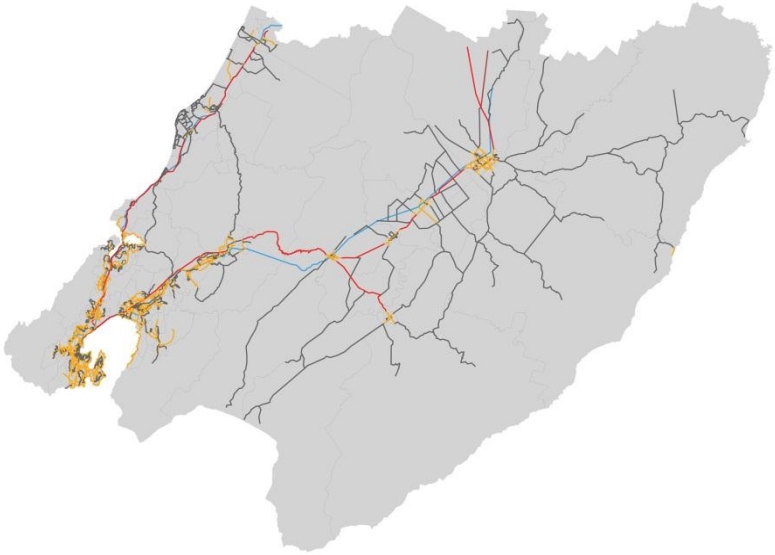
OPUS INTERNATIONAL CONSULTANTS AND ARUP

WELLINGTON TRANSPORT MODELS

Contract No C3079



TN20: WPTM Forecasting

Date: December 2012

ARUP OPUS

Wellington Transport Models

TN20: WPTM Forecasting

prepared for

Greater Wellington Regional Council

Prepared By

Dan Jones (Arup)

Opus International Consultants Limited
Wellington Office
Level 9, Majestic Centre, 100 Willis Street
PO Box 12003, Wellington 6144
New Zealand
Ph: +64 4 471 7000

Reviewed By

Bruce Johnson (Arup)

ARUP

Arup
Level 17, 1 Nicholson Street
Melbourne VIC 3000
Australia
Ph: +61 3 9668 5500

Date: December 2012
Reference: g:\localauthorities\wrc\proj\5-c2050.00 - c3079 wtsm wptm\600 deliverables\630 final tech notes\tn20 wptm forecasting final.docx
Status: Final
Revision: 1

Document History and Status

Issue	Rev	Issued To	Qty	Date	Reviewed	Approved
Draft	1			12/04/12		
Final Draft	2			31/07/12	MOR	BAJ
Final	1	Nick Sargent - GW	1 Hard & 1 CD	06/12/12	MOR	DEJ

This report takes into account the particular instructions and requirements of our client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

John Bolland: _____
(Peer Reviewer)

Nick Sargent: _____
(GWRC)

Confidential Information – Security Requirements

This document includes Confidential Information covered by Confidentiality Agreements between NZ Bus Limited, Mana Bus, GWRC, Opus and Arup or subject to legal privilege or copyright. Information in this document should be protected in accordance with requirements of the Agreements. If you are not the intended recipient and have not signed a Confidentiality Agreement please notify us immediately and destroy or delete the copy of the report.

Contents

1 Introduction

1.1 Overview

The base year public transport (PT) demand matrix in WPTM was developed from observed data sources. As such, it is a highly reliable and accurate representation of current PT demand. This matrix would be expected to change as time goes by as the population changes and as the network develops. Therefore, for modelling future years and alternative networks, it is necessary to apply adjustments to the base PT matrix to reflect changes in trip generation, induction, suppression, redistribution and switch between car and PT.

WPTM does not have any built-in functions to forecast these changes. Therefore WPTM is linked to WTSM growth rates.

In this technical note (TN), the method by which demand matrix changes in WTSM are passed to WPTM is described.

1.2 Report Structure

The remainder of this TN has been organised into the following structure:

- Section 2 – Demand growth model
- Section 3 – Zone disaggregation from WTSM to WPTM
- Section 4 – Demand growth methodology
- Section 5 – Correspondence between WTSM and WPTM segments
- Section 6 – Calibration of the growth model
- Section 7 – Validation of the growth model
- Section 8 – Car availability
- Section 9 – Conclusions

1.3 Relevant Documents

This TN forms part of the suite of reports produced for the WTSM update and WPTM development project. Other key TNs relating to the topic documented herein are listed below:

- TN7 – PT Matrix Development
- TN21 – Models User Guide and WTSM-WPTM Interface
- TN24 – Baseline Forecasting Report

2 Demand Growth Model

2.1 Overview

The 'base' and 'future' PT matrices produced by WTSM are used to calculate growth factors that are applied to the base public transport matrices in WPTM, resulting in what might be termed 'factored observed' matrices for use in future year and option test WPTM runs[1]. This has two advantages: (1) it retains the essential details of the observed travel patterns inherent in the base matrix; and (2) demand growth is consistent with WTSM.

The application of growth from a 'synthetic' (e.g. four-stage) model to an observed matrix is sometimes referred to as a 'pivot point' or 'incremental' method. The more general term of 'demand growth factoring' will be used in this note. A simplified diagram of the process is given in Figure 2-1.

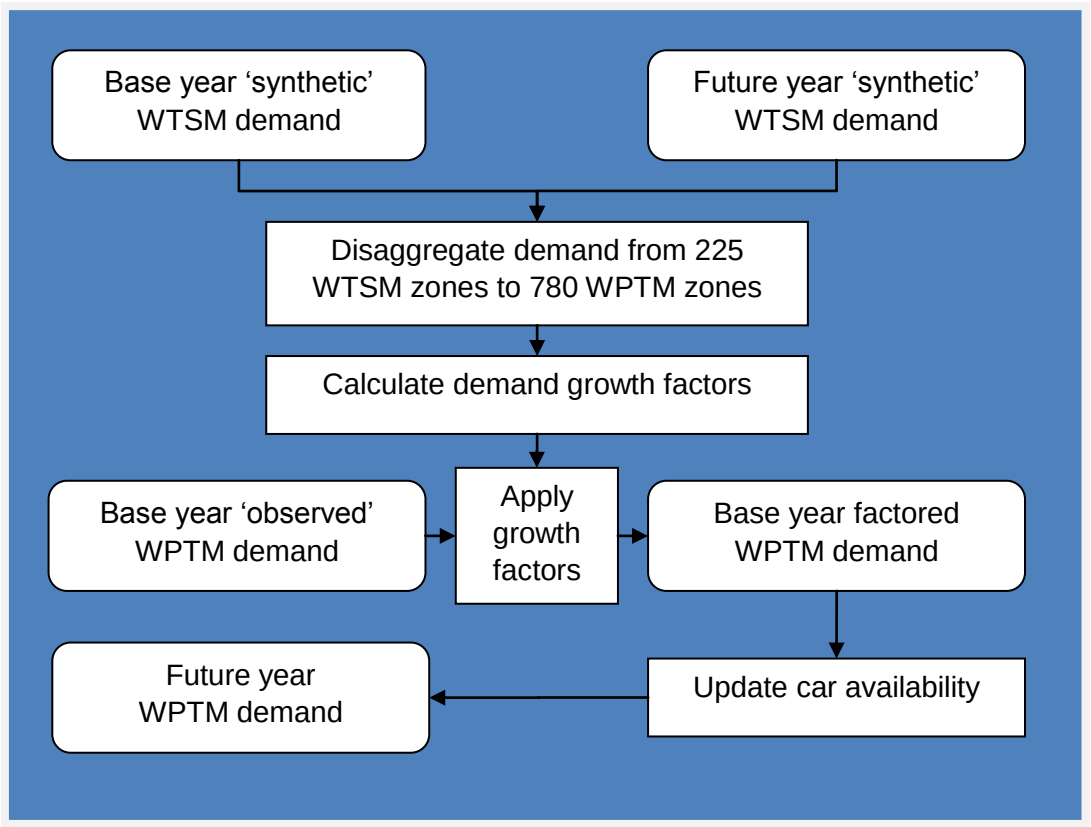


Figure 2-1: Preparation of WPTM Future Matrices

2.2 Discussion

Applying growth rates from a regional model to expand an observed matrix is becoming increasingly common as model developers gain access to new and more reliable datasets

[1] The term 'future matrix' is used throughout this TN to distinguish a matrix that is different to the 'base matrix', regardless of the cause. In reality the cause might be passage of time (e.g. growth in population, employment etc.) or a change to the network that induces demand changes (e.g. a new rail line will increase total PT demand).

to build observed matrices and scheme promoters come to appreciate the improved accuracy of matrices built from observed demand. With the SNAPPER electronic ticketing machine (ETM) system, Wellington is far ahead of most other cities in this regard.

In the UK, WebTag advice notes recommend this form of modelling where possible. It is particularly applicable for mature cities such as Wellington, though less applicable to fast changing cities where base demand patterns may rapidly become out of date.

Four key issues require resolution in designing a working system for WTSM / WPTM:

- Should the change in WTSM trips (future minus base) be added to the base WPTM demand, or should the WTSM ratio (future / base) be multiplied by the WPTM demand, or some combination of the two?

- How should large and 'greenfield' development sites be handled, where demand in the WPTM base may be low or zero and therefore cannot be multiplied?

- More generally, how does one deal with cells[2] that have low or zero demand in the observed matrix? If we see there is demand in WTSM (but not WPTM) and this is predicted to increase in the future, do we ignore it because we believe there should really be no trips, or do we consider there has been a material change at the zones in question (e.g. a new development) and therefore transfer the change to the WPTM matrix?

- Should demand growth processing be undertaken at WTSM zone level (225x225) or at WPTM zone level (780x780), and how can we make the most of the superior zonal resolution of WPTM?

2.3 Method Adopted

In answering these questions, we have drawn heavily on the guidance in the conference paper: "Pivot Point Procedures in Practical Travel Demand Forecasting", Andrew Daly, James Fox, Jan Gerrit Tuinenga (RAND Europe)[3]. We have first-hand experience of this method through our work with the Bureau of Transport Statistics in Sydney who use this methodology in the Sydney Strategic Transport Model (STM). It is also used in several other models in the Netherlands and the UK.

The proposed approach for WPTM is generally consistent with the RAND approach, plus some additional procedures to convert between the zoning systems. Key features are summarised below:

- WTSM demand is disaggregated to the WPTM zoning system in advance of processing to allow the detailed land use distribution at WPTM zone level to be captured (see Section 3). All growth calculations are therefore at the WPTM zone level.

[2] Cell = a cell of the trip matrix, i.e. a single origin to destination pair
[3] www-sre.wu-wien.ac.at/ersa/ersaconfs/ersa05/papers/784.pdf

- In the common situation where a matrix cell has trips recorded in the WPTM matrix and in the base and future WTSM matrices, a future/base ratio will be calculated from WTSM and **multiplied** by the WPTM observed demand.

- Where there are few or no trips in WPTM but there are trips in the WTSM future matrix, there are two possibilities:

    1. *Extreme growth*: if the WTSM future is much larger than the WTSM base, the cell is interpreted as a 'development zone' where something material is deemed to have changed. WTSM demand change is **added** to WPTM;
    2. *Normal growth*: if the change from WTSM base to WTSM future is modest, it is interpreted as normal (regular, background) growth and is ignored. The reason we ignore growth in this case is that many cells in WPTM are zero through sampling chance – there might be an origin-destination (O-D) pair with two trips and an adjacent (O-D) pair with no trips. The cell with two trips gets factored, while the cell with zero trips is left at zero. In reality, perhaps there should be one trip in each and both should be factored, or maybe two and zero is right. Either way, the correct volume of future demand results from this approach.

- Where there are few or no trips in the WTSM base but there are trips in the WTSM future, we know this is more than just background growth – something material must have changed e.g. land use – therefore the WTSM trips are **added** to WPTM

The alternative approach of adding the change in WTSM trips (future minus base) to the base WPTM demand rather than multiplying the base demand is less appealing for general application as it may result in negative values in the WPTM matrix and gross changes of scale in individual cells. However, as shown in bullet points three and four above, the additive approach is useful in some circumstances.

3 Zone Disaggregation Methodology

3.1 Overview

In advance of running the growth process, WTSM PT demand must be read in and disaggregated from the larger WTSM zones to the smaller WPTM zones, the demand growth calculations being at the WPTM zone level to allow for more detail in land use to be captured.

The disaggregation is achieved by sharing out the WTSM trips at O and D ends among the constituent WPTM zones in proportion to trip generation or attraction potential in each. This is closely related to the procedure employed in smoothing the observed rail matrices and reallocating the base bus demand from stops to zones when the base matrices were prepared.

Table 3-1 below shows the trip generation and attraction variables used for each segment

Table 3-1: Land Use Data for Disaggregating WTSM to WPTM

Segment	Trip end	
	Origin	Destination
AM Adult Work	(RFTE*a) + (RPTE*b)	Jobs
AM Adult Educ & Child	(RFTS*a) + (RPTS*b) + (Residents, 11-16 years)	ROLL_17 + ROLL_TER + ROLL_SEC
AM Adult Other	Total Residents	Jobs
IP Adult Work	(RFTE*a) + (RPTE*b) + Jobs	
IP Adult Educ & Child	(RFTS*a) + (RPTS*b) + (Residents, 11-16 years) + ROLL_17 + ROLL_TER + ROLL_SEC	
IP Adult Other	Total Residents + Jobs	

Where:

RFTE, RPTE	= Resident FT and PT employees
RFTS, RPTS	= Resident FT and PT students aged 15+ (based on 2006 census data)
a, b	= weighting factors, a = full-time (1.67), b = part-time (1.00)
ROLL_17	= Enrolment numbers, students aged 17+
ROLL_SEC	= Enrolment numbers, secondary school students
ROLL_TER	= Enrolment numbers, tertiary education students

It should be noted that child trips and adult trips are not separately available from WTSM. Therefore, the WTSM HBE purpose is used to grow both Adult education and Child trips in WPTM. The zonal disaggregation uses both child and adult education indicators.

3.2 Disaggregation Example

If we assume 100 ‘Adult Other’ trips travelling between WTSM zones A and B; WTSM zone A contains two WPTM zones: A1 and A2; and WTSM zone B contains two WPTM zones: B1 and B2. The assumed zone data is given in Table 3-2.

Table 3-2: Disaggregation Example - Zone Data

Zone	Total Residents	Jobs
A1	1500	
A2	2300	
B1		80
B2		700

The 100 'adult other' trips will be disaggregated as shown in Table 3-3.

Table 3-3: Disaggregation Example - Results

Movement	Calculation	Result
A1 – B1	{ 1500 / (1500+2300) } * { 80 / (80+700) } * 100	4.0
A1 – B2	{ 1500 / (1500+2300) } * { 700 / (80+700) } * 100	35.4
A2 – B1	{ 2300 / (1500+2300) } * { 80 / (80+700) } * 100	6.2
A2 – B2	{ 2300 / (1500+2300) } * { 700 / (80+700) } * 100	54.3
TOTAL		100

3.3 Zone Definition for Land Use Data

The future zone data for the variables shown in Table 3-1 is currently specified at WTSM zone level and the distribution of the zone data among constituent WPTM zones is assumed to remain the same in future years as it is in the base year. However, to take full advantage of the WPTM zoning system, model users should be developing the future year zone data at a WPTM zone level in local areas, as appropriate to each study.

3.4 Alternative Disaggregation Approaches

In recent years, the standard approach to disaggregating WTSM highway demand for use in local area highway models (with finer zoning systems) has been to estimate the big zone to small zone proportions using a function that relates car demand to multiple independent variables such as employment, population and education, in a single function. Our understanding is that this approach is used because WTSM highway demand has not been available at a trip purpose level, therefore the all-purpose demand must be split using a function with multiple independent variables as some trips are generated by schools, some by workplaces, some by households, and so on.

This approach is not necessary for the WTSM to WPTM disaggregation because WTSM and WPTM PT demand matrices are available by purpose; they are not added together. So, commuter demand, for example, can satisfactorily be disaggregated using a single generation variable, working residents, and the single attraction variable, employees, as described above.

4 Demand Growth Methodology

4.1 Ten Cases

The RAND approach recognises ten possible 'cases' when undertaking demand growth factoring. The 'case' is determined by the value found in the WPTM observed matrix, the disaggregated WTSM Base matrix and the disaggregated WTSM Future matrix.

Table 4-1 shows the 10 cases and the calculations applied in each case. Illustrations are given of the circumstances where each might occur.

Table 4-1: Ten 'Cases' for Demand Growth

Case	Input matrices			Result matrix	Illustration
	WPTM Observed Base (A)	WTSM Synthetic Base (B)	WTSM Synthetic Future (C)	WPTM Future (D)	
1	0	0	0	0	Empty zone
2	0	0	+	C	Greenfield development
3	0	+	0	0	Removal of development
4a	0	+	+ (C>5B)	C – 5B	Significant development, not greenfield
4b	0	+	+ (C<5B)	0	Normal background growth
5	+	0	0	A	Maintain observed base into future
6	+	0	+	A + C	New development
7	+	+	0	0	Removal of development
8a	+	+	+ (C>X)	A*X/B + (C-X)	Significant development, not Greenfield.
8b	+	+	+ (C<X)	A*C/B	Most cells will fall into this category

Adapted from Table 2 of "Pivot Point Procedures in Practical Travel Demand Forecasting".
The interpretation of parameter 'X' is described in the paragraphs below.

In practice, most cells in the matrix fall into cases 1, 4b or 8b:

- **Case 4b**: normal growth, in cells that have WTSM demand but no WPTM demand
- **Case 8b**: normal growth, in cells that have both WTSM demand and WPTM demand

In case 4b, the cell value in WPTM future remains at its base value (zero).

In case 8b, the WTSM growth is transferred to WPTM through multiplication.

The other cases apply in a relatively small number of cells where growth (or contraction) is extreme, or where there are zero cells. Matrices developed from observed data tend to have a high proportion of cells that are empty. This may be because there truly are no (or almost no) trips made in these cells, or it may be due to limitations of the sample used to create the matrix – trips are made but, by chance, none were captured. RAND recommends

a definition of 'zero' value as less than 0.001. However, this is subject to calibration (see Section 6).

Case 8a applies when there is extreme growth between base and future years in WTSM in a zone that has some base demand. An example of when this may occur is 'brownfield' redevelopment. In this case (8a), the 'normal' part of the growth is applied by **multiplication**, and the 'extreme' growth component of demand is **added** on top. The 'X' value shown in Table 4-1 is the critical value at which growth switches from multiplicative (normal component) to additive (extreme component). In the RAND paper, X is defined as $B * \{K_1 + \max(5K_2/A, K_1)\}$. Whilst the RAND paper uses a default value of 0.5 for K_1 and a default value of 5 for K_2, the values of K_1 and K_2, and also the multiple of K_2 used in case 4 to distinguish between normal and extreme growth, need to be confirmed or recalibrated to the local context (see Section 6).

4.2 Worked Examples

Table 4-2 gives worked examples of how the results come out in each case.

Table 4-2: Examples for Each Case

	Input matrices			Result matrix	Example
	WPTM Observed Base (A)	WTSM Synthetic Base (B)	WTSM Synthetic Future (C)	WPTM Future (D)	
1	-	-	-	-	Empty zone
2	-	-	120	120	Greenfield development
3	-	30	-	-	Removal of development
4a	-	30	220	190	Significant development, not greenfield
4b	-	30	120	-	Normal background growth
5	50	-	-	50	Maintain observed base into future
6	50	-	220	270	New development
7	50	30	-	-	Removal of development
8a	50	30	120	190	Significant development, not greenfield
8b	50	30	90	150	Most cells will fall into this category

In cases 8a and 8b, the shoulder value 'X', using the default RAND parameters, works out to be 105. In the bottom row of the table, C=90 which is less than 105 so the standard multiplicative approach is used: 90/30*50=150. In the row above, C=120 which is above the shoulder value of 105, so the standard multiplicative approach is used up to 105 and beyond that, an additive approach: (105/30)*50 + (120-105) = 190.

5 Matrix Correspondence

The growth factoring process is applied to each demand segment in WPTM individually, using the most appropriate Public Transport (PT) matrices from WTSM. The correspondence between WPTM matrices and WTSM matrices is given in Table 5-1.

Table 5-1: Correspondence Between WPTM and WTSM Segments

WPTM Segment	WTSM Period, Segment, Mode	WTSM Base Matrix Location in WPTM databank	WTSM Future Matrix Location in WPTM databank
AM adult work car-available	AM HBW PT	mf460	mf464
AM adult work no-car-available			
AM adult educ. car-available	AM HBE PT	mf461	mf465
AM adult educ. no-car-available			
AM adult other car-available	AM HBS PT + HBO PT + NHBO PT	mf444	mf454
AM adult other no-car-available			
AM child	AM HBE PT	mf461	mf465
IP adult work car-available	IP HBW PT	mf462	mf466
IP adult work no-car-available			
IP adult educ. car-available	IP HBE PT	mf463	mf467
IP adult educ. no-car-available			
IP adult other car-available	IP HBS PT + HBO PT + NHBO PT	mf449	mf459
IP adult other no-car-available			
IP child	IP HBE PT	mf463	mf467

6 Calibration

The parameters for calibration are:

- The minimum value, below which cells are considered to be zero values;
- The growth multiple, where normal growth switches to extreme growth; and
- The parameter in the calculation of the switching value X for case 8.

The default (RAND recommended) values and final calibration values are shown in Table 6-1.

Table 6-1: Pre- and Post-Calibration Parameter Values

Parameter	Pre-calibration	Post-calibration
Value below which cells are considered to hold a zero value	0.001	0.0001
Growth multiple above which growth is considered extreme	5	8.5
Parameter for switching value X	0.5	0.7

The calibration was undertaken by running the growth model with the initial values and checking whether both the absolute and percentage growth in the WTSM matrices was transferred successfully to the WPTM matrix. The outcomes were:

- The minimum cut-off value was reduced from 0.001 to 0.0001. The disaggregation of the WTSM matrix to WPTM zoning led to a more than usual number of cells with tiny values (below 0.001). The cut-off was therefore reduced to 0.0001 to include the majority of these cells; and

- The growth multiple and switching parameter were both increased so that more growth was factored by multiplication and less by addition. Wellington has a relatively small mode share compared with other world cities, particularly in the Inter peak which makes it very difficult to obtain a reliable forecast (at individual cell level in WTSM). In recognition of this, the parameters were adjusted to limit the additive treatment to only more extreme growth cases. This gave a superior validation against WTSM for absolute and percentage growth.

The effect of these calibrations is to increase the number of cells that are treated as ‘background’ growth and reduce the number treated as extreme, which seems appropriate to Wellington where growth is generally spread smoothly (steady growth of existing suburbs being the norm).

Table 6-2 shows the percentage of matrix cells, for all demand segments combined, that fall into each case category and the total number of trips in each input and output matrix. This example is for the application of 2011 to 2021 growth using the latest model runs available on 26/6/12. For the growth to 2031 or 2041, or for land use developments at specific zones, more instances of extreme growth (cases 4a and 8a) would result.

Table 6-2: Inputs and Outputs by Case (AM, 2011 to 2021, all segments)

Case	% of cells (average over all segments)	Input matrices			Result matrix
		WPTM Observed Base (A) Sum of trips	WTSM Synthetic Base (B) Sum of trips	WTSM Synthetic Future (C) Sum of trips	WPTM Future (D) Sum of trips
1	38.1%	2	35	41	0
2	3.3%	0	8	14	13
3	0.2%	0	1	1	0
4a	0.1%	0	2	28	15
4b	42.5%	6	6,438	7,285	0
5	1.0%	467	1	1	467
6	0.1%	42	0	3	45
7	0.0%	21	0	0	9
8a	0.2%	594	26	62	854
8b	14.4%	26,656	23,146	27,466	31,275
ALL	100%	27,791	29,658	34,901	32,677

The difference between the WPTM and WTSM matrices can be seen in the table above by referring to case 4b: this indicates that some 44% of cells – around 250,000 cells – contain non-zero demand in WTSM (summing to 6,438 trips) but zero demand in WPTM. This is to be expected when comparing a 'smooth' synthetic matrix (WTSM) with a sample-based observed matrix (WPTM).

(Although the demand in the WPTM matrices has been 'locally smoothed' – for rail by sharing demand among neighbouring zones, and for bus by allocating the O and D probabilistically using the gravity model – the spread of PT demand remains far more clustered around PT accessible locations in WPTM than in WTSM.)

While the distribution at a cellular level is quite different, the total number of trips in the WPTM matrix is within 7% of WTSM (27,791 versus 29,658)

In WTSM, 41% of cells in the base total PT matrix have zero[4] values (cases 1, 2, 5, 6); while in WPTM, the percentage is 84% (cases 1, 2, 3, 4a, 4b).

There are very few trips in WTSM passing between the Wairarapa and other Territorial Authorities (TAs) in Wellington and also there are unexpected falls in demand predicted in future years. For these reasons, the WTSM growth estimate is not thought to be reliable and, as a temporary measure pending resolution, the WTSM to WPTM growth model has been deactivated for trips to and from the Wairarapa. Instead, PT demand is maintained at base levels in future years and option cases. When this problem can be resolved in WTSM, the growth model can be reactivated for this area.

[4] Less than 0.0001

7 Validation

The growth procedures are validated by demonstrating that the growth is transferred from the WTSM matrices to the WPTM in the correct proportions and the correct places.

The transfer of growth from the WTSM matrices to the WPTM matrices is summarised in Table 7-1. This confirms that growth is transferred satisfactorily in both absolute and percentage terms. While the absolute increase in trips is lower in WPTM than WTSM, the relative size of the matrices – base WTSM containing 7% more trips than base WPTM – has been correctly preserved.

Table 7-1: Summary of Growth (AM, 2011 to 2021, all segments)

Matrix	Base	Test	Change	% Change
WTSM	29,658	34,901	5,242	17.7%
WPTM	27,791	32,677	4,887	17.6%
WTSM / WPTM	1.07	1.07	0.00	0.1%

AM demand growth in WTSM and WPTM are summarised in 6 by 6 (TA to TA) format in Table 7-2 (work), Table 7-3 (education and child), Table 7-4 (other) and Table 7-5 (all purposes combined).

Table 7-2: Summary of Growth – Work Purpose (AM, 2011 to 2021)

WTSM Base								
Trips		gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gd01	Wellington	9793	211	29	107	26	2	**10168**
gd02	Lower Hutt	3137	683	51	10	1	6	**3888**
gd03	Upper Hutt	924	121	129	3	0	9	**1186**
gd04	Porirua	1816	26	2	218	9	0	**2072**
gd05	Kapiti Coast	1036	10	1	58	141	0	**1246**
gd06	Wairarapa	26	1	1	0	0	174	**203**
ALL		**16732**	**1052**	**214**	**395**	**177**	**192**	**18763**

WPTM Base							
Trips	gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gd01	10123	247	23	92	1	0	**10487**
gd02	3607	564	158	1	0	0	**4331**
gd03	817	113	77	0	0	0	**1006**
gd04	1869	0	5	124	18	0	**2017**
gd05	926	0	0	40	61	0	**1027**
gd06	618	55	43	0	0	0	**716**
ALL	**17960**	**979**	**306**	**257**	**80**	**0**	**19584**

WTSM Future								
Trips		gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gd01	Wellington	12780	281	37	139	38	6	**13280**
gd02	Lower Hutt	3686	729	64	13	1	17	**4510**
gd03	Upper Hutt	1027	137	141	3	0	24	**1332**
gd04	Porirua	2215	33	3	222	11	1	**2486**
gd05	Kapiti Coast	1514	16	1	77	151	1	**1761**
gd06	Wairarapa	17	1	1	0	0	208	**228**
ALL		**21237**	**1198**	**247**	**454**	**201**	**258**	**23595**

WPTM Future							
Trips	gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gt01	13192	312	27	117	2	0	**13649**
gt02	4178	603	191	2	0	0	**4973**
gt03	910	129	84	0	0	0	**1124**
gt04	2230	0	7	131	22	0	**2391**
gt05	1344	0	0	55	64	0	**1463**
gt06	618	55	43	0	0	0	**716**
ALL	**22473**	**1100**	**352**	**304**	**87**	**0**	**24316**

WTSM								
Growth		gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	Wellington	2987	70	8	32	12	4	**3112**
gt02	Lower Hutt	548	46	13	3	0	11	**621**
gt03	Upper Hutt	103	16	11	1	0	14	**146**
gt04	Porirua	398	7	1	4	2	1	**414**
gt05	Kapiti Coast	478	7	1	19	10	1	**514**
gt06	Wairarapa	-9	0	0	0	0	34	**25**
ALL		**4505**	**145**	**33**	**59**	**24**	**65**	**4832**

WPTM							
Growth	gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	3068	65	3	25	1	0	**3162**
gt02	571	38	32	1	0	0	**642**
gt03	94	16	8	0	0	0	**118**
gt04	361	0	2	8	4	0	**374**
gt05	418	0	0	14	3	0	**436**
gt06	0	0	0	0	0	0	**0**
ALL	**4512**	**121**	**46**	**47**	**7**	**0**	**4732**

WTSM								
% Growth		gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	Wellington	31%	33%	26%	30%	44%	185%	31%
gt02	Lower Hutt	17%	7%	25%	30%	39%	182%	16%
gt03	Upper Hutt	11%	13%	9%	24%	23%	155%	12%
gt04	Porirua	22%	28%	44%	2%	21%	243%	20%
gt05	Kapiti Coast	46%	66%	87%	33%	7%	311%	41%
gt06	Wairarapa	-35%	-6%	10%	20%	100%	20%	12%
ALL		27%	14%	15%	15%	13%	34%	26%

WPTM							
% Growt	gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	30%	26%	15%	27%	65%		30%
gt02	16%	7%	20%	48%	42%		15%
gt03	11%	15%	10%		33%		12%
gt04	19%		37%	6%	20%		19%
gt05	45%			36%	4%		42%
gt06	0%	0%	0%				0%
ALL	25%	12%	15%	18%	9%		24%

Table 7-3: Summary of Growth – Education and Child Purpose (AM, 2011 to 2021)

WTSM Base								
Trips		gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gd01	Wellington	3532	32	2	69	57	0	**3691**
gd02	Lower Hutt	670	1260	55	21	24	0	**2028**
gd03	Upper Hutt	175	135	561	7	7	0	**885**
gd04	Porirua	169	6	0	575	194	0	**943**
gd05	Kapiti Coast	2	0	0	2	578	0	**582**
gd06	Wairarapa	137	102	57	5	7	140	**448**
ALL		**4685**	**1535**	**674**	**678**	**866**	**140**	**8579**

WPTM Base							
Trips	gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gd01	3433	69	8	46	0	0	**3556**
gd02	693	704	126	1	0	0	**1524**
gd03	121	89	161	0	0	0	**371**
gd04	558	0	5	266	15	0	**844**
gd05	108	0	0	37	115	0	**260**
gd06	106	21	1	0	0	0	**128**
ALL	**5019**	**883**	**301**	**350**	**130**	**0**	**6683**

WTSM Future								
Trips		gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gd01	Wellington	3746	39	3	83	68	0	**3939**
gd02	Lower Hutt	693	1210	51	28	33	0	**2014**
gd03	Upper Hutt	200	145	509	10	11	0	**876**
gd04	Porirua	148	5	0	528	200	0	**882**
gd05	Kapiti Coast	2	0	0	2	593	0	**598**
gd06	Wairarapa	174	121	58	9	12	116	**491**
ALL		**4962**	**1521**	**621**	**661**	**918**	**116**	**8799**

WPTM Future							
Trips	gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gt01	3538	86	10	54	0	0	**3688**
gt02	701	695	113	1	0	0	**1510**
gt03	134	96	150	0	0	0	**381**
gt04	479	0	4	252	15	0	**750**
gt05	111	0	0	36	110	0	**258**
gt06	106	21	1	0	0	0	**128**
ALL	**5070**	**898**	**278**	**343**	**126**	**0**	**6714**

WTSM								
Growth		gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	Wellington	214	7	1	14	12	0	**247**
gt02	Lower Hutt	23	-50	-4	8	9	0	**-14**
gt03	Upper Hutt	25	10	-51	3	4	0	**-9**
gt04	Porirua	-21	-1	0	-46	7	0	**-61**
gt05	Kapiti Coast	0	0	0	0	15	0	**16**
gt06	Wairarapa	37	19	1	4	5	-24	**42**
ALL		**278**	**-14**	**-53**	**-17**	**52**	**-24**	**221**

WPTM							
Growth	gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	104	17	2	8	0	0	**132**
gt02	8	-9	-14	0	0	0	**-14**
gt03	14	7	-11	0	0	0	**10**
gt04	-79	0	-1	-14	0	0	**-94**
gt05	4	0	0	-1	-4	0	**-2**
gt06	0	0	0	0	0	0	**0**
ALL	**50**	**15**	**-23**	**-8**	**-4**	**0**	**31**

WTSM								
% Growth		gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	Wellington	6%	23%	30%	21%	20%		7%
gt02	Lower Hutt	3%	-4%	-7%	36%	38%		-1%
gt03	Upper Hutt	14%	7%	-9%	47%	51%	0%	-1%
gt04	Porirua	-12%	-9%	-12%	-8%	3%		-6%
gt05	Kapiti Coast	11%	25%	0%	16%	3%		3%
gt06	Wairarapa	27%	18%	2%	76%	76%	-17%	9%
ALL		6%	-1%	-8%	-2%	6%	-17%	3%

WPTM							
% Growt	gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	3%	25%	33%	17%	75%		4%
gt02	1%	-1%	-11%	14%	100%		-1%
gt03	11%	8%	-7%				3%
gt04	-14%		-14%	-5%	-1%		-11%
gt05	3%			-4%	-4%		-1%
gt06	0%	0%	0%				0%
ALL	1%	2%	-8%	-2%	-3%		0%

Table 7-4: Summary of Growth – Other Purpose (AM, 2011 to 2021)

WTSM Base								
Trips		gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gd01	Wellington	1277	73	11	36	14	12	**1422**
gd02	Lower Hutt	101	264	22	4	5	14	**409**
gd03	Upper Hutt	13	9	76	1	1	7	**107**
gd04	Porirua	56	4	1	120	14	3	**199**
gd05	Kapiti Coast	27	2	1	8	81	1	**119**
gd06	Wairarapa	7	5	3	1	0	44	**59**
ALL		**1480**	**357**	**114**	**169**	**116**	**80**	**2316**

WPTM Base							
Trips	gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gd01	951	23	0	19	0	0	**993**
gd02	128	107	5	0	0	0	**240**
gd03	29	28	12	0	0	0	**69**
gd04	68	0	0	26	0	0	**94**
gd05	59	0	0	6	34	0	**99**
gd06	17	8	4	0	0	0	**28**
ALL	**1252**	**166**	**21**	**50**	**34**	**0**	**1523**

WTSM Future								
Trips		gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gd01	Wellington	1374	85	15	40	17	30	**1562**
gd02	Lower Hutt	106	263	25	4	5	28	**430**
gd03	Upper Hutt	13	10	77	1	1	13	**115**
gd04	Porirua	57	5	2	114	14	7	**198**
gd05	Kapiti Coast	29	2	1	8	85	2	**127**
gd06	Wairarapa	13	9	4	2	1	44	**73**
ALL		**1593**	**374**	**124**	**169**	**122**	**123**	**2505**

WPTM Future							
Trips	gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gt01	1040	28	1	20	0	0	**1090**
gt02	138	107	6	0	0	0	**251**
gt03	30	29	12	0	0	0	**71**
gt04	70	0	0	25	0	0	**96**
gt05	66	0	0	6	39	0	**111**
gt06	17	8	4	0	0	0	**28**
ALL	**1362**	**172**	**22**	**52**	**39**	**0**	**1647**

WTSM								
Growth		gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	Wellington	97	12	4	4	3	19	**139**
gt02	Lower Hutt	5	-1	3	0	0	14	**22**
gt03	Upper Hutt	1	0	1	0	0	6	**8**
gt04	Porirua	1	0	0	-6	0	4	**-1**
gt05	Kapiti Coast	2	0	0	0	4	1	**7**
gt06	Wairarapa	6	5	2	1	0	0	**14**
ALL		**113**	**17**	**10**	**0**	**7**	**44**	**189**

WPTM							
Growth	gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	89	5	1	2	0	0	**97**
gt02	10	0	0	0	0	0	**10**
gt03	2	1	0	0	0	0	**3**
gt04	2	0	0	0	0	0	**2**
gt05	7	0	0	1	5	0	**12**
gt06	0	0	0	0	0	0	**0**
ALL	**109**	**6**	**1**	**2**	**5**	**0**	**124**

WTSM								
% Growth		gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	Wellington	8%	16%	38%	12%	21%	162%	10%
gt02	Lower Hutt	5%	0%	11%	10%	5%	106%	5%
gt03	Upper Hutt	5%	5%	1%	8%	-5%	80%	7%
gt04	Porirua	2%	10%	20%	-5%	-2%	122%	0%
gt05	Kapiti Coast	8%	10%	10%	2%	5%	147%	6%
gt06	Wairarapa	89%	98%	69%	113%	74%	1%	24%
ALL		8%	5%	9%	0%	6%	55%	8%

WPTM							
% Growt	gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	9%	22%	200%	8%			10%
gt02	8%	0%	8%		89%		4%
gt03	7%	2%	2%		0%		4%
gt04	3%			-2%			2%
gt05	11%			12%	15%		13%
gt06	0%	0%	0%				0%
ALL	9%	4%	6%	4%	16%		8%

Table 7-5: Summary of Growth – All Purposes Combined (AM, 2011 to 2021)

WTSM Base								
Trips		gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gd01	Wellington	14602	316	43	211	96	14	**15282**
gd02	Lower Hutt	3908	2206	128	35	29	20	**6326**
gd03	Upper Hutt	1111	266	766	11	9	16	**2179**
gd04	Porirua	2041	36	4	913	217	3	**3214**
gd05	Kapiti Coast	1065	12	1	67	801	1	**1947**
gd06	Wairarapa	170	108	60	6	7	358	**710**
ALL		**22897**	**2945**	**1002**	**1242**	**1159**	**412**	**29658**

WPTM Base							
Trips	gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gd01	14508	339	31	157	1	0	**15036**
gd02	4428	1375	290	2	0	0	**6096**
gd03	966	230	249	0	0	0	**1445**
gd04	2496	0	10	416	33	0	**2955**
gd05	1092	0	0	83	209	0	**1385**
gd06	741	84	47	0	0	0	**872**
ALL	**24232**	**2028**	**628**	**658**	**244**	**0**	**27790**

WTSM Future								
Trips		gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gd01	Wellington	17900	405	55	261	122	36	**18780**
gd02	Lower Hutt	4484	2201	139	45	39	45	**6954**
gd03	Upper Hutt	1240	292	727	15	13	37	**2323**
gd04	Porirua	2420	43	5	864	225	8	**3566**
gd05	Kapiti Coast	1545	19	2	87	830	2	**2485**
gd06	Wairarapa	203	132	63	12	13	369	**791**
ALL		**27793**	**3092**	**992**	**1284**	**1241**	**497**	**34900**

WPTM Future							
Trips	gd01	gd02	gd03	gd04	gd05	gd06	**ALL**
gt01	17769	426	37	191	3	0	**18427**
gt02	5017	1405	309	3	1	0	**6734**
gt03	1075	254	246	0	0	0	**1576**
gt04	2780	0	12	409	36	0	**3237**
gt05	1521	1	0	97	213	0	**1832**
gt06	741	84	47	0	0	0	**872**
ALL	**28904**	**2170**	**652**	**700**	**252**	**0**	**32677**

WTSM								
Growth		gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	Wellington	3298	89	12	51	26	23	**3498**
gt02	Lower Hutt	576	-4	11	11	9	26	**629**
gt03	Upper Hutt	129	26	-39	4	4	20	**144**
gt04	Porirua	379	7	1	-48	8	4	**352**
gt05	Kapiti Coast	480	7	1	20	29	2	**538**
gt06	Wairarapa	34	23	3	5	6	11	**82**
ALL		**4896**	**148**	**-11**	**42**	**82**	**85**	**5242**

WPTM							
Growth	gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	3261	87	6	34	1	0	**3390**
gt02	588	30	19	1	0	0	**638**
gt03	109	24	-3	0	0	0	**130**
gt04	284	0	1	-7	3	0	**282**
gt05	429	1	0	14	3	0	**446**
gt06	0	0	0	0	0	0	**0**
ALL	**4672**	**142**	**24**	**42**	**8**	**0**	**4888**

WTSM								
% Growth		gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	Wellington	23%	28%	29%	24%	27%	166%	23%
gt02	Lower Hutt	15%	0%	9%	32%	33%	130%	10%
gt03	Upper Hutt	12%	10%	-5%	38%	42%	123%	7%
gt04	Porirua	19%	20%	30%	-5%	4%	135%	11%
gt05	Kapiti Coast	45%	56%	50%	29%	4%	184%	28%
gt06	Wairarapa	20%	22%	5%	81%	75%	3%	12%
ALL		**21%**	**5%**	**-1%**	**3%**	**7%**	**21%**	**18%**

WPTM							
% Growt	gt01	gt02	gt03	gt04	gt05	gt06	**ALL**
gt01	22%	26%	21%	22%	98%		**23%**
gt02	13%	2%	6%	38%	62%		**10%**
gt03	11%	10%	-1%		150%		**9%**
gt04	11%		13%	-2%	10%		**10%**
gt05	39%			16%	2%		**32%**
gt06	0%	0%	0%				**0%**
ALL	**19%**	**7%**	**4%**	**6%**	**3%**		**18%**

8 Car Availability

The final step, after applying demand growth, but before using the matrices in WPTM, is to update the car availability for future years. A small proportion of the trips in the future year 'no-car-available' matrices are transferred into the corresponding 'car-available' matrix. This is to capture the increase in forecast car availability in future years in proportion to changes in WTSM car ownership.

The no-car available matrices are factored to reflect the change from 2011. The WTSM family structure spreadsheet contains the following forecasts for average car ownership (cars per person) across the region:

- 2011: 0.5920
- 2021: 0.6453
- 2031: 0.6863
- 2041: 0.7166

The no-car-available matrices in 2021 are factored by 5920/6453=0.92; and similarly for 2031 (0.86) and 2041 (0.83). The trips taken out of the no-car-available matrix in this way are then added back in to the corresponding car-available matrices to maintain the same overall trip totals.

9 Conclusions

WPTM has been linked to WTSM for the purpose of applying demand growth to the observed base PT matrix.

A tried and tested approach has been applied, based on the method used in the Sydney Strategic Travel Model, the Netherlands National Transport Model and the PRISM model of the West Midlands in the UK.

Parameters have been calibrated to ensure the right magnitude of growth is transferred from WTSM to WPTM.

Validation shows this to result in growth in the WPTM matrices within 0.1% of WTSM, while retaining the essential observed demand patterns of the WPTM base matrix.