fuel related VoC was another matter and required more detailed investigation. The analysis was broken down again into two main avenues of investigation:

- Fuel price forecasts; and
- Vehicle efficiency forecasts.

3.10.1 Fuel Price Forecasts

With regards to fuel, the starting point was an assessment of the forecasts used in the Auckland model. Auckland Council were approached and supplied fuel forecasts made in 2008 / 2009 through a McCormick Rankin Cagney report. These forecasts were compared against the Ministry of Economic Development (MED) forecasts made by their Energy Modelling team and were found to be significantly different to all forecast scenarios supplied by MED. Figure 3-1 shows some of the forecast scenarios made available by the MED while Figure 3-2 compares the Auckland forecast against the MED high oil forecast scenario.

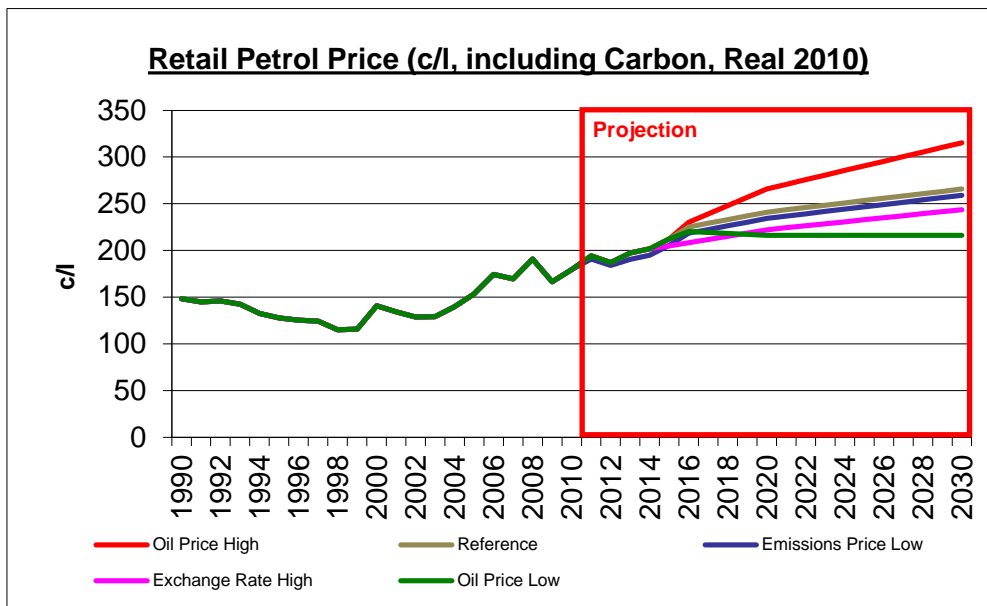


Figure 3-1: Fuel Cost Predictions (Sourced from Ministry of Economic Development)

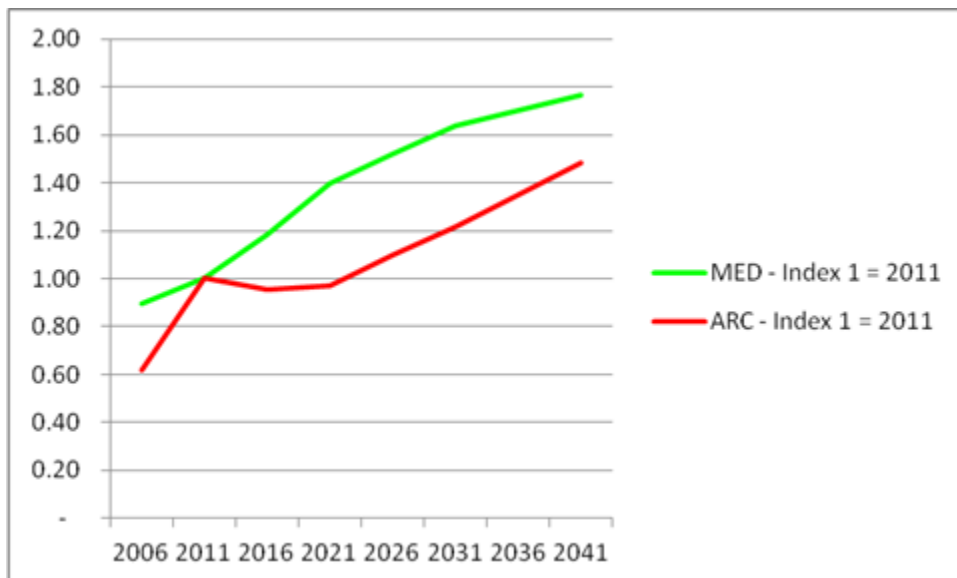


Figure 3-2: Comparison of ARC and MED Forecasts (High oil price scenario)

The Auckland forecasts appeared to track very closely to MED high oil forecasts between 2021 and 2041 but were relatively flat between 2011 and 2021. Ultimately it was decided that while the Auckland information was very useful for context and explaining influencing factors on oil prices, it was somewhat out of date when compared with the MED forecasts. Also being considered was the fact that:

- NZTA are looking for a set of fuel forecasts that can be applied consistently across all of NZ;
- Commissioning a separate fuel price forecasting model for Wellington is not considered a practical move particular given that MED already have one; and

- The MED forecasts provide both NZTA, and regional advisors a wider range of fuel forecast scenarios to be considered.

It was therefore concluded that the MED forecasts would be used - this resulted in the need to select a fuel price forecast scenario. The MED reference case scenario was selected first but the results presented for peer review caused concern as it generated an increase in fuel related VoC that was less than PT fares and the technical steering committee did not consider this to be intuitively correct. While a good part of the reason for this effect was explained by the forecast vehicle efficiency changes (described below) there was serious concern that the results would not be believable.

Ultimately the 'high oil price' scenario produced by MED was selected to generate baseline forecasts that were more intuitively correct. However, there are several other MED scenarios available so should the decision be made to revisit these assumptions flexibility has been added to the model to make this process easier and more transparent (documented in TN21).

The MED fuel forecasts stopped at 2031 so it was necessary to develop an approach to detail fuel prices between 2031 and 2041. To address the issue the average percentage increase in real fuel prices between 1990 and 2011 (1.3%) was calculated and applied to the fuel price increase between 2031 and 2041.

3.10.2 Vehicle Efficiency Forecasts

With regards to vehicle efficiency adjustments advice was received to use the Ministry of Transport (MoT) Fleet Emissions Model which was obtained via the Auckland Council. Figure 3-3 illustrates those forecasts and shows that the average litres of fuel consumed per 100 kilometres falls from approximately 10 litres/100km in 2000 to approximately 6.5 litres/100km by 2040. Concern was raised over the fact that the forecast assumes an ever increasing rate of vehicle efficiency improvements and that this seemed improbable. For the baseline forecasts it was therefore decided to:

- Adopt Auckland Regional Council's (ARC – now "Auckland Council") estimates between 2011 and 2031; and
- Maintain 2031 forecast to 2041. This decision was taken in consultation with the Peer Reviewer who recommended that the part of the MoT Fleet Emissions Model dealing with 2031-2041 be investigated more thoroughly.

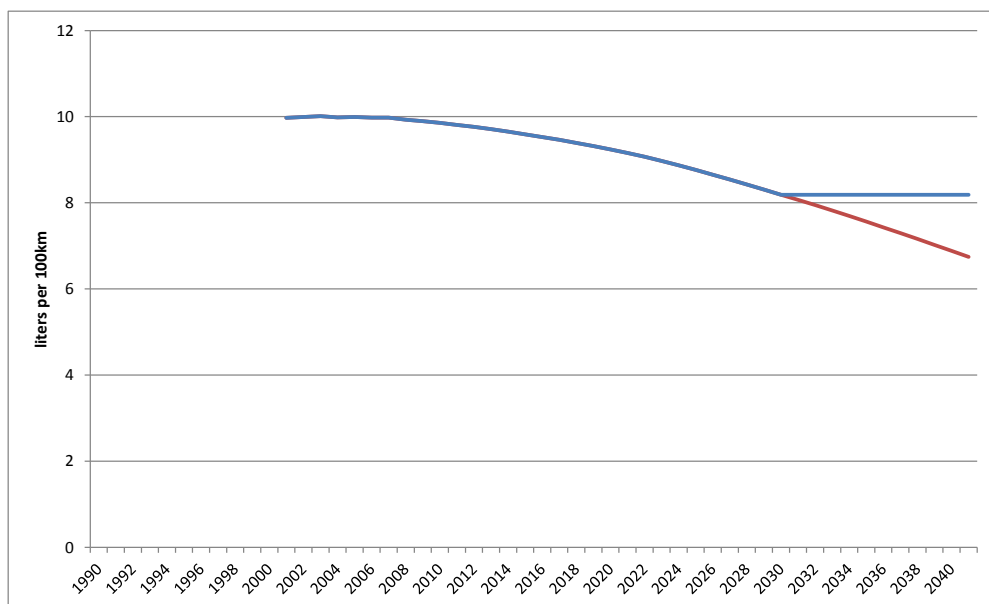


Figure 3-3: Projected Vehicle Efficiency

As mentioned above, this caused a level of VoC increase that appeared counter intuitive which resulted in the high oil price scenario being selected for the baseline forecasts. As with the fuel price forecasts, should the decision be made to revisit these assumptions, flexibility has been added to the model to make this process easier and more transparent (documented in TN21).

Table 3-9 summarises the values of time selected for the baseline forecasts. It shows that fuel related VoC is forecast to increase by 29% between 2011 and 2021 before easing to increases of 35% and 54% by 2031 and 2041, respectively.

Table 3-9: Forecast VoC (Real values in 2001 prices)

Class	Values of Time				Adjustment Factors (Index 1=2011)		
	2011	2021	2031	2041	2021	2031	2041
Car-EB fuel	15.83	20.37	21.43	24.35	1.29	1.35	1.54
Car-EB non-fuel	12.60	12.45	12.60	12.60	1.00	1.00	1.00
Car - EB Total	28.43	32.82	34.03	36.95	1.15	1.20	1.30
Car - Other (inc GST)	17.81	22.92	24.11	27.39	1.29	1.35	1.54
Trucks - fuel	84.87	109.21	114.90	130.55	1.29	1.35	1.54
Trucks -non-fuel	44.03	43.50	44.03	44.03	1.00	1.00	1.00
Trucks - total	128.90	152.71	158.93	174.58	1.18	1.23	1.35

It is important to reiterate that there are two main factors that go into the final adjustment factors and they act against each other - fuel price forecasts drive VoC up while vehicle efficiency forecasts drive fuel VoC down. This relationship has been illustrated in Figure 3-4 and shows, were it not for the inflationary vehicle efficiency adjustment, that fuel VoC would increase by a factor of 3.35 by 2041

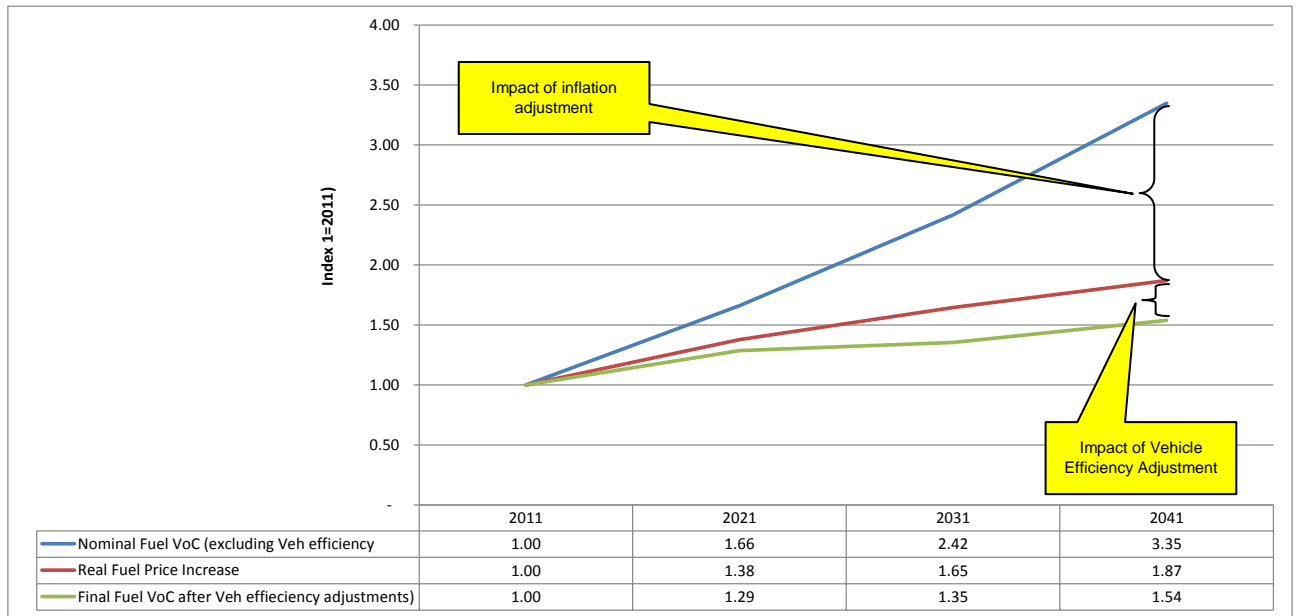


Figure 3-4: Fuel VoC Adjustment (Impact of inflation and vehicle efficiency)

4 Car Parking Costs

4.1 Summary of the 2006 Update Approach

Parking costs are incorporated in WTSM by trip purpose (work and non-work) for two Wellington CBD areas, lower and upper. The actual costs applied take into account the proportion of trips that do pay, which was derived from the 2001 HTS i.e. the final costs calculated are a weighted average of those that do pay and those that don't pay. Figure 4-1 below illustrates the locations and zone number for both the lower and upper parking sectors in WTSM.

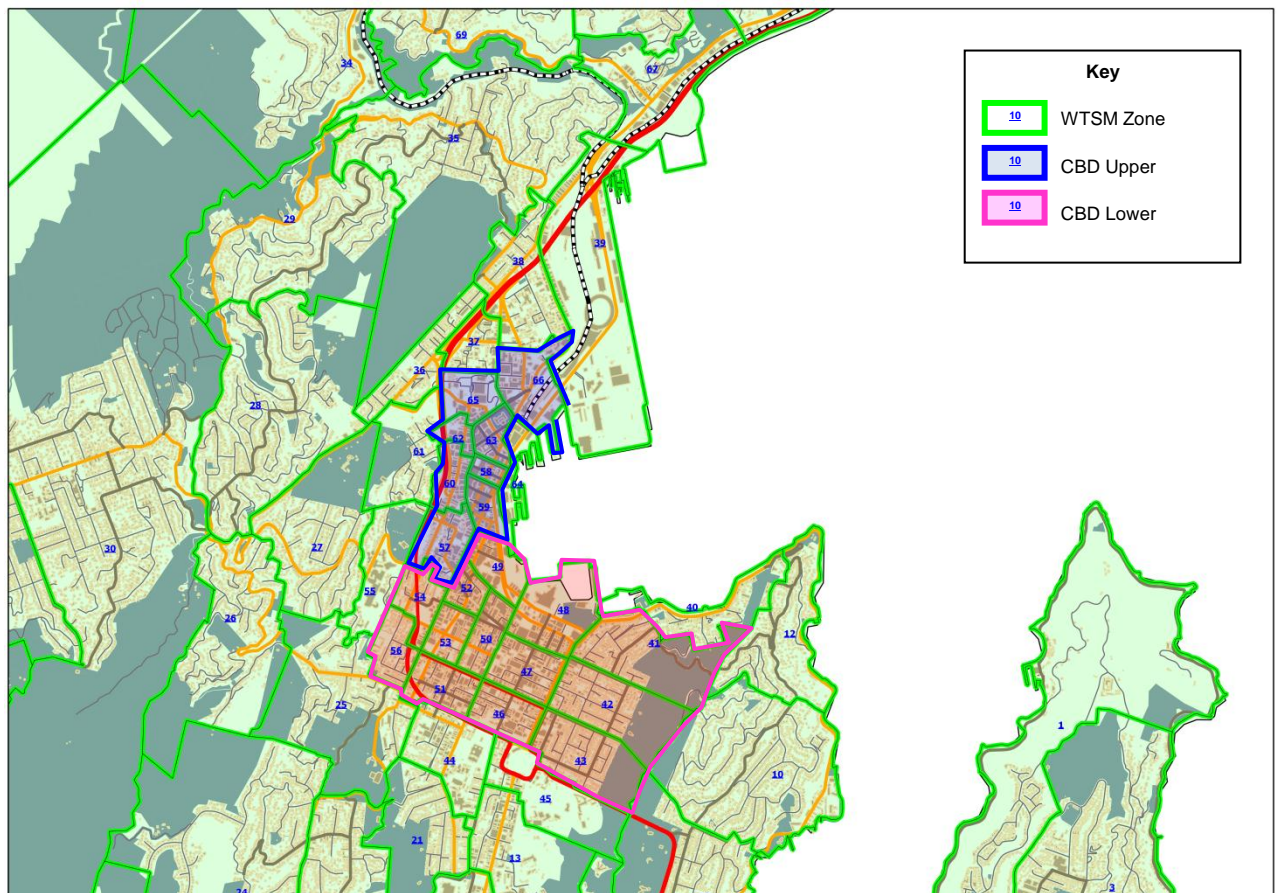


Figure 4-1: Wellington CBD Parking Zones

Parking costs for 2006 were increased from 2001 levels using information available from Wellington City Council (WCC) and an assumed 20% increase in the proportion of cars that do pay for parking.

WCC provided information on the costs for three metered on-street areas and for the designated commuter area. In 2001 WCC operated all parking buildings in the CBD. These were sold around 2004 and are now operated privately. Hence it was not possible to obtain information on historical increases, so:

- A 25% increase was assumed for commuter parking from 2001 to 2006; and

- A 50% increase was assumed for other parking.

4.2 Car Parking Cost Forecast

Given the uncertainty surrounding forecast parking charges, particularly in light of the fact that a large part of the supply in Wellington is privately priced and controlled, there was some debate about the issue. Two main approaches were considered:

- Advice from the industry advisors (see Section 1.2) was to hold the parking costs constant and in line with the levels assumed for 2011 and to report on the parking demand. However, the option was later discarded as unrealistic. All else being equal, Wellington CBD is forecast to experience the largest increase in employment and without any planned (or known) increase in parking supply it is likely real prices will increase.
- Adjust parking charges with respect to GDP per capita with an elasticity of 1.2 for commuter travel and 1.0 for non-commuter travel. This approach was chosen because the purpose of using GDP per capita was that it would reflect the fact that peoples incomes were increasing and the more a person earned the more money they were prepared to devote to parking charges.

Table 4-1 below shows the factors used for forecasting in the 2011 WTSM model. It confirms the approach used in Auckland.

Table 4-1: Car Parking Factors

Area	Inflation Adjusted to 2001				Final Model Input factors		
	2011	2021	2031	2041	2021	2031	2041
HBW Lower Wellington	4.20	5.94	6.89	8.00	1.42	1.64	1.91
HBW Upper Wellington	6.79	9.61	11.15	12.94	1.42	1.64	1.91
EB Lower Wellington	0.74	0.88	1.02	1.18	1.18	1.37	1.59
EB Upper Wellington	1.32	1.56	1.81	2.10	1.18	1.37	1.59
Other Lower Wellington	0.61	0.72	0.84	0.97	1.18	1.37	1.59
Other Upper Wellington	1.22	1.44	1.67	1.94	1.18	1.37	1.59

5 Public Transport Fares in Generalised Costs

5.1 Introduction

PT generalised cost calculations in WTSM use a fare matrix to represent the monetary cost of travelling between O-Ds in the regions. In the 2006 WTSM update PT fares were adjusted from the 2001 model by assuming an average 10% increase in rail fares, but no increase in bus fares. Given that all PT modes are aggregated together in WTSM, the increase in fares was implemented at a Territorial Authority (TA) level, by applying this 10% increase only for TA to TA movements which have a high rail mode share.

For the 2011 update, it was decided not to use the 2001 PT fare matrix with further adjustment, but to produce a new matrix replicating more accurately the current Metlink fare region² system for both bus and rail. The proposed methodology would provide a more appropriate tool as:

- Fare regions have changed since 2001; and
- Bus routes and fares are expected to change again with the Wellington City bus review. Having a more dynamic approach would enable the fare matrices to be recalculated automatically for each major permutation of the transit line and fare policies e.g. the new approach makes it easier to test integrated fares (where users pay one boarding fare for the total number of fare regions travelled).

The adopted approach is as follows:

1. *Implement Metlink fare regions in WTSM*

This was done both by allocating the Metlink fare region number for all 225 zones in the model, and by creating a link attribute to identify all roads and rail links crossing a fare region boundary. The resulting network containing the fare region information as illustrated in the Figure 5-1.

² Metlink uses the “fare zone” description. “Fare regions” have been used in this TN to avoid confusion with model centroid zones.

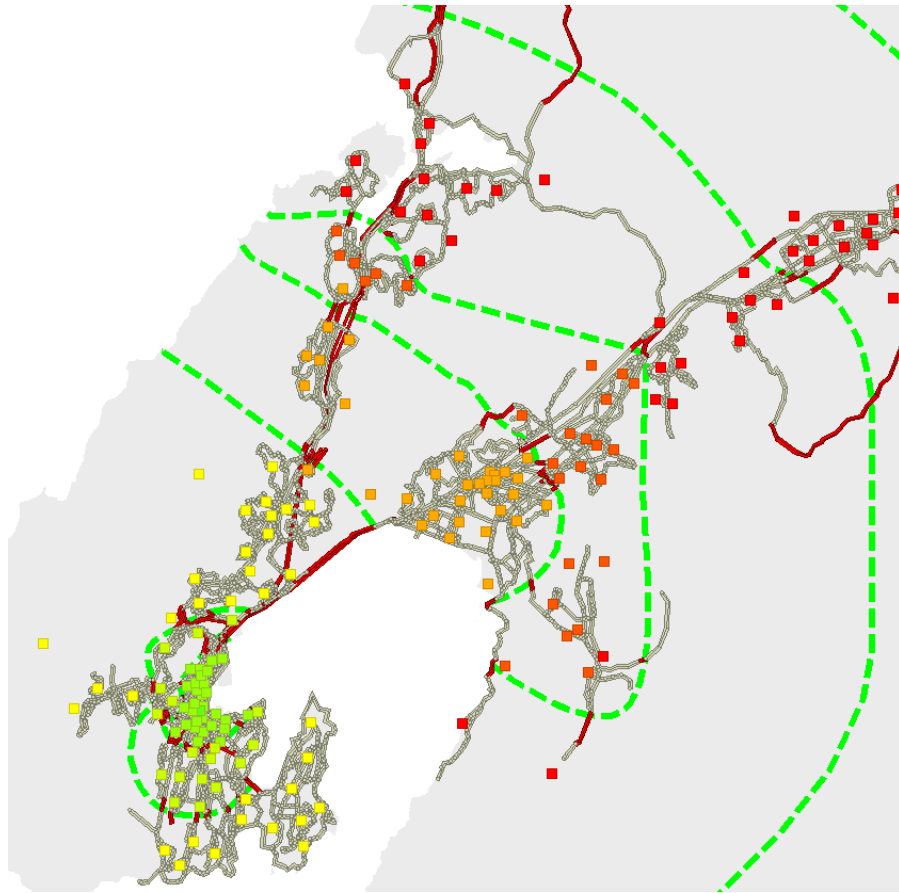


Figure 5-1: Fare Regions and Boundaries

2. *Calculate the number of fare region boundary crossings for each Origin-Destination pair*

A unit matrix was assigned on the transit lines (for both AM and Inter peak periods), producing, for each time period, two output matrices containing, respectively, the number of boardings and fare region boundary crossings between each origin/destination (O-D) pair. These were then rounded to an average value to counter the fact that passengers travelling from one zone to another might have a choice and use a number of PT services with different routing and transfer characteristics.

An exception was also implemented within Wellington (fare regions 1 to 3) to reproduce the current rule that fares within this area are limited to 3 regions only. This, however, only applies to single leg trips, and not to journeys which include boarding of more than one service.

3. *Calculate full fare for each O-D*

The full fare (adult cash fare) was then calculated for both AM and Inter peak periods, based on the number of region boundary crossings and service boardings.

Metlink effectively includes the fare regions where the service is boarded, therefore counting every boarding as being a fare region. As an example, a service that travels

across two fare boundaries will be counted as having travelled three regions, because it includes the initial boarding region. This applies to any additional boarding which will count as another zone, therefore equivalent to a transfer penalty.

The resulting matrices containing the number of boardings, boundary crossings, and full fares were compared to the 2006 WTSM as well as checked against the Metlink Journey Planner service. This was carried out for wide ranging types of journeys including bus and rail trips, journeys with 2 or more transfers, within Wellington or between different TAs, etc.

Table 5-1 below shows the results of this checking exercise for the AM Peak, comparing the number of boardings, zone crossing and full fares estimated by WTSM 2011 and the same results from Metlink Journey Planner (as well as the PT fares as modelled in WTSM 2006 for reference).

Table 5-1: PT Fare Comparison, AM Peak Period

Origin	Destination	Journey Planner			WTSM11			WTSM06*
		No. Board.	No. Zones	Fare	No. Board	No. Zones	Fare	Fare
Owhiro Bay	Manners Mall	1	3	450	1	3	450	396
Evans Bay Parade	Rail Station	1	2	350	1	2	350	227
Seatoun	Karori	2	6	900	2	6	800	736
Wilton Bush	Maupuia	2	5	800	2	5	700	623
Houghton Bay	Ngaio	2	6	900	2	6	800	623
Porirua	Rail Station	1	5	600	1	5	600	544
Petone	Rail Station	1	4	500	1	4	500	374
Karori	Lyll Bay	1	3	450	1	3	450	680
Eastbourne	Kilbirnie	2	9	1200	2	9	1150	947
Upper Hutt	Newlands Road	2	10	1300	2	10	1300	1489
Masterton	Newton	2	16	2100	2	16	2050	2041
Masterton	Rail Station	1	14	1750	1	14	1750	1729
Pukerua Bay	Lower Hutt Central	2	11	1350	2	11	1400	1121
Paraparaumu	Rail Station	1	9	1100	1	9	1100	1076
Rail Station	Airport	1	3	450	1	3	450	340
Featherston	Whitby	3	18	2300	3	18	2350	1908
Waikanae	Wainuiomata	3	16	2050	3	16	2150	1482
Petone	Willis Street	1	4	500	1	4	500	374

*Fares output by WTSM 2006 are discounted fares to take into account both full and concessions fares. These were converted to full fare using an average discount value of 0.64 (sourced from the 2001 document TN14.2 Base Public Transport Network) and then growthed to 2011 by using an increase of 25%. These values are therefore given for comparison only.

As shown by the table above, the applied methodology returns results that are a good representation of journey characteristics estimated by the Metlink Journey Planner, with the numbers of boardings and boundary crossing being identical for every O-D pair. The modelled full fare is generally correct for trips with one boarding, but fluctuates slightly for multi-leg trips (although it is always within \$1 of the real fare).

This variation is caused by the fact that fare increments are not constant for each additional boundary crossed in the Metlink fare region system (varying between \$0.5 and \$1.5). The model however calculates the number of zones travelled, applies the corresponding fare, and then adds \$2 per additional boarding (equivalent to an additional initial zone being travelled). It therefore doesn't pick up the various possible breakdowns of multi-leg trips.

It is, however, estimated that this is a reasonable approximation given the possibilities offered by this methodology to analyse future changes in fare region structure and potential removal of / changes to transfer penalties.

4. *Apply discount factor to full fare*

A discount factor was then applied to the full fare (adult cash fare) to take into account the various type of Metlink fares and the proportion of passengers paying each type, for both AM and Inter peak periods.

The categories of fares considered were as follows:

Bus

- Adult
 - Cash;
 - Period (30 day pass, etc);
 - Purse (Snapper Card); and
 - Gold Card.
- Child
 - Cash;
 - Period (30-day pass, etc); and
 - Purse (Snapper Card).

Train

- Adult
 - Cash & off-peak cash;
 - Period (monthly pass); and
 - Purse (10-trip train ticket).
- Child
 - Cash;
 - Period (monthly pass, school term ticket); and
 - Purse (10-trip train ticket).

Monthly passes were treated as 40-trip tickets and rail school term as 100-trip tickets.

A weighted average fare was calculated, using the fare category above and patronage numbers from the Electronic Ticketing Machine (ETM) data and rail survey. This was carried out for both bus and rail and was calculated for every number of fare region crossings, to take into account the variations in fare structure depending on the journey length. Figure 5-2 below show the resulting discount factors to apply to the full fare.

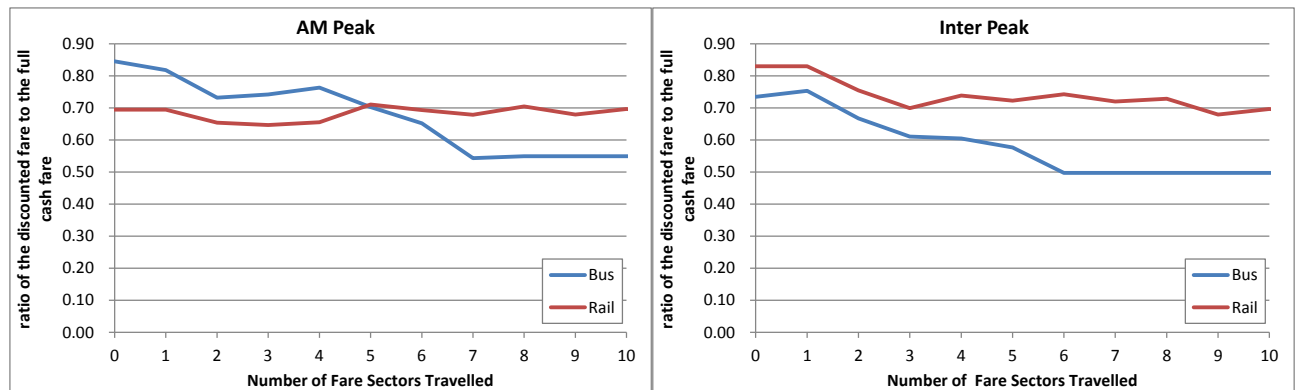


Figure 5-2: Fare Discount

Final discount factors were calculated using the weighted average of bus and rail factors and were applied to the full fares calculated in the previous step to obtain the final discounted fare for each O-D.

These fares do not include variations for services with a different fare structure such as the Airport Flyer and the Ferry. These will be incorporated at the assignment stage of the model.

2011 Nominal Fare matrices are adjusted to 2001 levels using a factor of 0.76 derived from Statistics NZ CPI data.

5.2 Transfer Penalties

Transfer / boarding penalties have been coded into the model using guidance from the 2006 WTSM User Manual which is summarised in Table 5-2.

Table 5-2: Transit Penalties Coded into the @board Attribute

Mode	Fare element (all represented in the model in Generalised Minutes)	Standard Interchanges	Purpose Built Interchanges	High Quality / Planned Interchanges
Bus	Fare	10.0	10.0	10.0
	Boarding	3.0	3.0	3.0
	Penalty	10.0	8.0	5.0
	Total	23.0	21.0	18.0
Rail	Fare	10.0	10.0	10.0
	Boarding	3.0	3.0	3.0
	Penalty	7.5	5.5	2.5
	Total	20.5	18.5	15.5

The following figures, Figure 5-3 to , illustrate the nodes where both the purpose built and high quality interchanges have been coded.

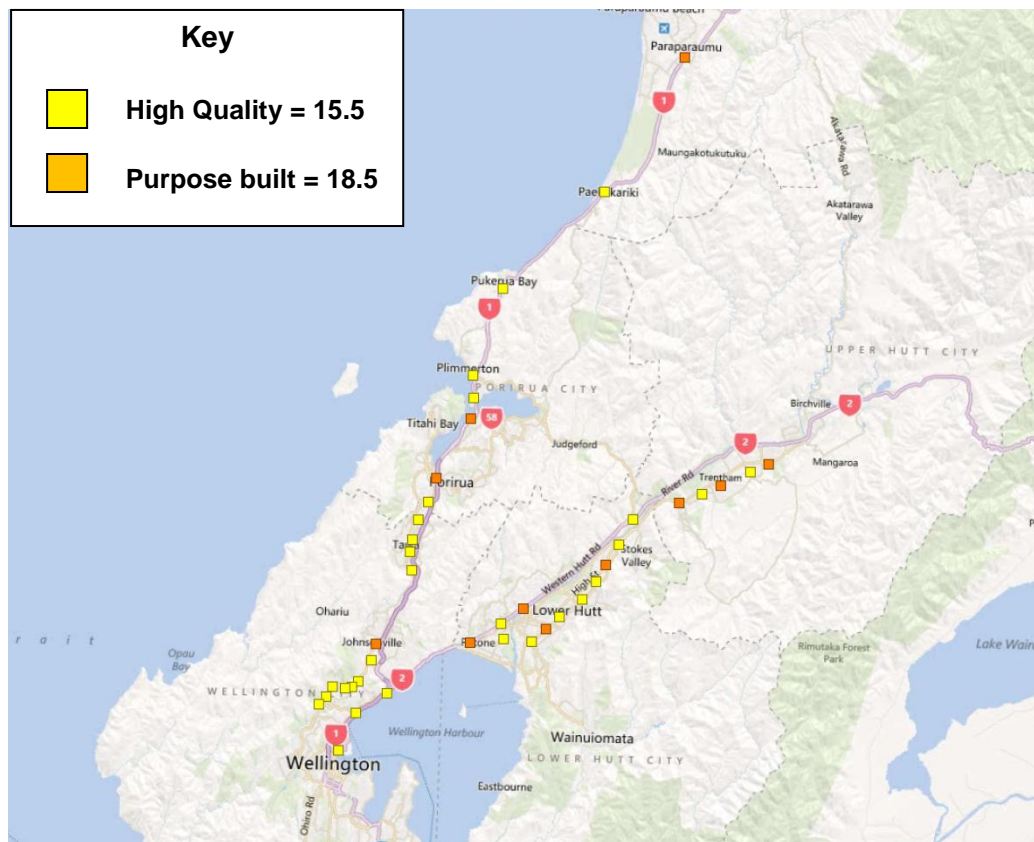


Figure 5-3: Regional Map Showing Boarding Penalties Applied at Rail Stations

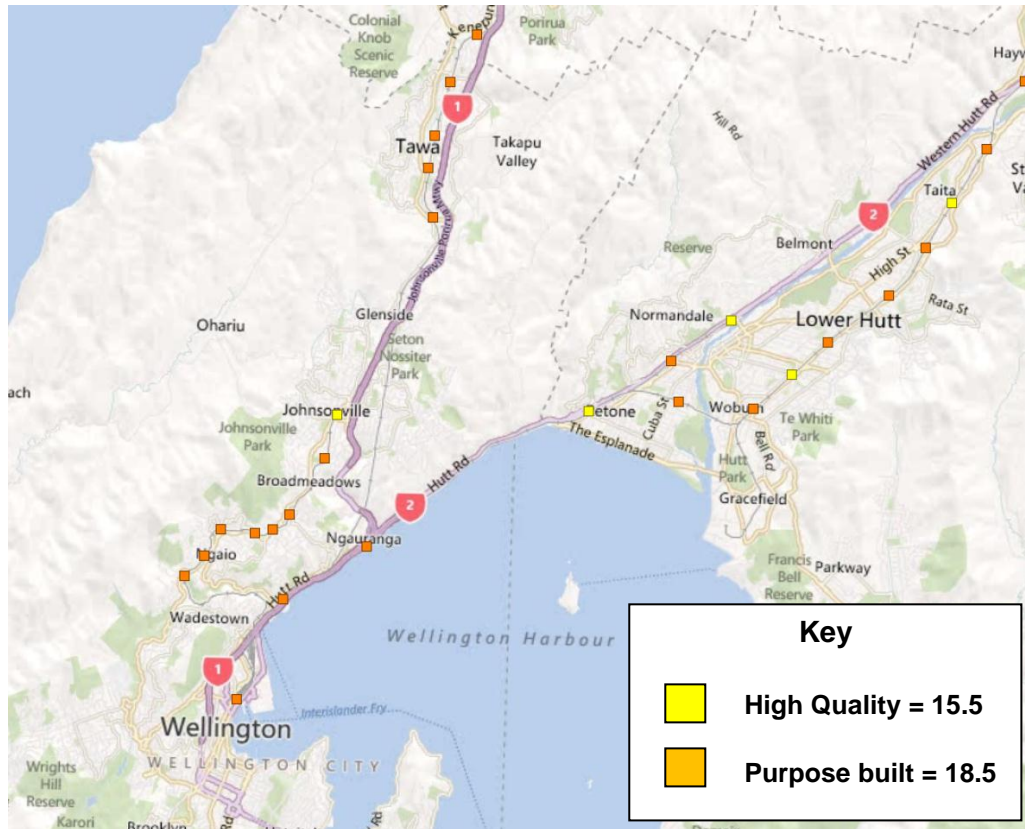


Figure 5-4: Local Map Showing Boarding Penalties Applied at Rail Stations

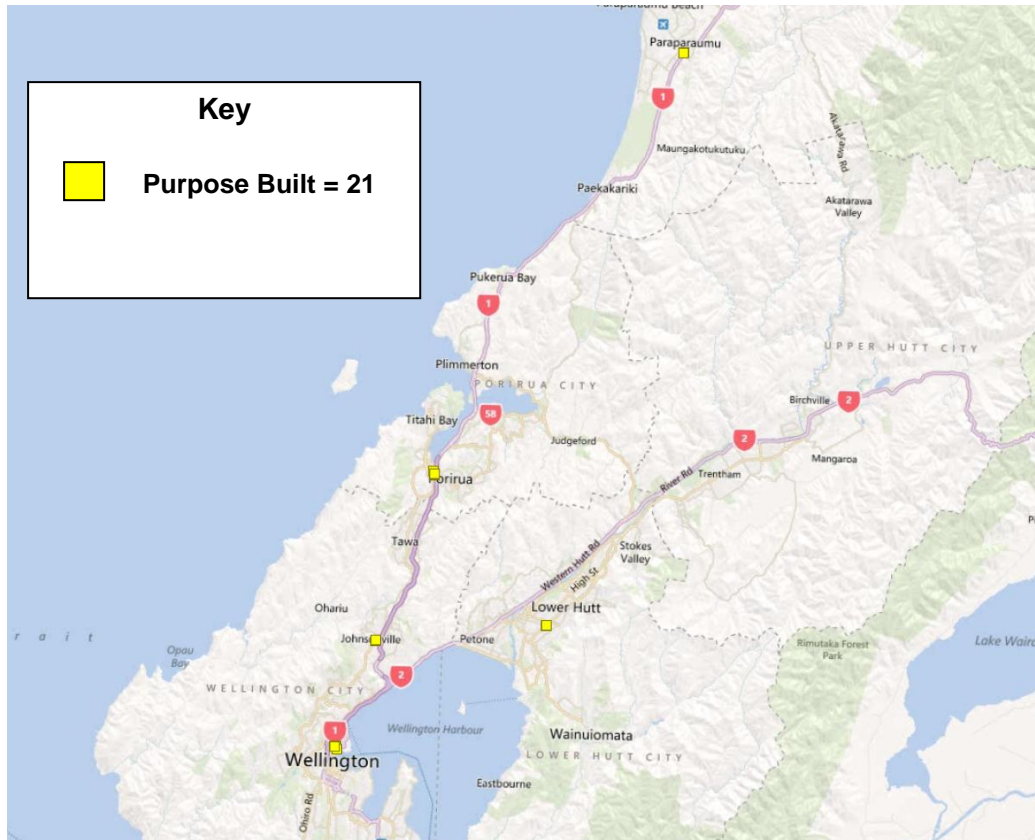


Figure 5-5: Regional Map Showing Boarding Penalties Applied at Bus Stations/Stops

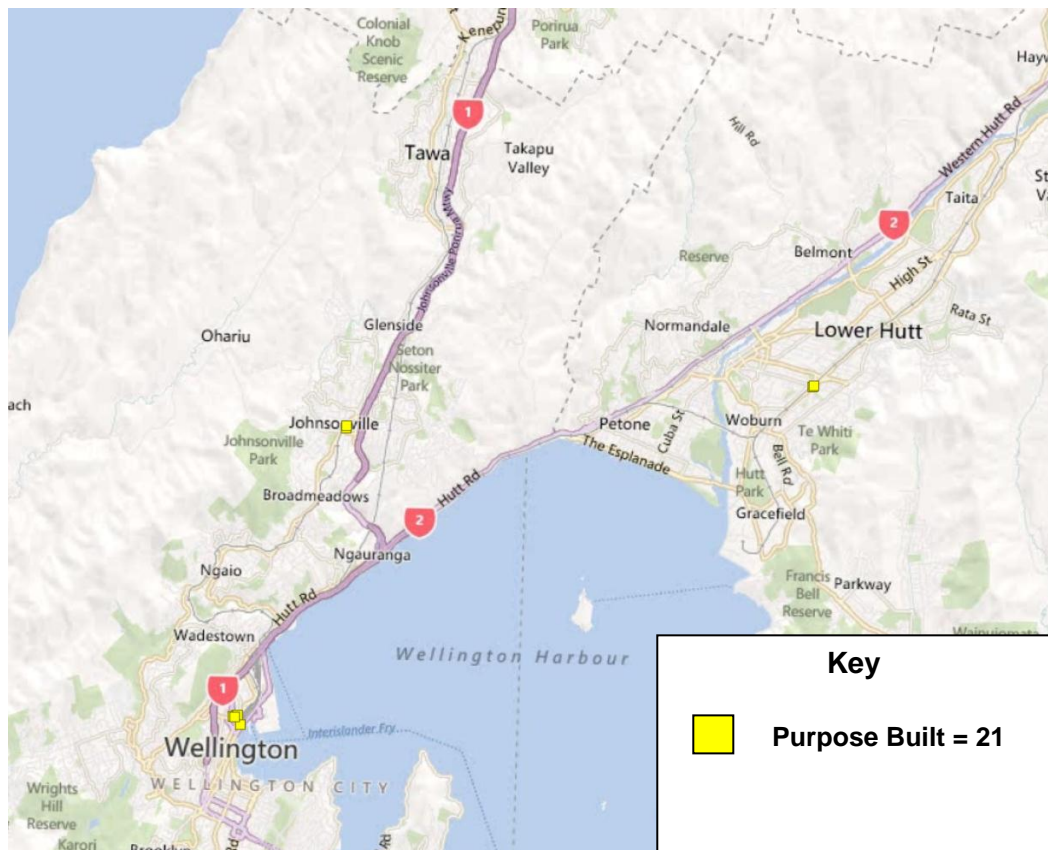


Figure 5-6: Local Map Showing Boarding Penalties Applied at Bus Station/Stops

5.3 Public Transport Fares Forecast

Two approaches to public transport forecasting were discussed and assessed during the confirmation of the baseline forecast PT fares:

- A “policy” based approach using GWRC PT fare policy of a nominal increase of 3% per annum (reducing to 1% per annum once forecast inflation was taken into account). This produced some counter intuitive forecasts in terms of balance between real PT fare increases and fuel related VoC (once vehicle efficiency savings had been taken into account) i.e. it was found that using this assumption resulted in a bigger real increase in PT fares than VoC between 2011 and 2041. This was not considered reasonable by the Peer Review Committee as PT service systems are generally able to spread VoC over a greater number of users giving them a competitive cost advantage over private transport.
- While there is some uncertainty over the fare elasticity, the approach of using growth in GDP per capita is generally accepted. David Young’s forecasting memo recommended that the Auckland approach be adopted. This is described below:

“PT fares in ART3 are increased with respect to GDP/capita growth (1.8% p.a.), with an elasticity of 0.25. This relationship was arrived at following analysis of adult 1-stage cash fares in Auckland, fuel prices, and GDP/capita over the period 1994-2008. Different elasticities were applied to best fit the fares with GDP/capita. Ian Wallis, in his review of this, noted that overall the average fares

paid have remained close to constant between 2000 and 2010, depending on which PT mode and which measure (passengers or passenger-km) are considered. He then recommended that an elasticity of 0.25 be used as the base case, which results in a fare increase of about 0.45% p.a., but that 0.5 should be used as a sensitivity test where required.”

It was decided to use the 0.25 elasticity approach adopted in the Auckland model for the baseline forecasts until better information from Wellington became available. Table 5-3 below shows the resulting forecast adjustment factors for PT fares. The net result is a forecast increase of 15% (in real terms) by 2041 which compares to an increase of 54% in fuel related VoC.

Table 5-3: PT Fare Forecast Adjustment Factors

	2021	2031	2041
Real_GDP/labour_force Index	1.18	1.37	1.59
PT Fare Adjustment factor (using 0.25 elasticity)	1.04	1.09	1.15

6 Travel Demand Management Parameters

As described in David Young's memo WTSM Forecasting Inputs Note (Appendix D) "the effects of workplace travel initiatives in WTSM has, to date, assumed to be 5% of HBW trips by car to the Wellington CBD are removed with 90% of these transferred to the same trip by PT and the remaining 10% not allocated, so assumed to either not-travel or to walk or cycle to a destination close to the home. There is now the facility in WTSM to vary these percentages, including setting them to zero."

The model received by Opus had assumed some form of TDM effect by 2011. This function was subsequently switched off during the model update process as it interfered with the calibration. However, the function has been activated for 2021, 2031, 2041. Without new information on the TDM measures being collected (as such an exercise was excluded from the project scope), it was decided to maintain the following approach for future years:

- 3% of HBW trips originally allocated to car travel are partially reallocated to the PT matrices. The reason for the slight reduction assumed for baseline forecasting was:
 - 90% of the reallocated demand was put to PT matrices; and
 - 10% was assumed to be walking and cycling and so was removed from the assigned matrices.

7 Model Response to Parameters Adjustments

The following section documents the tests undertaken to assess the impact of various changes to input parameters on percentage trip increases between 2011 and 2021. The tests were as follows:

- Test 1: PT fares increased by 10% by 2021;
- Test 2: PT fares increased by 10% and Vehicle Operating Costs increased by 29%;
- Test 3: PT fares increased by 10%, Vehicle Operating Costs increased by 29%; and Parking increased by 23%
- Test 4: PT fares increased by 10%, Vehicle Operating Costs increased by 29%, Parking increased by 23%, and Value of Time increased by 23%.

Table 7-1 and Figure 7-1 illustrate the results of the tests.

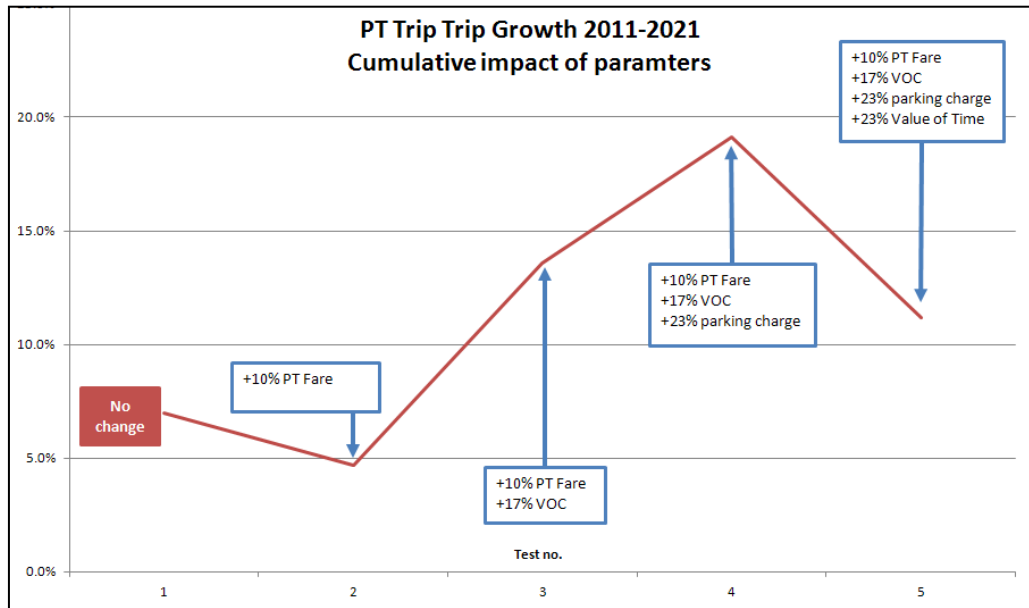
Table 7-1: Tests Showing Impacts of Different Combinations of Inputs on Travel Demand

Test no.	PT Fare	VoC	Parking	Value of Time	Increase in TOTAL Trips 2011-2021	Increase in CAR Trips 2011-2021	Increase in PT Trips 2011-2021
Base					8.6%	8.8%	7.0%
1	110%				8.5%	9.1%	4.7%
2	110%	129%			7.6%	6.7%	13.6%
3	110%	129%	123%		7.7%	5.9%	19.1%
4	110%	129%	123%	123%	8.5%	8.0%	11.2%

Increasing PT fares by 10% between 2011 and 2021 causes the PT demand-increase to drop from 7% to 4.7%. However, this impact is mitigated when combined with a corresponding increase of 29% in VoC which allows PT demand-increase to rise to 13.6% instead of 7%.

When CBD parking charges are increased by 23% PT demand increases by the highest amount out of the tests considered – 19.1%. However, this increase is then dampened once the 23% increase in VoT is included – PT demand-increase decreases to 11.2%.

Figure 7-1: PT Trip Growth 2011-2021 (Cumulative impact of parameters)



8 Conclusions

Opus International Consultants Limited (Opus) and Arup Australia (Arup) were commissioned by Greater Wellington Regional Council (GWRC) to rebase the existing 2006 Wellington Transport Strategy Model (WTSM) to a new base year of 2011. Opus updated the WTSM while Arup developed a Wellington Public Transport Model (WPTM) based on figures from WTSM and detailed public transport surveys. The whole process of model updates and development is complex and involves several steps which have each been individually reported in a series of technical notes.

This note has documented the development of the following parameters:

- **Values of time.** The approach taken in the 2011 update was to adjust all inputs to nominal values in 2011 before making an inflation adjustment to 2001. Real GDP per capita forecasts from NZ Government Treasury Department were used to adjust values of time, with an elasticity of 1 on work travel and 0.8 for non-work travel. This corresponds with advice in the UK's Department for Transport Webtag.
- **Vehicle operating costs.** Vehicle operating costs covered two main elements – fuel related VoC and non-fuel related VoC. The two sets of data inputted from the model were guided by the EEM (2008 prices). Fuel related costs were affected by congestion, stoppage costs and change in speed costs whereas non-fuel costs related to road surface condition costs i.e. the rougher the road, the faster the tyres, suspension wears out. Fuel related costs were then adjusted to 2011 values using fuel price data from Statistics NZ while non-fuel prices were adjusted using CPI data from Statistics NZ. Both fuel and non-fuel costs were adjusted to 2001 levels using CPI. The forecasting approach was to use both Ministry of Economic Development (MED) fuel price forecasts and vehicle efficiency changes from the Ministry of Transport Fleet Emissions Model to forecast VoC for 2021, 2031, and 2041.
- **Parking Costs.** Parking charges were applied in WTSM but only in the CBD. The 2011 update of parking charges were complicated by the fact that the 2001 parking charges were not corroborated by data collection. Similar problems were encountered in the 2006 update resulting in an estimation of parking cost changes in the future. After collecting parking charge information from parking management companies in Wellington the conclusion was reached that the same adjustment applied in 2006 would be applied to 2011 (before being adjusted back to 2001 prices). While there was substantial debate around this approach amongst industry representative it was decided to accept David Young's recommendation which was to use the real GDP per capita forecasts from the NZ Treasury to forecast parking costs.
- **PT Fares.** There are two components to the PT fares in WTSM – assignment based fares and matrix based fares (used in the trip distribution and mode split models). The update approach is summarised below:
 - *Assignment based PT fares* are incorporated into the @board penalty attribute. These are used in the calibration of routing so relate more to the perceived penalty of boarding buses and trains rather than 'actual' PT fares i.e. these values are not passed back into the trip distribution and mode choice models.
 - *Matrix based PT fares* are values used in the calculation of PT generalised costs so are used in the trip distribution and mode choice models. The 2011 update used PT assignment macros to count the number of fare-zone boundary crossings. These were updated using a PT assignment macro which:
 - Identified boarding and distance based components separately; and

- Counted the number fare-zone boundary crossings.

Two approaches to forecasting PT fares were considered – one was to follow a policy based increase of 1% a year (in real terms) while the other was to apply real GDP per capita forecasts with an elasticity of 0.25.

- **Travel Demand Management Parameters.** The effects of workplace travel initiatives in WTSM is an assumed removal of 3% of HBW trips by car to the Wellington CBD with 90% of these trips transferred to the same trip by PT modes and the remaining 10% not allocated.

APPENDIX A – Indexing of Economic Indicators

Indexing of Economic Indicators (nominal prices)

Quarter	GDP per Capita	Average Weekly Wage	Consumer Price Index	Fuel Price	Adjustment of VoT from 2001 to 2011	Adjustment of Non Fuel VoC from 2008 to 2011	Adjustment of Fuel VoC from 2008 to 2012	Adjustment of VoT and VoC from 2011 to 2001
Mar. 2001	1.00	1.00	1.00	1.00				1.32
Jun. 2001	1.02	1.01	1.01	0.98				
Sep. 2001	1.03	1.02	1.01	0.97				
Dec. 2001	1.05	1.03	1.02	0.97				
Mar. 2002	1.07	1.04	1.03	0.98				
Jun. 2002	1.08	1.05	1.03	1.01				
Sep. 2002	1.10	1.06	1.04	1.00				
Dec. 2002	1.10	1.07	1.04	1.00				
Mar. 2003	1.11	1.08	1.04	1.00				
Jun. 2003	1.12	1.09	1.05	1.00				
Sep. 2003	1.13	1.10	1.05	1.05				
Dec. 2003	1.15	1.10	1.06	1.08				
Mar. 2004	1.16	1.11	1.07	1.11				
Jun. 2004	1.18	1.12	1.08	1.13				
Sep. 2004	1.20	1.13	1.08	1.15				
Dec. 2004	1.22	1.14	1.09	1.21				
Mar. 2005	1.22	1.15	1.10	1.26				
Jun. 2005	1.24	1.16	1.11	1.33				
Sep. 2005	1.26	1.18	1.12	1.42				
Dec. 2005	1.27	1.19	1.13	1.48				
Mar. 2006	1.28	1.21	1.14	1.48				
Jun. 2006	1.29	1.23	1.15	1.47				
Sep. 2006	1.29	1.24	1.15	1.44				
Dec. 2006	1.31	1.25	1.16	1.42				
Mar. 2007	1.33	1.27	1.17	1.47				
Jun. 2007	1.35	1.28	1.17	1.54				
Sep. 2007	1.37	1.30	1.19	1.64				
Dec. 2007	1.39	1.31	1.20	1.75				
Mar. 2008	1.41	1.33	1.21	1.73				
Jun. 2008	1.42	1.35	1.22	1.69				
Sep. 2008	1.42	1.36	1.23	1.66				
Dec. 2008	1.43	1.37	1.23	1.61				
Mar. 2009	1.43	1.38	1.24	1.68				
Jun. 2009	1.43	1.38	1.24	1.77				
Sep. 2009	1.42	1.39	1.25	1.81				
Dec. 2009	1.42	1.39	1.25	1.84				
Mar. 2010	1.43	1.40	1.27	1.90				
Jun. 2010	1.44	1.42	1.28	1.98				
Sep. 2010	1.45	1.43	1.30	2.07				
Dec. 2010	1.48	1.45	1.31	2.15				
Mar. 2011	1.49	1.46	1.32	2.21	1.49	1.09	1.28	
Jun. 2011	1.50	1.46	1.33	2.22				
Sep. 2011	1.52	1.47	1.34	2.20				

APPENDIX B – Survey of Wellington CBD Parking Charges (2011)

Survey of Wellington CBD Parking Charges (2011)

Car Park	Casual Fee (/1/2 hr)	Early Bird	Non Commute (2 hours)
139 The Terrace	\$ 2.00	\$ 13.00	\$ 8.00
157 Lambton Quay	\$ 5.00	\$ 22.00	\$ 20.00
80 Boulcott Street	\$ 5.00	\$ 12.00	\$ 20.00
Bolton Street	\$ 2.00	\$ 16.00	\$ 8.00
Bond Street	\$ 3.00	\$ 13.00	\$ 12.00
Bute / Garrett Street	\$ 3.00	\$ 11.00	\$ 12.00
Chews Lane	\$ 4.00	\$ 17.00	\$ 16.00
Cuba Street	\$ 2.00	\$ 10.00	\$ 8.00
Ebor Street	\$ 4.00	\$ 11.00	\$ 16.00
Frank Kitts Park	\$ 4.00	\$ 16.00	\$ 16.00
Ghuznee Street	\$ 2.00	\$ 10.00	\$ 8.00
Gilmer Terrace	\$ 3.00	\$ 13.00	\$ 12.00
HP Tower / Intercontinental Hotel	\$ 5.00	\$ 17.00	\$ 20.00
HSBC Tower	\$ 3.00	\$ 18.00	\$ 12.00
James Cook Hotel	\$ 6.00	\$ 12.00	\$ 24.00
Kate Sheppard Place	\$ 2.00	\$ 20.00	\$ 8.00
Knigges Avenue	\$ 2.00	\$ 9.00	\$ 8.00
Little Pipitea Street	\$ 2.00	\$ 20.00	\$ 8.00
Lower Willis Street	\$ 4.00	\$ 12.00	\$ 16.00
Mowbray Street		\$ 16.00	\$ -
Pipitea Marae	\$ 2.00	\$ 17.00	\$ 8.00
Queens Wharf	\$ 6.00	\$ 17.00	\$ 24.00
Station Carpark	\$ 4.00	\$ 12.00	\$ 16.00
Taranaki Street	\$ 2.00	\$ 10.00	\$ 8.00
Upper Willis Street	\$ 3.00	\$ 11.00	\$ 12.00
Victoria Street	\$ 2.00	\$ 9.00	\$ 8.00
Westpac Stadium		\$ 9.00	\$ -
Average		\$ 13.81	\$ 12.15

Source: <http://www.wilsonparking.co.nz/go/regions/wellington-cbd>

APPENDIX C – Initial Approach to Parking Charge Update

The 2011 update suffered from a similar lack of data to the 2006 update over historical increases in fares. To compensate the following sources were used:

- Metered on street parking:
<http://www.wellington.govt.nz/services/parking/councilparking/councilparking.html>
- Commuter: early bird prices from the table in Appendix B; and
- Other: non-commute (e.g. two hours) taken from the table in Appendix B.

The table below shows both:

- The raw parking costs extracted from the modelling reports for 2001 and 2006 and from the WCC and Wilsons Parking websites for 2011; and
- Final parking charges once adjusted for the proportion actually paying parking charges.

As discussed in the main body of the report the approach was subsequently abandoned due to the magnitude of some of the parking charge increases. For example, using the approach below HBW Lower Wellington charges were estimated to have increased 295% between 2001 and 2011. Without raw data collected in 2001 it was impossible to corroborate this sort of change.

Parking Costs – Initial Attempt to Estimate CBD Parking Charges (Approach abandoned but reported for completeness)

Raw costs		2001 WTSM		2006 WTSM		2011 Nominal		2011 WTSM	
Metered on-street (\$/hr)		\$1.00		\$1.50		\$ 1.50			
		\$2.00		\$3.00		\$ 3.00			
HBW Cost		\$3.00		\$4.00		\$ 4.00			
		\$2.50		\$3.50		\$ 3.50			
Commuter (\$/day)		\$4.00		\$5.00		\$ 13.81			
Other (assumed) (\$/day)		\$4.00		\$6.00		\$ 12.15			
Other Cost		\$4.00		\$5.50		\$12.98			

Final Costs entered in the model		% trips paying	2001		2006		2011		Final 21011 Cost (post CPI Adjustment)
			Cost	% Increase in trips paying	Cost	% Increase in trips paying*	Cost		
HBW Lower Wellington	43%	\$1.70	20%	51%	\$2.81	0%	51%	\$5.02	
HBW Upper Wellington	69%	\$2.75	20%	83%	\$4.54	0%	83%	\$8.12	
EB Lower Wellington	23%	\$0.59	20%	28%	\$0.98	0%	28%	\$0.74	
EB Upper Wellington	42%	\$1.04	20%	50%	\$1.75	0%	50%	\$1.32	
Other Lower Wellington	19%	\$0.48	20%	23%	\$0.81	0%	23%	\$0.61	
Other Upper Wellington	38%	\$0.96	20%	46%	\$1.61	0%	46%	\$1.22	

Source: K:\Z_Drive\WTSM_2011\Economic Parameters[Updated 2011 VoT, VoC & Parking.xlsx]Parking Charges

* 2011 Update assumed no increased in the proportion of trips paying for parking

APPENDIX D – David Young’s WTSM Forecasting Inputs Note

David Young’s WTSM Forecasting Inputs Document

WTSM Forecasting Inputs - DRAFT

1 Background

The Wellington Transport Strategy Model (WTSM) is presently based in year 2006 and has been used in forecasting by Greater Wellington Regional Council (GWRC) as far as year 2041. This forecasting has been in relation to development of the Regional Land Transport Strategy (RLTS) and investigations into specific projects.

WTSM is being updated to a base year of 2011 following which new base forecasts will be produced.

Due to the timing of the updated model, the 2006-based WTSM is to be used in the initial stage of the PT Spine Study and New Zealand Transport Agency (NZTA) wish to make use of WTSM for the evaluation of the Wellington Roads of National Significance (RoNS).

The updated 2011-based model will be used, in the first instance, in the latter stages of the PT Spine Study, along with the new Wellington Passenger Transport Model (WPTM).

There has been recent debate about the inputs to WTSM in forecasting (e.g. NZTA Modelling Panel) and, given the upcoming uses of the 2006-based WTSM and then the 2011-based model, the need to develop inputs that fit with good modelling practice and are agreed by GWRC and stakeholders, notably NZTA.

Similar debate has occurred in Auckland in respect of the Auckland Regional Transport (ART3) model over the past 2 years, culminating in a set of inputs that has been agreed by the model owners (Auckland Council) and stakeholders (Auckland Transport, NZTA, MoT, etc). A key aspect arising from this debate is that there should be consistency of approach to the economic inputs in forecasting; that is, either they are not increased from the base year values, or if they are, then all should be. This follows good international modelling practice, but is relatively new to New Zealand as generally these inputs have not changed in forecasting.

2 This Note

This note is intended to assist with the process of reaching agreed inputs. As such it:

- lists the WTSM forecasting inputs,
- describes which inputs are currently varied from the base year (2006),
- describes the situation with these inputs for the Auckland model, ART3,

- sets out, for each input, the effect of changing the input, the current situation with both WTSM and ART3, and makes a recommendation on what should occur with WTSM, and
- provides a tabular summary at the end.

3 Forecasting Inputs

The key forecasting inputs to WTSM are as follows:

Land use

- Zonal persons, households, employment and educational rolls by category

Transport improvements

- Rooding infrastructure
- PT infrastructure
- PT services (routeings and frequencies)

Economic and policy inputs

- GDP/capita growth
- Values of time
- Private vehicle operating costs
- Car parking costs
- PT fares

TDM non-pricing effects

- Assumed effects of travel plan initiatives

The future land use and transport improvements are usually determined through their own processes, and that is the case for the up-coming forecasting. As such these aspects are not discussed further here. This includes the effects of integrated ticketing and fares real time information, which are incorporated into WTSM forecasts when specified.

4 Current WTSM Forecasting Inputs

In the WTSM forecasting undertaken in recent years some of the inputs listed above, excluding land use and transport improvements, have been varied from the base year, 2006:

- Vehicle operating costs have been increased to account for both increases in real fuel prices and improvements in vehicle efficiency.
- The 2006 PT fares have been increased by 20% in all forecast years due to this actual increase occurring shortly after the 2006 update.

- The effects of workplace travel initiatives have been included in the forecasts.

Other inputs have not been varied, but have remained at 2006 levels.

5 Forecasting Inputs in Auckland

The case in Auckland with regard to forecasting inputs for ART3 is relevant to WTSM given the debate and development of these inputs over the past several years.

As with WTSM, vehicle operating costs in ART3 were increased in the forecasts undertaken around 2009 in response to the increases in pump petrol prices and the high-profile concerns about peak oil. The future fuel prices taken from an ARC-commissioned report by McCormick Rankin Cagney (MRC) which developed estimates of future fuel prices (they were undertaking a research project on a similar topic at the time). These estimates were included in the forecasting along with assumed TDM non-pricing effects which transferred significant numbers of trips by car to PT and active modes.

The result was much lower growth in car trips than previous forecasts and much higher growth in PT and active mode trips.

The use of these lower forecasts in car trips in evaluating a specific project led to a review of the inputs, and incorporating increases in other economic and policy inputs and more conservative assumptions on the TDM effects. Further reviews and revisions of these inputs occurred in the context of other individual studies.

In undertaking the modelling for the Auckland Plan, Auckland Council then sought to achieve a set of inputs agreed by stakeholders, including Auckland Transport, NZTA, MoT. This occurred, including a review and input by Ian Wallis.

The agreed economic and policy inputs are of particular relevance to WTSM.

6 Economic and Policy Inputs

6.1 Introduction

The following sections describe each economic and policy input as implemented in WTSM currently and the ART3 model, and then makes a recommendation.

6.2 GDP/Capita Growth

The growth in GDP per capita impacts on future car ownership levels and the growth in HCV trips. The future values of other economic and policy inputs can be dependent on the growth in GDP/capita as well (see below).

WTSM

The current value used in WTSM is 1.8% p.a. This is based on historic data and was established during the original 2001 WTSM calibration. The historic data was updated for the 2006 update which did not alter the value.

ART3

In ART3 the same growth, 1.8% p.a., is used.

Recommendation

Hence it is recommended that the GDP/capita growth of 1.8% p.a. be retained and that this is reviewed as part of the 2011 update.

6.3 Values of Time

The values of time in WTSM vary by purpose and are the same for car and PT. They are used in the generalised costs to convert between monetary values (\$) and time (minutes); generalised costs in WTSM are in minutes. If the values of time increase, and all other parameters remain the same, the non-time components of generalised costs (VOC, parking costs, fares) will reduce, therefore reducing the overall generalised costs. This would occur for both car and PT costs, so the net effects on distribution and mode shares are not clear-cut.

WTSM

The values of time in WTSM vary by purpose (HBW, HBEd, EB, Other) and car availability (expressed as captive, competition, or choice trips). The 2001 values were updated to 2006 values as part of the 2006 update. These values have not been altered in forecasting.

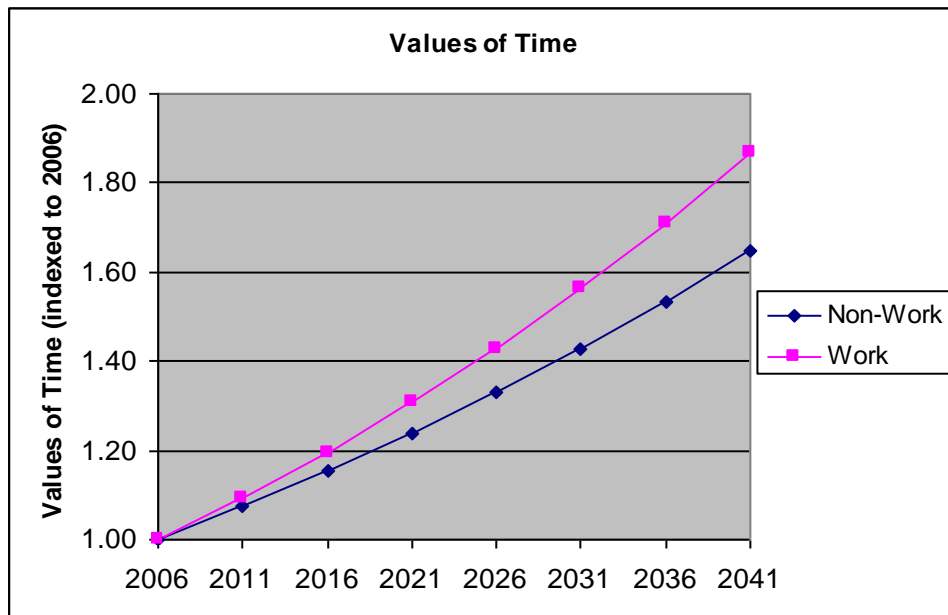
ART3

With ART3 the values of time are increased from those in the base year (2006) with respect to GDP/capita growth (1.8% p.a.), with an elasticity of 1 on work travel and 0.8 for non-work travel. This corresponds based on advice in the UK's Department for Transport Webtag.

Recommendation

It is recommended that the values of time be increased in the same manner as with ART3. Using the above GDP/capita growth and elasticities, Figure 1 shows how the work and non-work values of time increase with respect to 2006 values. They increase by 87% and 65% respectively by 2041.

- **Figure 1 - Values of Time (Indexed to 2006 Values)**



6.4 Private Vehicle Operating Costs

Private vehicle operating costs (VOC) are a component of the car generalised costs. Increasing VOC over time will increase car costs relative to PT (all other things remaining constant), and hence reduce the car mode share and also tend to shorten average trip length.

VOC is made up of fuel costs, fuel consumption rates per kilometre (vehicle efficiency), and non-fuel related costs (maintenance, licencing, etc). Private travel purposes include the fuel-related components including GST in the generalised costs, but not maintenance etc as these are not taken into account in trip-making decisions. Work-related travel (employers business) includes all three components, but does not include GST.

Non-fuel-related costs do not change in forecasting based on the assumption that these costs do not increase in real terms over time. The fuel costs and vehicle efficiency are considered below.

WTSM

VOC have been increased in WTSM forecasting though there has been some uncertainty over the increases, their basis and whether they were just fuel increases or included vehicle efficiency improvement as well. The correct situation is that GWRC have increased the 2006 VOC (fuel and vehicle efficiency combined) by 20% to year 2016 and to year 2026, that is, VOC remains constant from 2016 onwards.

The basis for the increases is the estimation of future nominal fuel prices and of inflation effects to determine real fuel price increases, and accounting for improvements in the efficiency of vehicle fuel use.

The nominal fuel price increases are based on estimated nominal values of the barrel price of fuel and the estimated exchange rate of the NZ dollar with the US dollar. The basis of these is unclear though may have been derived from historical data on the price of Dubai crude oil and the US:NZ exchange rate. The inflation forecasts are based on Treasury forecasts for 2011/12, assuming that these continue at the same rate to 2026.

The vehicle efficiency improvements to 2016 and 2026 are based on a version of the MoT's Vehicle Fleet Emissions Model that has now been superseded.

The factors for fuel price increases in real terms (excluding vehicle efficiency improvements) over 2006 to 2016 and 2026 are 1.535 and 1.618 respectively. The corresponding factors for vehicle efficiency improvements are 0.786 and 0.749.

When these two sets of factors are combined the factors for fuel-related VOC to are 1.206 and 1.212 to 2016 and 2026 respectively. That is, it is coincidence that the VOC increases to 2016 and 2026 are both 20%.

ART3

In ART3 VOC are increased over time with fuel prices increasing in line with estimates arising from MRC's report for the ARC (refer to Section 4 above). For shorter horizon forecasts a variant to the MRC estimates was developed by Beca, which adjusts the MRC estimates to align with actual fuel prices in 2010 and then linearly interpolates between this and the 2026 MRC estimate.

Vehicle efficiency improvements are based on the latest MoT projections of fleet composition, fuel types, and efficiency improvements.

Figure 2 shows how fuel prices, both the MRC and adjusted estimates, and vehicle efficiency change over time and Figure 3 shows the fuel-related VOC (which is the product of the first two).

The MRC estimates have fuel prices increasing rapidly to 2011 and then declining slightly to 2021 before increasing again. The adjusted estimates show a steady linear increase to 2026 from which the two coincide. By 2041 the real price of fuel is 2.4 times that in 2006.

Vehicle efficiency improves at a steady rate to 30% improvement by 2041 over 2006 levels.

The combination of these, the fuel-related VOC, increase by 65% by 2041, with clear differences in the early years between that using the MRC fuel price estimates and that using the adjusted estimates.

Figure 2 – Fuel Prices and Vehicle Efficiency (Indexed to 2006 Values)

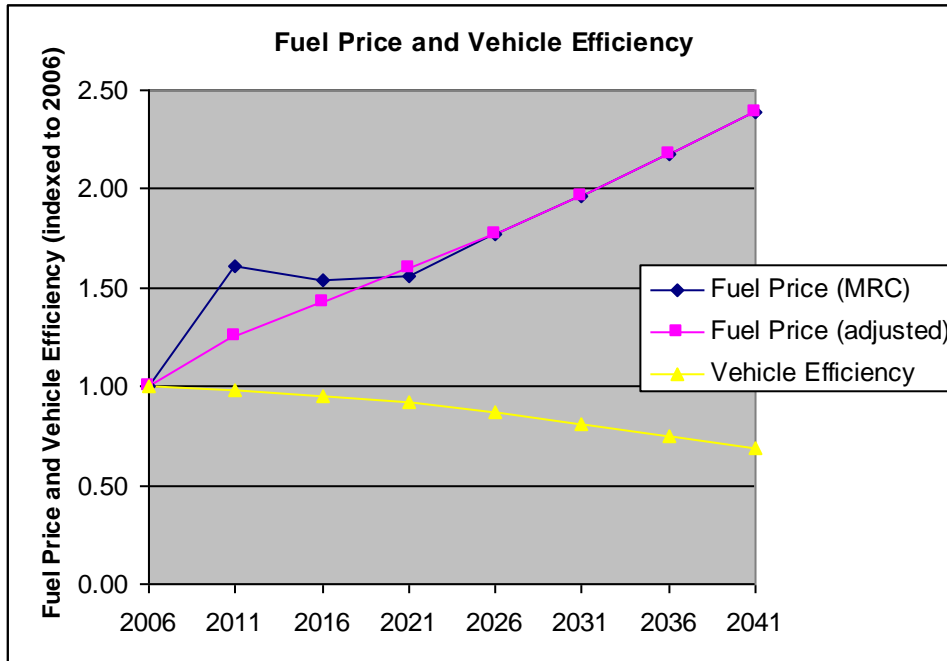
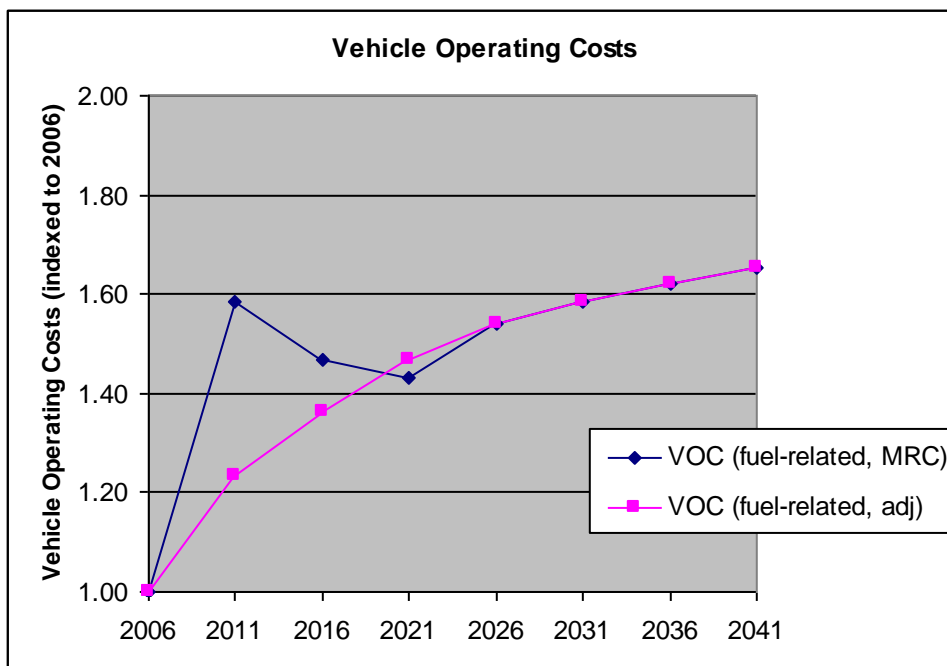


Figure 3 – Vehicle Operating Costs (fuel-related) (Indexed to 2006 Values)



WTSM vs ART3

The future fuel, vehicle efficiency and VOC values current being used in WTSM and ART3 in years 2016 and 2026 are given in Table 1.

WTSM and ART3 have the same fuel increase factor in 2016, and in 2026 WTSM's is slightly lower than ART3's. WTSM assumes greater improvements in vehicle efficiency than ART3.

Combining these two, WTSM has lower fuel-related VOC factors in both years, plus ART3's factors increase over time; that is the fuel price effect is greater than the vehicle efficiency effect between 2016 and 2026.

Table 1 - WTSM and ART3 Fuel, Vehicle Efficiency and Fuel-Related VOC Factors

	2016		2026	
	WTSM	ART3	WTSM	ART3
Fuel price increase	1.535	1.535	1.618	1.774
Vehicle efficiency improvement	0.786	0.955	0.749	0.867
Fuel-related VOC factor	1.206	1.466	1.212	1.538

Recommendation

The basis for the WTSM fuel price increase is not totally clear and the estimates of vehicle efficiency are now out of date, whereas the basis for the ART3 future values is clear and have been reviewed and agreed within the Auckland region. The WTSM values are for 2016 and 2026 only, whereas ART3 values are available for the future years 2016 to 2051 at 5-year intervals.

It is recommended that the VOC used in WTSM forecasts align with those used in ART3 from year 2026 onwards, but that, for the shorter-term forecasting the 2011 estimate is compared against the actual price and the estimates to 2026 adjusted accordingly.

6.5 Car Parking Costs

Car parking costs are a component of the car generalised costs that are applied to specified zones by trip purpose. Parking costs do not affect routeing but do impact on car demand; higher parking costs will result in lower car demand to those zones.

WTSM

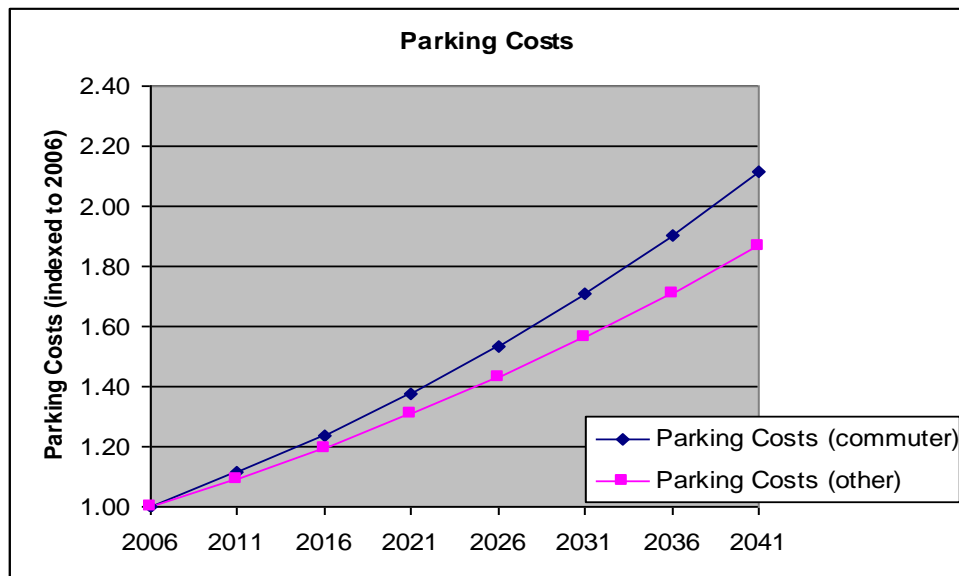
Car parking costs in WTSM are applied by trip purpose (HBW, EB, Other) to two Wellington CBD areas, upper and lower. The actual costs take into account the proportion of trips that do pay, which was originally derived from the 2001 HTS. The 2001 costs were increased for the 2006 update based on information available and the proportion paying was assumed to increase by 20%.

These costs are currently used in forecasting, though the current system for creating scenarios, Netcreator, does have the facility to apply a generic percentage increase to the CBD zones. Parking costs are not applied to other locations such as sub-regional CBDs.

ART3

In ART3 parking costs are escalated with respect to GDP/capita growth (1.8% p.a.), with an elasticity of 1.2 for commuter travel and 1.0 for non-commuter travel. These elasticities gave similar increases to those being used in the ARC's modelling in 2009. The location of parking costs also changes over time and is specific to the land use scenario being modelled. Commuter parking costs in ART3 increase by 54% from 2006 to 2026, and 112% to 2041 as shown in Figure 4.

▪ **Figure 4 – Parking Costs (Indexed to 2006 Values)**



Recommendation

If it is considered that parking costs in the Wellington CBD will increase in real terms over time in line with regional and local policies, it is recommended that parking costs be increased in forecasting in the same manner as with ART3. Different elasticities could be used to align the increases with regional parking policies.

6.6 PT Fares

PT fares are one component of the PT generalised costs. Increasing the fares will increase the costs, which – all other costs remaining constant – will reduce the PT mode share. It should be noted that for an average PT trip of 30 minutes in-vehicle-time a fare of, say, \$3 would make up approximately 20% of the generalised cost when access, egress and wait time are considered.

WTSM

In WTSM forecasts PT fares are increased from the 2006 levels by 20% to account for the fare increase that occurred shortly after the update. This level is currently maintained in all forecast years.

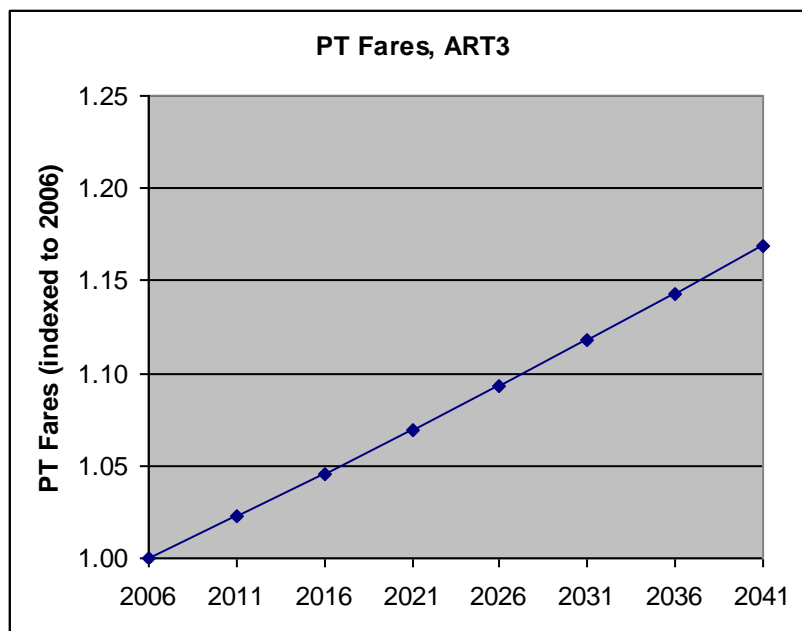
ART3

PT fares in ART3 are increased with respect to GDP/capita growth (1.8% p.a.), with an elasticity of 0.25. This relationship was arrived at following analysis of adult 1-stage cash fares in Auckland, fuel prices, and GDP/capita over the period 1994-2008. Different elasticities were applied to best fit the fares with GDP/capita.

Ian Wallis, in his review of this, noted that overall the average fares paid have remained close to constant between 2000 and 2010, depending on which PT mode and which measure (passengers or passenger-km) are considered. He then recommended that an elasticity of 0.25 be used as the base case, which results in a fare increase of about 0.45% p.a., but that 0.5 should be used as a sensitivity test where required.

The 0.25 elasticity was adopted in Auckland and the future values, indexed to 2006, are given in Figure 5.

▪ **Figure 5 – PT Fares, ART3 (Indexed to 2006 Values)**



Recommendation

While there is some uncertainty over the fare elasticity, the approach of using growth in GDP/capita is generally accepted. Hence it is proposed that this approach be used for WTSM following the 2011 update, and that data is collated and analysis undertaken to

determine the most appropriate elasticity for Wellington. For the upcoming modelling using the 2006-based model, it is suggested that the current PT are used.

7 TDM Non-Pricing Inputs

The effects of TDM non-pricing initiatives are inserted into WTSM and ART3 having the effect of reducing car trips and increasing trips by PT and/or active modes.

WTSM

The effects of workplace travel initiatives in WTSM has, to date, assumed to be 5% of HBW trips by car to the Wellington CBD are removed with 90% of these transferred to the same trip by PT and the remaining 10% not allocated, so assumed to either not-travel or to walk or cycle to a destination close to the home.

There is now the facility in WTSM to vary these percentages, including setting them to zero.

ART3

In Auckland the TDM non-pricing effects are considered in more detail, with increased working from home, and workplace, education and community travel initiatives. The assumed effects of these have been debated at length, the key difficulty being the lack of evidence of the effects.

A set of inputs has been agreed for use in all forecasting generally, which are:

- Working from home increases from 6.9% in 2006 to 12.9% in 2041, with a straight line interpolation for years in-between;
- Workplace travel initiatives resulting in an 8% reduction in car trips to Auckland CBD, 7.5% reduction to specified intensified town centres, and reductions to all other urban areas which increase over time (1.5% in 2026) and corresponding increases in PT and walk/cycle trips;
- Education travel initiatives resulting in reductions in car trips to schools and tertiary institutions which increase over time (9% in 2026) and corresponding increases in PT and walk/cycle trips;
- Community travel initiatives resulting reductions in short distance car trips which increase over time (1.5% in 2026) and corresponding increases in walk/cycle trips.

Recommendation

While Auckland has different and more extensive assumptions on the effects of TDM initiatives, they are implemented in a similar manner in both models. The processes used in WTSM should be retained and the percentage reduction in commuting trips by car to the

CBD should be based on the latest information on the effectiveness of the TDM programmes.

8 Summary

Table 2 summarises the forecasting inputs for WTSM and ART3 currently, and those proposed for WTSM.

Table 2 – Summary of Current WTSM and ART3 Inputs and Proposed WTSM Inputs

Input	Current WTSM	ART3	Proposed WTSM
GDP/capita growth	1.8% p.a. based on historic data	1.8% p.a. based on historic data	retain current growth
Values of time	not changed	increased using GDP/capita	increase using GDP/capita the same as ART3
Fuel price	increased, but basis unclear	increased based on MRC estimates	use the MRC estimates, but assess 2011 value against actual fuel price and adjust shorter term forecasts accordingly
Vehicle efficiency	improved, but based on older data	improved based on latest MoT data	use the latest MoT data
Parking costs	not changed	increased based on GDP/capita growth	increase using GDP/capita with elasticities to fit with policy
PT fares	2006 fares increased by 20% to account for actual increase shortly after; not increased further	increased based on GDP/capita growth	retain current fares at this time, but analyse historic data to determine changes
TDM non-pricing	% reduction in commuting trips by car to CBD	% reductions in car trips for workplace, education, and community travel initiatives	retain current process, % reduction to fit with latest information

David Young

7 October 2011

APPENDIX E – Economic Evaluation Manual Tables

Economic Evaluation Manual - Tables

www.nzta.govt.nz

First edition, Amendment 0

Effective from January 2010

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Table A5.1: Passenger car VOC by speed and gradient (cents/km - July 2008)

Speed (km/h)	Gradient in percent (both directions)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
10	43.9	44.0	44.1	44.2	44.2	44.3	44.4	44.5	44.7	45.0	45.2	45.6	46.1
15	38.2	38.3	38.5	38.6	38.7	38.9	39.1	39.3	39.6	39.9	40.4	40.9	41.5
20	34.0	34.2	34.3	34.5	34.6	34.9	35.1	35.4	35.7	36.1	36.6	37.2	37.9
25	31.0	31.1	31.3	31.5	31.7	31.9	32.2	32.5	32.9	33.3	33.9	34.5	35.3
30	28.8	28.9	29.1	29.2	29.5	29.7	30.0	30.3	30.8	31.3	31.9	32.6	33.4
35	27.1	27.3	27.4	27.6	27.8	28.1	28.4	28.8	29.2	29.7	30.4	31.1	31.9
40	26.0	26.1	26.3	26.4	26.7	26.9	27.2	27.6	28.1	28.6	29.3	30.1	30.9
45	25.1	25.3	25.4	25.6	25.8	26.1	26.4	26.8	27.3	27.9	28.5	29.3	30.2
50	24.6	24.7	24.9	25.1	25.3	25.5	25.9	26.3	26.8	27.4	28.0	28.8	29.8
55	24.3	24.4	24.5	24.7	24.9	25.2	25.5	26.0	26.5	27.0	27.7	28.6	29.5
60	24.1	24.3	24.4	24.6	24.8	25.1	25.4	25.8	26.3	26.9	27.6	28.4	29.4
65	24.2	24.3	24.4	24.6	24.8	25.0	25.4	25.8	26.3	26.9	27.6	28.5	29.4
70	24.3	24.4	24.5	24.7	24.9	25.2	25.5	25.9	26.4	27.0	27.8	28.6	29.6
75	24.5	24.6	24.7	24.9	25.1	25.4	25.7	26.1	26.6	27.3	28.0	28.9	29.8
80	24.9	24.9	25.1	25.2	25.4	25.7	26.0	26.4	26.9	27.6	28.3	29.2	30.2
85	25.3	25.3	25.4	25.6	25.8	26.0	26.4	26.8	27.3	28.0	28.7	29.6	30.6
90	25.7	25.8	25.9	26.0	26.2	26.5	26.8	27.2	27.8	28.4	29.1	30.0	31.0
95	26.3	26.3	26.4	26.5	26.7	27.0	27.3	27.7	28.3	28.9	29.6	30.5	31.6
100	26.8	26.9	27.0	27.1	27.3	27.5	27.9	28.3	28.8	29.4	30.2	31.1	32.1
105	27.5	27.5	27.6	27.7	27.9	28.1	28.4	28.9	29.4	30.0	30.8	31.7	32.7
110	28.1	28.1	28.2	28.3	28.5	28.7	29.1	29.5	30.0	30.6	31.4	32.3	33.3
115	28.8	28.8	28.9	29.0	29.1	29.4	29.7	30.1	30.7	31.3	32.1	33.0	34.0
120	29.5	29.5	29.6	29.7	29.8	30.1	30.4	30.8	31.3	32.0	32.7	33.6	34.7

Table A5.2: LCV VOC by speed and gradient (cents/km - July 2008)

Speed (km/h)	Gradient in percent (both directions)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
10	49.8	49.8	49.8	49.9	50.1	50.3	50.7	51.1	51.6	52.3	53.0	53.9	54.9
15	42.8	42.9	43.0	43.2	43.5	43.9	44.4	45.0	45.7	46.5	47.4	48.5	49.7
20	37.7	37.8	38.0	38.3	38.6	39.1	39.6	40.3	41.1	42.0	43.1	44.3	45.7
25	34.0	34.2	34.4	34.7	35.0	35.6	36.2	36.9	37.8	38.8	39.9	41.2	42.7
30	31.4	31.5	31.7	32.0	32.5	33.0	33.7	34.4	35.3	36.4	37.6	39.0	40.5
35	29.5	29.6	29.9	30.2	30.6	31.2	31.9	32.7	33.6	34.7	36.0	37.4	39.0
40	28.2	28.4	28.6	28.9	29.4	29.9	30.6	31.5	32.4	33.6	34.8	36.3	37.9
45	27.4	27.5	27.7	28.1	28.5	29.1	29.8	30.7	31.7	32.8	34.1	35.6	37.3
50	26.9	27.0	27.3	27.6	28.1	28.6	29.4	30.2	31.2	32.4	33.7	35.2	36.9
55	26.7	26.9	27.1	27.4	27.9	28.4	29.2	30.0	31.1	32.2	33.6	35.1	36.8
60	26.8	26.9	27.1	27.4	27.9	28.5	29.2	30.1	31.1	32.3	33.7	35.2	37.0
65	27.0	27.1	27.3	27.6	28.1	28.7	29.4	30.3	31.3	32.6	33.9	35.5	37.2
70	27.4	27.5	27.7	28.0	28.5	29.1	29.8	30.7	31.7	32.9	34.3	35.9	37.7
75	28.0	28.0	28.2	28.5	29.0	29.6	30.3	31.2	32.2	33.5	34.9	36.5	38.2
80	28.6	28.7	28.9	29.2	29.6	30.2	30.9	31.8	32.9	34.1	35.5	37.1	38.9
85	29.4	29.4	29.6	29.9	30.3	30.9	31.6	32.5	33.6	34.8	36.2	37.8	39.6
90	30.2	30.2	30.4	30.7	31.1	31.7	32.4	33.3	34.4	35.6	37.0	38.6	40.4
95	31.1	31.1	31.3	31.6	32.0	32.5	33.3	34.2	35.2	36.5	37.9	39.5	41.3
100	32.1	32.1	32.2	32.5	32.9	33.5	34.2	35.1	36.1	37.4	38.8	40.4	42.3
105	33.1	33.1	33.2	33.5	33.9	34.4	35.2	36.0	37.1	38.4	39.8	41.4	43.2
110	34.1	34.1	34.2	34.5	34.9	35.5	36.2	37.1	38.1	39.4	40.8	42.4	44.3
115	35.2	35.2	35.3	35.6	36.0	36.5	37.2	38.1	39.2	40.4	41.8	43.5	45.3
120	36.4	36.3	36.4	36.7	37.1	37.6	38.3	39.2	40.3	41.5	42.9	44.6	46.4

Table A5.3: MCV VOC by speed and gradient (cents/km - July 2008)

Speed (km/h)	Gradient in percent (both directions)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
10	71.8	72.0	72.9	74.5	76.5	79.0	81.8	84.8	87.9	91.0	94.1	97.0	99.6
15	64.3	64.4	65.3	66.9	69.1	71.7	74.6	77.9	81.3	84.7	88.2	91.5	94.6
20	58.8	58.9	59.8	61.4	63.6	66.2	69.3	72.7	76.3	79.9	83.6	87.2	90.6
25	55.1	55.1	55.9	57.5	59.7	62.4	65.5	69.0	72.7	76.5	80.4	84.1	87.7
30	52.5	52.5	53.3	54.8	57.0	59.7	62.9	66.4	70.2	74.2	78.1	82.1	85.8
35	50.9	50.8	51.6	53.1	55.2	58.0	61.2	64.8	68.6	72.6	76.7	80.7	84.7
40	50.0	49.8	50.5	52.0	54.2	56.9	60.1	63.8	67.6	71.7	75.9	80.0	84.0
45	49.6	49.4	50.0	51.5	53.6	56.4	59.6	63.3	67.2	71.3	75.5	79.8	83.9
50	49.6	49.3	50.0	51.4	53.5	56.3	59.5	63.2	67.1	71.3	75.6	79.9	84.1
55	50.0	49.7	50.2	51.6	53.7	56.5	59.7	63.4	67.4	71.6	75.9	80.3	84.5
60	50.6	50.2	50.8	52.2	54.2	57.0	60.2	63.9	67.9	72.1	76.5	80.9	85.3
65	51.5	51.1	51.6	52.9	55.0	57.7	60.9	64.6	68.6	72.9	77.3	81.8	86.2
70	52.5	52.1	52.5	53.8	55.9	58.6	61.8	65.5	69.6	73.9	78.3	82.8	87.2
75	53.7	53.2	53.6	54.9	56.9	59.6	62.9	66.6	70.6	74.9	79.4	83.9	88.4
80	55.1	54.5	54.9	56.1	58.1	60.8	64.1	67.8	71.8	76.1	80.6	85.2	89.7
85	56.5	55.9	56.2	57.5	59.4	62.1	65.3	69.0	73.1	77.5	82.0	86.6	91.1
90	58.0	57.4	57.7	58.9	60.8	63.5	66.7	70.4	74.5	78.9	83.4	88.0	92.6
95	59.6	58.9	59.2	60.4	62.3	65.0	68.2	71.9	76.0	80.3	84.9	89.5	94.2
100	61.3	60.5	60.8	61.9	63.9	66.5	69.7	73.4	77.5	81.9	86.4	91.1	95.8
105	63.0	62.2	62.4	63.6	65.5	68.1	71.3	75.0	79.1	83.5	88.1	92.7	97.4
110	64.7	63.9	64.1	65.2	67.1	69.7	72.9	76.6	80.7	85.1	89.7	94.4	99.1
115	66.5	65.7	65.9	67.0	68.8	71.4	74.6	78.3	82.4	86.8	91.4	96.1	100.8
120	68.4	67.5	67.7	68.7	70.6	73.1	76.3	80.0	84.1	88.5	93.1	97.9	102.6

Table AS.4: HCVI VOC by speed and gradient (cents/km - July 2008)

Speed (km/h)	Gradient in percent (both directions)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
10	134.6	135.0	137.7	142.4	148.6	156.1	164.5	173.4	182.4	191.3	199.5	206.8	212.7
15	124.3	124.4	126.9	131.5	137.9	145.7	154.5	163.9	173.6	183.3	192.5	200.8	208.0
20	115.3	115.1	117.6	122.2	128.6	136.6	145.7	155.5	165.6	175.8	185.7	194.8	202.9
25	108.6	108.2	110.6	115.2	121.7	129.8	139.0	149.1	159.7	170.3	180.7	190.4	199.1
30	103.8	103.4	105.6	110.2	116.7	124.9	134.4	144.7	155.5	166.5	177.3	187.5	196.8
35	100.7	100.1	102.3	106.8	113.4	121.7	131.3	141.8	152.9	164.1	175.3	185.9	195.6
40	98.9	98.1	100.2	104.8	111.4	119.8	129.4	140.1	151.4	162.9	174.4	185.3	195.4
45	98.0	97.2	99.3	103.8	110.4	118.8	128.6	139.4	150.9	162.7	174.4	185.6	196.1
50	98.0	97.1	99.1	103.6	110.3	118.7	128.6	139.5	151.2	163.1	175.1	186.6	197.4
55	98.7	97.7	99.6	104.1	110.8	119.3	129.3	140.3	152.1	164.2	176.4	188.1	199.2
60	99.9	98.8	100.7	105.2	111.9	120.4	130.5	141.6	153.5	165.8	178.2	190.1	201.4
65	101.5	100.4	102.3	106.7	113.4	122.0	132.1	143.3	155.4	167.8	180.3	192.5	204.1
70	103.6	102.4	104.2	108.6	115.3	124.0	134.1	145.5	157.6	170.2	182.9	195.2	207.0
75	105.9	104.7	106.5	110.9	117.6	126.3	136.5	147.9	160.1	172.8	185.7	198.2	210.2
80	108.6	107.3	109.0	113.4	120.1	128.8	139.1	150.6	162.9	175.8	188.7	201.4	213.5
85	111.4	110.1	111.8	116.2	122.9	131.6	141.9	153.5	165.9	178.9	192.0	204.8	217.1
90	114.5	113.1	114.7	119.1	125.9	134.6	145.0	156.6	169.1	182.2	195.4	208.4	220.8
95	117.7	116.2	117.9	122.2	129.0	137.8	148.2	159.8	172.4	185.6	198.9	212.1	224.7
100	121.1	119.6	121.2	125.5	132.3	141.1	151.5	163.3	175.9	189.2	202.6	215.9	228.6
105	124.6	123.0	124.6	128.9	135.7	144.5	155.0	166.8	179.5	192.9	206.4	219.8	232.7
110	128.2	126.6	128.1	132.5	139.2	148.0	158.6	170.4	183.2	196.6	210.3	223.8	236.8
115	131.9	130.2	131.7	136.1	142.8	151.7	162.2	174.1	187.0	200.5	214.2	227.9	241.0
120	135.6	133.9	135.4	139.8	146.5	155.4	166.0	177.9	190.9	204.4	218.3	232.0	245.3

Table AS.5: HC VII VOC by speed and gradient (cents/km - July 2008)

Speed (km/h)	Gradient in percent (both directions)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
10	180.0	186.0	196.4	210.5	227.5	246.7	267.2	288.3	309.1	328.9	347.0	362.5	374.6
15	177.2	181.1	190.0	202.9	219.1	237.8	258.3	279.7	301.3	322.3	341.8	359.3	373.7
20	170.8	173.6	181.7	194.0	210.0	228.8	249.6	271.6	294.1	316.3	337.3	356.5	372.9
25	165.0	167.3	174.9	187.1	203.1	222.1	243.4	266.1	289.5	312.8	335.1	355.8	374.1
30	160.8	162.6	170.0	182.2	198.4	217.7	239.5	262.9	287.1	311.5	335.1	357.2	377.0
35	157.9	159.5	166.9	179.1	195.5	215.2	237.5	261.6	286.7	312.0	336.7	360.1	381.3
40	156.3	157.8	165.2	177.5	194.2	214.3	237.1	261.9	287.7	313.9	339.7	364.3	386.8
45	155.8	157.3	164.6	177.2	194.1	214.7	238.0	263.4	290.0	317.0	343.8	369.4	393.2
50	156.2	157.6	165.1	177.9	195.1	216.0	239.9	265.8	293.2	321.0	348.7	375.4	400.2
55	157.4	158.8	166.4	179.4	196.9	218.2	242.6	269.1	297.1	325.8	354.3	381.9	407.8
60	159.1	160.7	168.4	181.6	199.4	221.1	245.9	273.0	301.7	331.1	360.4	388.9	415.8
65	161.5	163.1	170.9	184.3	202.5	224.6	249.9	277.5	306.8	336.8	367.0	396.3	424.2
70	164.3	165.9	174.0	187.6	206.0	228.5	254.2	282.4	312.3	343.0	373.9	404.0	432.8
75	167.4	169.2	177.4	191.3	210.0	232.9	259.0	287.7	318.1	349.5	381.0	412.0	441.5
80	170.9	172.8	181.2	195.3	214.3	237.5	264.1	293.3	324.2	356.2	388.5	420.1	450.5
85	174.7	176.7	185.3	199.6	218.9	242.5	269.5	299.1	330.6	363.2	396.1	428.5	459.6
90	178.8	180.9	189.6	204.2	223.8	247.7	275.1	305.2	337.2	370.3	403.8	436.9	468.7
95	183.0	185.3	194.2	209.0	228.9	253.1	280.9	311.4	343.9	377.6	411.7	445.4	478.0
100	187.5	189.9	198.9	214.0	234.1	258.7	286.8	317.8	350.8	385.0	419.7	454.0	487.2
105	192.1	194.6	203.8	219.1	239.5	264.4	292.9	324.3	357.8	392.5	427.7	462.7	496.6
110	196.8	199.5	208.9	224.4	245.1	270.3	299.2	330.9	364.8	400.0	435.8	471.4	505.9
115	201.7	204.5	214.1	229.8	250.8	276.3	305.5	337.6	372.0	407.7	444.0	480.1	515.2
120	206.7	209.6	219.4	235.3	256.5	282.3	311.9	344.4	379.2	415.4	452.2	488.8	524.5

Table A5.6: Bus VOC by speed and gradient (cents/km - July 2008)

Speed (km/h)	Gradient in percent (both directions)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
10	104.2	105.1	107.6	111.4	116.3	122.1	128.6	135.3	142.2	149.0	155.4	161.1	166.0
15	97.0	97.6	100.0	103.8	108.9	114.9	121.7	129.0	136.6	144.1	151.4	158.2	164.2
20	90.2	90.6	92.8	96.6	101.7	107.9	114.9	122.5	130.4	138.4	146.3	153.7	160.5
25	85.2	85.4	87.4	91.1	96.2	102.4	109.6	117.4	125.6	133.9	142.2	150.1	157.5
30	81.9	81.9	83.8	87.4	92.4	98.7	105.9	113.8	122.2	130.9	139.4	147.7	155.5
35	80.0	79.8	81.5	85.0	90.0	96.3	103.6	111.6	120.2	129.0	137.8	146.4	154.5
40	79.2	78.8	80.4	83.8	88.8	95.1	102.4	110.5	119.1	128.1	137.1	146.0	154.4
45	79.4	78.8	80.3	83.6	88.5	94.7	102.0	110.2	119.0	128.1	137.3	146.3	155.0
50	80.2	79.5	80.8	84.0	88.9	95.1	102.4	110.7	119.5	128.7	138.0	147.3	156.1
55	81.7	80.7	82.0	85.1	89.9	96.1	103.5	111.7	120.6	129.9	139.4	148.7	157.8
60	83.6	82.5	83.7	86.7	91.5	97.6	105.0	113.2	122.2	131.6	141.1	150.6	159.8
65	85.9	84.7	85.8	88.7	93.4	99.5	106.9	115.1	124.1	133.6	143.3	152.9	162.2
70	88.6	87.3	88.2	91.1	95.7	101.8	109.1	117.4	126.5	136.0	145.7	155.5	164.9
75	91.5	90.1	90.9	93.7	98.3	104.4	111.7	120.0	129.0	138.6	148.4	158.3	167.9
80	94.7	93.2	93.9	96.6	101.1	107.2	114.5	122.8	131.9	141.5	151.4	161.3	171.0
85	98.1	96.4	97.1	99.7	104.2	110.2	117.5	125.8	134.9	144.5	154.5	164.5	174.3
90	101.6	99.9	100.4	103.0	107.4	113.4	120.6	129.0	138.1	147.8	157.8	167.9	177.8
95	105.3	103.5	103.9	106.5	110.8	116.7	124.0	132.3	141.4	151.2	161.2	171.4	181.3
100	109.1	107.2	107.6	110.0	114.3	120.2	127.4	135.8	144.9	154.7	164.8	175.0	185.0
105	113.1	111.0	111.3	113.7	118.0	123.8	131.0	139.3	148.5	158.3	168.4	178.7	188.8
110	117.1	114.9	115.2	117.5	121.7	127.5	134.7	143.0	152.2	162.0	172.2	182.5	192.7
115	121.2	118.9	119.1	121.3	125.5	131.3	138.4	146.7	155.9	165.8	176.0	186.4	196.6
120	125.3	123.0	123.1	125.3	129.4	135.1	142.3	150.6	159.8	169.6	179.9	190.3	200.6

Table A5.0(a):
Breakdown of base
VOC by component

Vehicle class	Percentage of total base VOC by component			
	Fuel and oil	Tyres	Maintenance and repairs	Depreciation
PC	49.5	5.1	24.9	20.5
LCV	54.9	7.1	20.6	17.4
MCV	53.3	5.2	32.7	8.8
HCVI	58.2	6.9	29.7	5.2
HCVII	55.3	9.4	29.1	6.2
Bus	61.9	4.4	26.0	7.7
Road type				
Urban arterial	51.1	5.8	25.4	17.6
Urban other	51.1	5.6	25.6	17.7
Rural strategic	52.3	6.3	26.4	15.0
Rural other	52.0	6.1	26.2	15.7

Table A5.22: Additional VOC due to bottleneck delay by vehicle class (cents/minute - July 2008)

PC	LCV	MCV	HCVI	HCVII	Bus
2.892	3.73	4.484	6.678	6.678	5.247

Table A5.12: Urban additional VOC due to roughness by vehicle class (cents/km - July 2008)

Roughness		Additional VOC in cents/km by vehicle class					
IRI (m/km)	NAASRA (count/km)	PC	LCV	MCV	HCVI	HCVII	Bus
0-2.5	0-66	0.0	0.0	0.0	0.0	0.0	0.0
3.0	79	0.3	0.3	0.5	0.9	1.5	0.8
3.5	92	0.7	0.6	1.7	2.5	4.1	2.5
4.0	106	1.4	1.3	3.5	5.1	7.8	5.0
4.5	119	2.4	2.3	5.8	8.4	12.3	8.0
5.0	132	3.7	3.7	8.5	12.3	17.4	11.4
5.5	145	5.1	5.4	11.5	16.6	22.9	15.1
6.0	158	6.7	7.3	14.7	21.2	28.7	19.0
6.5	172	8.3	9.3	18.0	25.9	34.7	23.0
7.0	185	10.1	11.4	21.4	30.8	40.8	27.0
7.5	198	11.8	13.6	24.8	35.7	46.9	31.1
8.0	211	13.5	15.7	28.2	40.6	53.0	35.1
8.5	224	15.3	17.9	31.6	45.4	59.0	39.1
9.0	238	16.9	19.9	34.9	50.2	65.0	43.0
9.5	251	18.6	22.0	38.1	54.9	70.9	46.9
10.0	264	20.2	23.9	41.2	59.4	76.6	50.7
10.5	277	21.7	25.7	44.3	63.9	82.3	54.3
11.0	290	22.6	26.6	46.0	66.3	85.8	56.7
11.5	304	23.3	27.3	47.5	68.4	89.1	58.8
12.0	317	24.0	28.0	49.0	70.5	92.3	60.9
12.5	330	24.8	28.7	50.5	72.7	95.6	63.0
13.0	343	25.5	29.4	52.0	74.8	98.9	65.1
13.5	356	26.3	30.1	53.5	76.9	102.2	67.2
14.0	370	27.0	30.7	55.0	79.0	105.5	69.3
14.5	383	27.7	31.4	56.5	81.2	108.7	71.5
15.0	396	28.5	32.1	58.0	83.3	112.0	73.6