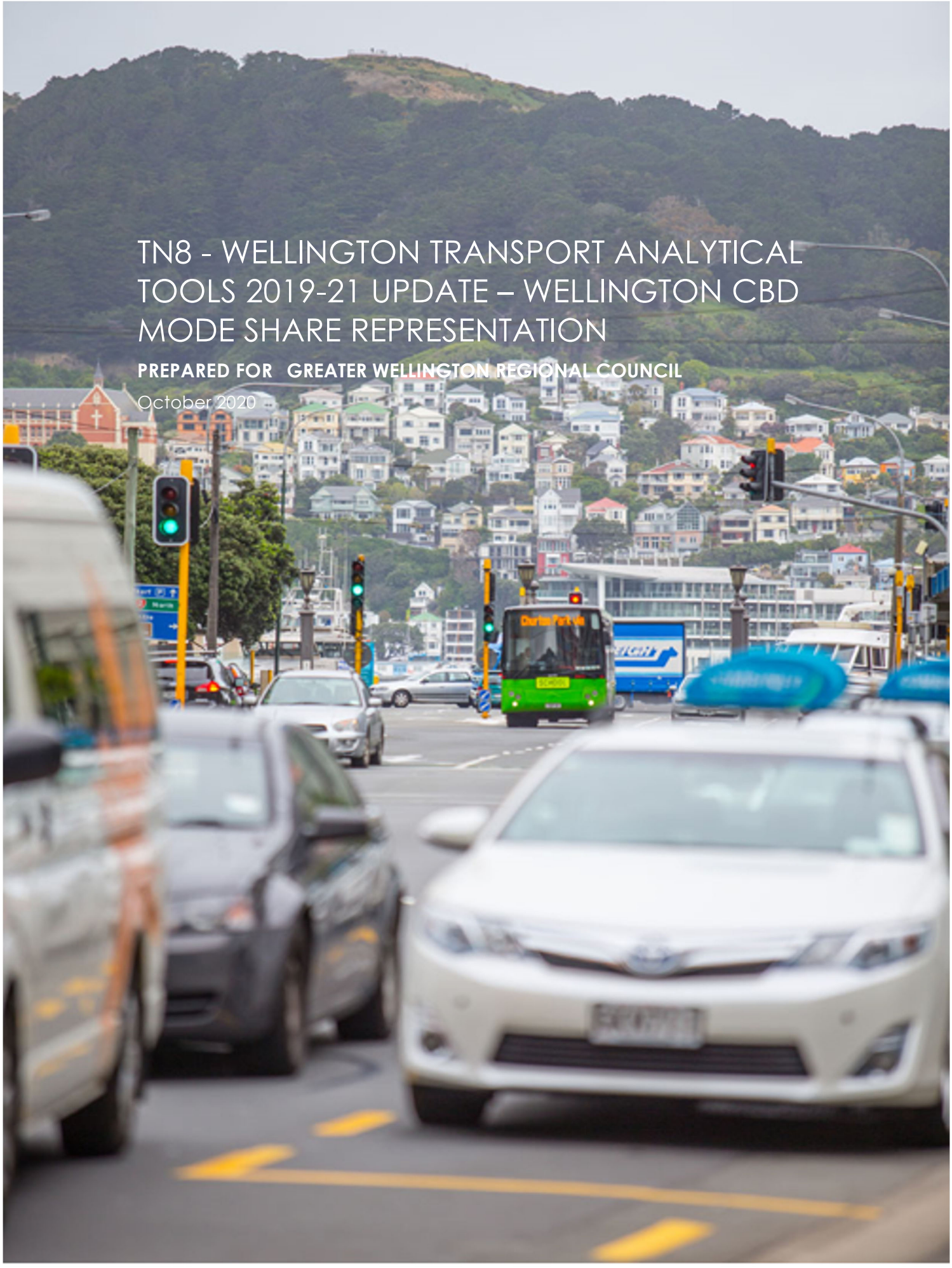

TN8 - WELLINGTON TRANSPORT ANALYTICAL TOOLS 2019-21 UPDATE – WELLINGTON CBD MODE SHARE REPRESENTATION

PREPARED FOR GREATER WELLINGTON REGIONAL COUNCIL

October 2020

Stantec | JACOBS

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Greater Wellington Regional Council

TN8 - Wellington Transport Analytical Tools 2019-21 update – Wellington CBD Mode Share Representation

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1. Introduction

1.1 Project Overview

This technical note is part of a series documenting the 2019-2021 update of components of the Wellington Regional Transportation Planning Analytical Tools ("Analytical Tools", "Tools"). The higher-level Analytical Tools are maintained and operated by Greater Wellington Regional Council (GWRC), who are the client for this project. This project is being primarily delivered by Stantec and Jacobs, supported by GWRC transport planners.

1.2 Purpose of this Report

This report covers:

- The investigation into the over-representation of intra-Wellington CBD car trips in the Wellington Transport Strategy Model;
- Changes made to the model to address this issue; and
- Impact of these changes on model results and validation.

2. CBD Trips Over-representation in WTSM

The 2013 version of the Wellington Transport Strategy Model (WTSM) is perceived to have an issue with too many short car trips being output in the Wellington CBD area. This was already apparent in the version of the model updated to 2011, but it was unclear if it was also an issue in earlier versions (either the 2006 update or the original 2001 model development) or if the cause was genuine changes in travel patterns and WTSM not correctly replicating more recent intra-CBD demand and mode share.

2.1 Comparison with Observed Data

Traffic volumes, public transport (PT) patronage, and the resulting private vehicles vs PT modal share were satisfactorily validated against observed patterns during the 2013 model update, region-wide and at a number of screenlines in the area covered by the model. This includes a screenline around the CBD, for which modelled volumes in and out of the CBD are compared against traffic counts and PT surveys.

No specific checks have been carried out for the CBD area itself (defined as the area within the CBD cordon) during the successive model updates nor does reporting from the 2001 model development show any comparison of modelled demand against observed patterns within the CBD. In addition, there appears to be no validation checks of active mode demand (called "slow modes" in WTSM) as it is largely a by-product of the model.

High level sense-checking of WTSM output however indicates that the model over-represents private vehicle trips in the CBD, especially for short distance trips that have both their origin and destination in the CBD and would be much more likely to be active modes.

For active modes demand, an issue is that there is little observed data than can be used for validation purposes. In order to assess validation of the model within the CBD, information from the 2001 Household Travel Survey that was specifically carried out for the WTSM development was investigated. While it is acknowledged that using this data does not allow verifying if potential changes in travel patterns have occurred since the model was built, it does allow checking if modelled modal shares in the CBD are broadly in line with observed data the model was calibrated against.

For trips to and from work (defined as 'Home-Based Work' or HBW in WTSM) data from the more recent 2013 Census Journey to work (JTW) survey data is available and was therefore used, which corresponds to the current base year of WTSM.

The table below shows observed number of trips and modal shares for trips within the CBD area from the Household Travel Survey (or Census JTW for home-based work trips) against the same metrics from WTSM 2013.

Table 2-1: 24 Hr Intra-CBD Trips and Mode Share

		24hr TRIPS			24hr MODE SHARE		
		Car	PT	Active	Car	PT	Active
HBW	Observed 2013	710	540	6,860	6%	7%	87%
	WTSM 2013	2,890	1,220	3,050	40%	17%	43%
Other Home-Based	Observed 2001	2,460	0	1,970	56%	0%	44%
	WTSM 2013	12,490	2,550	8,620	53%	11%	36%
Non-Home Based and Employer Business	Observed 2001	27,120	570	56,130	32%	1%	67%
	WTSM 2013	63,200	900	43,580	59%	1%	40%
Total trips	Observed 2001	30,290	1,110	64,960	31%	1%	67%
	WTSM 2013	78,580	4,670	55,250	57%	3%	40%

From this a number of observations can be made:

- Comparison of modelled vs observed mode shares confirms that the model largely over-estimates car use and under-estimates active modes, both compared with the 2001 HTS and 2013 census data for commuting trips within the CBD. Public transport mode share is less of an issue being very low in both cases, although it is too high especially for home-based work trips.
- Total trips within the CBD are circa 40% higher in WTSM 2013 than in the 2001 HTS. This compares with a population increase of approximately 70% in the CBD during this period, and 10% employment growth (source: Statistics NZ).
- Home-based work trips only represent a small portion of total trips (despite these being sourced from the more recent 2013 census compared with other trips being from the 2001 HTS). Generally, home-based trips (trips between home and work, education, shopping and other purposes) only represent circa 10% of trips in the CBD in the 2001 HTS. This proportion increases to 18% in WTSM, likely caused to some extent by the increase in population in the CBD to 2013. As a result up to 90% of trips in the CBD are for non-home based or employer business purposes (82% in WTSM 2013).

2.2 Suggested Approach

A number of causes have been identified that could result in the car demand over-representation issue, including, from easiest to most difficult to adjust in the model:

- 1 – The car ownership model in WTSM, which has been found to return higher car ownership than observed in the CBD.
- 2 – The method of distance-based removal of active modes demand (including walk and cycle) from either the car or PT matrices (varies by trip purpose) which may be under-estimating demand for active modes.
- 3 – CBD parking associated costs being too low, and other issues such as circulation time to find a park and parking capacities not being taken into account.
- 4 – Trip rates for all modes being too high in the CBD area, or mode choice model and/or trip length distribution being inaccurate.

As part of Stage 2 of this project, it is anticipated that WTSM will be fully re-estimated, which will eliminate this issue as calibration of the model can be targeted to address person trip rates and modal share in the CBD are an accurate representation of observed.

However in the interim, targeted improvements were carried out to improve modal share representation and correct the number of short car trips in the CBD. The improvements implemented and described in this note relate to items 1 and 2 above, that is the car ownership model and active mode factoring. CBD parking costs will be updated in a separate workstream in this project, which will consider the impact on travel patterns in the CBD.

Adjusting trip rates or the distribution and mode choice models were only envisaged if items 1 and 2 did not lead to a significant change in mode share for intra-CBD trips, but this was ultimately not the case and items 3 and 4 were not deemed necessary for this interim period.

3. Car Ownership Model

3.1 Description

The car ownership module in WTSM is part of the spreadsheet-based trip generation calculations and predicts the probability of owning 0, 1 or 2+ cars for each household size and in each zone of the model. The resulting probabilities then feed into the family structure model, with each household category (by size and number of vehicles) leading to different trip rates for the various demand segments:

- By trip purpose: home-based work, home-based other, non-home based, etc.
- By car availability: captive (no car available), competition (more adults than cars in the households) or choice (as many cars as adults or more).

All these demand segments then have their own distribution and modal choice parameters. As a result, car ownership has a direct impact on the number of trips generated and the car modal share for each zone.

The inputs to the car ownership model are the following:

- Overall model parameters Alpha (coefficient applied to household income) and Delta (constant), for each household category.
- Zonal Adjustment factors Lambda for every zone, by household category and by model ('P1+' = model for probability of owning 1 or more cars, and 'P2+/1' = model for probability of owning 2 or more cars given ownership of at least 1 car).
- Time Series Adjustment Factors, by year, to ensure overall modelled car ownership levels match those forecasted from other sources.
- Income growth, for all years after the 2001 model development year i.e. including new base year 2013 and forecast years.

3.2 Comparison with 2013 Census Car Ownership

The proportion of households with 0, 1 and 2+ car availability where extracted from the 2013 Census Data[1], both for Wellington City overall and for the CBD only. These are presented in the following table, along with the same proportions from WTSM.

Table 3-1: 2013 Car Ownership

	OBSERVED			WTSM		
	0	1	2+	0	1	2+
Wellington City	15%	47%	38%	12%	43%	45%
Wellington CBD	52%	41%	8%	29%	48%	22%

Results for the whole city are reasonably close, although the model does over-estimate car ownership generally, under-estimating the proportion of households with only 1 or no cars.

For the CBD only area however, the trend is much more marked, with the number of estimated households with 2+ cars being almost three time higher than observed while the number of households without cars is close to half of observed.

One possible explanation for this disconnect is the significant increase in population in the CBD as mentioned in section 2.1, which includes more households with high incomes but low car ownership compared with the rest of the region. This is shown in the following figure that illustrate the proportion of households per income bracket and car ownership, both in the region as a whole and in the CBD.

[1] https://profile.idnz.co.nz/wellington/car-ownership?WebID=840

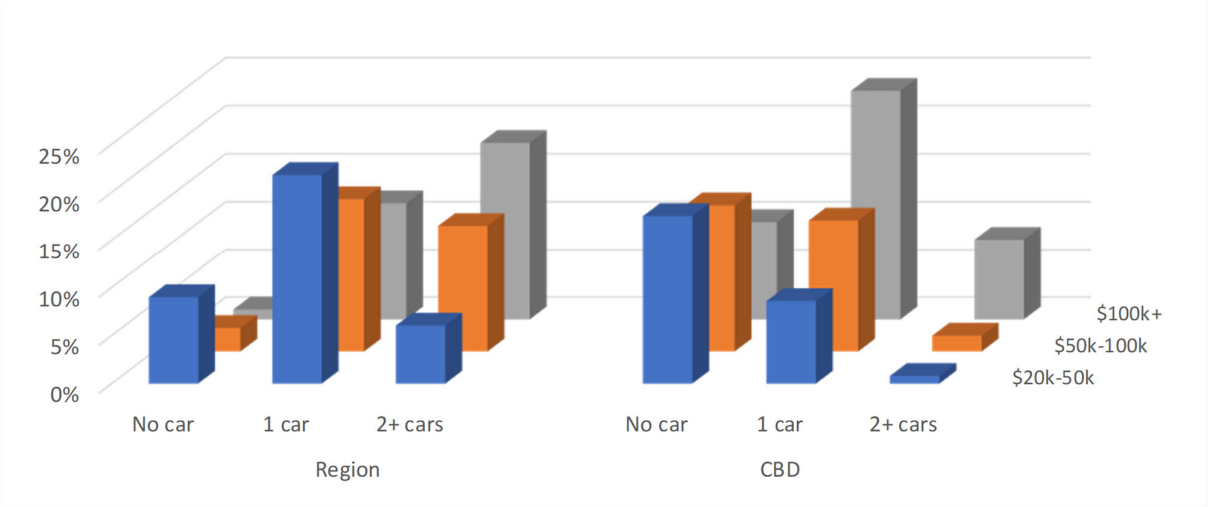

Figure 3-1: Household Proportions by Car Ownership Per Income, CBD and Region-wide

3.3 Adjustments to the Car Ownership Model

Car ownership is a log function of income in the car ownership model, therefore higher income in the CBD will lead to higher levels of car ownership. In order to correct this, adjustments included manually editing lambda parameters for zones in the CBD.

Lambdas differ for each zone in the CBD, as well as for each household category and for both models (P1+ and P2+/1). To ensure that the adjustment is simple and transparent, it was not intended to adjust every single lambda and fit observed data very closely but rather to apply a limited number of adjustments to address the overall imbalance. After testing, a simple adjustment of -5 was applied to all lambdas in the CBD and for all households categories, but only for the P1+ model. Given that the P2+/1 model itself depends on the probability of owning at least a car, it was found that this adjustment was sufficient to correct the issue in aggregate.

The resulting overall car ownership proportions after adjustments are shown in the following table.

Table 3-2: 2013 Car Ownership (adjusted)

	OBSERVED			WTSM ADJUSTED		
	0	1	2+	0	1	2+
Wellington City	15%	47%	38%	14%	42%	44%
Wellington CBD	52%	41%	8%	50%	41%	8%

Compared with results from the non-adjusted WTSM in Table 3-1, these show a clear improvement.

The number of households per car ownership category for CBD zones are shown in the table below, for observed, WTSM base (before adjustments) and WTSM adjusted. While the fit is not perfect as a single correction is made to all zones and category, adjusted car ownership levels are more in line with observed.

Table 3-3: 2013 Car Ownership per CBD Zone

	OBSERVED			WTSM BASE			WTSM ADJUSTED		
Zones	0	1	2+	0	1	2+	0	1	2+
46	58%	38%	4%	13%	46%	41%	28%	51%	21%
47	37%	53%	10%	19%	57%	23%	39%	51%	10%
48	39%	50%	11%	30%	45%	24%	52%	40%	8%
49	14%	67%	19%	12%	48%	40%	25%	53%	23%
50	64%	30%	6%	34%	49%	18%	56%	38%	6%
51	59%	34%	7%	31%	45%	24%	51%	39%	9%
52	64%	31%	5%	33%	49%	18%	56%	39%	5%
53	59%	34%	7%	37%	43%	20%	60%	34%	6%

	OBSERVED			WTSM BASE			WTSM ADJUSTED		
Zones	0	1	2+	0	1	2+	0	1	2+
54	53%	36%	10%	44%	40%	16%	66%	30%	5%
56	33%	51%	15%	24%	56%	20%	45%	47%	7%
57	56%	39%	5%	27%	51%	22%	50%	42%	8%
58	100%	0%	0%	2%	97%	1%	4%	96%	0%
59	-	-	-	4%	29%	67%	12%	50%	38%
60	57%	39%	3%	41%	39%	20%	65%	31%	4%
64	0%	100%	0%	22%	41%	37%	44%	32%	24%

The impact of the car ownership model adjustment on trip patterns in the CBD is shown in section 5 of this note.

4. Active Modes Factoring

4.1 Description

Active modes in WTSM are a by-product of total demand and are not explicitly represented in the mode choice model. They are however included in trip rates and grouped with car demand in mode choice, with the exception of 'Home-Based Education' trips and 'Home-based work, Choice' trips for which they are grouped with PT.

Active modes demand is then removed from car or PT matrices based on factors, at a 24hr production-attraction level. The factors used are distance-based, with each distance band (0 to 0.5km, 0.5 to 1.5km, etc) having a separate 'a' constant and 'b' multiplier applied to the distance to calculate the active modes factor for each origin-destination zone pair.

The parameters a and b vary for each trip purpose and car ownership segments but are the same across the whole region with no local adjustments.

Active modes matrices are then subtracted from other modes and are not then used in further analysis in WTSM in its current form.

4.2 Comparison with Observed

Proportion of active modes for each trip purpose and distance band were calculated using the model a and b parameters, and compared against the same proportion derived from the 2001 household travel survey (or Census Journey to Work in the case of Home-Based Work trips).

Results for the whole region are shown in the following figures, for Home-Based Work, Home-Based Shopping and Non-Home Based trips respectively. Other trip purposes show similar patterns and are therefore not shown in this note.

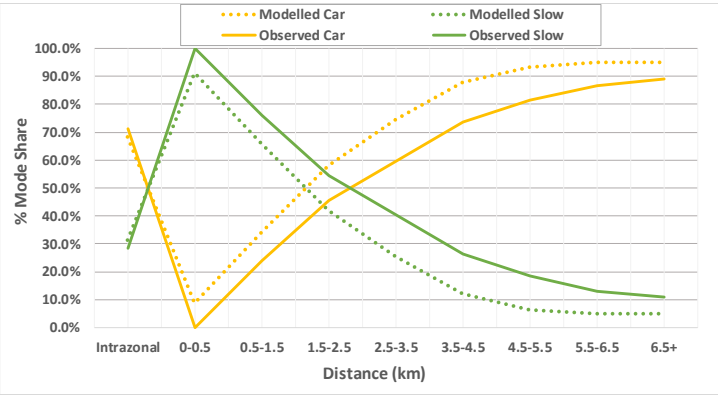

Figure 4-1: Mode Share per Distance Band – Home-Based Work – Regionwide

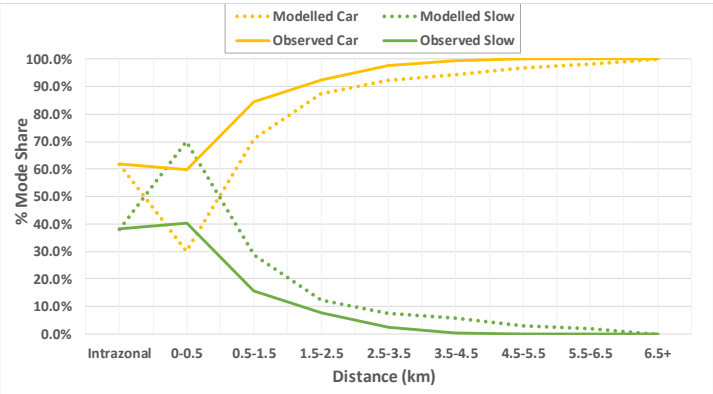

Figure 4-2: Mode Share per Distance Band – Home-Based Shopping – Regionwide

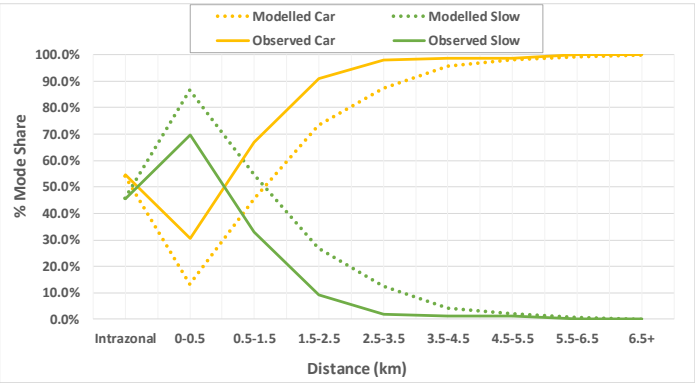

Figure 4-3: Mode Share per Distance Band – Non Home-Based Other – Regionwide

The comparison shows that the modal proportion of car vs active modes, defined as 'Slow' modes in WTSM, follows broadly similar patterns in WTSM and in the HTS, although there are issues with a general tendency to over-estimate slow modes for Home-Based Shopping and Non-Home Based and over-estimate them for Home-Based Work. Results are similar for other trip purposes and are therefore not shown here for conciseness.

The same analysis was then carried out but only looking at trips within the CBD area. Due to the sparsity of households in the CBD in the HTS data, in line with the much lower population in the CBD in 2001, data from inner city suburbs directly next to the CBD including Mount Victoria, Mount Cook and Kelburn was also included.

Results are shown in Figure 4-4 below for Home-Based Work, Home-Based Shopping and Non-Home Based. It must be noted that due to the limited number of households living in the CBD in the HTS, a few combinations of trip purposes and distance bands did not have any data, for example for Home-Base Shopping 2.5 – 3.5 km in the figure below.

As the same factors apply region-wide, modelled proportion are the same as in the previous figures.

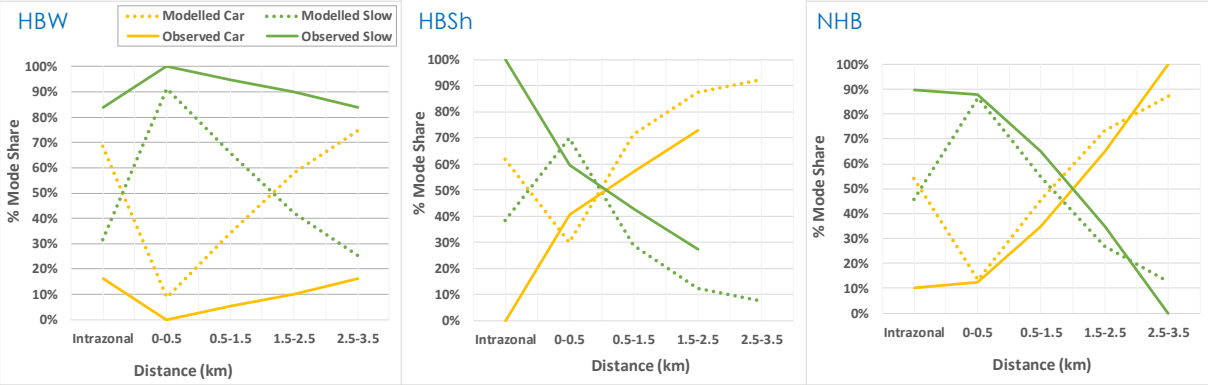

Figure 4-4: Mode Share Per Distance Band – CBD

Clearly, the assumptions regarding share of active modes per trip purpose and distance that are reasonably accurate at a regional level do not hold in the CBD area, which exhibits very different patterns and generally less car use.

It can also be observed that intrazonal trips, which are not distance-based but use fixed proportions, are particularly incorrect. This is caused by distances for intra-zonal trips (estimated as half the distance to the nearest zone in WTSM) being much shorter in the CBD at 0.3 km in average compared with 1.3 km in the region as a whole.

4.3 Adjustments to Active Modes Factoring

In order to improve the representation of active mode share within the CBD and surrounding inner suburbs, the a and b parameters used to estimate the active modes demand factor were manually adjusted so that the profile more closely aligns with observed. The following approach was used:

- The target shares for each distance band were used to calculate b (i.e. the slope parameter), and the resulting a constant for this distance band.
- Given the much smaller intrazonal distances in the CBD, the fixed proportion of active modes were adjusted so that they align more with the 0 – 0.5 km distance band.
- Due to the sparsity of data for some trips and distance bands, as well as the HTS dating from 2001, it was not intended for the resulting profile to be a perfect match to observed, but only to be generally a more accurate representation with minimal intervention. For this reason, Home-Based Education trips in particular were not adjusted as minimal observed data was available, and they represent a small proportion of trips within the CBD.

The resulting active mode share profiles are shown below, again for Home-Based Work, Home-Based Shopping and Non-Home Based purposes, compared against observed proportions. Adjusted profiles show a much closer fit. For Home-Based Shopping intra-zonal, the 100% observed active mode share was based on a very low sample, for this reason the same share as the '0-0.5km' band was used instead.

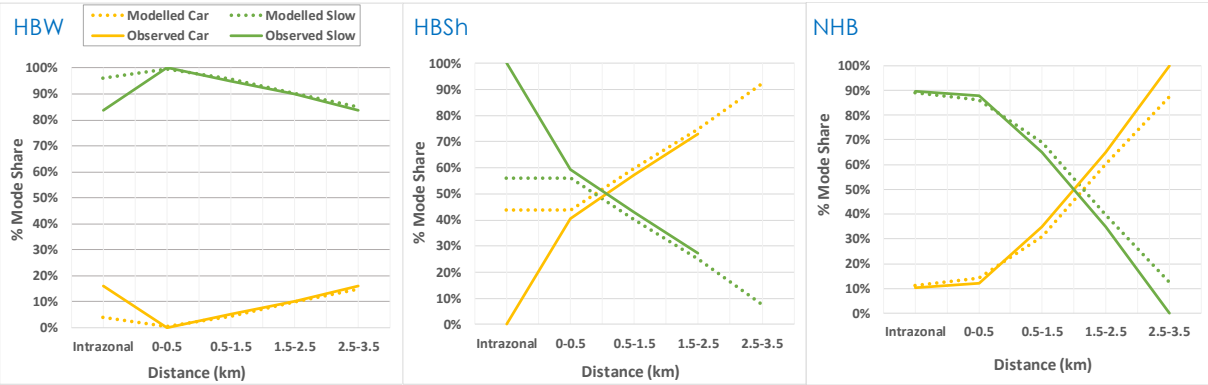

Figure 4-5: Adjusted Mode Share per Distance Band – CBD

5. Results and Impact on Validation

5.1 Results

The modal share within the CBD are shown in the following table for:

- Observed (HTS and Census JTW)
- Base WTSM (2013)
- WTSM (2013) with adjusted car ownership
- WTSM (2013) with adjusted car ownership and active modes factoring

Table 5-1: CBD Trips and Mode Share

		24hr TRIPS			24hr MODE SHARE		
		Car	PT	Active	Car	PT	Active
Home-Based Work	Observed	710	540	6,860	9%	7%	85%
	WTSM	2,890	1,220	3,050	40%	17%	43%
	WTSM + Car Ownership	2,250	1,150	3,720	32%	16%	52%
	WTSM + Car Ownership + Active modes	1,100	1,120	4,930	15%	16%	69%
Other Home-Based	Observed	2,460	0	1,970	56%	0%	44%
	WTSM	12,490	2,550	8,620	53%	11%	36%
	WTSM + Car Ownership	8,780	1,830	5,350	55%	11%	34%
	WTSM + Car Ownership + Active modes	6,470	1,810	7,700	40%	11%	48%
Non-Home Based and Employer Business	Observed	27,120	570	56,130	32%	1%	67%
	WTSM	63,200	900	43,580	59%	1%	40%
	WTSM + Car Ownership	63,060	920	43,490	59%	1%	40%
	WTSM + Car Ownership + Active modes	44,130	910	62,390	41%	1%	58%
Total Trips	Observed	30,290	1,110	64,960	31%	1%	67%
	WTSM	78,580	4,670	55,250	57%	3%	40%
	WTSM + Car Ownership	74,090	3,900	52,560	57%	3%	40%
	WTSM + Car Ownership + Active modes	51,700	3,840	75,020	40%	3%	57%

It can be observed that adjusting car ownership does reduce the share of car trips for Home-Based Work although to a limited extent (the same applies to other Home-Based trips purposes). However, because these Home-Based trips represent only about 18% of all intra-CBD demand, it has a limited impact on overall mode share, as most trips in the CBD area are made by people living outside it and therefore not impacted by the change in car ownership.

The change in active modes factoring has a much more marked effect, leading to modal shares that are closer to observed and a notable drop in car trips. Figure 5-1 below shows the percentage of active modes share for each distance band, comparing observed with each model's results. Again, the active mode adjustment shows a significant impact and clear improvement in matching with observed.

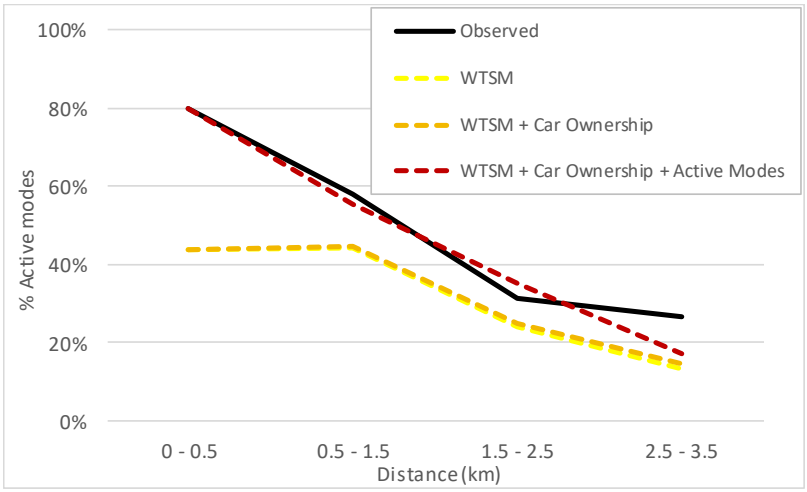

Figure 5-1: CBD Trips Active Modes Share

The resulting modal share, although closer to the HTS results, still shows higher proportions of car trips. The following potential causes have been identified:

- The HTS used for comparison is from 2001, with both demography and travel behaviours having changed since and supporting data is not yet available to assess the impact of the latter. This makes like with like comparison difficult. As an example, Table 5-2 below shows the number and proportions of each trip purpose in the 2001 HTS and in the WTSM 2013 base year. WTSM shows a higher proportion of Home-Based Trips. This could be explained by the 70% increase in population since 2001 (compared with 10% increase in employment) but no results from the 2001 version of WTSM were available to support this hypothesis.

Table 5-2: Intra-CBD Trips Per Purpose

	HBW	HBEd	HBSh	HBO	NHB	EB	Total
	Number of Trips						
Observed 2001	4,540	420	2,360	1,650	65,250	18,580	92,800
WTSM 2013	7,170	1,410	7,280	7,790	75,320	32,360	131,330
	%						
Observed 2001	5%	0%	3%	2%	70%	20%	100%
WTSM 2013	5%	1%	6%	6%	57%	25%	100%

- Some of the modal shares result not from active mode share factoring but from the WTSM mode choice model itself. This mostly explains why PT shares are largely unchanged, but also some of the car demand. As an example, for the Home-Based Work 'Choice' (no. of cars>= no. of adults per household) segment, active modes are grouped with PT and therefore adjusting the factoring of active modes post-mode choice model does not change the number of car trips.
- Finally, the main reason for more car trips is likely due to intra-CBD trips being somewhat longer in WTSM than in the HTS, as shown in Figure 5-2. As a result, although the share of active modes for each distance band has largely been corrected, the total share is lower than observed. Again it must be noted that the HTS information dates from 2001 when the population living in and around the CBD was significantly lower, and no information is available to quantify how much this impacts on results.

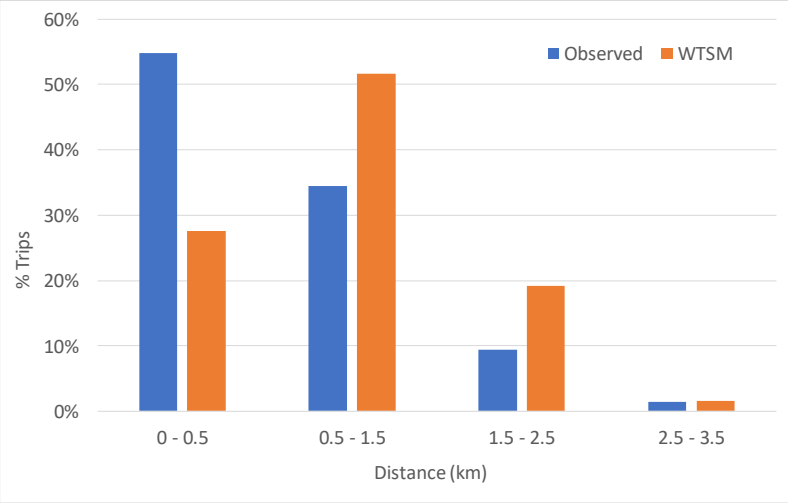

Figure 5-2: Intra-CBD Trips Length Distribution

5.2 Impact on Traffic Volumes

Figure 5-3 to Figure 5-5 show the changes in 2hr traffic volumes resulting from the CBD trips adjustments. Results show that the impact is mostly limited to the CBD as intended.

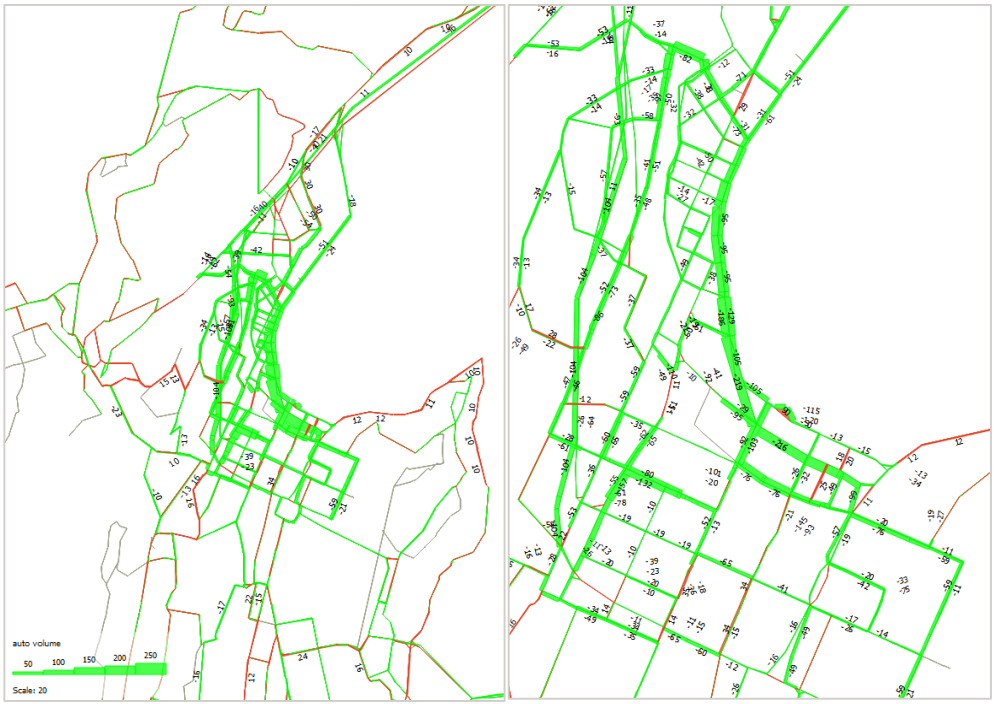

Figure 5-3: AM Peak 2hr Traffic Volume Changes

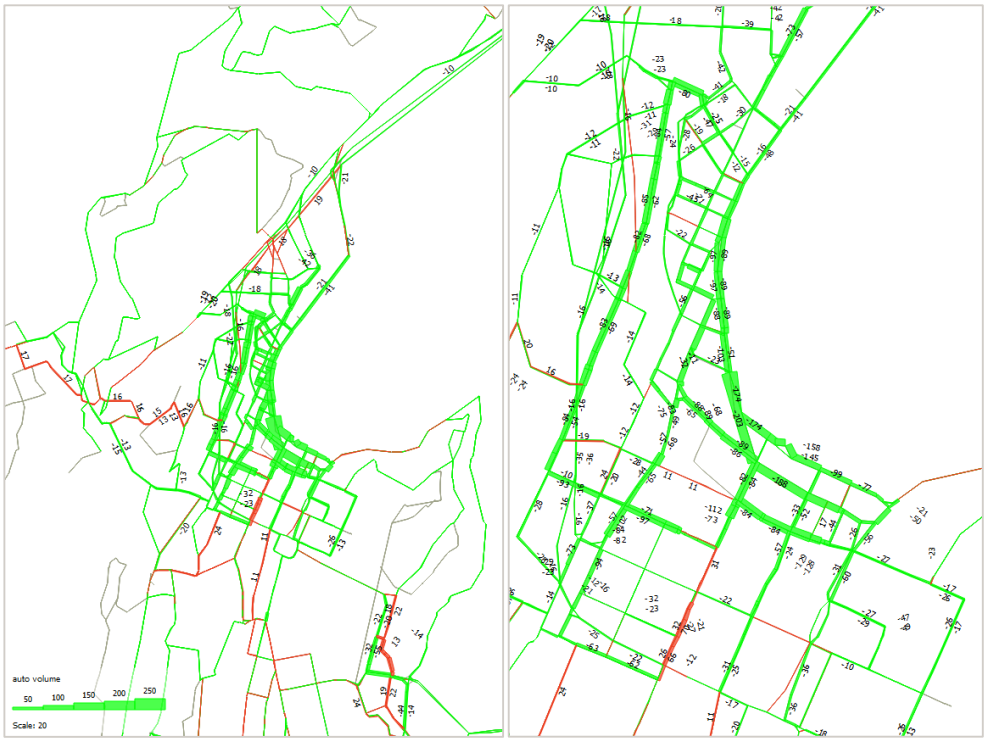

Figure 5-4: Inter Peak 2hr Traffic Volume Changes

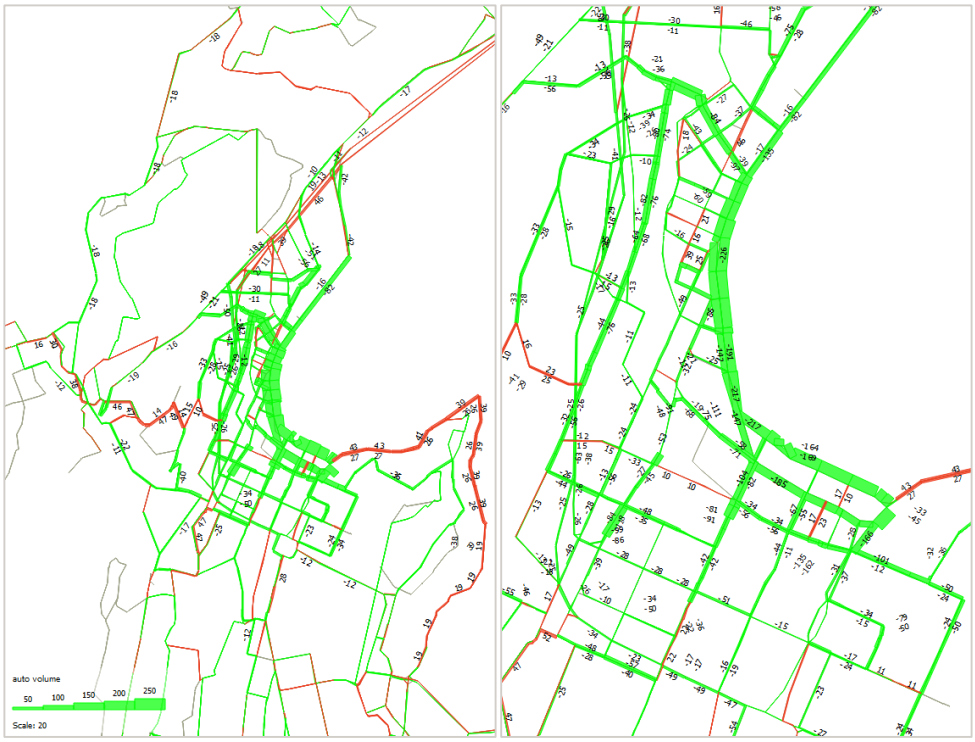

Figure 5-5: PM Peak 2hr Traffic Volume Changes

5.3 Impact on Validation

The effect of the changes in car ownership and active modes factoring in the CBD on validation were checked using the same metrics as used for the 2013 validation of WTSM. Tables 5-3 and 5-4 below show the overall impact on traffic screenlines and individual counts validation, comparing the 2013 WTSM before and after adjustments. It must be noted that the version of the model used includes a number of other modifications since the 2013 WTSM was delivered and the results shown for the base model therefore differ slightly from the results reported in the 2013 model validation report.

Table 5-3: Screenline Validation

	WTSM BASE			WTSM ADJUSTED		
	AM	IP	PM	AM	IP	PM
GEH < 5	54%	39%	57%	54%	43%	57%
GEH < 10	93%	89%	82%	93%	89%	82%
GEH < 12	93%	93%	86%	93%	93%	86%

Table 5-4: Individual Traffic Counts Validation

	WTSM BASE			WTSM ADJUSTED		
	AM	IP	PM	AM	IP	PM
Counts with GEH < 5	50%	54%	46%	50%	51%	44%
Counts with GEH < 10	78%	83%	81%	80%	83%	82%
Counts with GEH < 12	83%	90%	88%	83%	91%	89%
R2	0.93	0.91	0.92	0.93	0.91	0.92

Results show that the adjustments have no significant impact on traffic validation. The same checks were carried out for public transport volumes and traffic travel times validation but showed no discernible impact, and are therefore not reported in this note.

6. Conclusions

This technical note has described the investigation into the over-representation of car trips in the Wellington CBD in WTSM, presenting the suggested improvements to the model and their impact on model results and validation.

Two interim adjustments were made to WTSM:

- Adjustment of the car ownership model, by applying an additional lambda to all zones in the CBD to lower car availability, based on Census data. This was found to have a moderate impact on Home-Based trips, although only a limited impact for overall demand.
- Adjustment of the factors used to subtract active modes demand from car and PT matrices, based on 2001 HTS data and 2013 Census Journey to Work. The parameters used to calculate these factors for each trip purpose and distance band were adjusted in the CBD, to replicate observed active modes share. This was found to have a much more noticeable impact.

The resulting modal shares, including share of car trips, is now a closer representation to observed, albeit based on older 2001 HTS data.

The remaining difference can largely be explained by WTSM estimating longer trips in the CBD area than observed in the HTS data, although it is hard to assess if this is a calibration issue or a genuine change in patterns since 2001 caused by changes in demography.

In the absence of available information, it was not deemed feasible or warranted to intervene in the distribution or modal choice components of WTSM, which would be a much more complex task and necessitate more supporting travel patterns observed data.

As part of Stage 1 of the WTSM update, monetary and other costs associated with parking in the CBD will be updated. This will likely have an impact on trip length, distribution and mode choice in the CBD and the potential impact on car trips over-representation will need to be assessed.

These interim adjustments will allow the improved representation of car trips within the Wellington CBD until the demand model is fully recalibrated, which is expected to be carried out during Stage 2 of this project.

Addendum

Please note that the comments below have been paraphrased in some places.

Question from Peer Reviewer

The main (possibly only) change in this version is the addition of Section 5.2: impact on traffic volumes […]. The plots within this section show the effects on modelled traffic flows, but not the validation (either through the addition of an extra CBD screenline, or on key streets within the CBD). Indeed, the text above the plots notes that the main effects of the changes in modelled flows are within the CBD, but the subsequent section (5.3) on validation gives information on all screenlines, rather than those around the CBD – which may conceal either good or bad results within the area of change.

Response from Consultant

Results for the CBD screenline specifically are shown in the following table. Base model validation for this screenline was generally good but showed a slight over-estimation of traffic volumes. The decrease in car demand resulting from the adjustments described in this report lead to a reduction in GEH and therefore an improved validation in almost all time periods and directions.

	WTSM BASE			WTSM ADJUSTED		
	AM	IP	PM	AM	IP	PM
CBD Inbound	5.6	5.5	2.3	5.2	4.5	0.7
CBD Outbound	0.8	3.9	2.9	0.9	2.6	2.1

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