- Adding park-and-ride sites as zones and associated connectivity to the updated macro strategic model networks;
- Processes to car times and costs from the road network being modelled and applying them to the p-connectors;
- Processes to extract p-connector flows and add them – or a proportion of them where information is available - to the vehicle trip matrices for assignment; and
- Co-ordination with the macro PT model so coding of stations and catchments are is now via a single, consistent process.

The macro PT model uses a different method (matrix-based) for assigning park-and-ride trips, as well as different coding methods that are not appropriate to replicate within the macro strategic model. However, the enhancements provide consistency and efficiency in the coding of the Park and Ride zones and catchments between the two models.

The following sections describe the changes made to the model, but the final calibrated parameters are included in the validation section of this report.

Park-and-Ride Zones

The park-and-ride zones added to the macro strategic model have the same numbering as those in the macro PT model. These, and the associated connectivity between the PT and road networks, are part of the overall improvements in consistency between the models. In the refresh it was also agreed with AFC that only formal park-and-ride sites should be included. It should be noted that in creating the observed PT demands from the HOP data, only a selection of park-and-ride stations had been surveyed. This meant that when calibrating the sub-mode split module in the Macro PT model only those same surveyed sites were included. However, the full model run will include all defined park-and-ride stations.

Car Times, Generalised Costs and Vehicle Flows

Car travel times and generalised costs are updated on p-connectors every demand-supply iteration of the macro strategic model. These generalised costs include a transfer penalty and a parking/walking time. In addition, p-connector flows are extracted and added to the vehicle matrices for each demand-supply iteration of the macro strategic model.

Consideration of Kiss-and-Ride and Parking Capacity

Parking capacity constraint is not directly reflected in either the macro PT or the macro strategic models. However, the assumptions about the proportion of park and ride trips occurring in the peak period in the macro strategic model arguably could reflect parking constraint as passengers seek to travel prior to the morning peak due to capacity issues. As well as time-period issues, parking capacity is difficult to reflect due to uncertainty and variability in off-site parking and kiss-and-ride proportions. As such, direct representation of capacity has not been added to either model. However, the consistency now added between how park-and-ride zones are represented in both MSM and MPTM allows consideration of parking costs to be added to both models.

Representation of parking capacity was however indirectly represented by an additional walk time. This represents the typical situation of demand exceeding supply of spaces, and hence users either

having to travel earlier than desired to secure a car park, or having to walk further from a more remote park. This is coded as a constant rather than as a function of parking capacity, as the demand was assumed and expected to exceed capacity in all locations, irrespective of the size of car the park.

Kiss-and-ride has two implications for modelling, namely that such trips are not constrained by parking capacity, and secondly they add another, possibly reverse-direction, trip to the network. Kiss-and-ride trips are not currently explicitly reflected in either the MSM or MPTM, and it is not intended to add extra functionality because neither the additional effective capacity reflected, nor is the destination of the additional/reverse trip known.

Co-ordination with the macro PT model

The information provided from the MSM to the MPTM now includes:

- the park-and-ride zones and associated network.
- the park-and-ride catchments defined in terms of the MSM zones.

The same zone input file used in the updating of car times is used for providing the latter. This means that Park-and-ride facilities now need only be coded in the macro strategic model, with automated transfer to the macro PT model.

Summary

The functionality added to the macro strategic model in regard to car-access to public transport has addressed the key weaknesses in the current methods by:

- Using assigned car network travel times and costs in the generalised costs for the access links (p-connectors)
- Assigning park and ride car trips to the road network
- Providing a single method for coding park and ride zones and catchments in the macro strategic model that automatically transfers the same information to the macro PT model.

4.6 Improved Network Consistency Between Models (Task 3.4)

The MSM and MPTM interface in various ways. The MSM provides a range of link and matrix data to the MPTM, which is required for the MPTM. Subsequently, the MPTM can provide the MSM with a diverted car matrix. Information on the elements that are passed between the models are outlined in the model user manual.

Following the interim 2013 update of the APT model, the two models had the same road and bus networks in terms of nodes and links, but differing rail and ferry networks and differing attributes, which complicated network coding and reduced consistency between the two models. The Phase 1 2016 refresh has aligned these aspects where appropriate to enable much easier interfacing of networks and services.

Items made consistent include:

- Rail and ferry networks
- Mode codes, transit vehicle codes and travel time function numbers
- Park-and-ride zones, connecting links and catchments
- Bus lanes
- Rail and ferry travel times
- Transfer penalties and unplanned/planned transfers locations and definitions
- No-boarding and no-alighting nodes

These are discussed in more detail below.

4.6.1 Networks

Previously, the macro strategic and macro PT models had the same road and bus networks but different rail and ferry networks and park-and-ride coding. The networks have been aligned so that the macro PT model now uses the macro strategic model rail and ferry networks. The method for modelling park-and-ride still differs between the models, however they both now share the same input coding of stations and catchments

The only remaining differences between the model networks are:

- Centroids and centroid connectors (due to the different zone systems)
- Waiheke road network (not required in the macro strategic model)
- p-connectors (not required in macro PT model)

4.6.2 Modes

Previously the transit modes differed between the macro strategic and macro PT models as shown in **Table 4-6**. For the refresh, the modes have been aligned as follows:

- The additional bus modes coded x and o have been removed from the macro PT model and mode i for the airport bus has been added
- LRT mode coded l is included in both models
- The City Walk mode c has been included in the macro strategic model, and replaces walk mode on CBD links. However the speed in the macro strategic model has been set to 4.0kph, the same as Walk mode. This means that the macro strategic model properties do not change, but the networks can be exported to the macro PT model with no changes required.

The only differences now are with school bus modes in the macro PT model and the p-connector modes, p and z, in the macro strategic model.

Table 4-6 - Transit Modes Previously in the macro strategic and macro PT models

Mode code	Description	Type	ART3 model	APT3 model	Updated Macro Strategic model	Updated Macro PT model
a	Auto	auto	✓	✓	✓	✓
r	Rail	transit	✓	✓	✓	✓
l	LRT	transit		✓	✓	✓
f	Ferry	transit	✓	✓	✓	✓
b	Bus	transit	✓	✓	✓	✓
x	Bus-Exp	transit		✓		
s	Bus-School	transit		✓		✓
o	Busway	transit		✓		
i	Airbus	transit	✓		✓	✓
w	Walk	aux. transit	4.0kph	4.8kph	4.0kph	4.0kph
c	City-Walk	aux. transit		3.7kph	4.0kph	4.0kph
p	Car-access	aux. transit	✓		✓	
z	temp	aux. auto	✓		✓	

For implementation, the mode changes are imported in the scenario set up file, and the PT assignment macros were edited to refer to mode c where required.

4.6.3 Transit Vehicle Codes

Previously the macro PT model had more vehicle types than the macro strategic model, due to the crowding model requiring accurate vehicle capacities and due to changes in codes over time. In the update, the vehicle codes in the macro strategic model have been changed to match the currently used codes in the macro PT model. The new vehicle codes are imported in the scenario setup file, and the service files have been changed accordingly. The following codes are used:

- Bus:
  - 4 (all)
- Rail:
  - 9 (DMU – Pukekohe)
  - 10 (EMU 6-car – Others)
  - 16 (EMU 3-car – Onehunga)
- Ferry:
  - 17 (Small - Pine Harbour, West Harbour)
  - 18 (Medium - Others)
  - 19 (Large - Half Moon Bay, Devonport, Waiheke)

4.6.4 Travel Time Functions

The travel time function numbers for transit in the macro strategic model have been changed to match those in the macro PT model, although the functions themselves are still different. The new function numbers are as follows:

- Bus: ttf=1 for normal and ttf=2 for express
- Rail: ttf=11 for all lines
- Ferry: ttf=4 for all lines

[Note: MPT travel time functions were updated in Phase 2 and are now consistent with MSM]

4.6.5 Rail and Ferry Times

The rail and ferry times in both models were reviewed against observed and scheduled times from which:

- The rail times were updated to fit with 2016 observed times, and the process for implementing them in the macro strategic model was altered to be the same as used the macro PT model.
- The ferry times in the macro PT model match the 2016 scheduled, so were retained and implemented in the macro strategic model, though the process in the macro PT model was altered from a speed on each link to the total time between terminals on one link.

4.6.6 Park-and-Ride

As noted earlier, the coding of stations and catchments is now via a common, consistent input.

4.6.7 Transfer Penalties and Unplanned/Planned Transfers

The locations and values of 2016 transfer penalties for purpose built and high quality stations and interchanges have been confirmed with AFC and are now consistent between the models, as are the locations of unplanned/planned transfers. Britomart is defined as “very high quality” with a reduced transfer penalty of 3 minutes. The transfer input file used in both the macro strategic and macro PT models.

Changes were required to the macro PT model procedures to enable consistency. The previous coding system was discarded and new node extra attributes created to specify the mode of each

node, the transfer penalty at each and whether unplanned or planned transfer. The 2016 information is provided from the macro strategic to the macro PT model as part of the interface. The transfer input file used in the macro strategic model is now also used with the macro PT model.

4.6.8 No Boarding and No Alighting Nodes

The specification of nodes where no boarding or alighting are allowed is now consistent between the models, with the input file previously used with the macro PT model now also used with the macro strategic model.

The same procedures for applying the input file in the macro PT model are used in the macro strategic model.

The no boarding and alighting information is provided from the macro strategic model to the macro PT model as part of the interface.

4.6.9 Interface

The macro strategic to macro PT model interface provides the following macro strategic model information to the macro PT model for 2016:

- Land use data: population, households, employment, education rolls (this data is not used in 2016)
- Network
- PT services
- Road speeds
- Bus lanes
- Transfer penalties and unplanned/planned transfers
- No boarding and alighting nodes
- Park-and-ride catchments, station mode tag, transfer penalties, parking availability penalties, parking costs
- PT and car mode shares (this data is not used in 2016)
- Total PT trips (inclusive of airport PT trips)
- School bus trips (presently not used in 2016)
- Rail and ferry times, LRT speed, Panmure Busway

The enhancements in consistency and in the interface have focussed on the 2016 models. These will be considered further in forecasting which may lead to some slight changes to the present processes. For standalone MPTM runs with a change in network from that provided from the macro strategic model will require additional coding to be included. At this stage there is no WTP related information that is passed from the MSM to MPTM.

[The interface was further improved and the process made more seamless in Phase 2. This is explored in **Section 9.1**].

5 Phase 1 MSM Update

This chapter outlines the process undertaken to update and calibrate key inputs to the refreshed 2016 Macro Strategic Model. Data overview

The macro strategic and macro PT models are validated to a March 2016 base. This means that as much as possible, data has been collated from this period.

Where data sources have been used for each of the project tasks, it is referred to within the relevant section. Data sources include:

- **Land use data** including population, households, employment, divided into categories in both macro strategic and macro PT zone systems, and educational rolls including primary, secondary and tertiary numbers.
- **Economic inputs** GDP/Capita growth, Values of Time, car ownership levels
- **Parking** rates/information provided in tables
- **Intersection and turn coding** of 675 signalised intersections, including shape files and SCATS signal timing information.
- **PT networks and services**
- **List of bus lanes** and hours of operation, and list of cycle lanes
- **Shape files** for link and route alignment as well as zone systems
- **Travel time data** for various segments across multiple time periods
- **AT HOP data** for patronage, transfers, origin and destination stops, screen line patronage counts
- **Car ownership information** from statistics NZ
- **Private vehicle link count information across all screenlines** for model validation and calculation of under reporting factors
- **HCV matrices** from Auckland Transport's Dynamic Traffic Assignment model
- **Airport information** on flight numbers, parking cost, passenger numbers and PT/taxi fares

A significant component of the model refresh was checking and cross checking data sources to create clean data with as much consistency as possible.

5.1 Inputs

5.1.1 Land use Inputs

Full census-level land use data was not available for 2016, but was for 2013. Regional growth estimates from 2013 to 2016 and spatial distributions were developed by Statistics NZ, and processed into the model zone system.

5.1.2 Economic inputs (Task 2.1.2)

There are a number of economic inputs to the model, which generally relate to monetary values. These include:

- Gross Domestic Product (GDP)
- Values of Time (VoT)
- Vehicle Operating Cost (VOC)
- Parking Costs
- Public Transport (PT) fares

The economic inputs initially calculated in 2006 have been rebased and updated to $2016 values.

The update is to reflect changes in market rates (such as for fuel and parking) and changes in policy

(public parking and PT fares) since 2006.

A number of methodologies and data sources were collated and compared for the updating of each of the economic inputs. This analysis resulted in the following chosen update methodology for each economic input:

GDP

The real GDP per capita growth rate is not used explicitly in any of the base model updates but is required for the future year forecasting. These growth rates vary between a long term trend (1991-2016) of 1.8% per annum to a shorter term trend (2006-2016) of 0.6% per annum.

Average VoT

A thorough review of research into Values of Time was undertaken before updating them. Values of Time have been updated from the 2006 values using the annually published update factors in the NZ Transport Agency economic evaluation manual (EEM). The original 2006 values used EEM base values adjusted to account for taxation (resource to perceived cost correction), and the higher income in Auckland compared to the national values quoted in the EEM. The EEM update factors include allowances for changes both in GDP per capita and other behavioural influencers of values of travel time.

Vehicle Operating Costs

VOC for light vehicles were initially estimated using the Vehicle Fleet Emissions Model (VFEM), which was updated in 2015. Model forecasts for 2016 vehicle km travelled (VKT) and fuel consumed were used. However, when data from the Ministry of Transport was used to generate 2016 fleet composition and fuel costs, a VOC was produced that was slightly lower than when using VFEM estimates. The MoT fleet composition data and actual 2016 fuel prices is used in the final VOC used in the model refresh.

Business and commercial VOC for passenger car and LCV were taken from the EEM, since those values are resource costs. To get a single commercial VOC for light vehicle business trips, the VOC for passenger cars and LCVs were averaged. This produces a final VOC

Table 5-1- ART3 and MSM VOC

Trip Purpose	ART 2006 ($2016)	MSM 2016 ($2016)
Commuter and Other	0.19	0.17
Business and Commercial	0.32	0.24

Parking costs

Parking costs used for the 2006 model came from a survey of parking undertaken in 2007. This survey focused on the CBD and the suburbs of Takapuna, Newmarket, and Henderson. From the survey data, average 2006 prices were calculated for the zones surveyed.

With no updated parking survey for the 2016 rebase, growth rates (in real terms) of parking costs were calculated from a range of online resources (including online parking maps provided by Auckland Council and parking companies Wilson, Tournament, and Secure Parking). These resources were used to look up individual parking locations that were surveyed in 2006 and find their current cost. The 2006 cost was converted to $2016 to calculate a per cent change in real cost. Then the parking supply from the 2006 survey was used to calculate a supply-weighted average change in the real cost of parking.

Of note is that no additional information was available regarding any changes in the supply of parking which users do not pay for directly (and therefore may not perceive this cost in making travel choices). The 2006 proportions of people paying for parking have however been updated from 30% to 50% in the 2016 update, as part of the calibration.

PT fares

Since 2006 there have been a number of changes made to PT fares. These changes include the implementation of an integrated fare system and discounts for tertiary students and senior citizens. Note that the zone based fare system was not in force in March 2016.

The rollout of an integrated ticketing system was initially announced in 2008. The “Snapper” card was announced in 2010, however difficulties with the development saw this terminated, and the “AT HOP” card was first introduced in 2012 and rollout completed in 2014. The introduction of the integrated ticketing system saw a fare reduction for card users. Once the rollout was complete, boarding from one bus route to another, or to a different mode, no longer required the payment of a new fare.

A comprehensive HOP database from March 2016 was analysed, incorporating an expansion to account for paper tickets, to establish PT fares in a format consistent with that required in the macro strategic model. This meant converting the stage-based fares in the HOP data to a distance based cost with an initial boarding penalty; both of these depend partially on the typical trips undertaken by each purpose (students receive a significant discount).

For each time period, mode, and trip purpose, trips were plotted by fare paid and length of trip. A line was fitted to the data. The intercept of the line is the boarding fare, and the gradient is the additional fare per km.

Summary

From each of the economic input updates discussed above, the following values have been used in the 2016 update of the macro strategic model.

Table 5-2 - Average Values of Time (in $2016/hour)

	2006	2016
HBW	10.40	13.11
EB	33.10	41.73
Other	8.70	10.97
M/HCV	25.40	32.03

Table 5-3 - Vehicle Operating Cost (in $2016/km)

Trip Purpose	2006	2016
Commuter and Other	0.19	0.17
Business and Commercial	0.32	0.24

Table 5-4- Parking costs ($2016)

Zone	Long Term, 2006	Short Term, 2006	Long Term, 2016	Short Term, 2016	Long Term, per person
110	8.54	1.22	9.64	1.38	0.96
181	3.66	0.00	4.00	1.00	0.40
184	3.66	0.00	4.00	1.00	0.40
214	10.98	2.44	17.28	2.79	5.02
215	10.98	1.22	17.28	1.39	5.02
216	12.20	2.44	17.28	2.79	5.57

Zone	Long Term, 2006	Short Term, 2006	Long Term, 2016	Short Term, 2016	Long Term, per person
217	12.20	2.44	17.28	2.79	5.57
218	12.20	2.44	17.28	2.79	5.57
219	12.20	4.88	17.28	5.57	5.57
220	12.20	2.44	17.28	2.79	5.57
221	10.37	2.44	17.28	2.79	4.74
222	10.37	4.88	17.28	5.57	4.74
256	11.59	2.44	8.79	1.85	0.88
255	11.59	2.44	8.79	1.85	0.88
473	NA	1.22		1	0.96

Table 5-5 - PT fares, in $2016

		Bus		Ferry		Train	
		Boarding ($)	Per km ($)	Boarding ($)	Per km ($)	Boarding ($)	Per km ($)
2006 all purposes		2.14	0.17	4.12	0.37	1.53	0.17
2016 HBE		0.91	0.13	2.73	0.27	0.92	0.13
2016 HBW/EB		1.55	0.18	3.81	0.33	1.66	0.17
2016 Other	AM	1.65	0.18	3.87	0.31	1.71	0.16
	IP	0.81	0.14	2.02	0.37	1.37	0.11
	PM	1.19	0.17	3.22	0.34	1.73	0.13

5.1.3 Network Updates (Task 2.2.2)

A number of updates to the supplied networks were implemented to reflect changes within the region for the March 2016 rebase.

This included extensive network realignment, the introduction of local roads, and inclusion of new roads, with the major areas of improvement being along the State Highways, and development areas such as Silverdale and Hobsonville. GIS road centrelines were utilised for this process.

Similarly, with the assistance of SCATS shape files, new signalised intersections were identified. The majority of those required updating existing intersections that were previously coded as either a prioritised intersection or roundabout.

A general review of the network coding was also undertaken – in particular, the consideration of zone connector lengths and link parameters.

In areas of the network where the model was underestimating congestion as a result of queuing, typically motorway on ramps, adjustment factors were applied to links using lane operation codes. Affected links were assigned a factor corresponding to an operation code of either 5, 8, or 9, depending on the severity of the underestimation and observed congestion. This was in addition to an automated queue blocking back process set up on motorways (see **Section 5.1.4**).

Globally, zone connectors were adjusted to have a free speed of 40 km/hr. There were also minor changes made to the generic link parameters used in the existing model. These are listed in Error! Reference source not found. Table 5-6 and Table 5-7.

Table 5-6 - Link speed changes

Link Type	Description	Existing Free Speed (km/hr), @v0	New Free Speed (km/hr), @v0
14	Collector – high friction/poor alignment	50	48
15	Collector – low friction/good alignment	52	48
16	Urban arterial – low speed	52	50
17	Urban arterial – high speed	55	50
19	Motorway	100-105	100

Table 5-7- Link capacity changes

Link Type	Description	Existing Lane Capacity (veh/hr/lane), @q	New Lane Capacity (veh/hr/lane), @q
15	Collector – low friction/good alignment	1250	1200
16	Urban arterial – low speed	1350	1300
17	Urban arterial – high speed	1450	1400
19	Motorway	2050	2000

5.1.4 Review of volume delay functions

To more accurately reflect the current extent of congestion on the network, a number of update tasks were undertaken to address underestimation of travel times in over-capacity conditions. Based on initial testing, it was found that there was sufficient flexibility in parameters of the existing methods to improve the validation of travel times, without requiring new methods. A number of reasons were identified as to why changes to the model capacity parameters were considered necessary:

- increasing levels of queueing reducing access to short turning lanes at intersections
- increased signal lost time due to extended all-red/intergreen phases for safety reasons
- reduced effective green time due to extra pedestrian protection time
- higher traffic density meaning traditional definitions of 'free-speed' used in the link VDFs are no longer applicable (they were traditionally set higher than the speed limit, but recent data indicates even interpeak speeds below the speed limits)
- Longer ramp-signal red times (previously capped at shorter levels)

Changes to the vehicle (car or HCV) capacity parameters included:

- **Adjustments to the motorway blocking macro**: The previous ART3 model uses a very early version of the motorway 'queuing' macro. This macro was subsequently updated for the Western Ring Route and AMETI EMME project models. The latest version of this macro was therefore implemented in this update with minor modifications. This new motorway macro includes an off-ramp queueing process, an update of merge capacity calculations, and an update of the queue propagation process.
- **Adjustments to the ramp metering procedures:** The previous ART3 model treats a ramp signal as an intersection, and ramp signal capacities are coded as either 750 vehicles/hour or 1,200 vehicles/hour. The new ramp signal macro has the ability to adjust ramp signal capacity based on the level of congestion at the downstream merge point. There are three options to represent ramp metering in the new procedure. They are:

- Option 1 - @rs = 0 = ramp signal off, use coded @q for capacity
- Option 2 - @rs = 1 = ramp signal ON with FIXED capacity: use coded @q for capacity (as above)
- Option 3 - @rs = n = ramp signal ON with variable capacity. n is minimum: n<@q<1800 (this option was used in the validated model. Ramp signal minimum capacities are coded as 800 veh/hr for one channel, and 1200 veh/hr for dual channel ramps.

- An adjustment to the definition and allocation of link free speeds, with links on certain parts of the network now altered to reflect low-flow speeds as experienced in the three assignment periods, rather than a 'zero-flow' situation.
- The existing MSM model uses @jcalc=1 for the majority of intersections, which allows for longer green time for major roads and hence less delay. In reality, the green times are more or less share equally across the approaches at most intersections so this @jcalc parameter was updated to 3 for all intersections. Intersection delays across the network were then reviewed and the @jcalc value was set to 1 for intersections where the minor approach volume was very low. .
  A number of parameter changes within the intersection capacity and delay procedure, listed in

Table 5-8- Intersection capacity and delay parameters

Parameter	Previous value	New value
Saturation flow per lane per hour	1950	1850
Assumed lost time per phase (sec)	4	6
Lost time for full ped phase (including Barnes dance diagonal pedestrian movements, jcalc=2) [sec]	18	30
Max/min change allowed to assumption of equal green per approach (jcalc=3,4)	0.2	0.3
Max intersection capacity in relation to link capacity	-	1.1

5.1.5 Zone Refinement (Task 2.2.3)

The zone structure was updated from 564 to 603 zones (internal plus external) to provide additional resolution in areas where significant development is proposed. This includes the following areas:

- South: Takanini, Opaheke-Drury, Drury West, Paerata, and Pukekohe.
- North: Warkworth, Wainui, and Silverdale-Dairy Flat.
- North-west: Whenuapai, Red Hills, Kumeu, Huapai, and Riverhead.

All macros were updated to use the new zone system. This meant replacing all references to old zones with the new zone number in the macro strategic model macros, for example, zone 564 in the old system becomes zone 603 in the new system. This replacement was undertaken using simple "find and replace" strings in text editors. The zones that were split in the old system (and the corresponding new zones) are shown in**Table 5-9**.

Table 5-9 - Zone Refinement

Area	Original zone	New zones
Takanini	503	532,533,534,535
Opaheke-Drury	522	554,555
Drury West	524,525,526	557,558,559,560,561,562
Paerata	531	567,568
Pukekohe	538,541	575,576,579,580

Area	Original zone	New zones
Wellsford	1	1,2,3,4,5
Warkworth	4,5,7	8,9,10,11,12,14,15
Wainui	23	31,32
Silverdale	27	36,37
Dairy Flat	28,29,30,31	38,39,40,41,42,43,44,45,46
Whenuapai	144,145,146,147,148	165,166,167,168,169,170,171,172,173,174,175,176,177
Red Hills	140	157,158,159,160,161
Kumeu	135	151,152
Huapai	127	142,143

Where zones were split, meshblocks were allocated according to the new zone system. A consequence of this was the updating of several land use input files which also required disaggregating to the new zone structure. These files included population, households, employment and education data.

To do this, firstly the matrices were expanded to the new zone system using ensembles. Factors which were calculated using 2013 census data were then used to split the land use data and recorded in input matrices. They were applied using matrix calculations in EMME.

5.1.6 Car Ownership Model (Task 2.4.1)

The car ownership model estimates the level of car ownership (cars/person) for each zone in the macro strategic model. The car ownership model is made up of three component sub-models, which are outlined below:

- The cross-sectional models
- Fitting the cross-sectional models to Census data
- The temporal model

The cross-sectional model is a sequence of hierarchical sub-models, which split households into 0, 1, 2, and 3+ cars owned, based on the number of adults in the household and how many adults are working. The original model used 2006 Census data to develop the models. They were updated in 2013 using 2013 Census data. With no census in 2016 it is not possible to undertake a similar update.

The temporal model forecasts future car ownership levels for the study area as a whole and is based on relating trends in cars per capita to GDP per capita, car prices, and a time trend. The 2006 adopted model found that car prices were not significant, so they were not used as an explanatory variable in the model.

A review of the temporal model incorporating updated data sets including data between 2006 and 2016 showed that the car ownership model developed in 2006 needed to be re-estimated to fit this more recent data set. New model parameters have been estimated which more closely reflect the change in trend as a result of the GFC and therefore considered an appropriate update to the car ownership model.

The car ownership model maintains the same form as in 2006 by transforming C (car ownership) to a new variable Y = C/(S-C) where S is the saturation level.

- $\ln Y = \text{constant} + \alpha.\ln GDP + \gamma.t$

The model parameters above have been updated to reflect the change in data series to include the 2006-16 information in line with **Table 5-10**.

Table 5-10- Updated model parameters

	Value
α (GDP/capita)	0.969
γ (time)	0.017
Const	-9.925

The results of the temporal model were used to calculate a temporal adjustment factor. This factor adjusts the cross-sectional model results to match the forecast car ownership for future years. The factor is calculated using Solver in Excel. Solver iterates through different adjustment factors until it gets as close as possible to a condition. In this case, the condition was to get the difference between the forecast car ownership and the census-adjusted car ownership as close as possible to zero. Once the factors are calculated for each year, the 2016 factor was subtracted from each year to put them all into a 2016 base. The temporal adjustment factors are shown in **Table 5-11.**

Table 5-11- Temporal adjustment factors

Year	Adjustment
2006	0.000
2011	0.099
2016	-0.080
2021	-0.244
2026	-0.401
2031	-0.557
2036	-0.712
2041	-0.866
2046	-1.021
2051	-1.176

Data Sources

National estimates from Statistics New Zealand (StatsNZ) were used to update the population, number of cars, and GDP for the temporal model. The number of cars was Statistics New Zealand Total Registered Vehicles, cars only, both 12-month and 6-month registrations. Real GDP (production based rather than expenditure based to reduce volatility) came from Statistics New Zealand National Accounts Series GDP Chain Volume Total (Annual, March) . The GDP data came in $2009/2010, and was updated to $2016 (March) using the Reserve Bank CPI conversion from 2010 Q2 to 2016 Q1 (a factor of 1.09). Testing the inclusion of vehicle price in the model used the StatsNZ vehicle purchase consumer price index, base of June 2006.

The methodology for updating the coefficients of the time series model follows the car ownership model documentation from 2007 (ART3 Car Ownership v7 – final.pdf).

Methodology

Currently available data on car ownership is about 3.6% lower than the car ownership implied by the 2006 model build as a result in differing historic GDP estimates and possible changes in the preference to own cars. The latest available estimates were used in formulating a new temporal model.

To improve the fit of the model to the entire time period from 1973 to 2016, car ownership rates were “back-forecast” from the new data back to 1973. The average difference between new and old of

3.6% was applied to the old car ownership rates to estimate new car ownership from 1973 to 1990.

GDP was available back to 1978, so GDP per capita was calculated for years 1978 to 1990 using

StatsNZ long-term data series population, which is not directly comparable to population after 1990, but is the best estimate available. Prior to 1978, GDP per capita was "back-forecast" using the annual compound growth rate. The GDP per capita growth rate was estimated by fitting an exponential curve to the GDP per capita and using the compound growth rate of 1.47% growth per year.

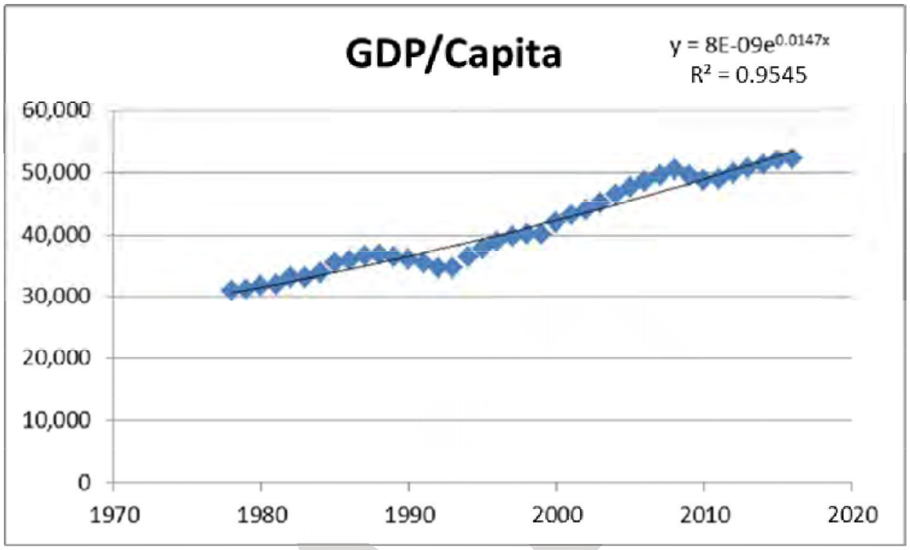


Figure 5-1- GDP per capita rate of growth

The results of updating the model parameters calculated from 1973-2016 based on the new dataset (the "new model") are shown alongside the model parameters from the 2007 analysis based on 1973-2007 in Table 5-12 . Important to note is the Global Financial Crisis (GFC) that occurred between 2007 and 2016 that the old model did not respond to. When the GFC is included in the analysis, the relationship between GDP/capita and car ownership is evidently much stronger, as GDP/capita is more significant in the new model. Time is still highly significant as well.

Table 5-12- Model results

	Old Model, 2007		**New Model, 2016**	
	Value	**t-stat**	**Value**	**t-stat**
α (GDP/capita)	0.899	2.869	0.969	3.755
γ (time)	0.025	6.166	0.017	4.604
Const	-8.436	-2.965	-9.925	-3.657
R^2	0.973		0.981	

Figure 5-2shows the fit of the 2007 model to the old car ownership data. **Figure 5-3** shows the fit of the newly estimated model to the new car ownership data.

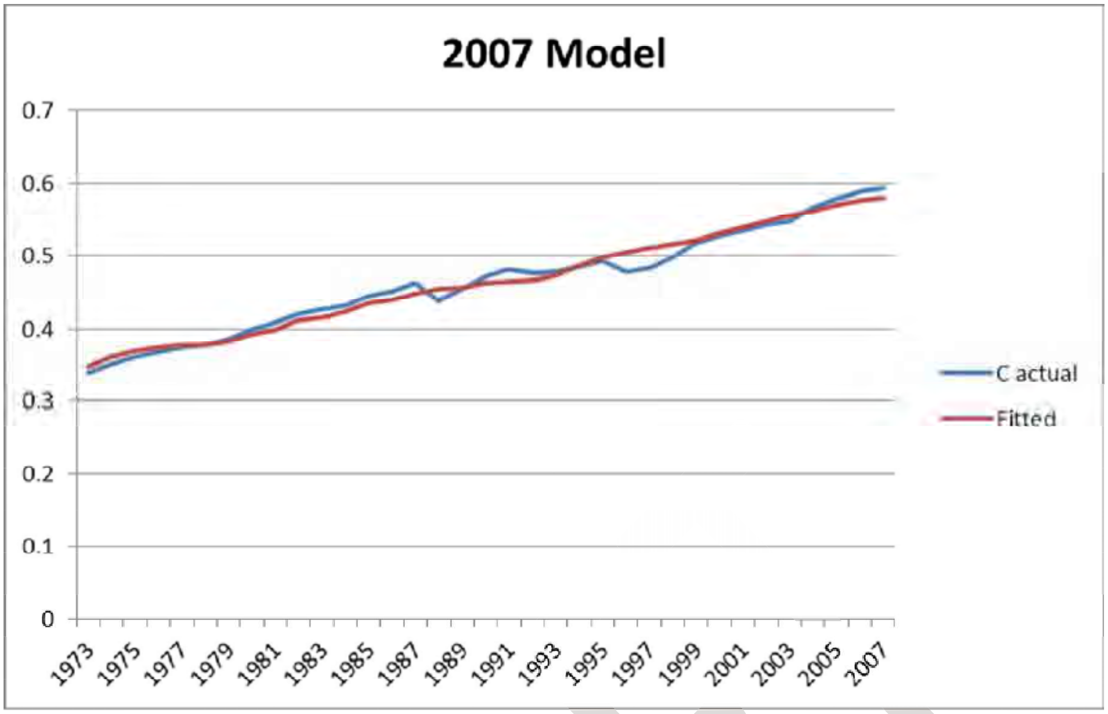


Figure 5-2- Car ownership from old dataset and fitted car ownership using 2007 model

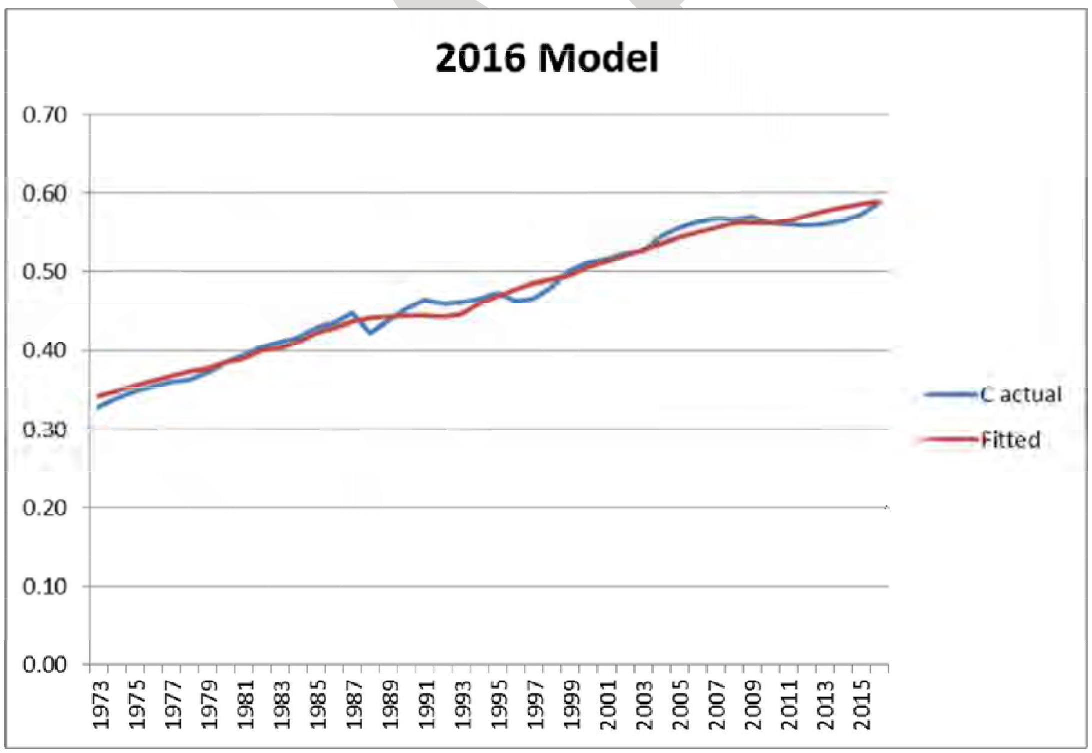


Figure 5-3 Car ownership from new dataset and fitted car ownership using new model

The old model, with a lower dependence on GDP/capita, does not account for the decline in car ownership that accompanied the GFC.

Test: Including Car Price in the Model

In 2007, vehicle purchase price index was proposed and tested as a variable in the model, but was omitted from the adopted model because it was not significant. A test was done using the new data and vehicle purchase price index from StatsNZ to see whether car price should be included in the new model. The test model had the form:

$$\ln Y = \text{constant} + \alpha.\ln GDP + \beta.\ln P + \gamma.t$$

where lnP is the natural log of the price index, and the other parameters and variables have the same names as above. **Table 5-13** shows the results of the test.

Table 5-13- Model test including car price

	Value	t-stat
α	1.059	4.129
β	-0.719	-5.028
γ	0.009	2.009
Const	-5.699	-1.759
R^2	0.978	

Price was found significant in the model and improved the model fit (R-squared). However, car price has been excluded from the model, because it would be very difficult to forecast the change in car price into the future. Moreover, the future introduction of Automated Vehicles will disrupt car ownership and may even eventually require the fitting of a new car ownership/use model.

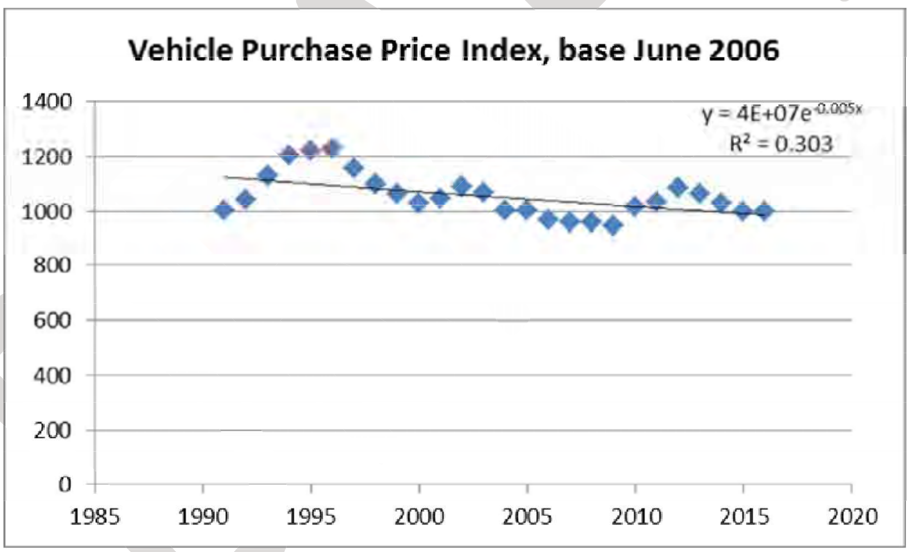


Figure 5-4 - Time series: vehicle purchase price indexTrip end models

The only change required to the trip end models was updating the trip ends for Waiheke Island. Unlike the rest of the model, the trip ends for Waiheke are ferry trips that arrive or leave the island and are inserted into the models using ferry count data, along with the proportions for each purpose. Updating this for 2016 used the 2016 daily ferry count and revised the trip purpose proportions.

An average daily ferry count for the month of March 2016 obtained from Auckland Transport encompasses all ferry passengers between Waiheke and the Auckland downtown terminal and Devonport on the Fullers and Explore services. The passengers on Sealink car ferry services to Wynyard Quarter and Half Moon Bay were excluded to retain consistency with the 2006 macro strategic and 2013 macro PT models, noting that these services are not included in the model transit line files, the count data does not differentiate between passengers in cars or otherwise and the service frequencies are low and the sailing times are high.

The average daily ferry count for March 2016 is **7,589** for both directions, half of which, 3,795, is used in each of the trip production and trip attraction models.

The only data available data that was potentially useful for updating the purpose proportions was the HOP data, which gives the numbers of users by full-paying adults, students, and free-travelling Supergold card users. However HOP card users make up only 4% of Waiheke patronage, 80% of which are Supergold card users, so this information source was of very limited use.

The one-way count of 3,795 was inserted into the relevant trip end macros replacing the corresponding 2006 count. The 2006 purpose proportions were adjusted so that:

- the proportions of HBSh trips from Waiheke have increased from 2% to 5%,
- HBO trips from Waiheke have increased from 14% to 20%.
- HBO trips to Waiheke have increased from 18% to 30%.
- The proportions by other purpose were adjusted accordingly on a pro-rata basis.

The rationale for these adjustments was that HBSh and HBO trips would include Supergold card users which did not exist in 2006, but now make a up a significant proportion of Waiheke ferry trips; this assertion is made from the high percentage (80%) such users are of the 4% of HOP card users, and from anecdotal evidence.

Table 5-14- Waiheke Ferry: Trip purpose proportions

	Purpose	2006	2016
Productions	**HBW**	0.46	0.41
	HBE	0.14	0.13
	HBSh	0.02	0.05
	HBO	0.14	0.20
NHB attractions	**EB**	0.12	0.11
	NHBO	0.12	0.11
	TOTAL	1.00	1.00
HB attractions	**HBW**	0.15	0.13
	HBE	0.00	0.00
	HBSh	0.00	0.00
	HBO	0.18	0.30
NHB attractions	**EB**	0.07	0.06
	NHBO	0.60	0.51
	TOTAL	1.00	1.00

These adjustments were reviewed during the model validation by comparing observed and modelled ferry flows by period. The free-travelling Supergold card trips occur only in the IP, so the HBO and HBSh proportions were adjusted in order to achieve closer fit with the observed ferry flows by time period.

[Note: Forecasting of Waiheke trip ends was implemented in Phase 2. Base year observed trip ends were adjusted based on the population growth]

5.2 Time of day models (Task 2.4.4)

The time of day models as applied in the macro strategic model are outlined in “ART3 Time of Day and Vehicle Driver Factors Report v5 – final - .PDF”. The time of day model structure is shown in Figure 5-5 for each of the four “tour time groups”:

- TG1: out in the am peak, return in the pm peak,
- TG2: out in the am peak, return not in the pm peak,
- TG3: out not in the am peak, return in the pm peak,
- TG4: all other trips.

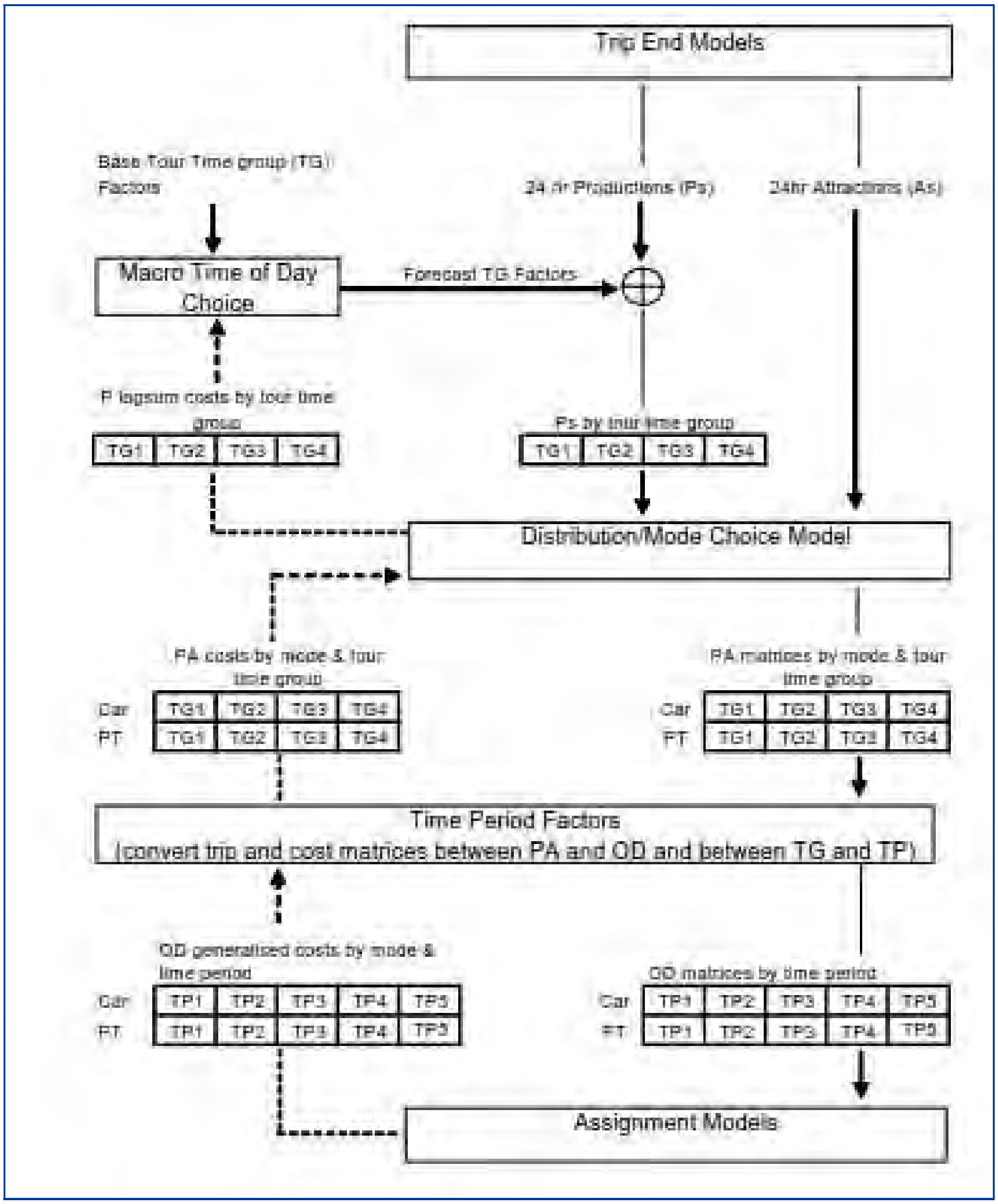


Figure 5-5 - Time of day model structure

As part of the Auckland macro strategic models refresh, the sensitivity of the time of day models has been reviewed using updated screen line count data and model tests. Screen line counts have been compared for 2006 and 2016 data to determine if the proportions of daily traffic flows by time period have changed over time.

In order to understand how the proportions by time period change over time three assessments were performed:

1. Growth ratio between 2006 and 2016 for each time period

2. Ratio of AM/PM to IP for 2006 and 2016 counts
3. Comparison of modelled trip matrix total with full daily counts on a small group of arterial links where 24 hour counts exist

It should also be noted that whilst the screenline locations have been maintained between 2006 and 2016, the number of links crossing them may have changed due to new infrastructure being in place (for example the introduction of the Central Motorway Junction reducing the number of links crossing screenline 1). The screenlines are shown in Figure 5-6

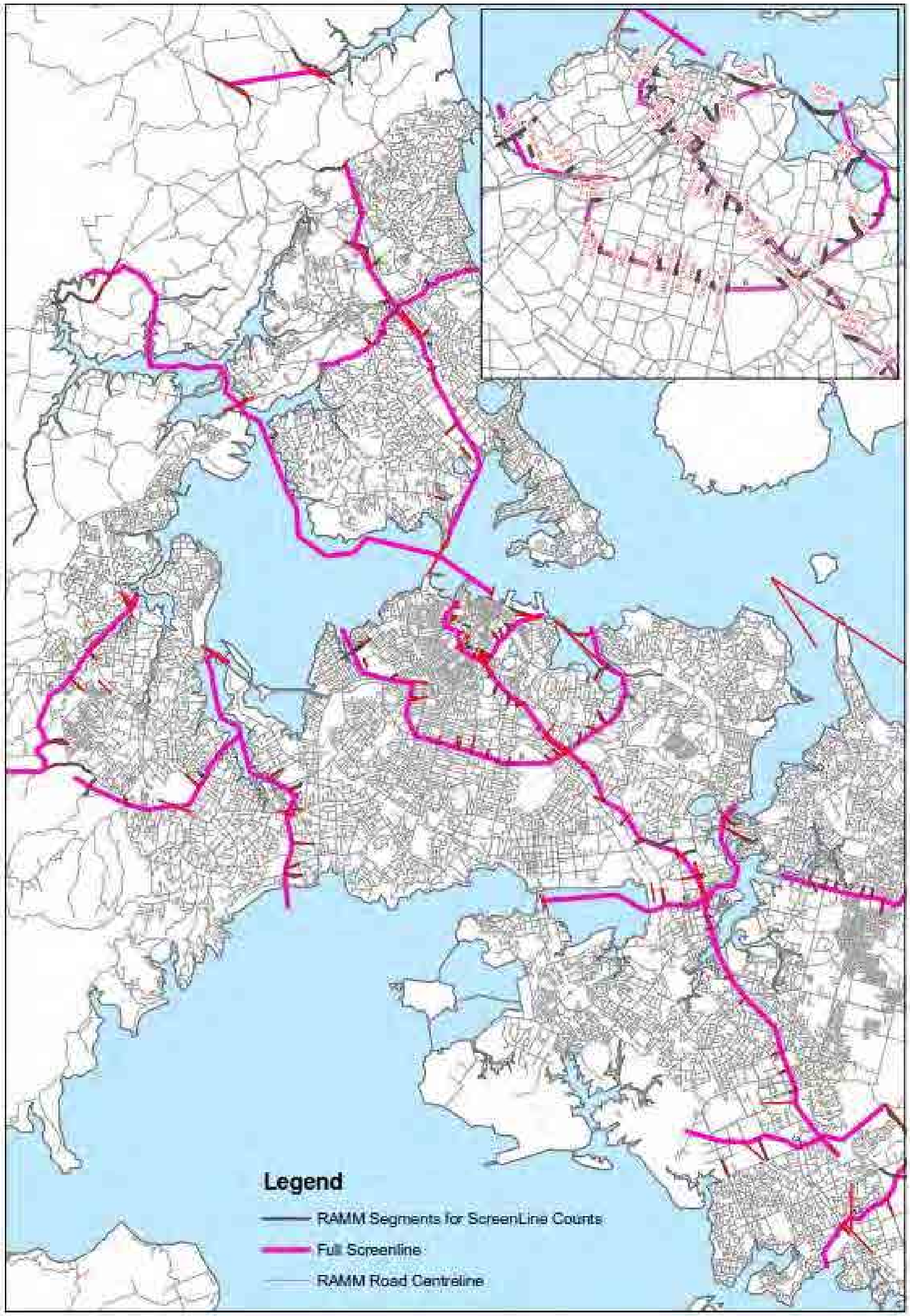


Figure 5-6 - Screenline locations

Figure 5-7 below demonstrates the changes in flow on each screen line and direction, for each time period. The graph demonstrates that although most screen lines experience some level of growth, there is a large range of growth levels from 0.73 (decrease in volume) to 1.48. It should be noted that this is only growth for the modelled periods of AM, IP and PM. Therefore any growth occurring outside of these periods is not included (the off peak and school peak are not assigned).

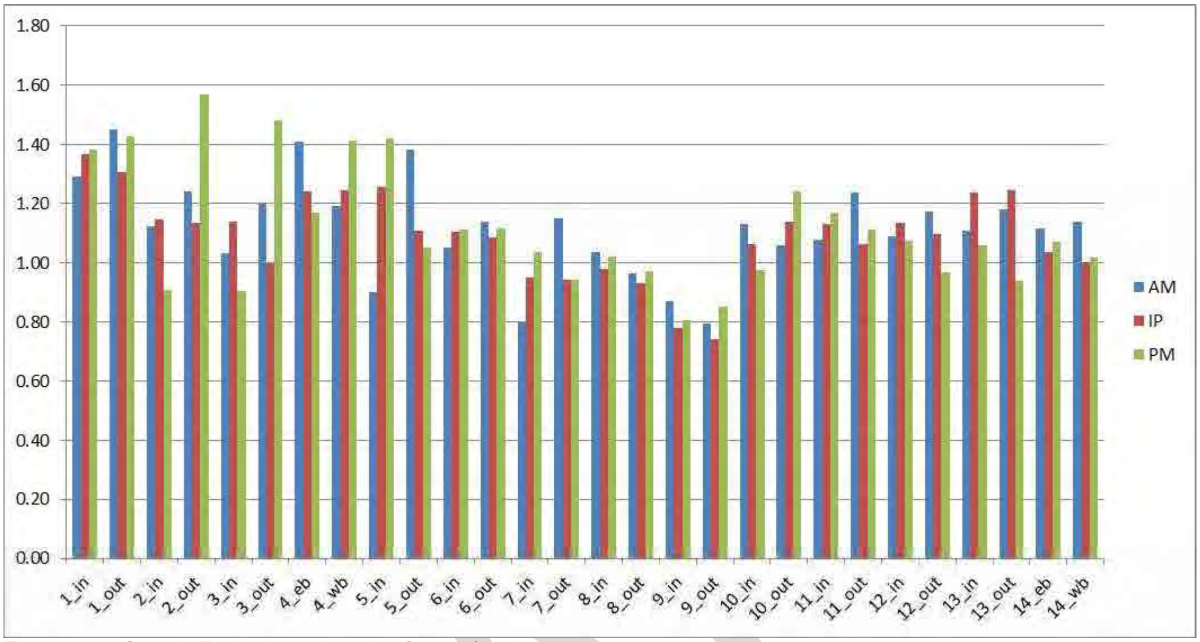


Figure 5-7- Growth Ratio 2016/2006 by Screenline by time

There are similar levels of growth by period for each screenline with no obvious trends. For example:

- "1 in": the PM growth is the highest and AM the lowest
- "14 EB/WB": the AM growth is the highest and PM the lowest
- "1 out": IP growth is lower than AM and PM
- "13 in/out": IP growth is higher than AM and PM

Given these unclear trends, this analysis does not provide a good basis for changing the time of day model.

Figure 5-8 shows the ratio of AM to IP observed screenline volumes in 2006 and 2016. If these ratios were unchanging, we would expect all points to lie on the line y=x. The trend line demonstrates that:

- If the 2006 ratio is above 1.5 (traffic volumes are 50% greater in the AM peak than IP) then the 2016 ratio is typically less than 1.5.
- At ratios around 1 (similar traffic volumes in the AM peak and IP), the 2016 and 2006 ratios are similar

Ratios of AM to IP volumes of greater than 1.5 indicate significant peaking of demand in the AM peak. When the AM to IP ratios are lower in 2016 than in 2006 this implies a trend to reduce peaking. Lower AM to IP volumes ratios may indicate either congestion across the day that results in peak spreading into the IP even in 2006.

Of note is that for 2006 ratios close to 1 most of the data points lie above the line y=x. In contrast, for 2006 ratios on or above 1.5 the data points lie below the y = x line. This implies that for flow profiles that display high AM peaking flows there has been more peak spreading in 2016 whereas for screenlines with low peak spreading in 2006 there has been an increase in peaking in 2016.

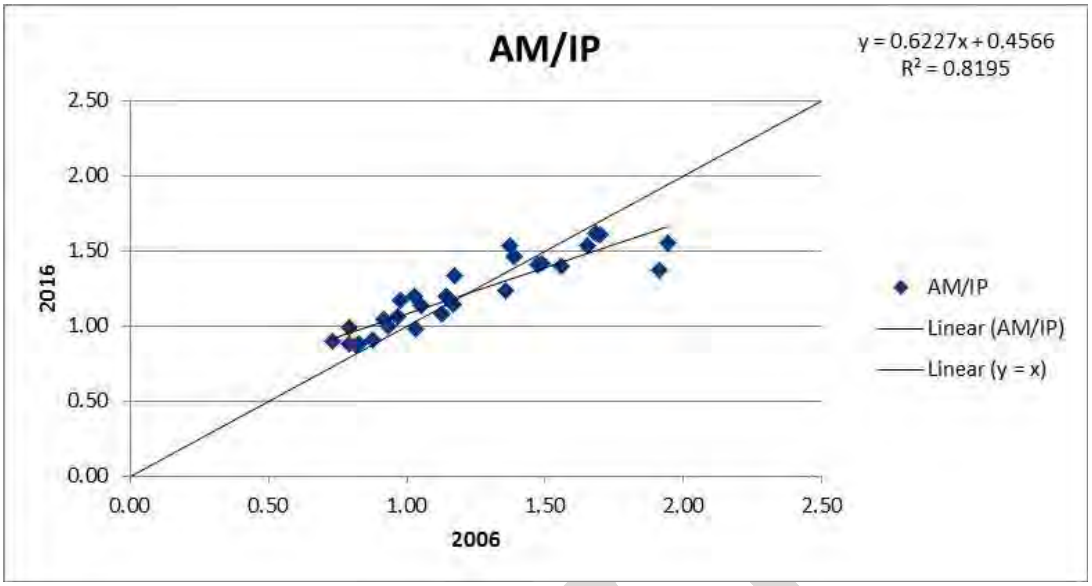


Figure 5-8- AM/IP Ratio 2016 vs 2006

Figure 5-9 shows the ratio of PM to IP screenline volumes in 2006 and 2016. There is a far lower correlation between the 2006 and 2016 ratios with lower dependence on the ratio in 2006. With the gradient of the line of best fit being closer to 1 than in the AM peak, there appears to be less change in the ratio of PM to IP flows between 2006 and 2016. Even at higher levels of peaking in 2006 (a ratio of 2), this level of peaking appears to be maintained in 2016.

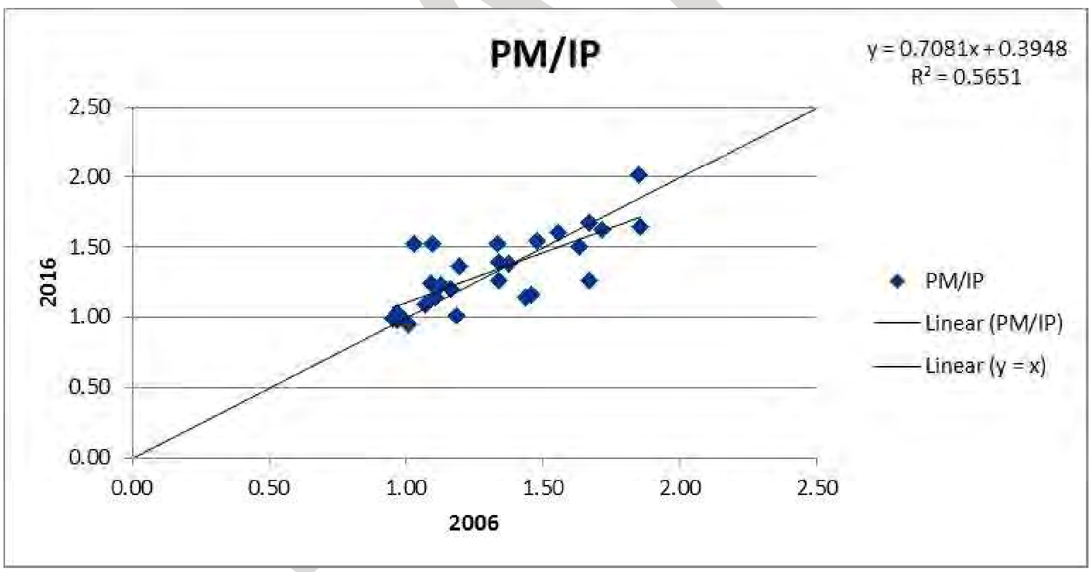


Figure 5-9 - PM/IP Ratio 2016 vs 2006

Further investigation has been undertaken to analyse count sites where data was available in 2006 and 2016 data over a full day. The following sites had data available for both 2006 and 2016:

Table 5-15- Count sites

Screenline	Count Site
2	Beach Road

Screenline	Count Site
2	Albany Highway
4	Rosedale Road
5	Triangle Road
5	Henderson Valley Road
6	Parrs Cross Road
7	Kinross Street
8	Meola Road
8	Sandringham Road
8	Dominion Road
9	Grafton Road
10	Kilkenny Drive
10	Harris Road
13	Mill Road
14	East Tamaki Road
14	Princes Street
14	Khyber Pass Road

Figure 5-10 below shows the proportion of daily volumes in each of the modelled periods between 2016 observed data and a preliminary 2016 model run (matrix totals). This shows that the observed data has a higher proportion of vehicles in the off-peak than had been accounted for in the model. The overall growth between 2006 and 2016 for the observed data shows that the off-peak experiences the highest overall growth. This is particularly evident in the counter peak direction. This is shown in **Figure 5-11** and **Figure 5-12**.

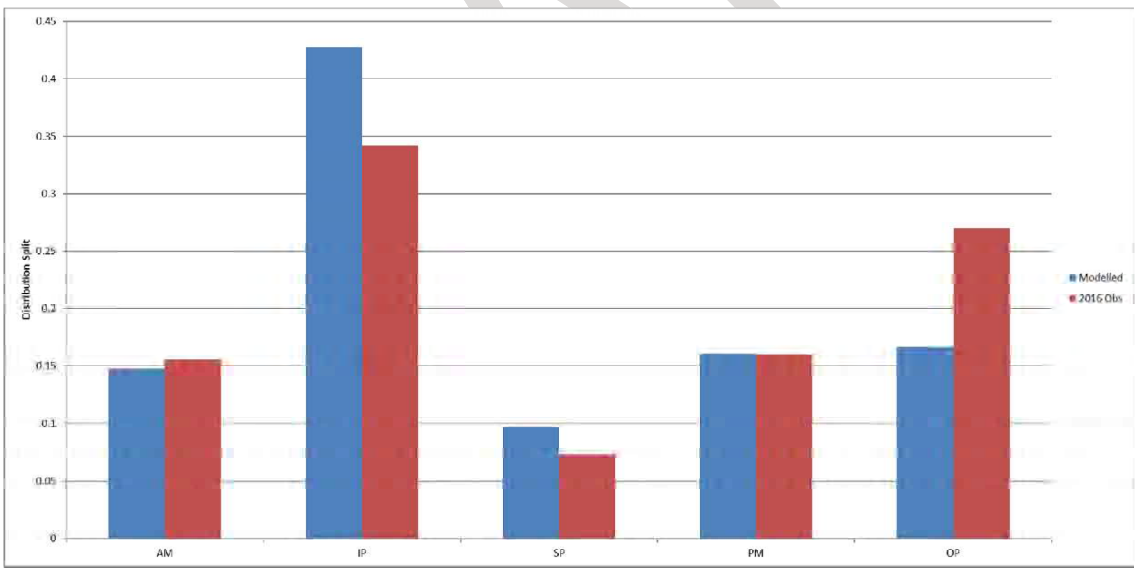


Figure 5-10- Modelled Period Distribution Split - Observed vs Modelled

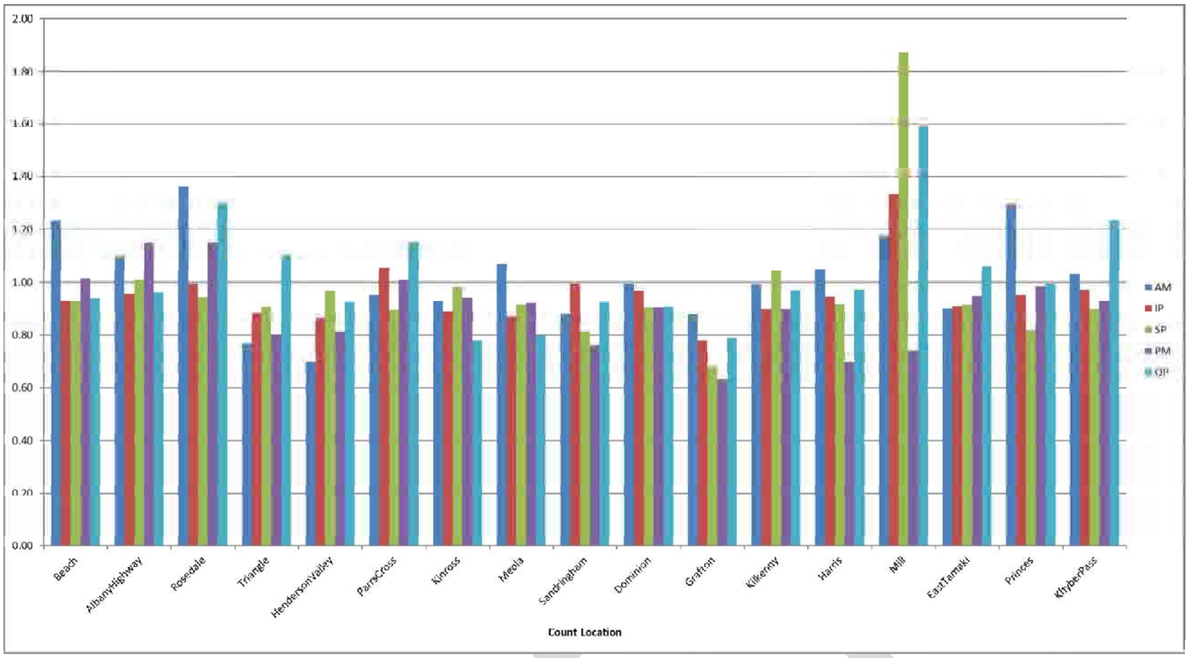


Figure 5-11- Ratio of observed volumes 2016/2006 for each time period

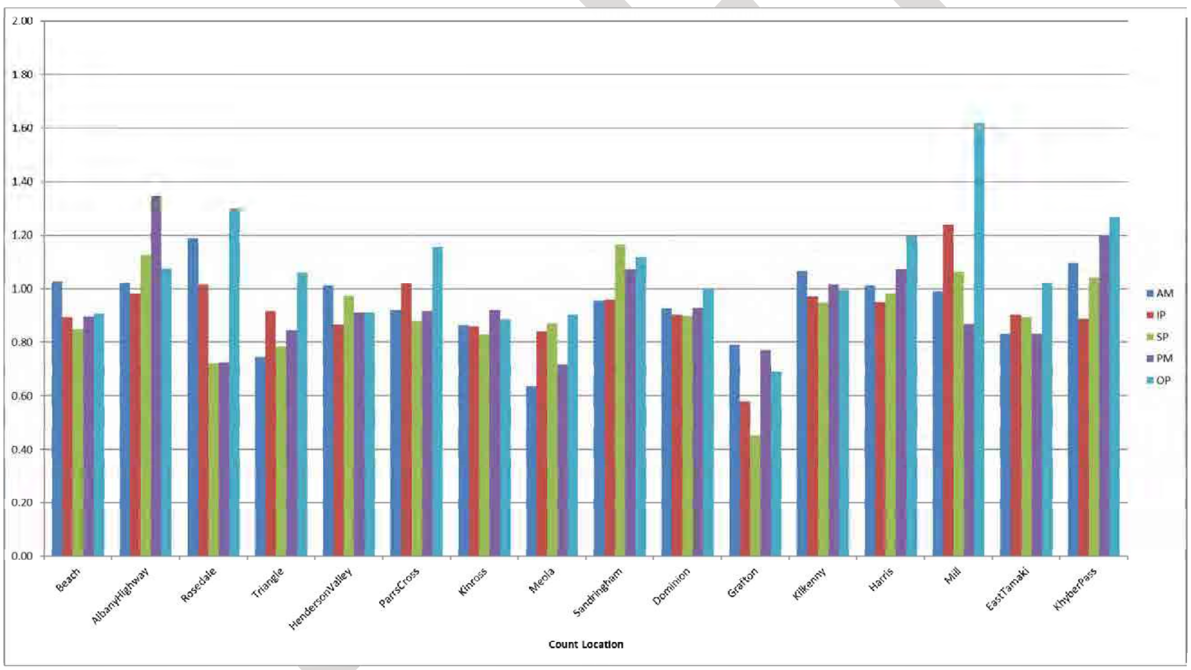


Figure 5-12- Counter Peak ratio of observed volumes 2016/2006 by time

When comparing observed data between 2006 and 2016, there are no clear trends in changes, with significant variation in these changes both by screenline and by period.

Comparing observed and modelled data in 2016 indicates that the IP has typically experienced lower growth than the model is currently estimating, meaning that both AM/IP and PM/IP ratios are lower for the modelled data compared with observed. However, this is not the case for every screenline location, and the difference between observed and model varies across the screenlines.

When comparing observed data between 2006 and 2016, there are no clear trends in changes, with significant variation in these changes both by screenline and by period.

Comparing observed and modelled data in 2016 indicates that the IP has typically experienced lower

growth than the model is currently estimating, meaning that both AM/IP and PM/IP ratios are lower for the modelled data compared with observed. However, this is not the case for every screenline location, and the difference between observed and model varies across the screenlines.

Given this variation, three options were considered for the time of day models:

1. Leave the models unchanged, and account for the lower relative growth in the IP through adjustment of under reporting factors.
2. Reduce the OP peak costs (currently not an assigned model period) as a proportion of the IP costs to attempt to transfer additional daily trips into the OP.
3. Reduce the sensitivity of the time of day model to retain more trips in the more congested AM and PM peaks, and fewer trips in the IP (and OP).

Option 3 was discounted as whilst this would reduce the number of trips in the IP, potentially more in line with observed data, it would have an adverse impact on the proportion of AM and PM peak trips.

Option 2 was tested to establish the impact of the OP costs on the distribution of trips throughout the day. The outcome of a reduction in OP costs was additional trips transferring from the AM and PM peaks to the OP with negligible changes in the IP. Option 2 has therefore been discounted also.

Option 1 has therefore been implemented acknowledging that there are no model parameters that can be transparently adjusted to modify the time of day model in the desired manner, within the existing model structure.

[Note: Additional TOD response has been implemented for home-based trip in the Phase 2 work. Please see **Section 7.6**]

5.3 Under-Reporting Factors (Task 2.4.5)

There are a set of under reporting (UR) factors in the Macro Strategic Model which adjust car and LCV trips to account for an under-reporting issue with the 2006 Household Travel Survey (HTS)[4].

A file note[5] (included in **Appendix C**, Task 2.4.5) was prepared during the model validation process which discusses different methods of updating these factors and resulting validation outcomes. These methods are:

- **Method 1 – Apply the existing UR factors**. This is no change to the existing method. These factors were applied using a 5 sector system.
- **Method 2 – Use revised UR factors**. Update UR factors to better match 2016 screenline counts. Generally these factors were reduced.
- **Method 3 – Apply additional factors on Method 2**. The updated UR factors (method 2) generally improve validation results, but there are some screenline movements where GEH statistics are poor.
- **Method 4- Apply matrix estimation (ME) directly to the DMS matrices**. This is to undertake the same process as in Method 3, but ME is applied directly to the matrices from the DMS model (i.e. no initial UR adjustment).

Error! Reference source not found. illustrates these methods.

[4] Documented in "Auckland Transport Models Project (ATM2), ART3 Model Testing and Validation Report", August 2008

[5] ATM2016_2.4.5-Matrix Adjustment Process for MSM.pdf

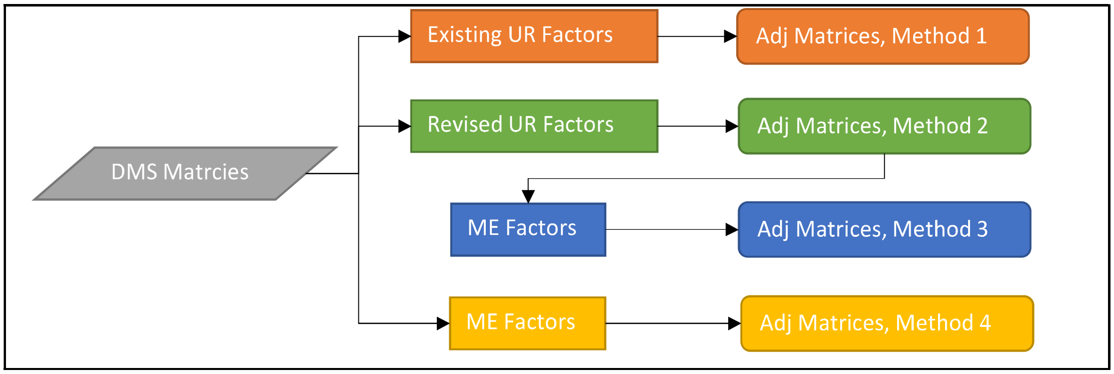


Figure 5-13- Matrix Adjustment Approaches

This file note was distributed to the model owners and the project Technical Director. Method 3 was selected collectively as it improves the model validation results significantly with very limited effects on the overall shape of the demand matrices or trip length. Hence this section only covers the outcomes of Method 3 and the effects of ME.

Updated Under Reporting Factors

The Under Reporting factors were updated by comparing observed and modelled screenline flows in all periods.

Table 5-16- Existing (ART3) and Revised UR factors for Cars

	Existing UR Factors					Revised UR Factors				
AM Peak										
Sector	**North**	**West**	**CBD**	**Isthmus**	**South**	**North**	**West**	**CBD**	**Isthmus**	**South**
North	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
West	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CBD	1.00	1.00	1.00	2.50	1.00	1.00	1.00	1.00	1.10	1.00
Isthmus	1.00	1.00	1.04	1.00	1.00	1.00	1.00	1.20	1.30	1.00
South	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Inter_peak										
Sector	**North**	**West**	**CBD**	**Isthmus**	**South**	**North**	**West**	**CBD**	**Isthmus**	**South**
North	2.28	1.48	1.85	1.85	1.82	1.90	1.29	1.34	1.26	1.00
West	1.49	1.82	1.72	1.72	1.82	1.29	1.82	1.65	1.29	1.08
CBD	1.83	1.83	1.82	5.02	1.83	1.33	1.75	1.74	3.81	1.42
Isthmus	1.83	1.83	4.72	1.85	1.78	1.00	1.33	4.35	2.11	1.00
South	1.82	1.82	1.53	1.59	1.85	1.00	1.25	1.27	1.00	1.85
PM Peak										
Sector	**North**	**West**	**CBD**	**Isthmus**	**South**	**North**	**West**	**CBD**	**Isthmus**	**South**
North	1.37	1.00	1.00	1.00	1.00	1.37	1.00	1.00	1.00	1.00
West	1.00	1.45	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.00
CBD	1.14	1.02	1.00	1.17	1.06	1.00	1.04	1.00	1.24	1.10
Isthmus	1.14	1.02	3.32	1.11	1.00	1.00	1.05	2.16	1.24	1.00
South	1.00	1.00	1.00	1.00	1.19	1.00	1.01	1.00	1.00	1.00

Table 5-17- Existing and Revised UR factors for LCVs

	Existing UR Factors					Revised UR Factors				
AM Peak										
Sector	**North**	**West**	**CBD**	**Isthmus**	**South**	**North**	**West**	**CBD**	**Isthmus**	**South**
North	3.67	1.00	2.38	9.91	1.31	1.00	1.00	2.38	1.00	1.00

	Existing UR Factors					Revised UR Factors				
West	1.00	4.21	3.45	12.38	4.29	1.00	1.00	3.45	1.00	1.00
CBD	1.66	2.42	5.33	35.63	5.15	1.00	1.00	5.33	28.70	1.83
Isthmus	1.65	2.15	244.42	5.11	4.72	1.00	1.00	244.42	9.22	1.00
South	1.11	1.14	20.48	4.10	5.42	1.00	1.00	1.00	1.00	7.63
Inter_peak										
Sector	**North**	**West**	**CBD**	**Isthmus**	**South**	**North**	**West**	**CBD**	**Isthmus**	**South**
North	2.91	2.74	2.97	2.10	1.00	2.34	1.00	1.00	1.00	1.00
West	2.36	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CBD	4.68	1.00	2.87	32.14	1.00	1.00	1.00	2.68	22.80	1.00
Isthmus	1.00	1.00	9.82	1.80	1.00	1.00	1.00	8.94	2.04	1.00
South	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PM Peak										
Sector	**North**	**West**	**CBD**	**Isthmus**	**South**	**North**	**West**	**CBD**	**Isthmus**	**South**
North	4.15	6.35	1.00	1.53	1.00	4.15	2.07	1.00	1.00	1.00
West	1.54	2.22	1.00	1.00	1.00	1.00	2.40	1.00	1.00	1.00
CBD	2.07	2.3	72.73	70.65	3.04	1.00	2.50	72.73	70.65	3.04
Isthmus	2.28	2.56	12.34	4.82	10.72	1.00	2.79	12.34	7.49	1.00
South	1.00	1.71	11.48	10.4	7.83	1.00	1.82	1.00	1.00	7.15

Table 5-16 and **Table 5-17** show revised Under Reporting factors are reduced noticeably. Note that some LCV factors are quite big, but they are not directly applied to trip matrices. There are used in conjunction with the LCV proportion matrices.

Effects of Validation Factors

Matrix Adjustments based on the Matrix Estimation (ME) technique was undertaken using screenline or sub screenline total counts. A 27 sector (Figure 5-14) system was developed and sector-to-sector validation adjustment factors were calculated using the before and after ME adjustment matrices. These sector factors were then capped as below to limit changes to the matrices.

- Sector to Sector individual cell factors are capped between 0.3 and 5
- Total sector production and attraction are not allowed to change more than 25% from the original value.

Table 5-18 provides matrix total changes before and after the application of validation factors.

Table 5-18- Car Matrix Totals with and without Validation Factors[6]

Peaks	Without	With	% Change
AM	511,018	505,927	-1.00%
IP	452,634	455,062	+0.54%
PM	547,517	556,815	+1.7%

From this, matrix total changes are considered minor. Table 5-19 provides average trip length comparisons before and after the application of validation factors.

Table 5-19 – Average Trip Length, km, with and without Validation Factors

Peaks	Without	With	% Change

[6] From the model run where ME and validation factors are calculated

Peaks	Without	With	% Change
AM	10.11	9.91	-2.0%
IP	9.41	9.12	-3.1
PM	10.14	9.95	-1.9%

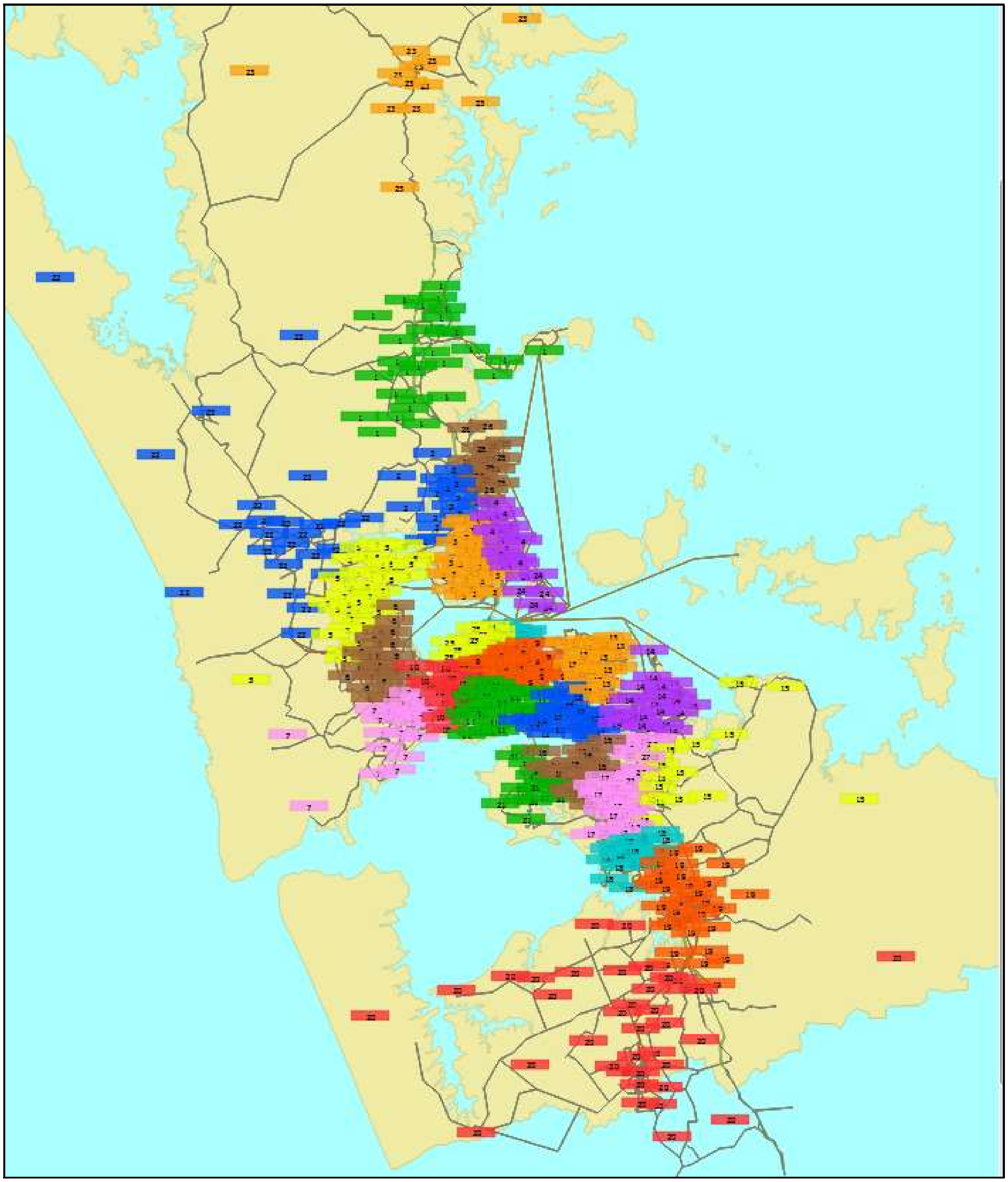


Figure 5-14- 27 Sector System

Figure 5-15 to **Figure 5-17** show trip length distribution changes with and without application of the Validation Factors.

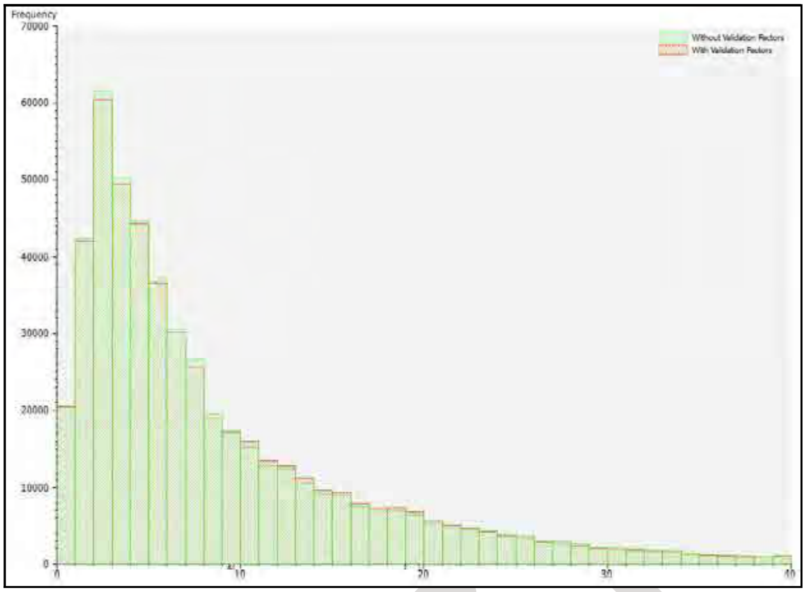


Figure 5-15 - Trip Length Distribution with and without Validation Factors (AM Peak)

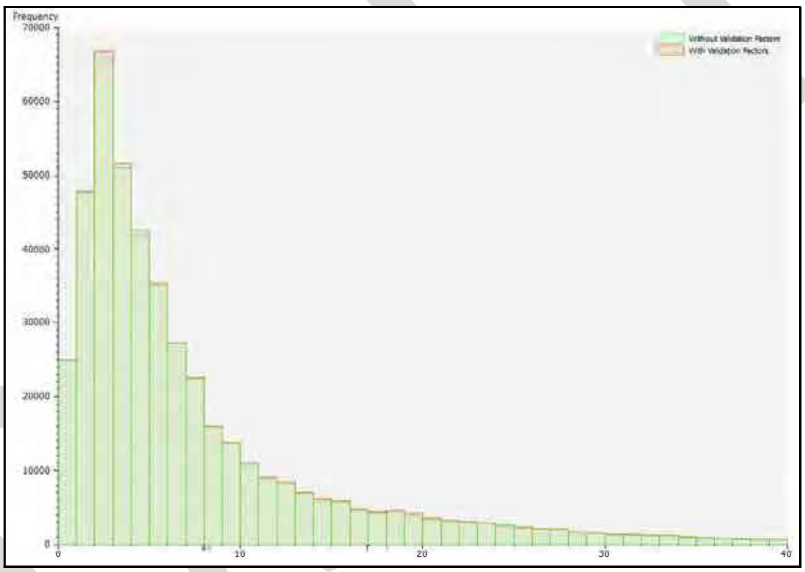


Figure 5-16 - Trip Length Distribution with and without Validation Factors (Inter-Peak)

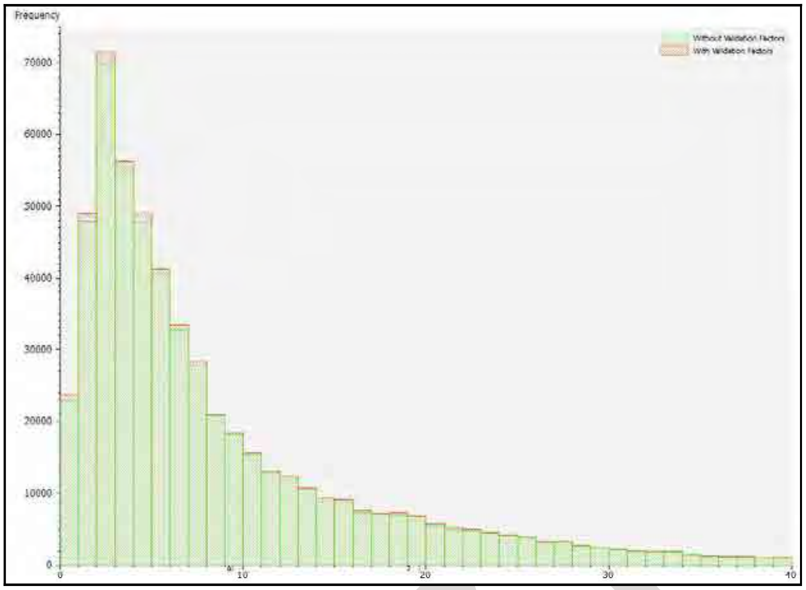


Figure 5-17- Trip Length Distribution with and without Validation Factors (PM Peak)

These graphs show very limited effects on trip length distribution as the result of Validation Factors.

Table 5-20 shows summary of screenline validation results with and without validation factors. Note that these are not the final validation statistics and they are from the earlier iteration model runs from which the validation factors were developed.

Table 5-20- Statistical Validation Results (Total Screenline)

	Without Validation Factors			With Validation Factors		
	AM	IP	PM	AM	IP	PM
Proportion of screenline with GEH<5	46%	43%	36%	64%	82%	82%
Proportion of screenline with GEH<10	61%	82%	82%	96%	100%	96%
Proportion of screenline with GEH<12	75%	93%	86%	100%	100%	100%
Proportion of screenline with % difference <10	75%	82%	86%	96%	100%	93%
R^2	0.982	0.986	0.985	0.994	0.995	0.994
RMSE	9%	8%	8%	6%	5%	5%
Screenline total difference	0%	-1%	-1%	-1%	-1%	1%

Table 5-20 shows that the use of validation factors improve the screenline validation results significantly, with further information on overall validation provided in **Section 10**.

[Note: The capping process and validation factors were updated during the Phase 2 work. Please see **Section 7.7**]

5.4 Medium and Heavy Commercial Vehicle (MHCV) matrices (Task 2.4.6)

The macro strategic model uses observed MHCV matrices for the AM peak, IP, and PM peak periods, which are growth forecast for future years. These observed matrices have been updated by the AFC based on GPS eRUC data. These observed matrices have then been disaggregated to the macro strategic model 603 zone system using trip disaggregation factors. These factors are created as follows:

- Land use (population, households, education roll and employment) was provided for both the old and new zone systems
- Trips ends were calculated for each old and new zone using the land use values, and regression parameters based on the time period
- Disaggregation factors were calculated based on the proportion of trips in new zones compared to old zones

Checks have been undertaken using mapping to establish whether the areas with high proportions of HCV trips correlate with areas with high employment to population ratios (typically industrial areas with low resident populations and higher medium and heavy commercial activity).

There are some areas where the high proportion of HCV trips does not appear to correspond to a high employment ratio, such as Silverdale, Westgate, and to a lesser extent either end of the Waterview tunnel. **Table 5-21** shows those zones which have an HCV % above 20% in any one of the time periods and for either origins or destinations, and an employment to population ratio of less than 50%. It is possible that the high HCV proportion may be due to construction during 2016, which could be expected to reduce in future years, and may need to be accounted for in forecasting.

Table 5-21 Zones with a HCV % > 20 and Employment/Population <50%

Zone Location	Zone Number	Max HCV %	Emp/Pop
Silverdale	22	25	36%
Silverdale	31	27	12%
Silverdale	32	29	13%
Silverdale	38	29	45%
Silverdale	39	29	14%
Dairy Flat	40	65	15%
Dairy Flat	41	68	20%
Albany Heights	68	28	14%
NW (Riverhead)	147	21	31%
NW (Kumeu)	151	21	8%
NW (Whenuapai)	166	41	10%
NW (Westgate)	174	35	22%
NW (Hobsonville)	178	29	27%
Ranui	192	20	17%
Waterview	295	20	9%
Waterview	296	20	13%
Mt Roskill	310	22	9%
Mt Roskill	311	20	12%
Pt England	385	28	36%
Flat Bush	444	26	15%
West of Airport	477	54	48%
Mangere	480	22	34%
Ardmore	536	33	21%

Zone Location	Zone Number	Max HCV %	Emp/Pop
Drury	556	30	47%
Karaka	566	26	45%
Paerata	570	34	13%
Glenbrook	594	24	30%

Figure 5-18 Error! Reference source not found. below shows an example of the visual checking that has been undertaken where:

- The red circles show HCV trips as a proportion of vehicle trips for that zone, using either origin or destination trips, for the three time periods.
- The yellow diamonds show areas where the employment/population ratio is greater than 50% (an arbitrary number to roughly identify non-residential or mixed use zones).

The areas with a high proportion of HCV trips generally look reasonable and correspond to major industrial areas (Wiri, Airport, Mt Wellington, East Tamaki, Port). They also generally have a yellow diamond, showing a higher ratio of employment to population, as expected.

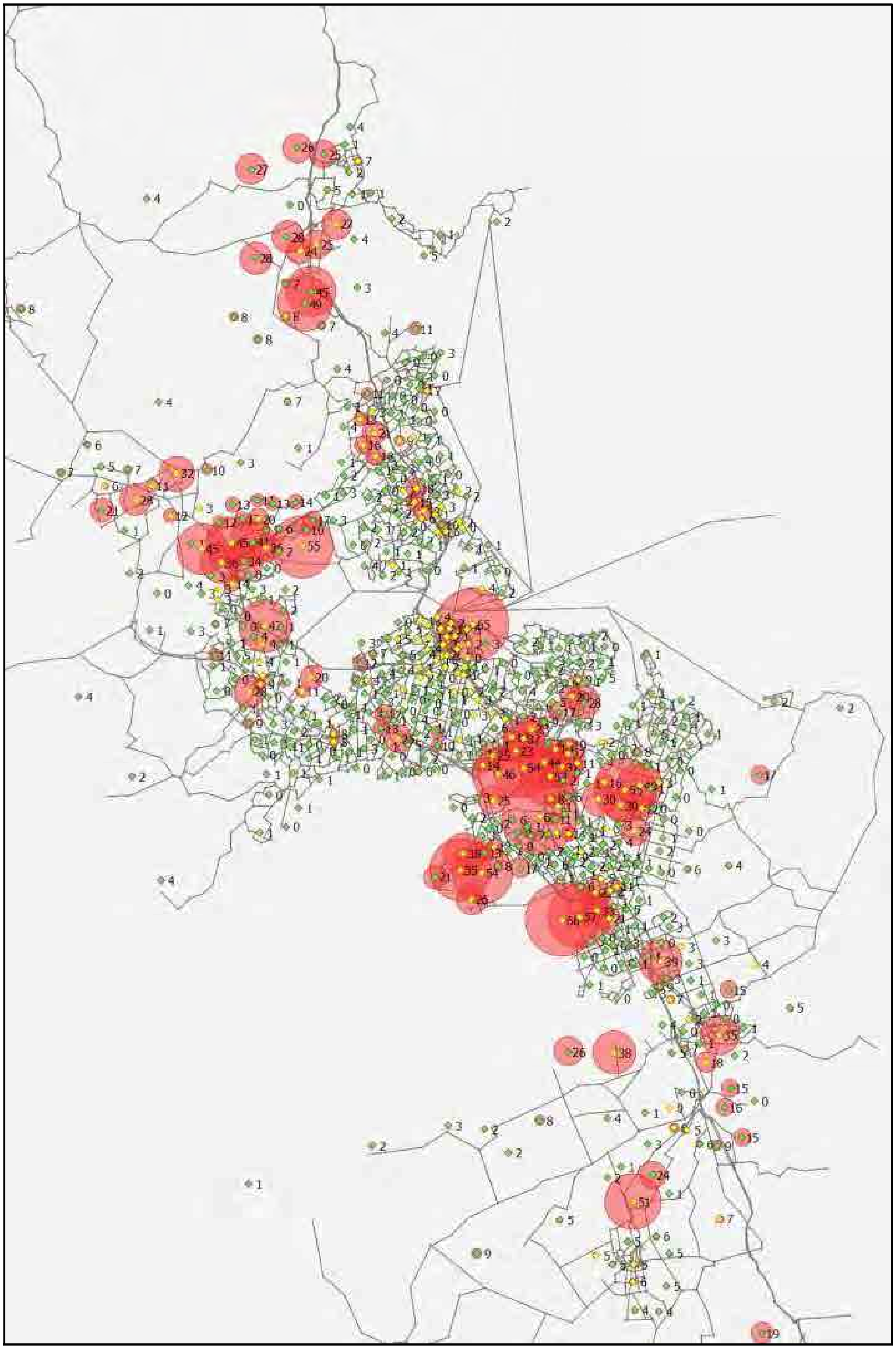


Figure 5-18 - HCV Sense Check – AM, Origin Trips

5.5 Airport model (Task 2.4.7)

The airport model was originally developed in 2011 by David Young Consulting to capture the variety of modes used to travel to and from the airport. Data from the Southwestern Multimodal Airport Rapid

Transport (SMART) project was used to develop the model. That study produced survey results from international and domestic airport passengers on mode of land transport to/from the airport and the location of non-airport destinations.

The airport model has the following features:

- It is a 2011 based model for flight-related passenger demands (excluding flight crews)
- The two terminals are represented by two zones in the macro strategic model, separating the employment-related transport demands from the flight-related demands
- All-day matrices of flight passengers to the airport (i.e. passengers departing on flights) by segment were developed from survey data and total passenger data
- Logit mode split models allocate the trips to modes using generalised costs developed from macro strategic model time and distance and other costs
- Time period factors are used to produce matrices by the macro strategic model assigned periods; AM peak, Interpeak, PM peak
- Trips from the airport by flight passengers (i.e. passengers arriving on flights) are the transpose of trips to the airport
- The additional trips of welcomers and farewellers by time period are included
- Matrices by mode are added to the macro strategic model vehicle or PT matrices prior to assignment in the macro strategic model

The survey data was segmented by terminal (international or domestic), residency of traveller (Auckland, the rest of New Zealand, or overseas), and reason for travel (personal or business). For each segment, the proportions of three trip origin sectors (CBD, Rest of Auckland, and External) were calculated from the surveys.

Mode split models for each segment allocate trips to 5 modes: Public transport, Kiss & fly, Park & fly (including rental car), Shuttle, and Taxi. These are logit models with sensitivity parameters derived from international examples.

For each mode and segment, generalised costs are calculated using the available macro strategic model drive time, distance, and toll matrices, and PT generalised cost matrices. Existing macro strategic model values of time and vehicle operating costs are used as appropriate (Employers Business for business purpose trips, Other for personal purpose).

In forecasting for future years, the numbers of trips in each segment are factored by the growth in air passengers and the non-airport ends of each will be allocated according to population and employment as appropriate. The proportions of trips to/from each locational sector in the base year are retained. The mode split models are run using the forecast generalised costs.

To update the model for 2016, several of the inputs needed to be updated with the latest information. The full documentation of the original model development is in “ART3 Airport Model v1.pdf”.

The airport provides parking rates for each of its car parks at the domestic and international terminals. To calculate the cost of parking for international and domestic, short term and long term, observed parking entry and exit data from 2008 was used to find average parking durations for each of these segments. The collated parking cost were applied to those average durations to get average parking costs for 2016. The parking costs from 2011 and 2016 are shown in**Table 5-22**. 2011 costs have been adjusted to $2016 using the CPI adjustment factor from 2011 Q2 to 2016 Q1, equal to 1.04.

Table 5-22 - Airport parking costs per trip

	2011 in $2016	2016	% change
International – long term	$62.40	$90.00	44%

	2011 in $2016	2016	% change
International – drop off	$9.36	$15.33	64%
Domestic – long term	$31.20	$65.00	108%
Domestic – drop off	$4.16	$9.67	132%

The costs of travelling to the airport using bus, taxi, train, or shuttle are updated from their 2011 values. Taxi fares were the rates posted outside the airport as of 20 March 2017. The $5 flag fare listed in **Table 5-23** is the pick-up rate for travel from the airport. It is a flat rate charged by the airport and does not vary by taxi company. The drop-off rate for travel to the airport is $2. It is not known whether the 2011 rate of $3 is for pick-up, drop-off, or both. The per km rate for taxis is the average rate of all the taxi companies listed in the airport.

The shuttle fare data came from the websites of SuperShuttle and Abacus Transport. The rates used were quoted prices for travel to the airport from the CBD and various suburbs. The rates were plotted against the distance between the airport and those suburbs, and a line was fitted to the plot (**Figure 5-19**). The equation of the line provided the flag fare (the constant) and the per km cost (the gradient). This method produced a flag fare very different from that used in 2011. However, no shuttle company provided their prices in terms of a flat flag fare and a per km cost.

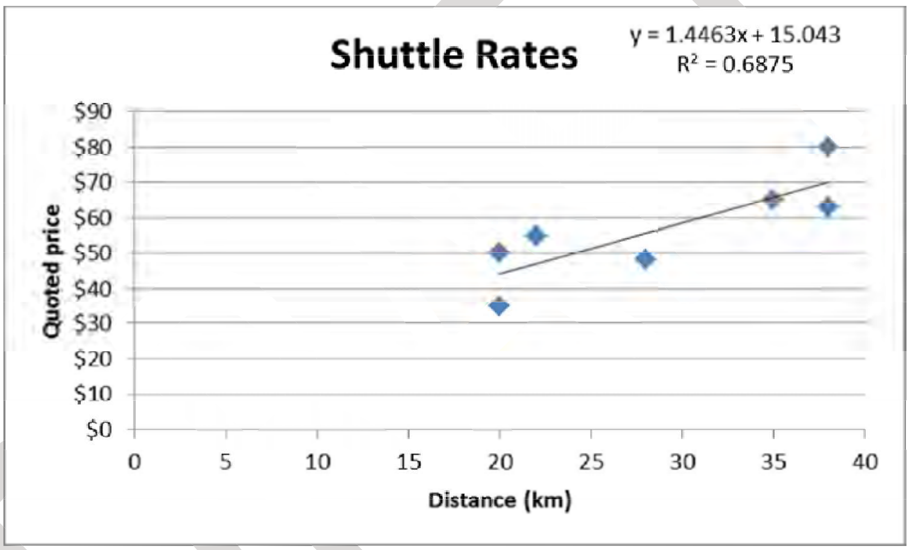


Figure 5-19- Shuttle rates to/from the airport

The price of the Skybus used in the 2011 model was $16 for a one-way trip. Currently, the cost is $18 one way and $32 with return. However, passengers with HOP cards only pay $16 for a one way trip.

Table 5-23 - Costs of transport to/from the airport

	2011	2011 in $2016	2016	% change
Taxi – flag fare (from airport)	$3.00	$3.12	$5.00	60%
Taxi – per km	$2.50	$2.60	$2.46	-6%
Shuttle - flag fare	$6.50	$6.76	$15.04	122%
Shuttle – per km	$1.60	$1.66	$1.45	-13%
Skybus	$16	$16.64	$18	8%

The airport provides monthly updates on the past year of passenger counts. The counts from the March 2016 report are shown in **Table 5-24**. Domestic passengers were not split into departures and arrivals in the March report, but they were split in the December 2016 report. The March total domestic passengers were split into arrivals and departures using the percentages from December.

Table 5-24 - Airport passenger counts, March 2016

	Month Total (March 2016)	Rolling 12 Month Total
International arrivals (excl. transits)	379,699	4,345,839
International departures (excl. transits)	403,458	4,266,363
Total international (excl. transits)	783,157	8,612,202
Transit movements	48,354	541,018
Total international passengers	831,511	9,153,220
Domestic arrivals	371,268	3,877,809
Domestic departures	373,830	3,789,779
Total domestic passengers	745,098	7,667,588

The totals for international (excl. transits) and domestic passengers were divided into purpose and residency using the proportions from the 2011 model. These proportions are given in **Table 5-25** The model uses daily counts, but those were not available from the airport for 2016. In order to address this, a factor to convert monthly to daily passengers was calculated from 2011 data (March 2011 monthly airport data to 2011 modelled daily passengers). This factor was used to convert the monthly information in **Table 5-24**

to daily passengers, shown in **Table 5-26.** The monthly to daily factor was approximately 1/30 for both terminals, indicating that travel rates are similar on weekdays and weekends. Since the same values will be used in the model for both arrivals and departures, the total passengers for each terminal was divided by two to get one way trips.

As noted in the 2011 documentation, welcomers and farewellers are not included until after the mode split, when the return trips of welcomers and farewellers are factored in.

Table 5-25 - 2011 daily flight passenger % to terminal

	Personal			Business			Total
	Akld	Other NZ	Overseas	Akld	Other NZ	Overseas	
International	17.96%	22.05%	47.09%	3.20%	3.92%	5.79%	100.00%
Domestic	19.04%	33.36%	11.10%	10.82%	18.94%	6.74%	100.00%

Table 5-26 - One way 2016 daily passengers

	Personal			Business			Total
	Akld	Other NZ	Overseas	Akld	Other NZ	Overseas	
International	2,361	2,899	6,190	421	515	761	13,147
Domestic	2,185	3,828	1,274	1,242	2,174	773	11,476

AIAL's annual passenger forecast (December 2016) has been provided[7]. The forecasts are for fiscal years (ending in June) and include a base case, a low scenario, and a high scenario. The forecasts

[7] Passenger forecasts were provided by AIAL. AIAL's flight forecasts are provided by third parties that study the global trends affecting air travel demand. Previous forecast were undertaken by AirBiz. The most recent two forecasts provided in May 2014 and Dec 2016 were provided by DKMA. There has been significant growth in air travel since 2011 which is factored into the latest forecasts.

for some future years are shown in **Table 5-27**. These forecasts are the **total arrivals and departures** of passengers on commercial airlines.

Table 5-27 - Commercial passenger forecasts (000) and % growth per annum from 2016

			2016	2021	2026	2031	2036	2041
Low	International	Total	8,779	11,115	12,991	15,152	17,327	19,451
		% growth		5.3%	4.8%	4.8%	4.9%	4.9%
	Domestic	Total	7,902	9,158	10,202	11,346	12,368	13,230
		% growth		3.2%	2.9%	2.9%	2.8%	2.7%
Base	International	Total	8,779	11,512	13,857	16,630	19,548	22,532
		% growth		6.2%	5.8%	6.0%	6.1%	6.3%
	Domestic	Total	7,902	9,613	11,046	12,652	14,188	15,598
		% growth		4.3%	4.0%	4.0%	4.0%	3.9%
High	International	Total	8,779	11,900	14,719	18,136	21,865	25,825
		% growth		7.1%	6.8%	7.1%	7.5%	7.8%
	Domestic	Total	7,902	9,892	11,691	13,753	15,826	17,834
		% growth		5.0%	4.8%	4.9%	5.0%	5.0%

5.6 External trips (Task 2.4.8)

The macro strategic model has five external zones, representing links to areas outside the model boundaries. One of these zones is to the north of Auckland and four are to the south (see Error! Reference source not found.). The external trip matrices are stored as text files for the base year and factored for future years.

Table 5-28 - External Zones

Zone Number	Site Location
599	SH1 North of Te Hana
600	SH2 East of SH1
601	SH1 South of Pokeno
602	River Rd
603	Wily Road

Count data for March 2016 was sourced for each of the external zones from either the Auckland Motorway Alliance or Auckland Transport RAMM data. The counts for each site, direction and time period are shown in **Table 5-29**. The number of vehicles crossing has increased by around 35% overall from 2006 to 2016 for the three time periods considered.

Table 5-29 - External Counts

			AM (7AM – 9AM)		IP (9AM – 3PM)		PM (4PM – 6PM)	
Direction	Zone	Site	2006	2016	2006	2016	2006	2016
Into Auckland	599	SH1 North of Te Hana	360	512	1421	2481	578	753
	600	SH2 East of SH1	580	728	2036	3351	658	1015

Direction	Zone	Site	AM (7AM – 9AM)		IP (9AM – 3PM)		PM (4PM – 6PM)	
			2006	2016	2006	2016	2006	2016
	601	SH1 South of Pokeno	952	1178	3054	4293	1322	1646
	602	River Rd	379	258	648	912	175	608
	603	Wily Road	317	32	510	130	106	92
Out of Auckland	599	SH1 North of Te Hana	524	523	1501	2335	684	905
	600	SH2 East of SH1	535	762	1906	3369	984	1264
	601	SH1 South of Pokeno	1022	1317	3231	4369	1443	1859
	602	River Rd	150	566	596	922	327	299
	603	Wily Road	69	82	541	138	321	43

In order to create the 2016 external matrices, two key steps were implemented:

1. Apply growth to and from north, central and southern sectors in proportions consistent with the 2006 model (which used intercept surveys to establish distributions). The sectors are shown in Figure 4 18Figure 5 7, and are as follows:

   a. in the north near external zone 599 (red zones)

   b. in the south near external zones 600-603 (blue zones)

   c. the rest of Auckland (green zones)

2. Apply growth within a sector proportionally to changes in zonal land use between 2006 and 2016. This was either households (AM outbound, IP, PM inbound) or employment (AM inbound, PM outbound).

The same process is also applied for the future year external matrix with growth applied at a sector level consistent with intercept surveys, but at a zonal level within a sector proportionally to the land use changes within that sector.

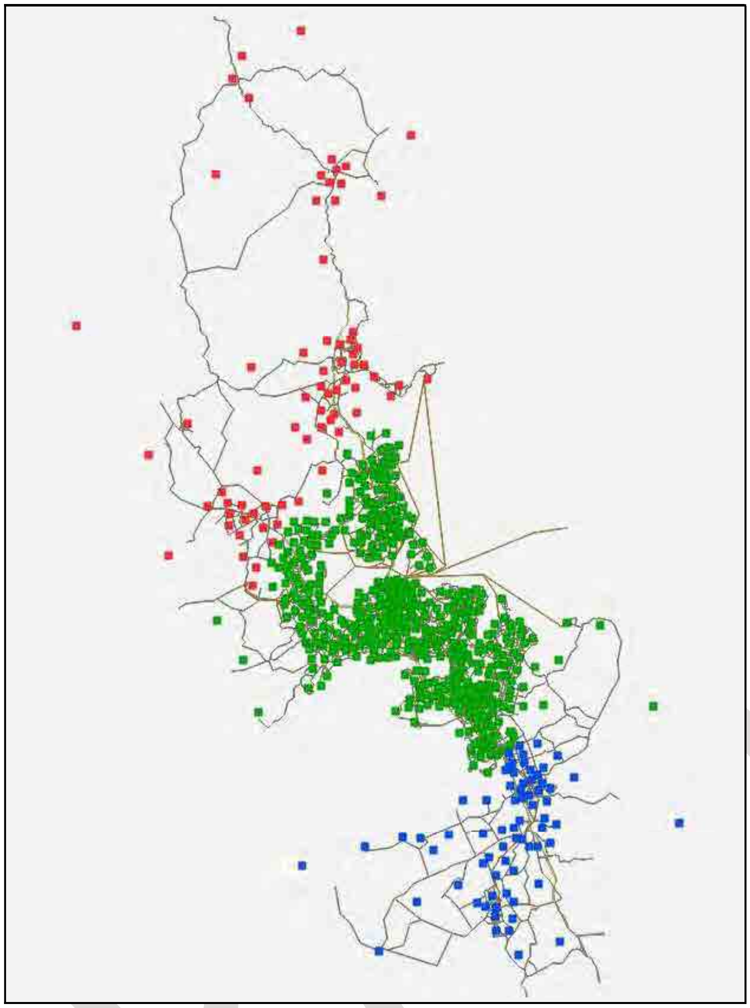


Figure 5-20 - Sectors used for external trips disaggregation process

The following data was used in this process:

- 2006 external trip matrices (AM/IP/PM)
- 2016 external counts (AM/IP/PM, both directions)
- 2006 and 2016 land use (households and employment)

5.7 Parking Costs

The original model allocated 50% of parking costs to the inbound and 50% to the outbound trip, however this was only applied to destinations, meaning the full all-day parking costs were not fully captured. This was modified to include parking costs for trips originating in zones with parking costs.

5.8 School bus trips (Task 2.4.9)

The MSM uses a set of time period factors for all HBE PT trips. These factors were initially developed as part of the ATM2 project using data from the 2006 HTS. Generally these factors are suitable for primary and secondary school trips which are mostly in the AM and SP periods. However these factors are not quite suited for tertiary trips, which are widely distributed across the whole day.

Tertiary time of day adjustments

Tertiary education trips were extracted from the HOP data for all periods and compared with the modelled tertiary trips. The modelled tertiary trips are defined as HBE trips to/from zones where tertiary school rolls are >300 and tertiary to primary/secondary roll ratios are greater than 3:4 or 75%. **Table 5-30**shows the comparison of daily distribution between the modelled and HOP data.

Table 5-30 - Tertiary Trip Comparison

	AM	IP	SP	PM	OP	Total
Modelled	20,150	5,980	11,930	12,800	2,610	53,480
Observed	12,350	6,580	3,930	10,610	10,830	44,300
% Diff	63%	-9%	203%	21%	-76%	
Ratio (obs/mod)	0.61	1.10	0.33	0.83	4.10	
Ratio with 10% allowance	0.71	1.00	0.43	0.93	4.04	

The table shows the model over-estimates tertiary trips significantly in AM and SP, and under-estimates in the OP period. Hence the following steps were made to adjust the modelled HBE PT trips:

- Modelled HBE trips were adjusted with a multiplicative factor for each period. 10% allowances are made which means the modelled numbers were not forced to match observed precisely.
- After the initial adjustment to all periods, another adjustment was made to maintain the modelled daily total to/from tertiary zones.
- Although most of the tertiary zones are generally separated from other activities, there could be some houses in these zones. Hence only ‘to’ tertiary zone trips were adjusted for AM and ‘from’ for PM peak. Both ‘to’ and ‘from’ trips were adjusted for other peaks.

School Bus & Under 14 Adjustment

The HBE PT trips generated by the DMS model include both those using public passenger transport and private contracted school buses, and they are not included for under 14 year students. Hence two adjustments were made as below:

- Private contracted school bus passenger trips (>=14 years) were estimated and removed from modelled HBE trips before the final assignments. This is because only scheduled public services are represented in the assignments. Previously, this was done by applying the 2006 HTS proportions of school bus trips to all HBE PT trips by 5 sectors by time period.
- An estimate of the proportion of under 14 year student trips was determined from HOP data and applied back to the HBE trip before the final assignment. This is because the observed HOP data includes HBE trips for all ages.

For the private school bus adjustment, observed school bus matrices were extracted from the HOP data. In the HOP data, there is a ‘Child’ ticket classification which represents students 15 years or younger. Hence some assumptions (20% of Child + Non Child) were made to estimate the school bus trips for students 14 years or older. Then the 2006 process was updated with a more refined 10 sector systems. A sector map is provided in **Figure 5-21** and the adjustment factors are tabulated in**Table 5-31**. Note that school bus trips are mostly in AM and SP and hence adjustment was only made to these two periods.

Figure 5-21- A 10 Sector Map for School Bus Adjustment

Table 5-31 - Adjustment Factors for School Bus

Sector	1	2	3	4	5	6	7	8	9	10
AM Peak										
1	0.95	0.65	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.95	0.95	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Sector	1	2	3	4	5	6	7	8	9	10
3	0.95	0.67	0.80	0.00	0.00	0.07	0.00	0.00	0.00	0.00
4	0.00	0.25	0.28	0.89	0.29	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.01	0.63	0.34	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.17	0.13	0.00
7	0.00	0.00	0.00	0.00	0.00	0.35	0.04	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.75	0.18	0.95
9	0.00	0.00	0.00	0.00	0.00	0.54	0.03	0.00	0.60	0.05
10	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.51	0.92
School Peak										
1	0.95	0.95	0.95	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2	0.42	0.95	0.46	0.20	0.00	0.00	0.00	0.00	0.00	0.00
3	0.22	0.29	0.74	0.13	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.70	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.27	0.51	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.03	0.00	0.29	0.40	0.02	0.15	0.47	0.06
7	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.02	0.00
8	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.62	0.03	0.00
9	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.45	0.47	0.28
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.04	0.61

After the school bus adjustment, an “under 14 HBE” adjustment was made in the MSM to be consistent with the observed HOP data (which includes under 14 year olds) and the MPT. This adjustment was not undertaken in the previous ART3 model where under 14 year olds were excluded from the data. Adjustment factors were estimated using the observed HOP data. AM peak estimated under 14 year olds trips are 20% of total HBE trips (which include both under and over 14 year olds) and in the PM peak this proportion is 33%. These trips are only added to zones where primary school rolls are located, rather than the global expansion.

5.9 Model Calibration and Validation

The 2016 model was calibrated in Phase 1, including documentation and peer review. Following some minor changes in Phase 2, the calibration and validation was updated. The updated validation is included later in the Phase 2 section of this report.

6 Phase 1 MPT Updates

6.1 Macro PT model Networks and Services

March 2016 services were provided by AFC, and the networks updated to 2016. This included making rail and ferry networks consistent with the MSM. The updated fare structure was applied and assignment and generalised costs tested.

6.2 Macro PT model demands

The base year PT model uses the observed total PT demand matrix directly, so a critical task of the refresh was updating the base year matrices.

Auckland HOP data provides a rich data source for PT trips in Auckland that covers <95% of all trips. This has required significantly less expansion that previously required in 2013 when this level of data was not available. A new system has been set up mostly in FME, with a SQL component in the beginning and an Access component at the end to convert the raw HOP database into PT matrices, screenline flows and transfer information. A semi-automated GIS process is also setup to snap screenline links to roads.

The **Figure 6-1** shows the HOP data analysis process:

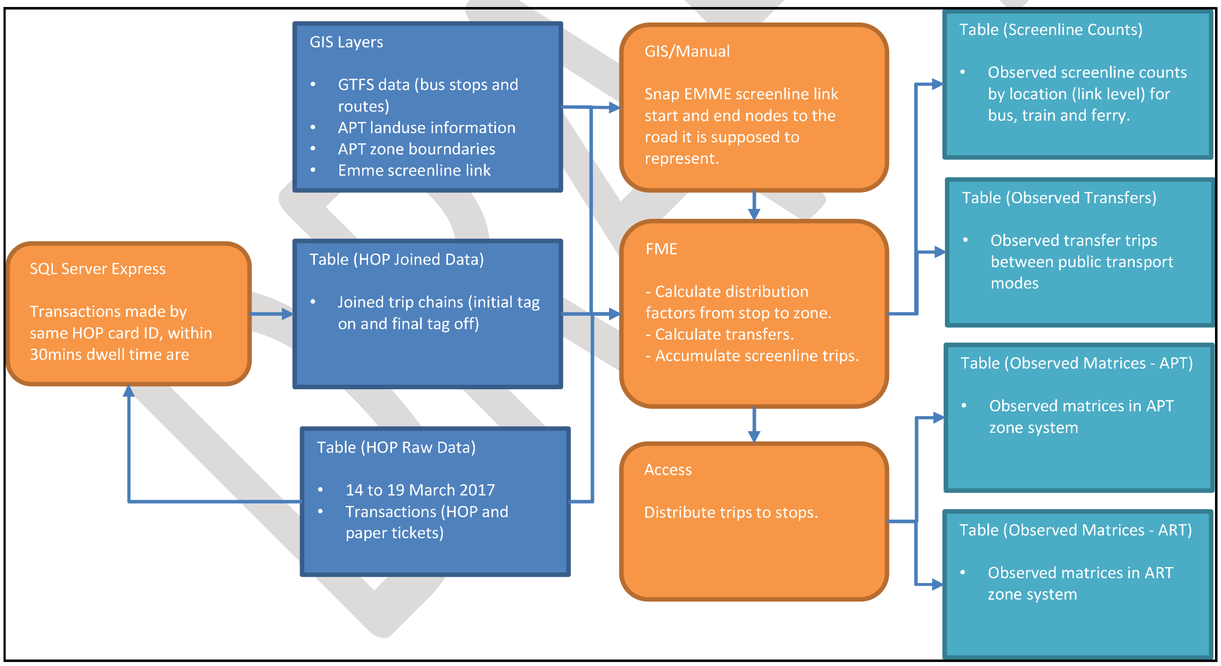


Figure 6-1- HOP processing system

The PT matrix generation process produces observed public transport matrices at the macro strategic and macro PT model zone level based on HOP data, for the following peak periods:

- AM: 07:00 to 09:00
- IP: 09:00 to 15:00
- SP: 15:00 to 16:00
- PM: 16:00 to 18:00
- OP: 18:00 to 07:00

~~All these matrices are produced by PT sub-mode (bus, train and ferry). Trips made by children less~~

than 14 years of age and via school buses also require separate matrices. Trips made via park and ride stations are split into walking and non-walking categories.

PT screenline counts have been generated from the HOP data at predefined individual screenline locations. This has been done by period (AM, IP and PM) and by mode. School bus trips are excluded from the screenline outputs. Table of observed transfers from also been generated from the HOP card data.

6.3 Model Calibration and Validation

The 2016 AM peak model was calibrated in Phase 1, including documentation and peer review. Following some minor changes in Phase 2, the calibration and validation was updated. The updated validation is included later in the Phase 2 section of this report.

7 Phase 2 MSM Updates

This chapter describes the minor refinements added to the MSM during Phase 2. The updated validation is included in a subsequent chapter. The task numbers in brackets refer to tasks explained in the Phase 2 specification report previously referred to.

7.1 Consideration of Zone Refinement

A number of options were considered for the zone refinement of the Macro Strategic Model (MSM). They were separate for PT and private vehicles and were aimed at improving the precision and responsiveness of the MSM.

The PT options were:

1) Disaggregate the PT zone system to the Macro PT model 1,100 zone system
    a. For the final assignment only
    b. For generating generalised costs for use in the DMS models; i.e. the costs from the finer zone system would be aggregated to the Macro Strategic model 600 zone system
2) Adopt the Macro PT model logit sub-mode split after the DMS models just prior to the final assignment
3) Incorporation of PT observed matrices from HOP data in the MSM
    c. In the final assignment only
    d. In the full DMS models

For the private vehicle options were:

4) Refine car zone system to the Macro PT model 1,100 zone system
    a. In the final assignment only and only output results from either 600 zone assignment or 1,100 zone assignment.
    b. For generating generalised costs for use in the DMS models; i.e. the costs from the finer zone system would be aggregated to the Macro Strategic model 600 zone system; for smoothing assignments and stability.

The following sections outline the work undertaken to assess both the PT options and the highway options, and provides a recommendation based on this assessment.

7.1.1 Re-estimation of the DMS model (Task 5.3)

As noted above, Phase 2 considered a detailed refinement of the MSM zone system to match the MPT system. It was however noted that such a task would fundamentally change the basis on which the original DMS was calibrated, and therefore be likely to need re-estimation of the DMS. This option was rejected as it was contrary to the guiding principles and scope of the refresh. Re-estimating the model to the 2006 data was not considered worthwhile given the age of the data.

Additionally, it was noted that the MSM and MPT models have different purposes and therefore different structures. MSM is structured to suit more aggregate, longer-term and ‘strategic’ forecasts with MPT focused on more detailed PT predictions. As such, the justification and even appropriateness of a more detailed zone system in MSM is considered questionable. For both these reasons detailed zone refinement[8] with recalibration of the DMS was not adopted.

7.1.2 Preferred PT Option Assessment (Task 4.1)

In the Phase 1 workshops a general preference was expressed for the Option 1b implementation, as detailed below.

Option 1b – Disaggregate the PT zone system to the Macro PT model 1,100 zone system. This would be done for the purpose of generating generalised costs for use in the DMS models; i.e. the costs from the finer zone system would be aggregated to the Macro Strategic model 600 zone system

The other options were rejected for the following reasons:

- Option 1a can be undertaken already in the Macro PT model
- Option 2 can be undertaken already in the Macro PT model
- Option 3a can be undertaken already in the Macro PT model
- Option 3b would produce inconsistencies with the MSM DMS calibration

Option 1b was thought to have potential benefits of smoothing assignments and potentially providing more stable results that have a greater level of consistency with the Macro PT model. As such it was decided not to take the other options forward for testing.

7.1.3 Testing Undertaken

In order to confirm (or otherwise) these benefits, the following tasks were undertaken:

- Update the Macro Strategic model (existing AM peak only at this stage) to assign PT trips at the 1,100 zone system level to skim costs off.
- Aggregate these costs and establish the impact upon the DMS model and fine tune the DMS models if required to more closely reflect observed data
- Confirm whether the option improves the representation of PT metrics in the Macro Strategic model in the AM peak
- Document the outcomes

7.1.3.1 Option 1b

Similar to the highway work undertaken, due to licence size limitations, a separate Emme database was required in order to test the more detailed zone system in the MSM. The separate database was created in a test environment with the required dimensions for running an AM peak highway assignment, so that results could be compared back to the standard MSM output.

Given that the networks between the MSM and MPT models take the same form aside from centroid connectors (and some extra attribute settings), it was possible to combine the two networks by taking links and nodes from the MSM (exported just prior to assignment in MSM) and adding centroid connectors from the MPT model which were aligned with the more detailed (1,122) zone system.

The PT assignment takes place on the already assigned highway network, and so exactly the same process was followed as for the highway network creation and assignment. The final PT assignment macro is self-contained (i.e. it does not call any other macros), but it does require some network inputs which are not included in the main network build stage. These include information on rail and ferry times and on airport trips. These files were not exported from the MSM, but instead the input

[8] Noting that Phase 1 included some zone refinement in greenfield growth areas. Those refinements were considered necessary for future forecasting of the growth areas, and recalibration of the DMS was not considered necessary as the extremely low volume of travel in the greenfield areas would not be likely to materially alter the 2006 DMS calibration.

files from the MSM assignment (for the year 2016) were copied into the relevant locations for the new network assignment.

In the PT assignment there is a specific “P” mode, which is used as a proxy for highway trips to park and ride sites – allowing the park and ride trips to be captured by the PT assignment. “P-connectors” connect centroids to key network nodes, with a fixed speed of 20km / h. Where a zone with a p-connector had been split into two zones, both of the new centroids were connected to the relevant network nodes with p-connectors the same length (and so the same travel time) as the original node.

During the final PT assignment there is a process which adjusts the network, and in doing so it acts to increase the number of links which are assigned mode p, and so can act as centroid connectors. During the initial testing process the treatment of these park and ride trips was not able to be fully updated due to complexities involved. As such in the initial assignment testing a large volume of auxiliary trips were observed, since users were able to travel large distances on the network at 20kp/h without experiencing any penalties normally associated with PT use (boarding, interchange etc).

To avoid the problems with a large level of auxiliary trips, the final PT assignment macro was adjusted to remove the park and ride connectors – users are still able to access park and ride sites but not at the increased speed. The relatively low number of people who travel large distances to access park and ride means that this was considered to be an appropriate compromise for initial testing purposes, and unlikely to have a significant impact on the assessment of the potential benefits of the new zoning system.

Network comparison plots for are provided below for public transport in the AM peak for 2016 based on initial testing.

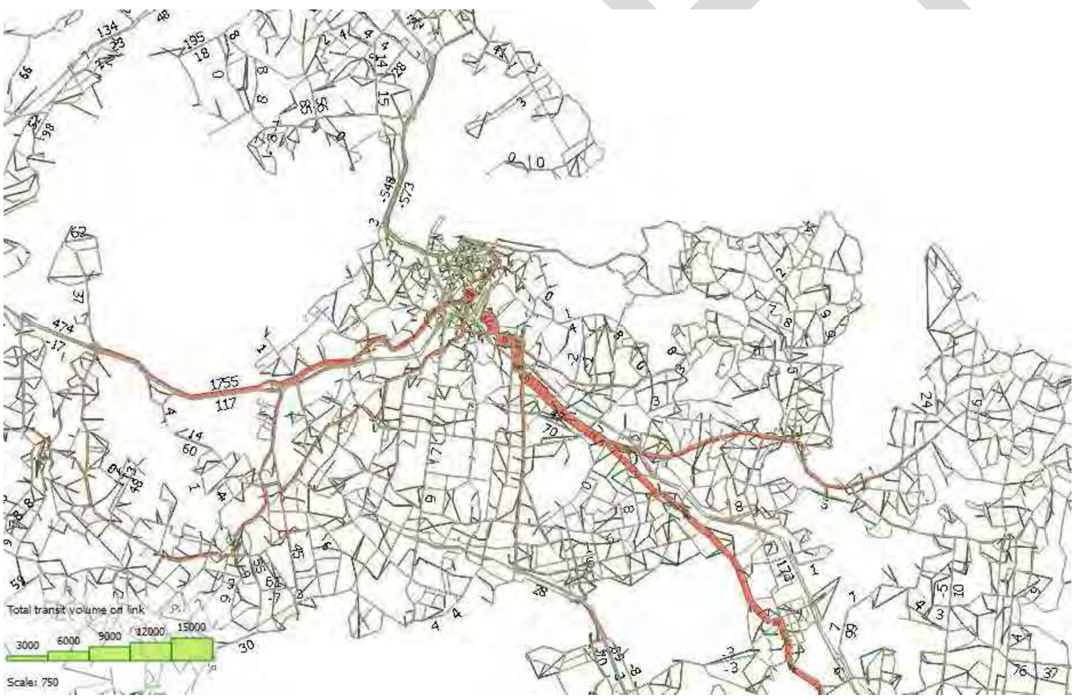


Figure 7-1- Absolute Change in Transit Volumes (Wide) – green bars indicate a decrease with the more detailed zones

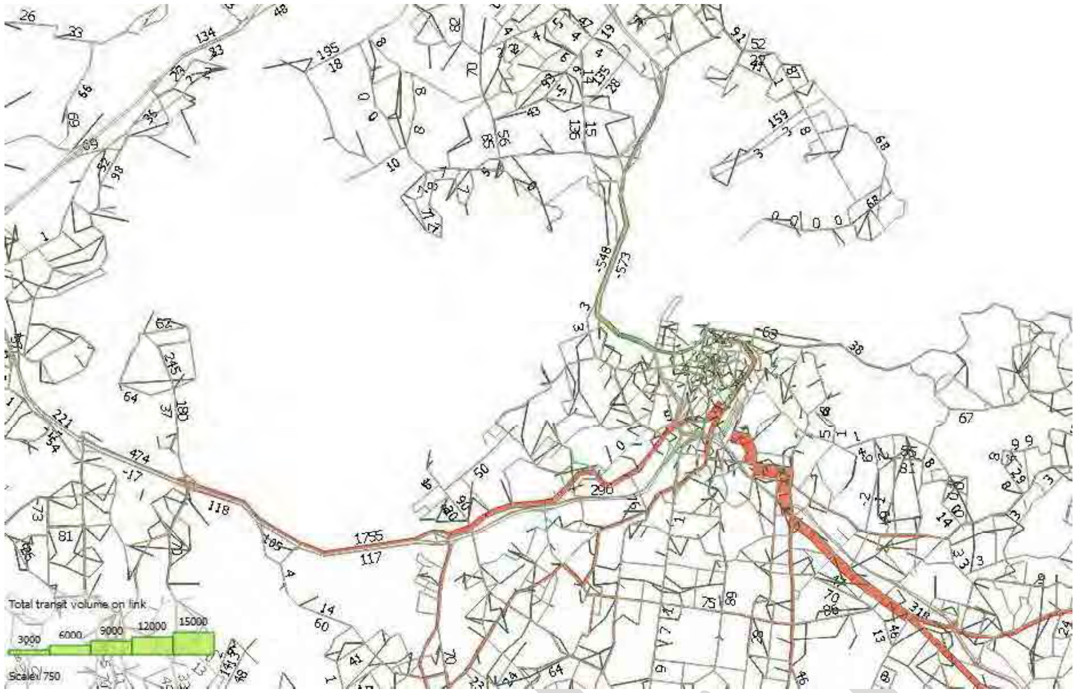


Figure 7-2- Absolute Change in Transit Volumes (Central) – green bars indicate a decrease with the more detailed zones

With the new model zoning there is a decrease in the number of rail trips taken, and an increase in the number of bus trips taken. This is reflected in both the screenline and boarding validation metrics, which show a switch in modes of nearly 20%. There is also a reduction in ferry usage with the new modelled zones.

Based on the issues encountered with the highway assignment zone disaggregation, the public transport disaggregation was not taken further than this initial testing.

Similar impacts were also expected for public transport in terms of cost aggregations for DMS, which could be comprised through the zone disaggregation/re-aggregation process and not be compatible with the calibrated DMS model parameters.

7.1.4 Recommendations

Based on the initial assessment of public transport assignment at the more detailed zone system, there was no compelling evidence to make the adjustment from the current 600 zone MSM process. This recommendation is also tied to the findings on the highway assignment testing.

Part of the recommendations outlined for the highway/auto assignment disaggregation considerations are even more relevant for the public transport assignment, in that the Macro PT model already assigns public transport at a more detailed level and this model can be used for planning needs at the more detailed level.

Whilst a more refined zone system in MSM may provide better “base” matrix data for the MPT model in terms of future growth at a more detailed level, the complexities and challenges/issues associated with setting this up to work correctly (and efficiently) mean that it is not recommended.

As for the highway/auto assignment, any future changes to the zone system in MSM should be tied to a re-calibration of the DMS model, using the more detailed zone system the entire way through the model.

7.1.5 Private Vehicle Option Assessment (Option 4) (Task 4.2)

~~In order to establish the value of a more precise assignment at the more detailed zone level, the~~

following tasks were undertaken:

- Develop and implement a disaggregation methodology from the 600 zone to 1,100 zone system for private vehicles.
- Design processes to run the Macro Strategic model road assignments at the 1,100 zone system
- Check the Macro Strategic model private vehicle validation and document the outcome
- Provide a recommendation on the preferred final assignment process (600 zone or 1,100 zone)

7.1.5.1 Option 4a

Due to licence size limitations, a separate Emme database was required in order to test the more detailed zone system in the MSM. This was opposed to a scenario where the alternate zone system would be built into the existing database. Creating such a scenario is generally not recommended due to the complexities it causes in terms of matrices within the database – not to mention likely impacts on model run times due to increased databank dimensions.

The separate database was created in a test environment with the required dimensions for running an AM peak highway assignment, so that results could be compared back to the standard MSM output.

Given that the networks between the MSM and MPT models take the same form aside from centroid connectors (and some extra attribute settings), it was nearly possible to combine the two networks by taking links and nodes from the MSM (exported just prior to assignment in MSM) and adding centroid connectors from the MPT model which were aligned with the more detailed (1,122) zone system. Due to a number of other processes involved in the network setup and assignment this proved challenging in terms of preparing the network precisely as per the standard MSM within the test environment created.

A number of Emme macro registry settings were also required to be copied over from the original MSM to the test environment in order to attempt running the more detailed zone assignment. In addition, a number of additional macros were required as there are several processes that make up the final assignment. These macros were copied over along with the relevant registry entries and attributes.

In total 55 attributes were copied from MSM, these were a mix of node, link, transit line, transit segment and turn attributes. These values were copied from the 2016 MSM model run, ensuring that (for those attributes not re-calculated by the final assignment process) the values used with the new network were appropriate – without the need to implement the entire model run process.

Standardised registry entries were copied from the main MSM assignment set up macro, and added to an edited version of the final assignment macro.

Edits were also made to macros to remove (where appropriate) reference to other time periods, as these were not required for the initial testing work which focused on the AM time period only.

For the demand matrices, a disaggregation process was required to convert the 603 zone MSM demands into the 1,122 zone system. Existing disaggregation factors that had been created for use in the MPTM were available and these factors were deemed suitable for testing purposes using the more detailed zone system. The factors were available initially for the AM and IP period, and these have been calculated previously based on demographic information at the sub-MSM zone level.

Following application of the disaggregation factors, a comparison of the matrix totals was undertaken to confirm that no trips had been lost during the disaggregation process. This resulted in less than 0.1% difference in matrix totals.

A trip assignment for the AM peak was carried out and compared against the original MSM assignment results. Due to complexities with matching all required link attributes, turn penalties and intersection/VDF calculations between the two models, a completely like for like scenario was not able to be produced without significant additional time and effort to bring the two networks to a perfect match.

The set up and testing demonstrated that it is not straight forward at all to set up an assignment at the more detailed zone system whilst maintaining all network characteristics as per the standard MSM. This outcome was anticipated prior to testing and adds to a number of other reasons why such a change to the MSM is not recommended in its current state. A summary of these issues is presented in the recommendations section of this chapter.

7.1.5.2 Option 4b

Given that a perfect like for like comparison could not be created without significant additional effort, the idea of aggregating costs back to the 600 zone level to be used in the DMS process was therefore not investigated further. In any case, it is expected that aggregation of such costs may lead to potential issues within the DMS, given that the distribution and mode choice models were calibrated based on the more detailed zone system, and therefore any change to the cost distribution will likely have an impact on distribution and mode shares produced by the DMS.

7.2 Review of Auto Assignment Parameters (Task 4.3)

This task involved developing appropriate methods to reflect road perception factors in the auto assignment. Tasks included:

- Consideration of methods, such as time or distance factors
- Testing
- Documentation and recommendation

7.2.1 International experience review

Road perception factors are included in a number of models within New Zealand, typically via a factor on distance. These have been found to be necessary to calibrate traffic assignment on roads where the travel time does not adequately represent the attractiveness of the road.

Some research was undertaken on potential approaches to the application of "road perception" factors in the MSM model. The inclusion of such parameters was not being targeted at any specific improvements or to address particular issues in the MSM, however such factors were considered to be a useful addition to the model in that it provides further flexibility to improve model route choice performance, particularly in the use of higher order versus lower order roads (and further, for toll roads).

Some brief discussion/thoughts are provided below verbatim based on current observations in the market, provided by a selection of senior transport consultants from the Jacobs Australia team.

Scott Wilkinson (Jacobs Sydney office – ANZ Technical Director Transport Modelling)

Application of quality of time factors rely on the time/delays being split into categories. Different perception weights can then be applied to result in a total "perceived time". Some observations on this are:

- *The time in categories might be calculated as*
- *a specific component of the volume delay curve (VDF) – e.g. intersection delays or*
- *time over a general threshold – e.g. using V/C or speed bands*
- *When we have applied this, we have used a single VDF (and therefore a single set of congestion weights) across all links. You could apply a varying parameters approach across your different types of links by using different VDFs although I am not convinced of the sense of that.*
- *We have applied weights in Sydney/Brisbane based on responses in SP/RP VTTS survey analysis for QML (now TransUrban) and WestConnex*
- *Weights applied this way could be considered to also represent some sort of reliability factor.*

- *We have generally been simplifying the weight to be a single value to increase impact of congested time – as opposed to splitting into more explicit congested and stop/start time. Matching the survey definitions and the application in a strategic model is a bit tricky so keep it simple.*
- *If the route choice in the model is generalised cost, then the relativity of these time weights and other weights for other items (like distance, tolls, etc.) will have to be considered. In Sydney model we also have distance weight originally calculated as a surrogate for perceived operating cost. In this instance we had different values for motorway vs non-motorway on the basis that travel speeds were higher on motorways.*
- *Setting up and sensitivity testing could be done readily although some route choice data will be required to verify that the approach and parameters are valid. Sensitivity testing could be used to inspect the sensibility of the approaches.*
- *Applying this presupposes that the VDFs are actually calculating the time on road links at varying demand levels accurately. Could be some challenges imbedding a new process within the existing intersection delay process. Weight on congestion time will tend to make the assignment less stable or at least take more time to converge.*
- *I notice that the range of @ja parameter values are fairly low. Recommended range wide and between 0.1 and 5. Values below in the table max out at 1.8. Higher values will tend to provide more impact at lower V/C ratios and help keep traffic out of low hierarchy roads.*

Scott Elaurant (Jacobs Adelaide office - Senior Transport Planner)

I have seen an assignment modelling approach used called "Space Syntax" which uses an entirely different approach to network assignment, based on the width of each corridor i.e. wider corridor = more attractive to user. However, I have also read some mathematical criticisms of this approach, and some potential paradoxes that can arise from it.

Having worked a lot in Auckland on the LRT project (doing microsimulation tram modelling, not strategic) I would say another large factor not considered is the amount of pedestrian movements and retail activity in a corridor influencing vehicle traffic assignment. You tend to want to avoid roads with lots of pedestrian activity. The free flow speeds of some CBD links in Auckland could be debated i.e. actual speed is lower than the 40-45 km/hr suggested in the table.

Peter Hunkin (Jacobs Melbourne office – ANZ Technical Director Transport Planning)

The whole 'perception' issue is an interesting consideration.

My past experience has been similar to Scott Wilkinson in that there are often weightings given to the link based on congestion levels (typically V/C ratio)

These have been shown to work in a generic sense but Scott Elaurant comments on the CBD conditions is a useful indicator that there may need to be some roads that are treated differently to reflect the conditions – perhaps the Ja values need further refinement, or maybe further parameters introduced to reduce the attractiveness of the 'shortest' route in some cases, especially CBD and high pedestrian activity areas

7.2.2 Options for Consideration

A distance based road quality perception approach had been tested back in 2006 for the ART model, and was considered a more simplistic approach, however was rejected at the time due to complexities with skimming pure distance from the resulting generalised cost matrix. This limitation is no longer an issue with the latest assignment algorithms and post assignment analysis available within the Emme software modules.

A summary of potential implementation options was prepared below for consideration.

Table 7-1 - Implementation Options

Option No.	Option Description	Level of Effort	Model Implication
1	Space Syntax - different approach to network assignment, based on the width of each corridor i.e. wider corridor = more attractive to user	High	Some mathematical criticisms and potential paradoxes that can arise. Would completely change current process.
2	Consider use of speed factors/adjustments for higher friction links	Low	Improved assignment route choice – likely small impact on model calibration
3	Further refinement of Ja parameters – increase range to between 0.1 and 5	Low	Improved assignment route choice – likely small impact on model calibration
4	Quality of Time factors	Medium-High	Improved assignment route choice. May have major issues with model stability and run times, potential impact on DMS calibration
5	Distance based road perception factors by link type	Low	Improved assignment route choice – likely small impact on model calibration. Skimming issues can be rectified with use of path based assignment.
6	Parameters to reduce attractiveness of 'shortest' route eg. CBD/high ped areas	Low? Probably applied with one of the methods described above	Improved assignment route choice – likely small impact on model calibration

7.2.3 Testing and results

In order to understand the implications of an environmental / road perception factor, it was proposed to test the more simplistic distance based factoring approach (option 5 from **Table 7-1** above).

In order to test such an approach, factors developed previously for testing in the ART model back in 2006 (as discussed above) were included in the MSM process, applied as follows.

The assignment path-build is based on a generalised cost which uses a combination of time and a link fixed cost. The link fixed cost in the standard MSM is made up of the toll cost and then the vehicle operating cost multiplied by the link distance. In order to test a distance based environmental factor,

the equation was updated as follows:

$$\text{Link Fixed Cost} = Toll + VOC * len * environmental\_factor$$

These environmental/road perception factors were applied by link type, with a minor penalty applied to local roads and a 'discount' applied to motorways as shown in the table below. It should be noted that link type 1 (zone connectors) do not have an environmental road perception factor associated with them.

Because these factors were applied to the perceived vehicle operating cost (8c/km) their effect is fairly subtle on route choice.

Table 7-2 - Current MSM Link Parameters with Environmental distance factor applied

Link Type	Description	Typical Free Speed (km/hr), @v0	Typical Lane Capacity (veh/hr/lane), @q	@ja	Factors tested	Adopted final factors[9]
1	Centroid Connector	40	5000	N/A	1	1
2	Centroid Connector – Walk/Cycle	40	5000	N/A	1	1
11	CBD/Shopping – high friction	40	600	1.8	1.5	1.5
12	CBD/Shopping – low friction	45	800	1.6	1.5	1.5
13	Local	45	1000	1.2	1.6	1.6
14	Collector – high friction/poor alignment	48	1100	1.2	1.4	1.4
15	Collector – low friction/good alignment	48	1200	1.0	1.4	1.4
16	Urban arterial – low speed	50	1300	1.0	1.3	1.3
17	Urban arterial – high speed	50	1400	0.8	1.1	1.1
18	Expressway	95	1800	0.8	0.8	0.9
19	Motorway	100	2000	0.2	0.8	0.9
20	On-ramp	70	1800	0.2	0.8	0.9
21	Off-ramp	70	1800	0.2	0.8	0.9
22	Rural – level	100	1400	1.4	1.0	1.2
23	Rural – rolling	85	1300	1.4	1.1	1.3
24	Rural – mountainous	75	1000	1.4	1.2	1.3
25	Rural highway – townships	70	1400	1.4	1.3	1.3
26	Rural highway	60	1000	1.4	1.4	1.4
27	Rural Other	50	850	1.4	1.5	1.4

Two model tests were undertaken, in model scenarios utilising the path based assignment algorithm (for both the base case and scenario tests).

Scenario 1 applied the factors in the final assignment only, whilst Scenario 2 applied the factors throughout the model looping process, enabling feedback of the updated route choice and related time/distance/cost skims to be fed back through the distribution and mode choice process.

A selection of AM peak Emme model output plots are following which to compare the auto link results between the scenarios with road quality factors applied compared to the standard MSM path based assignment model run. Red bars in the diagrams show higher volume with road quality factors applied.

Validation comparisons are also provided below between the various scenario tests in terms of GEH performance across both screenlines and individual links. These tables demonstrate that inclusion of road perception factors leads to a very minor improvement in performance, even without any validation adjustments to improve performance with the perception factors included. Comparison of the full looping process inclusive of distance factors with inclusion in final assignment only shows very little difference in overall results.

Either way, the tests also demonstrate that there does not appear to be any adverse effects from the inclusion of the road perception factors. Trip matrix totals were also checked and showed very little difference with or without the perception factors.

[9] These are the final parameters adopted during the MSM calibration

Table 7-3 - Base - Path based assignment - standard model run

Screenline Total

GEH	AM	IP	PM
< 5	64%	86%	71%
< 10	93%	100%	96%
< 12	96%	100%	100%
Proportion of screenlines with % difference < 10	96%	100%	93%
R^2	0.992	0.995	0.993
RMSE	6%	5%	5%

Individual Link

GEH	AM	IP	PM
< 5	38%	44%	34%
< 10	72%	76%	73%
< 12	81%	85%	78%
Proportion of screenlines with % difference < 10	62%	64%	59%
R^2	0.945	0.954	0.937
RMSE	26%	26%	27%

Table 7-4 - Scenario 1 - Path based assignment – with road quality factors applied in final assignment only

Screenline Total

GEH	AM	IP	PM
< 5	64%	82%	71%
< 10	93%	100%	96%
< 12	100%	100%	100%
Proportion of screenlines with % difference < 10	96%	100%	93%
R^2	0.992	0.995	0.994
RMSE	6%	5%	5%

Individual Link

GEH	AM	IP	PM
< 5	40%	45%	38%
< 10	72%	76%	71%
< 12	82%	85%	78%
Proportion of screenlines with % difference < 10	63%	62%	60%
R^2	0.945	0.953	0.938
RMSE	27%	26%	27%

Table 7-5 - Scenario 2 - Path based assignment – with road quality factors applied – full looping

Screenline Total

GEH	AM	IP	PM
< 5	68%	82%	71%
< 10	89%	100%	96%
< 12	93%	100%	100%
Proportion of screenlines with % difference < 10	96%	100%	96%
R^2	0.991	0.995	0.994
RMSE	7%	5%	5%

Individual Link

GEH	AM	IP	PM
< 5	40%	45%	39%
< 10	72%	77%	70%
< 12	81%	84%	78%
Proportion of screenlines with % difference < 10	65%	63%	61%
R^2	0.945	0.954	0.939
RMSE	27%	26%	27%

Volume differences were also compared for the Interpeak (IP) and PM peak periods and showed similar trends to the AM peak plots shown in this report. The plots demonstrate that there are some benefits to including the road perception factors purely in terms of providing additional route choice "levers" to help match observed travel behaviours across various link types. As a general rule the factors are set up in a way that favour higher order roads over lower order roads.

Model looping convergence statistics were also investigated between the various scenarios, with the resulting total number of demand loops by scenario:

- Base Case: 9 loops
- Scenario 1: 9 loops
- Scenario 2: 7 loops

This outcome would suggest that the inclusion of perception factors throughout the full model looping process leads to a quicker overall model looping convergence in terms of demand model trip matrix and network travel time changes.

7.2.4 Recommendation

Based on the testing undertaken it was recommended through project meetings with the client and peer review specialists that road distance factors be included in the MSM update as part of the full looping process. It is noted here that further minor adjustments to the road perception factors were incorporated during the model validation process, and final perception factors along with initial perception factors were provided in **Table 7-2.**

7.3 Review of auto assignment methods (Task 5.8)

Following on from the investigations completed in Phase 1 to assess latest innovations in Emme auto assignment algorithms, the Path-based algorithm was preferred over the SOLA assignment process.

Since the completion of Phase 1, the new version of Emme recently released (currently version 4.3.6) now has the capability to undertake cordon analysis, which previously was a minor flaw in its potential application. This recent improvement in the path based module, along with added benefits offered by path-based assignment including time efficiency and post processing (select link analysis) capabilities, complement the findings from Phase 1 as the preferred algorithm to adopt.

This task involved implementation of the new path-based assignment module along with associated macros for undertaking select link and cordon analysis. The assignment process was also reviewed and streamlined where possible, including a review of the assignment convergence cut-off parameters. The process was to be implemented through macros as there is no need or benefit in terms of efficiency to convert the process to Python scripting.

7.3.1 Overview of Assignment Options

The current macro strategic model uses the EMME standard highway assignment module (module 5.22 with multi-threading) for both the generalised cost assignments and final assignments. While this assignment method can be expanded to be a multi-class assignment process (and there are options as part of the MSM main model macro to run multi-class assignment in the final assignments or through the willingness to pay model), the assignment algorithm has effectively been replaced by INRO with faster more efficient highway assignment modules. There are two improved assignment modules now available that may be used for the macro strategic update as follows:

- Path based assignment (module 5.25)
- SOLA assignment (module 5.23)

Testing of the two assignment processes was carried out as part of the Phase 1 ART refresh work. The pros and cons of the two options were listed in the table below. However there have been some changes since this work was done with INRO releasing updates to both modules. Changes are highlighted in red below.

7.3.2 Pros and Cons of highway assignments

Table 7-6 - Pros and Cons Overview

	Pros	Cons
Path based assignment	▪ All analysis can be extracted from one assignment ▪ Assignment time improves (to a point) with each new assignment using previous paths ▪ Can be implemented via macros ▪ Can now do traversal/cordon assignments	▪ Does not have SOLA PToll capability to allow for toll capping ▪ Some minor proportionality issues exist with traversal assignments in terms of path and class flows
SOLA based assignment	▪ Should be able to implement intersection capacity update process similar to that tested using Path. (not tested as yet) ▪ Traversal assignments can be run hence will get answers much closer to the original assignment cf Path based assignment - no longer an issue since Path based can now do traversals also ▪ SOLA "PToll" capability can be used for complex toll modelling where toll capping on routes may occur. NB –toll modelling generally done as separate process/study as many more classes needed to model Value of Time (VoT) travel cost bins.	▪ Will need to be scripted (via python) to enable all necessary skims, volumes etc to be saved as part of the assignment setup– no longer required, can be implemented through macros ▪ Will require additional analysis assignment to get additional data (e.g. select links, traversals etc) – no longer required, can be implemented through macros ▪ Answers do vary depending on the number of PC processors used. This can be minimised by using very tight cut-off parameters in the assignment setup at cost of assignment run

		time– negligible issue

The path based algorithm was proposed as the preferred assignment algorithm to be adopted for the Phase 2 update (both for the generalised cost assignments and also the final assignments) combined with use of the pre-compiled volume delay functions (*.dll) file which speeds up the path based assignment process. It is noted that either the Path Based or SOLA assignment algorithm could be used for the Auckland models as both offer similar benefits in both speed and functionality. Path based assignment macros were set up during initial Phase 1 testing and were carried through to Phase 2 for efficiency, with the more recent Emme versions including these new features only becoming available during Phase 2 of the project. Some further comments on the SOLA algorithm are included below for completeness.

The alternative SOLA/PToll assignment process offers advantages for specific toll related project modelling (e.g. point to point/ramp to ramp tolls, toll capping), however due to some potential added complexities in implementation (requiring the use of Python depending on the specification required) it was not recommended as the preferred approach for the standard MSM. Standard toll modelling (without toll capping) can still be undertaken using the Path based method as it involves using more cost bins by vehicle class (i.e. more classes in the multi-class assignment) - noting that more classes will also lead to longer model run time. In order to more accurately model toll roads, additional Value of Time data (related to toll road use) is required by user type - usually requiring surveys.

The MSM updated in Stage 1 of the project was undertaken with quite relaxed assignment cut-off parameters and these can be tightened to achieve better convergence particularly for future year models. Run time increases as a result may need to be monitored, however the path based algorithm provide efficiencies in achieving a tighter convergence cut-off. It is noted that SOLA assignment can also achieve similar benefits in terms of tighter convergence and potentially faster run times than the Path based algorithm, depending on the specifications of the PC being used to run the model.

As mentioned, the path based algorithm also makes use of a pre-compiled Volume Delay Function file (*.dll format), which provides added efficiency to the model run times (usually performing at a rate of twice as fast or better when this file is stored with the model database).

The previous Stage 1 MSM used a single class assignment and therefore required two skim assignments per time period to obtain the necessary skims for distribution/mode choice. Both the newer assignment methods allow the skim matrices to be obtained from a single assignment. With the Path based assignment the skim matrices are obtained by post analysis using module 6.16. It should also be noted that the Path based assignment allows for post analysis for all data such as turns, assigned volumes, select link data as well as now cordon analysis. [As an aside, the SOLA assignment is now also capable of running multiple path analysis which needs to be pre-specified to save the necessary skims as part of its assignment specification.]

It is also noted that the Path based assignment requires matrix rounding for implementation and all matrices have been rounded to 3 decimal places. The algorithm is also capable of running up to 240 vehicle classes.

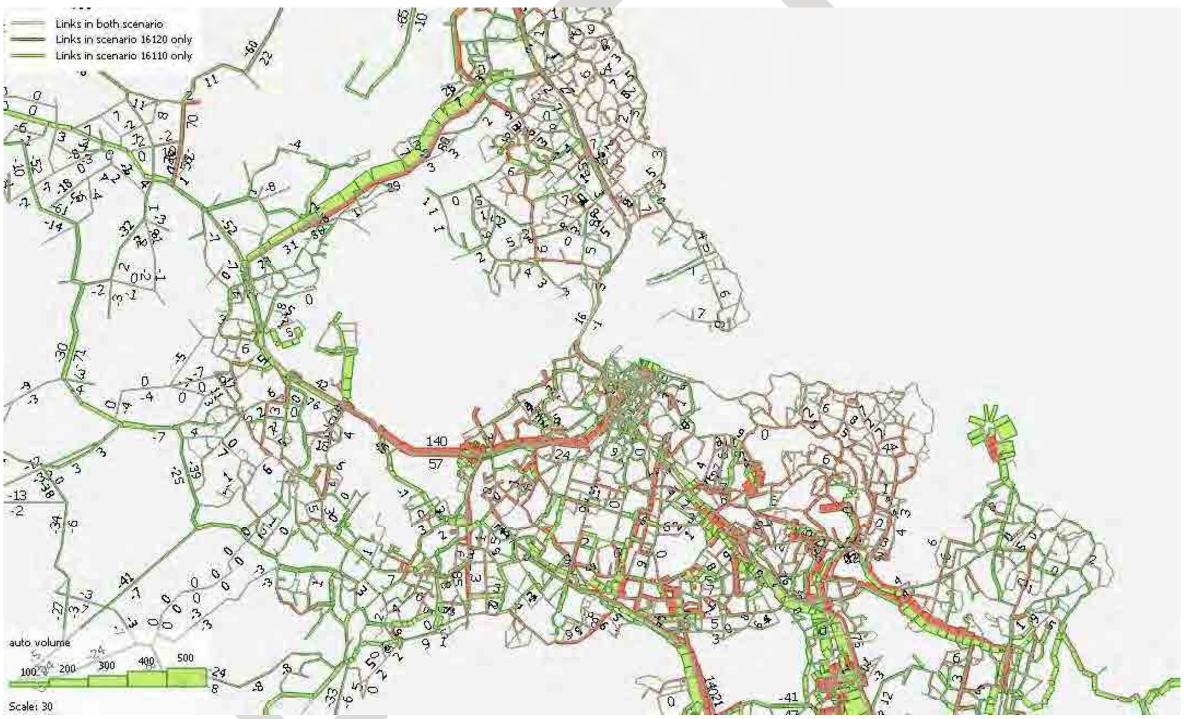
7.3.3 Assignment option testing

Initial testing (earlier in 2017) of a single class assignment showed that a full assignment with intersection capacity updates could be achieved in a similar time (6 minutes) with the Path based assignment; whilst using cut-off parameters resulting in convergence being achieved at a factor of 10 times better than the Standard assignment. This process was then expanded to 8 classes (hbw, hbe, hbs, hbo, eb, nhb, cv and externals) to test a full assignment (with intersection capacity updates) and the assignment run time was found to increase to 16 minutes. (Note – a simpler multi-class assignment can also be used for light vehicles and HCV's, and this has ultimately been included as an option in the updated MSM).

Recent testing with the new MSM (updated from Phase 1) showed that the path based assignment process had a slightly longer run time when compared with the standard single class parallel assignment. This included one additional demand-supply iteration (9 loops compared with 8 for the standard MSM base model). Results from this test are shown below, with the red bars on the plots illustrating more traffic on a link with the path based assignment test, and the green bars showing less traffic.

Results were found to be marginal in terms of screenline validation performance, with some criteria improving slightly and others decreasing in performance slightly. These results are tabulated following the volume difference plots shown below. Note, the volume difference plots illustrate results from the AM peak models. Interpeak (IP) and PM peak scenarios produced similar comparisons between the assignment tests.

Also note that these tests included adjustments to use the path based algorithm throughout the entire model looping process, as well as for the final assignment.



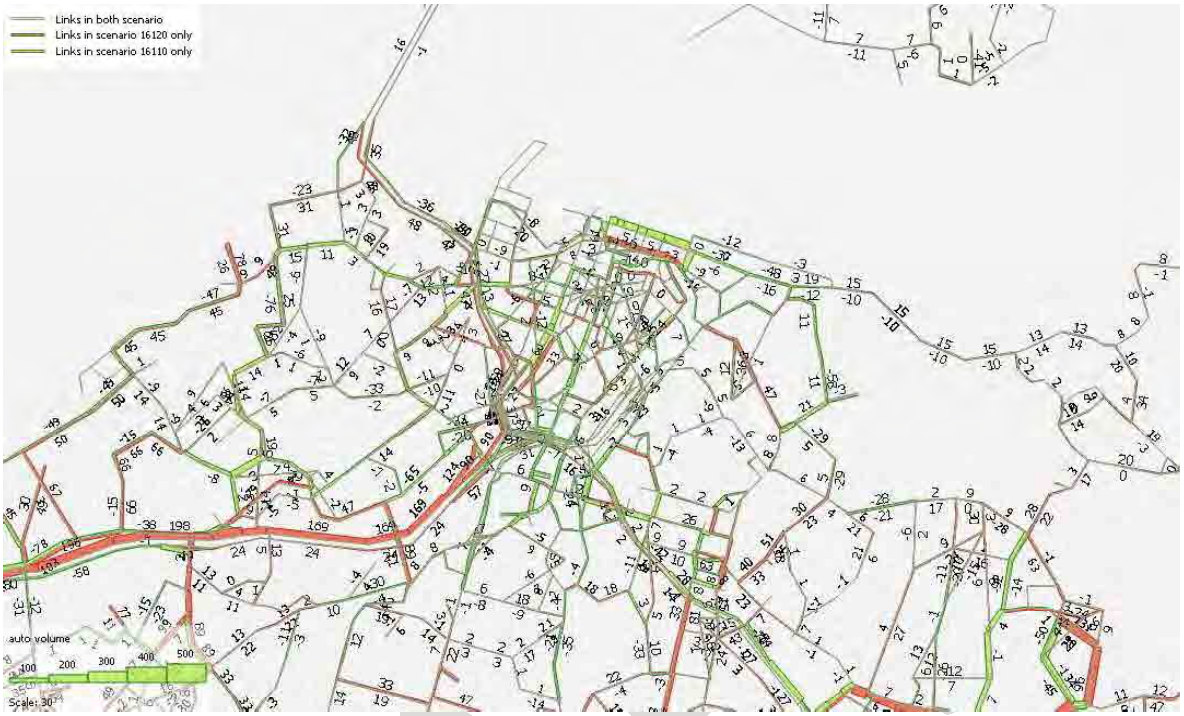


Figure 7-3- Comparison of Path Based Assignment vs Standard Parallel Assignment – AM Peak – red bars show more traffic in path based test, green bars show less traffic

Table 7-7 - Base - Standard parallel assignment - standard model run

Screenline Total

GEH	AM	IP	PM
< 5	64%	86%	82%
< 10	96%	100%	96%
< 12	100%	100%	96%
Proportion of screenlines with % difference < 10	96%	100%	93%
R^2	0.994	0.995	0.993
RMSE	6%	5%	5%

Individual Link

GEH	AM	IP	PM
< 5	39%	43%	34%
< 10	72%	75%	70%
< 12	81%	85%	78%
Proportion of screenlines with % difference < 10	62%	63%	59%
R^2	0.945	0.952	0.937
RMSE	26%	26%	27%

Table 7-8 - Base - Path based assignment – standard model run

Screenline Total

GEH	AM	IP	PM
< 5	64%	86%	71%
< 10	93%	100%	96%
< 12	96%	100%	100%

Individual Link

GEH	AM	IP	PM
< 5	38%	44%	34%
< 10	72%	76%	73%
< 12	81%	85%	78%

Proportion of screenlines with % difference < 10	96%	100%	93%
R^2	0.992	0.995	0.993
RMSE	6%	5%	5%

Proportion of screenlines with % difference < 10	62%	64%	59%
R^2	0.945	0.954	0.937
RMSE	26%	26%	27%

7.3.4 Additional Testing

Some additional testing was undertaken during model validation in the Stage 2 project to compare the option of implementing path based assignment in just the final assignment versus the entire model demand looping process. The results of this testing showed that by implementing the path based process with a tighter level of convergence throughout, this led to less overall demand loops being required, and was therefore considered a more robust approach with improved model convergence. This is particularly important for use of the model in business case type assessments requiring economic analysis, as it will lead to a more refined output with network flow changes resulting only from the project impact, rather than having potential spurious changes in traffic flows in unrelated parts of the network (model noise).

7.3.5 Updates to assignment processes – cold start vs warm start

A further consideration as part of the testing was the use of cold start versus warm start assignments. The path based assignment algorithm allows the user to define one of the following options at assignment set-up:

1= start with existing paths and continue iterations

2= start with existing paths and reset iteration counter

3= initialize paths and reset iteration counter

Option 2 is commonly used with the path based algorithm as it has the advantage of using existing path files (from previous demand loop) as a starting point for the assignment. This is known as "warm start" and means that the assignment convergence will generally occur more quickly on each subsequent demand loop, as the network travel times become more stable. This has obvious benefits in terms of overall model run times, particularly in congested networks.

This option is therefore adopted for the main model demand looping process (generalised cost assignments) in the MSM. It is also useful to apply a variant of this option (option 1 listed above) when undertaking additional iterations during the intersection capacity update process in MSM.

Since the MSM has the option of undertaking a full model run or an assignment only, it was decided that to ensure consistency in model output depending on which approach is adopted, that a cold start (option 3 from the list above) was required for the final assignment undertaken in MSM. Since the final assignment is set to achieve tighter criteria this was not considered to be a major issue, nor did it add excessive run time during model testing (for base or future years).

As a side note, it was advised by INRO that to undertake additional iterations on the same assignment using the SOLA module 5.23 within the Emme prompt, a minimum of 70 iterations is required to be run before this option becomes available. Scripting within Python/Emme modeller can get around this limitation.

7.3.6 Additional options – Traversal and select link analysis

With the adoption of path based assignment, post assignment analysis is very quick and easy due to the availability of the class specific path files produced during a model run.

Updates have been made to the traversal (cordon) and select link processes to be compatible with the path based assignment process.

a. Select link analysis

Select link analysis has been set up using Module 6.16 path analysis, for both the single and multi-class (2 class) assignments, and is called as part of the final assignment run option (note, does not require a new assignment to be run).

b. Traversal (cordon) analysis

The traversal process has also been updated for both the single class and 7 class (trip purpose) assignments, and this process utilises Module 6.16 path analysis. A separate assignment is not needed to undertake this analysis, so long as the corresponding vehicle class assignment is already available in the desired scenario. For example, if a 7 class traversal is required then a 7 class assignment would need to have been undertaken during a standard model run.

It is noted that some minor proportionality issues can exist with the path based traversal analysis. With any well converged traffic assignment, total link flows and origin-destination impedances are unique when converged, but path flows and class flows on links are not. This means that a select link or traversal analysis in Path-based traffic assignment may appear to have paths serving only certain O/D pairs whereas the same analysis using a different assignment algorithm e.g. SOLA will have equal representation from all possibly contributing ODs. For a traversal demand where gate flows need to be distributed to destinations inside the subarea, the incoming demand at the gates will be the same, but the distribution to internal destinations will be different – though only marginal.

A possible alternative to ensure uniqueness in the case of any issues with the path based process would be to run a final SOLA assignment and undertake select link/traversal analyses using SOLA.

7.3.7 Recommendations

Based on the testing undertaken, it was recommended that the path based assignment is included throughout both the generalised cost and final assignments – in other words implementation of path based assignment throughout the full model looping process and final assignment.

This includes a warm start process during the model looping, but then a cold start assignment for the final assignments undertaken. This is required to ensure compatibility between the “full model run” option versus an “assignment only” option when running the MSM.

Traversal and select link analysis is also updated to utilise path analysis options and not requiring additional assignments to be run.

7.4 WTP Segmentation in the DMS model (Task 5.4)

As part of Phase 1 Willingness to Pay (WTP) was investigated (see **Section 4.2**). The research led to the following recommendation for MSM:

“Taking into consideration the mean household incomes for each income segment produced in ASP, and the elasticities resulting from a review of national and international evidence, the proposed WTP for each income segment is provided below.”

Table 7-9 - Average VoT per Trip Purpose

	Average VoT ($/hr, 2016)			
Trip Purpose	Low Income	Medium Income	High Income	Average (DMS Model)
Proportion of mean	68%	93%	140%	
HBW	$8.85	$12.09	$18.38	$13.11
EB	$28.18	$38.49	$58.52	$41.73

Average VoT ($/hr, 2016)				
Other	$7.41	$10.12	$15.38	$10.97
M/HCV	$21.63	$29.54	$44.92	$32.03

As part of Phase 2, a short summary statement of international research regarding WTP in the Distribution-Mode Share (DMS) models was considered worthwhile to explore. The following questions were raised and international expertise was sought to address them:

1) Confirmation of the existence or otherwise of this type of DMS segmented WTP elsewhere in the world
2) Establish the response of DMS to WTP segmentation (if example unearthed)

In essence the international opinions received mentioned that WTP is typically related to toll road models and principally relates to the assignment (4th step) component of the 4-step model, while the DMS is the joint 2nd and 3rd step. It was proposed that we should use the term Value of Time (VoT) instead of WTP when referring to DMS impacts, as these values may be the same but they are commonly not and it therefore may easily get confused with toll road related VoT/WTP values.

- It is therefore suggested to rename WTP into VoT in the reporting.

International specialists have indicated that they are not aware of any aggregate models (such as the MSM) in which VoT segmentation has been implemented within a DMS model. In the past, segmentation by income group or blue/white collar (which might have been income correlated) has been considered in some aggregate models. Typically, DMS models do not include a detailed consideration of tolls (and by extension the willingness to pay tolls) in the generalised cost. Tolls are often implemented as a ‘point toll’ on the network, but implementing any more detail could over-complicate the DMS. In other words, seeking to include toll choice behaviours into the DMS could potentially be inappropriate, as it would distract the model process from the purpose of the DMS stages.

The situation may potentially be different in disaggregate strategic models (such as the Sydney model), where each individual characteristic is in principle modelled and individual/family income could be used to attribute a VoT. Alternatively, a small number of income categories might be used, but in any case this is not applicable for the MSM.

Appropriate model segmentation should be determined in estimation, where statistically significant parameters can be identified. For the DMS models, the relevant variable would be income group. However, income is also correlated with a number of other factors (for example car ownership), which modellers tend to prefer to use. In New Zealand it is rather problematic to identify a statistically significant income effect, as shown during the Phase 1 research, which makes it difficult to impossible to estimate due to not having enough real choice. Even if such an effect were to be determined, it would likely be included as a modification to one of the mode constants rather than as a VoT variation.

- Therefore, the current way MSM is operating in regards to VoT/WTP has not been changed during the Phase 2 tasks.

7.5 Interpeak Car Access Catchment

In the ART model, inter-peak catchment was limited to 1.2km radius only which was based on the 2006 survey results.

During this model refresh, using this 1.2km catchment resulted in modelled car access numbers that were significantly lower than the observed 2016 HOP data. The radius restriction was removed and therefore the same AM/PM peak catchment was applied to the IP in Phase 2, but allowed for both directions of travel between traffic zones and PnR stations (i.e. only zones to station movements were allowed for AM and opposite direction for PM). To represent low car access activity during the IP peak (due to a lack of available parking spaces), access (time+VOC) and parking availability costs were doubled for IP. This factor was determined based on the comparison of observed and modelled car access trips during IP.

In addition, the parking availability penalty was increased from 8 to 10 minutes and a global transfer penalty reduced from 12 to 10 minutes in Phase 2.

7.6 Additional Response in Time of Day Model (Task 5.7)

7.6.1 Introduction

This section documents the further review of the time of day (ToD) model in MSM that was undertaken during Phase 2. Firstly the current structure is reviewed, along with outlining the options for change, and subsequently the change implemented are described.

7.6.2 The Current Time of Day Models

The current time of day models were developed for the original 2006 base year ART3 model using observed data on trips by time period. They are documented in the following:

- ART3 Time of Day and Vehicle Driver Factors Report v5 – final - .PDF
- DMS Implementation Note V8_emme2.pdf

The time of day model structure is shown in Error! Reference source not found. for each of four "tour time groups":

- TG1: out in the am peak, return in the pm peak,
- TG2: out in the am peak, return not in the pm peak,
- TG3: out not in the am peak, return in the pm peak,
- TG4: all other trips.

The time of day models are by purpose (HBW, HBE, HBSh, HBO, EB, NHBO) and in some cases also by mode (car, PT).

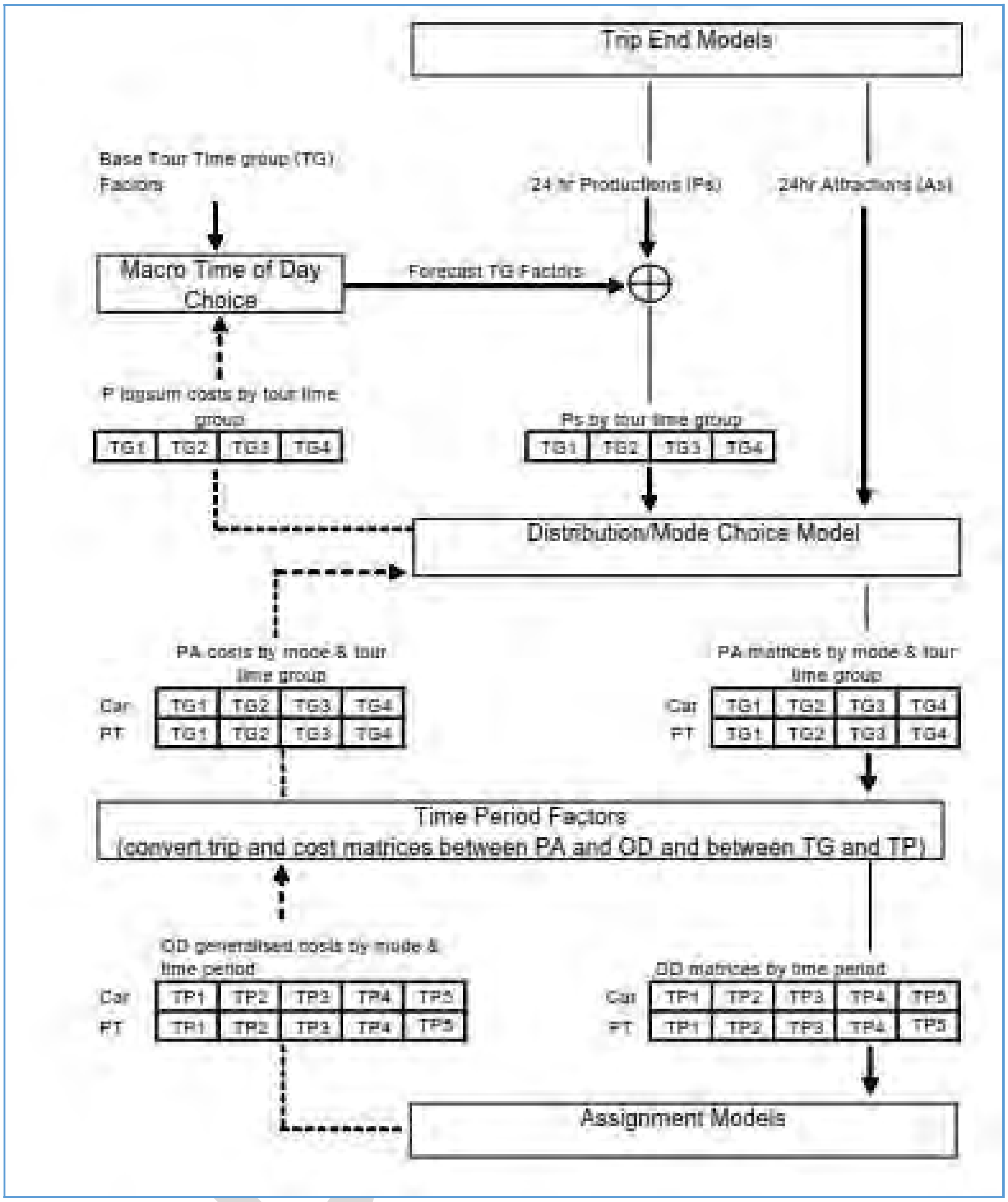


Figure 7-4- Time of Day Model Structure- Time of day model structure

There are two parts to time of day choice for HB purposes:

1. The 2006 observed trip proportions by tour group are used in the allocation of daily productions to tour groups. These proportions are global factors specific to each purpose.

   In forecasting the differences between 2006 and future modelled composite utilities for productions are used to adjust the 2006 observed trip proportions by tour group, the expression being:

   Forecast proportion = 2006 proportion * exp (sensitivity * difference in production composite utilities)

The DMS models for HBW, HBSh, and HBO purposes are simultaneous distribution-mode choice and hence the adjustment of ToD proportions are for car and PT combined. HBE, on the other hand, is a pre-distribution mode choice model with the ToD occurring after mode choice and before distribution – hence the adjustment of ToD proportions is by car and PT separately.

The above is shown near the top of the figure as "Macro Time of Day Choice".

Macros: dms_tod_<purp>.mac

2. The 2006 observed probabilities of travel from home for each purpose and mode (global factors) and the 2006 ToD factors of proportions of trips by time period from home and, separately, to home both by sector are used in the conversions of:

    - Origin-destination (O-D) generalised costs by time period (TP) into production-attraction (p-a) costs by tour group,

      Macro: dms_gc_sub.mac

    - P-a matrices by tour group from the DMS models into O-D matrices by time period.

      Macro: tg_disagg.mac

   These processes are shown in the lower section of the above figure. Note that the 2006 factors are used and are not adjusted in forecasting.

For the non-home-based (NHB) purposes (EB, NHBO) 2006 observed probabilities by time of day for both ends of the trip are used to allocate daily trip ends by mode to time periods. In forecasting the 2006 probabilities for car are adjusted using the differences in future and 2006 O-D composite utilities:

> Forecast proportion = 2006 proportion * exp (sensitivity * difference in O-D composite utilities[10])

The 2006 probabilities for PT are not updated in forecasting.

Macros: dist_<purp>_<mode>.mac

The composite utilities used for adjusting the 2006 HB tour group factors and the NHB time of day factors are based on generalised costs. The generalised costs are generated as follows for each model and period

Table 7-10

Period	Car	PT
AM	Network skims	Network skims
IP	Network skims	Network skims
SP	20% of IP + 80% of PM	50% of IP + 50% of PM
PM	Network skims	Network skims

[10] Although original ART documentation describes this as composite cost, in fact, they are generalised costs for Car and PT

Period	Car	PT
OP	70% of IP	Network skims using 1/3 of IP frequencies

The generalised cost purposes for car are HBW, EB and Other (all other purposes combined), and for PT are HBW, HBE, EB and Other.

7.6.3 Issues with the Current ToD Models

The previous **Section 5.2**, outlines the issue identified during Phase 1:

> *Comparing observed and modelled data in 2016 indicates that the IP has typically experienced lower growth than the model is currently estimating, meaning that both AM/IP and PM/IP ratios are lower for the modelled data compared with observed. However, this is not the case for every screenline location, and the difference between observed and model varies across the screenlines.*
>
> *Given this variation, three options were considered for the time of day models:*
>
> *1) Leave the models unchanged, and account for the lower relative growth in the IP through adjustment of under reporting factors.*
>
> *2) Reduce the OP peak costs (currently not an assigned model period) as a proportion of the IP costs to attempt to transfer more proportion of daily trips into the OP.*
>
> *3) Reduce the sensitivity of the time of day model to retain more trips in the more congested AM and PM peaks, and fewer trips in the IP (and OP).*
>
> *Option 3 was discounted as whilst this would reduce the number of trips in the IP, potentially more in line with observed data, it would have an adverse impact on the proportion of AM and PM peak trips.*
>
> *Option 2 was tested to establish the impact of the OP costs on the distribution of trips throughout the day. The outcome of a reduction in OP costs was additional trips transferring from the AM and PM peaks to the OP with negligible changes in the IP. Option 2 has therefore been discounted also.*
>
> *Option 1 has therefore been implemented acknowledging that there are no model parameters that can be transparently adjusted to modify the time of day model in the desired manner, within the existing model structure.*

The cause of this issue is that the macro ToD models operate on TG so there is no differentiation in the allocation of trips to all three non-peak periods (IP, SP, OP). That is, it is not possible to allocate fewer trips to the IP and more to the OP.

7.6.4 Potential possible solutions

Potential changes could include any combination of the following three items:

1. Alter OP GCs to lower % of IP GCs or relate OP GCs to other time periods, along with
2. Alter tod factors (tod_factors_<purp>.in using the change in composite utilities in similar manner to TG allocation.
3. Rebase models to 2016. This could be done along with or independent of the above items.

Item 1 was tested in Phase 1 - on their own they were not seen to be highly effective. While lower values could be used for the OP costs (e.g. 50% of IP skims), these risk providing unrealistic costs, especially for longer-distance trips.

In regard to adjusting the tod factors (item 2), a key question would be the form and sensitivity of the function applied. A starting point could be the same function as used for the TG macro time period choice. The sensitivity could be tested and compared against the 2006-to-2016 peak trip proportions to select an appropriate value.

In regard the rebasing to 2016 (item 3), the advantages are mainly pragmatic, namely a simpler process (that avoids linkages to 2006 model data) and avoidance of a revalidation of the 2016 model that was completed with Phase 1.

A tentative recommendation is to consider further the implications and testing of method 2. A decision on the 2016 rebasing could be taken following that initial testing.

7.6.5 Recommended Change

Following a workshop with AFC in early 2018, it was agreed to rebase the ToD model to 2016 and to implement and test the additional time-period response.

7.6.6 Implementation

This section documents implementation of two changes to the ToD model:

- Rebasing of the ToD model from 2006 to 2016; and
- Adding an elasticity to the home-based time period factors, similar to that applied to non-home based factors.

7.6.7 Rebasing the ToD Costs

In the current models the ToD response is based on comparing future travel costs to year 2006 costs. Phase included this 2006 base, meaning that the 2016 base model is a 'forecast' of the ToD factors. This adds complexity to the operation of the model with all other items being reset to 2016 base data. This task was therefore only to 'tidy up' the model operation so that all files had a 2016 base.

The ToD factors for 2016 were back-calculated to match the previous 2016 forecast values using the 2016 costs. Specifically this involved:

- For non-home based trips, the time-period factors were reset to match the estimated 2016 values;
- For home-based models, the tour-group proportions were reset; and
- Altering the forecasting process to utilise 2016 rather than 2006 costs.

This process was implemented and tested to retain the same 2016 proportions as in the Phase 1 models.

7.6.8 Implementation of Home-Based Time Period Factor Elasticity

In Phase 1 the ToD response was as follows:

- For non-home-based trips the peak-period factors are elastic in response to changes in cost; and
- For home-based trips, the proportion of trips in each of the four tour-groups was elastic in response to changes in cost.

This task was therefore to add a peak-period-factors response to home-based trips, similar to that used for non-home based trips. This means that home-based trips have both a tour-group and time-period factor response.

A key consideration for this change was that increasing congestion is leading to peak-spreading of car travel to the shoulder of the peaks (e.g. before 7 am or after 6pm). Such trips are represented by the Off Peak (OP) period in the model (6pm to 7am). The current ToD model was suspected to allocate too many of these trips to the interpeak period, rather than the OP period. It was not considered likely that such impacts would occur to the same extent on the PT network.

The EMME macros *dms_gc_sub.mac* and *tg_disagg.mac* are revised to include the additional Time of day (ToD) response. The formulae used are:

*new FH tod factors = current FH tod factors * exp(sensitivity *(%FH*(futureGC-2016GC)+(1-%FH)*(futureGC'-2016GC'))*

*new TH tod factors = current TH tod factors * exp(sensitivity *((1-%FH)*(futureGC-2016GC)+%FH*(futureGC'-2016GC'))*

Both From Home (FH) and To Home (TH) ToD factors were updated based on changes in GC between 2016 (base) and future years. Different sensitivity parameters were tested. The existing sensitivity parameters for NHB is -0.028. This additional model response was only applied to trips by cars. The process was implemented for PT trips but the sensitivity factor was set to 0 to to effectively deactivate this response.. The factors for both car and PT could be reviewed in future if greater data on peak spreading was available.

Because the elasticity response uses an exponential formula, mathematical errors can occur due to changes in large GC. This is very unlikely for Car GC where all zones are serviced, but possible for PT modes where a new service is provided to rural areas. This ToD model response was therefore only applied to matrix cells where GC changes are less than 200 minutes to prevent mathematical error which could result computer crash during model run.

7.6.9 Model Testing Results

Different sensitivity factors were used in a 2046 model run to understand the effects of the additional ToD model response. There is insufficient data to calibrate the elasticity value separately form the existing ToD response. Therefore, the elasticity value was selected relative to the NHB value, and being somewhat conservative in the effect. Three different levels of elasticity were tested, namely -0.028 (as used in the NHB models), -0.05 and -0.1. The resulting impact was analysed in regards to the effect on trip totals, cell values and geographic impact.

Table 7-11shows changes in total trips due to different levels of sensitivity factors:

Table 7-11 - Changes in Number of Trips, 2046

	Reference	Sensitivity -0.1			Sensitivity -0.05			Sensitivity -0.028		
	trips	trips	diff	% diff	trips	diff	% diff	trips	diff	% diff
AM Car Matrix	589,018	586,092	-2,926	-0.5%	587,763	-1,254	-0.2%	588,611	-407	-0.1%
IP Car Matrix	1,755,428	1,733,340	-22,088	-1.3%	1,745,069	-10,360	-0.6%	1,750,413	-5,015	-0.3%
SP Car Matrix	399,766	387,677	-12,089	-3.0%	392,975	-6,790	-1.7%	395,873	-3,893	-1.0%
PM Car Matrix	655,180	649,917	-5,264	-0.8%	652,119	-3,061	-0.5%	653,570	-1,611	-0.2%
OP Car Matrix	793,034	839,075	46,041	5.8%	816,365	23,331	2.9%	806,561	13,528	1.7%
AM PT Matrix	175,216	173,115	-2,101	-1.2%	174,286	-930	-0.5%	174,458	-758	-0.4%
IP PT Matrix	245,351	242,617	-2,735	-1.1%	243,982	-1,369	-0.6%	244,410	-942	-0.4%
SP PT Matrix	96,407	95,583	-824	-0.9%	95,958	-449	-0.5%	96,085	-322	-0.3%
PM PT Matrix	153,131	151,054	-2,077	-1.4%	152,170	-960	-0.6%	152,379	-752	-0.5%
OP PT Matrix	93,453	92,680	-772	-0.8%	93,073	-380	-0.4%	93,214	-238	-0.3%

The table shows most changes are for Car matrices but some minor changes are also noticed for PT matrices, although PT sensitivity factor was set to 0. This is probably due to secondary effects in which PT trips are reduced due to less congestion (i.e. mode shift to cars).

Car trips are reduced in all peaks (except OP), and mostly from IP and SP. OP car trips are increased 5.8%, 2.9% and 1.7% for sensitivity factors -0.1, -0.05 and -0.028, respectively. The IP+SP matrix growth between 2016 and 2046 is 27.4% while OP growth is 24.6%. Hence IP+SP matrix growth is higher than the OP. AM and PM peak matrix growths are only 16.4% and 17.3%, respectively.

From the Phase 1 study, 2006 to 2016 data suggests OP is growing faster than IP and SP. This additional ToD model removes trips mostly from IP and SP, and adds it to OP. Hence this response matches to what we are trying to achieve from the ToD model (i.e. increasing OP Car trips from IP/SP).

The existing sensitivity parameter for non home-based trips is -0.028. We consider ToD effects will be higher for home-based trips which are more likely to respond to congestion effects. Hence, we suggest adopting a sensitivity parameter of **-0.05** which is higher than non home-based parameter. This parameter increases the OP matrix by 2.9%. This is not a significant change to the OP matrix, but provides the OP matrix growth of 28.2% which is slightly higher than the IP+SP growth of 26.4%.

7.6.10 Geographic (Sector) Analysis

A sector analysis was undertaken to understand changes in travel patterns as the results of additional ToD model response. The existing ToD (gd ensemble) sector was used for this analysis. Changes in off-peak matrices are tabulated in Error! Reference source not found..

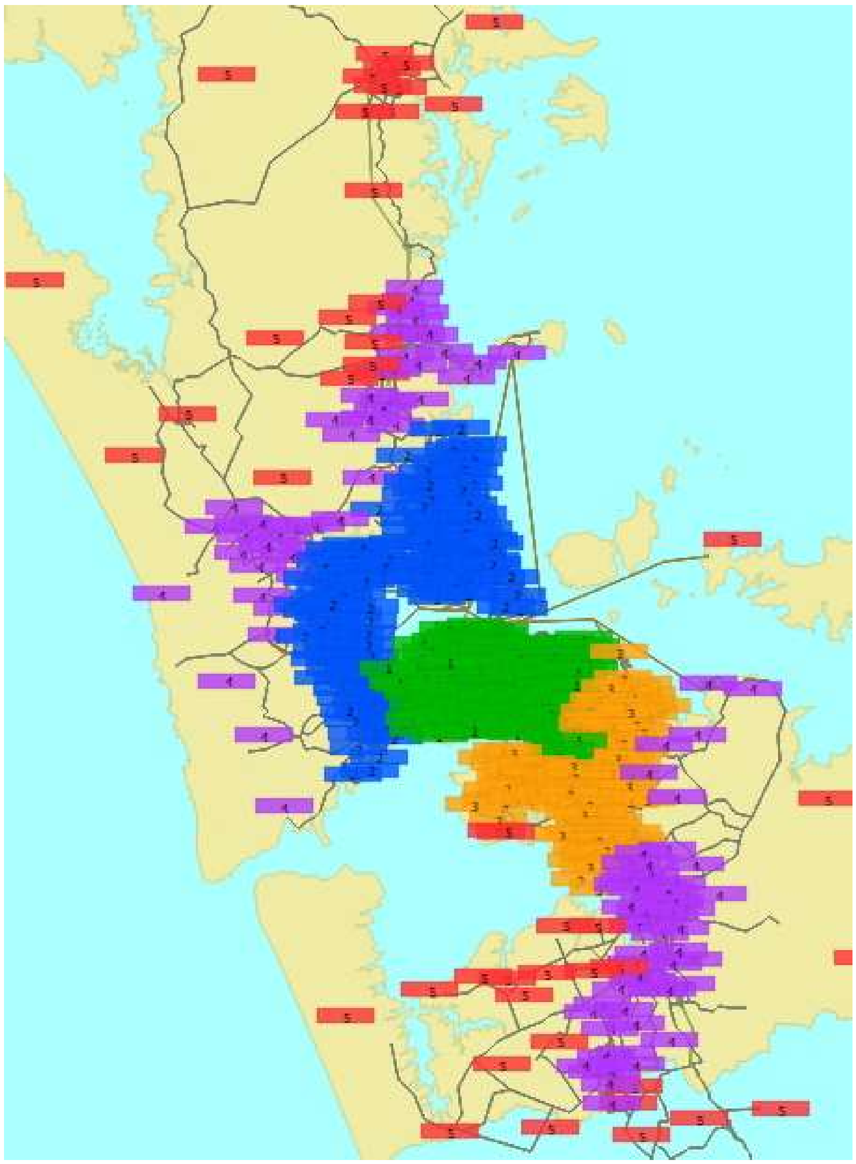


Figure 7-5 - ToD Sector System

Table 7-12 - OP Matrix Changes, 2046

Ref	matrix=mf270					
#a	OP_car	-9999	OP	Car	Matrix	
col/row	gd01	gd02	gd03	gd04	gd05	
gd01	208,509	26,227	19,864	6,780	1,942	263,322
gd02	28,040	171,214	3,830	11,394	3,871	218,348
gd03	17,693	4,486	114,753	13,651	2,565	153,149
gd04	4,840	10,016	14,650	64,391	11,012	104,909
gd05	1,387	3,214	3,040	10,837	34,828	53,306
	260,468	215,157	156,137	107,053	54,219	793,034
Sen -0.05	matrix=mf670					
#a	OP_car	-9999	OP	Car	Matrix	
col/row	gd01	gd02	gd03	gd04	gd05	
gd01	212,895	27,660	21,012	7,702	2,315	271,584
gd02	29,590	173,781	4,340	12,088	4,157	223,955
gd03	18,708	5,088	116,805	14,645	2,909	158,155
gd04	5,423	10,594	15,806	65,165	11,248	108,237
gd05	1,635	3,449	3,484	11,058	34,809	54,435
	268,252	220,572	161,447	110,658	55,437	816,365
Diff						
col/row	gd01	gd02	gd03	gd04	gd05	
gd01	4,387	1,433	1,147	922	373	8,261
gd02	1,550	2,567	510	694	286	5,607
gd03	1,015	601	2,052	994	344	5,006
gd04	584	579	1,156	774	235	3,328
gd05	248	235	445	221	- 19	1,129
	7,784	5,414	5,310	3,605	1,218	23,331
%Diff						
col/row	gd01	gd02	gd03	gd04	gd05	
gd01	2%	5%	6%	14%	19%	
gd02	6%	1%	13%	6%	7%	
gd03	6%	13%	2%	7%	13%	
gd04	12%	6%	8%	1%	2%	
gd05	18%	7%	15%	2%	0%	

This table shows that most of the changes in % are between long-distance sectors and this is considered reasonable for the ToD model response as it correlates where the peak-spreading is most evident

7.6.11 Cell Analysis

The most significant impact was on the OP period so the distribution of cell values was also checked to see the range of cell-values around the overall average response. The following table summarises the key results, with the distribution of cell values for the OP matrices shown in the following figures.

Table 7-13 - Distribution of OP Change in Cell Values

Value	E=-0.1	E=-0.05	E=-0.028
Cell Average	5.8%	2.9%	1.7%
Standard deviation	9.9%	5.1%	2.86%

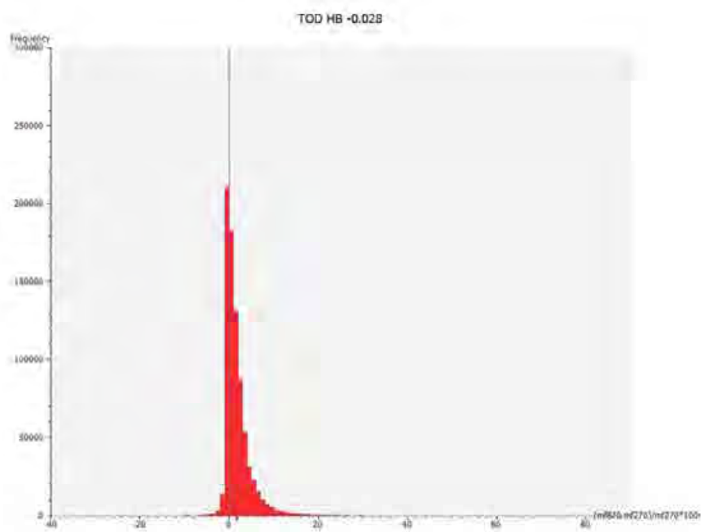


Figure 7-6 - Distribution of change of cell values AM Peak

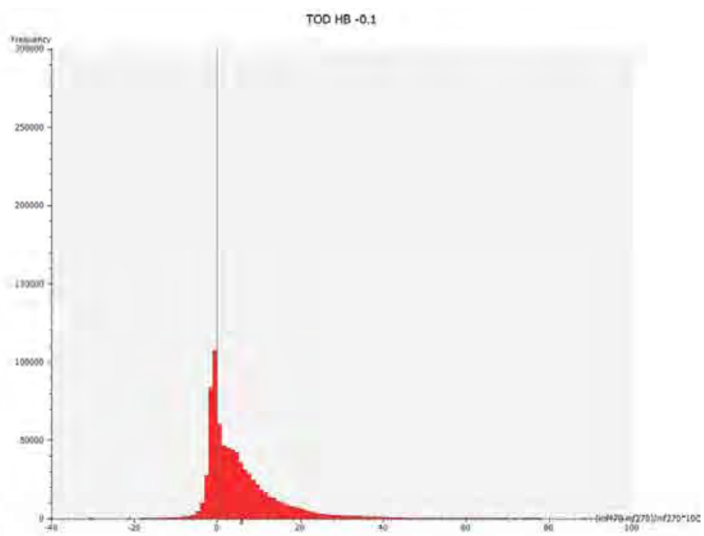


Figure 7-7 - Distribution of change of cell values Inter Peak

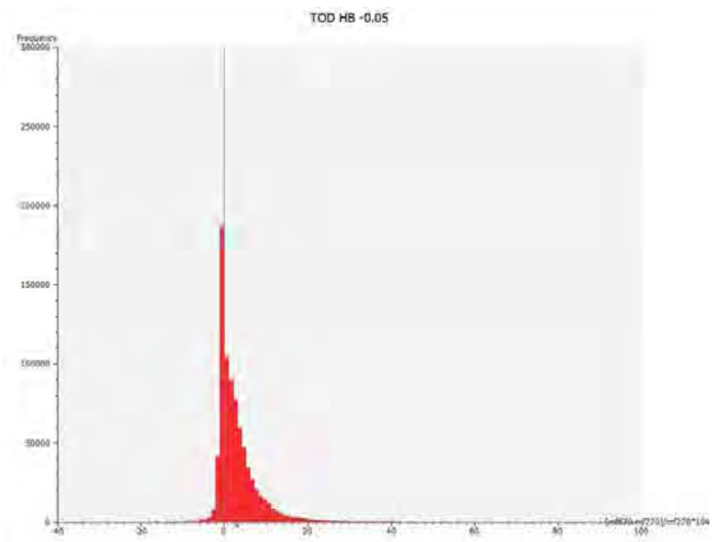


Figure 7-8 - Distribution of change of cell values PM Peak

Overall, it was considered that response with an elasticity factor of -0.1 was too significant, while that for -0.028 was likely to be too small (bearing in mind that these are the additional ToD response, not the full ToD response). Although the uncertainty in appropriate value is recognised, a response with an elasticity of -0.05 was recommended.

7.6.11.1 Conclusions

From Phase 1, it was noted that the existing ToD model allocated more trips to IP+SP than OP, which is not likely to reflect the peak-spreading effect of trips travelling in the peak shoulders (pre AM peak or post PM peak). A few tests were undertaken in Phase 1 which found that it was not possible to control the allocation of peak-spread trips between interpeak and off peak without altering the structure of the model. The intent of this task was therefore to refine the allocation between interpeak and off peak periods.

This exercise introduced additional a time-period factor response for home-based car trips (in addition to the existing tour-group response). The model formula was adopted from the existing non home-based ToD model. The test results show it has limited effects on AM and PM peak matrices, but it increases OP matrices by removing trips mostly from IP and SP.

Regarding the model sensitivity parameter, we suggest adopting a parameter of -0.05 which is slightly higher than non-home based model sensitivity parameter, -0.028. This is because we consider home-based trips are more likely to response to congestion effects than non home-based trips. Additionally, it is recommended that this additional response only be applied to trips by car (the functionality has been added to PT trips but currently deactivated by using a scale factor of 0.)

Also observed 2006 and 2016 data suggests OP matrix growth is higher than IP+SP growth. Using --0.05 parameter achieves a slightly higher OP growth between 2016 and 2046.

7.7 Validation Factors and Capping Process Update

Due to the changes described in the earlier sections, the matrix estimation process was re-run and a revised set of validation factors was used in Phase 2. More comprehensive documentation about validation factors can be found in **Section 5.3**. Also the sector to sector individual cell validation factors were capped between 0.5 and 3 (0.3 and 5 in Phase 1).

Table 7-14shows the matrix total changes before and after the application of validation factors.

Table 7-14 Car Matrix Totals with and without Validation Factors[11] (Phase 2)

Peaks	Without	With	% Change
AM	558,299	561,445	+0.56%
IP	499,627	500,541	+0.18%
PM	591,365	606,700	+2.59%

From this, matrix total changes are considered minor. Table 7-15 provides average trip length comparisons before and after the application of validation factors.

Table 7-15 - Average Trip Length, km, with and without Validation Factors (Phase 2)

Peaks	Without	With	% Change
AM	10.15	10.00	-1.5%
IP	9.35	9.07	-3.0%
PM	10.11	9.92	-1.9%

Based on the table, it can be seen that average trip length changes are minor and maximum change is -3% for IP. **Figure 7-9** to **Figure 7-11** show trip length distribution changes with and without application of the Validation Factors.

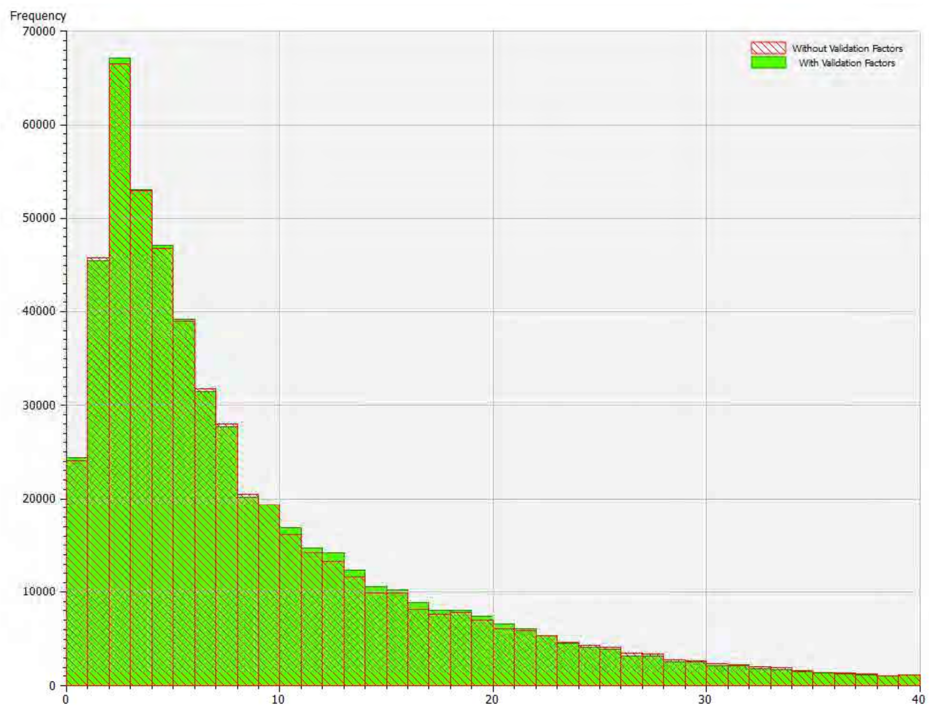


Figure 7-9- Trip Length Distribution with and without Validation Factors (AM Peak) (Phase 2)

[11] From the model run where ME and validation factors are calculated.

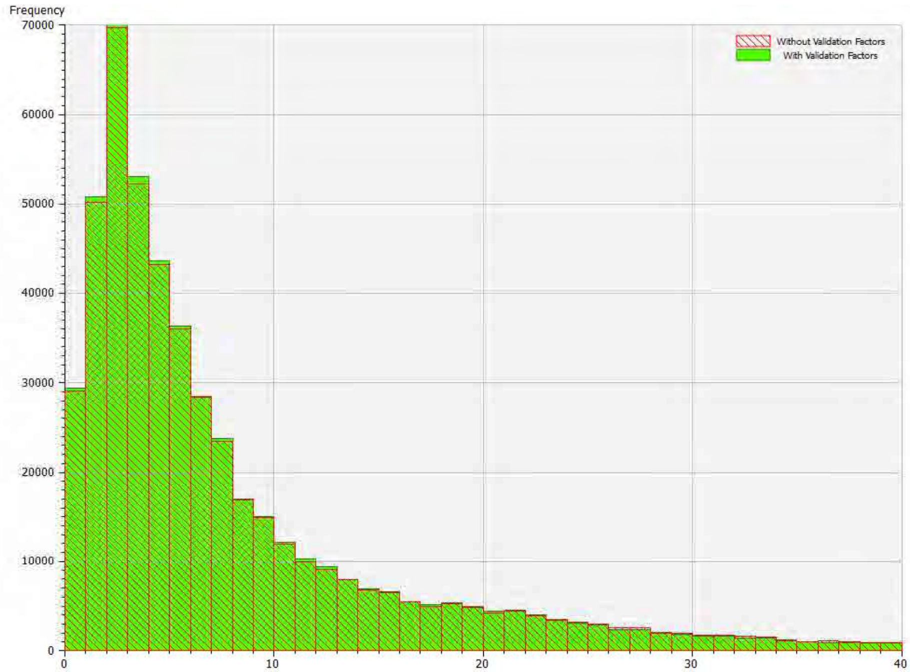


Figure 7-10 - Trip Length Distribution with and without Validation Factors (Inter-Peak) (Phase 2)

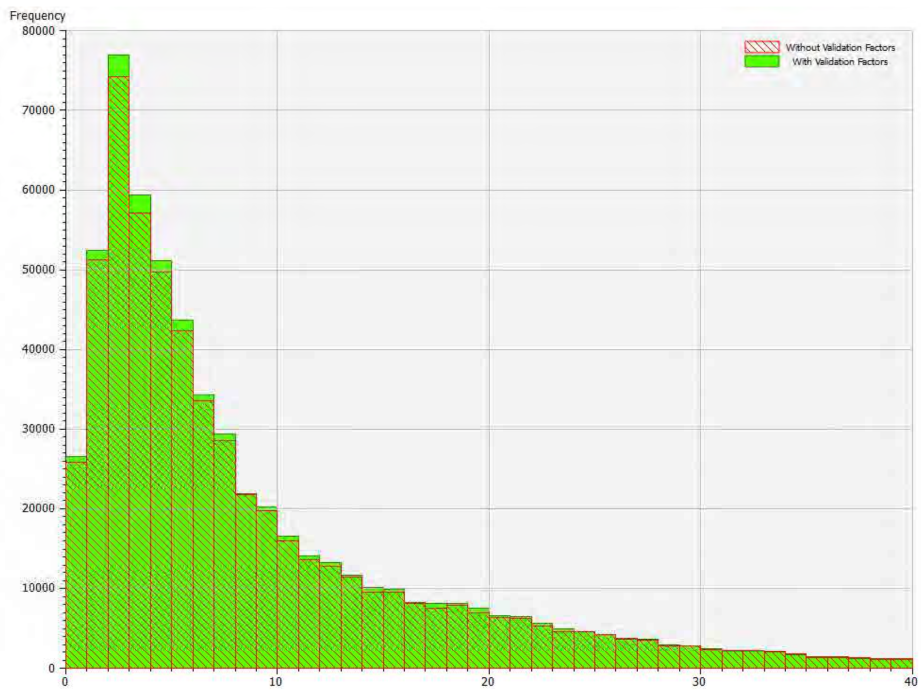


Figure 7-11 - Trip Length Distribution with and without Validation Factors (PM Peak) (Phase 2)

Based on these figures, trip length distribution changes are considered insignificant for all three peaks.

7.8 Summary of Phase 2 MSM updates

In summary the following changes were made to the MSM in Phase 2:

- Review of the auto-assignment methods
- Application of road perception factors
- Removal of the radius constraint in the inter peak Park and Ride
- An additional elasticity response added to the ToD model
- Recalibration and validation of the 2016 model

8 Phase 2 MPT Updates

8.1 Specification of Phase 2 MPT Updates

A draft technical specification for the MPT was develop in late 2017, followed by a workshop in January 2018. Specific decisions were made on the key design decisions for MPT. The draft specification report is attached as **Appendix B** including the recorded workshop decisions.

Items that were progressed in the model update are documented in this chapter, or the separate Model Testing Report. Items that were not progressed further are not discussed again here.

8.2 Model Structure

8.2.1 Previous Model

Phase 2 significantly revised the forecasting method used in the MPT model. The Phase 1 MPT model (like the previous APT model) created future year PT demand matrices by a combination of:

- Trip generation estimates from input land use data;
- A gravity trip distribution model;
- Predictions of PT demand change (via the pivot model) due to PT network changes between the base year and future year; and
- Transfer of various data from the MSM model to the MPT model, such as mode split factors, demand changes due to TDM assumptions and PT demand changes due to changes in car costs

8.2.2 Revised Model Operation

The identified issues with that structure are outlined in the attached MPT Specification Report, but mostly resulted in inconsistent growth forecasts between the MSM and MPT models. In Phase 2, the structure was altered to apply PT growth factors from MSM to the MPT 2016 observed PT demands. This removed the need for independent trip generation and distribution models and the need for passing a range of data from MSM. The proposed revised operation of the MPT is shown in the following Figure.

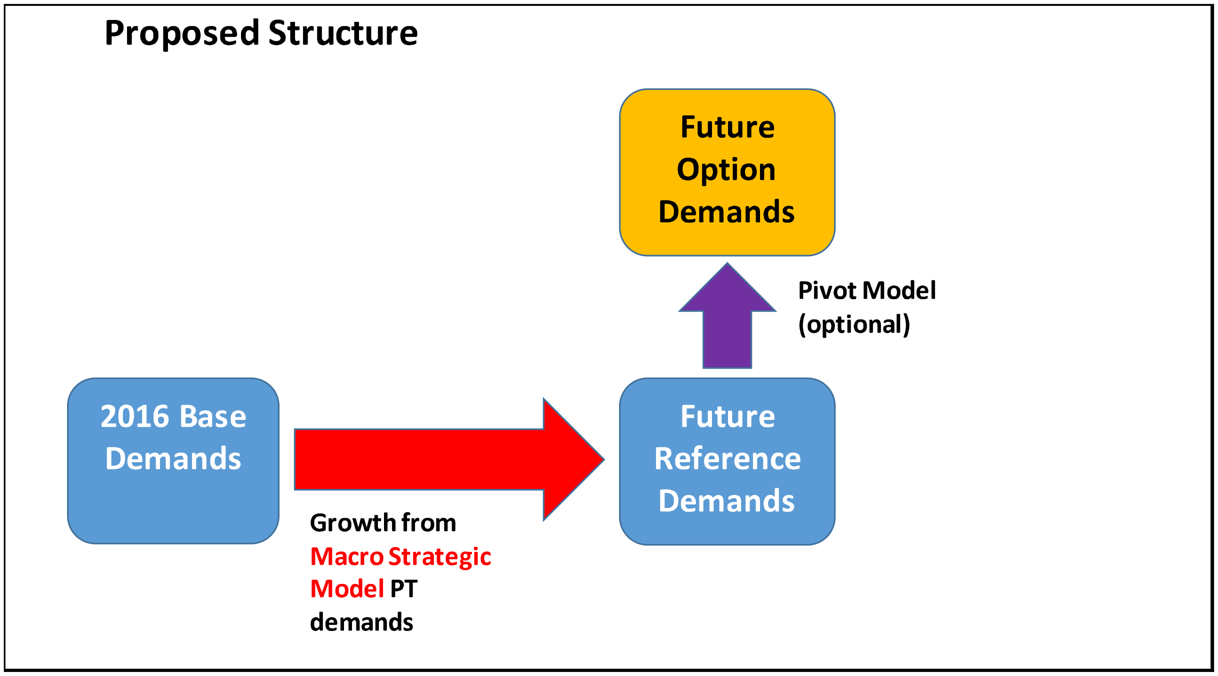


Figure 8-1Proposed Outline Structure for Macro PT Model

Here future scenarios can be created in two ways, depending on the scale and impact of the scheme:

1. Running all scenarios first in the Macro Strategic Model, with unique growth factors that create unique forecasts in the Macro PT model (i.e. without using the pivot model); or

2. Running a Reference scenario in the Macro Strategic Model and applying the resulting growth factors to create a Reference Macro PT model scenario. Additional scenarios are created directly in the Macro PT model using the pivot model.

Typically, method 1 may could be more appropriate to compare multi-modal schemes with significant regional impact and strongly differentiated, while method 2 could be more appropriate to assess a more localised PT schemes. The methods for undertaking the growth factoring are discussed in the following chapter.

8.2.3 Detailed Model Structures

The structure of the revised MPT model is shown in the following figures, for the three modes of operation:

1. The 2016 Base Year

2. The future Year Reference Scenario

3. The Future Year option scenario (using the pivot model)

The detailed structure of the pivot model is discussed later in this report.

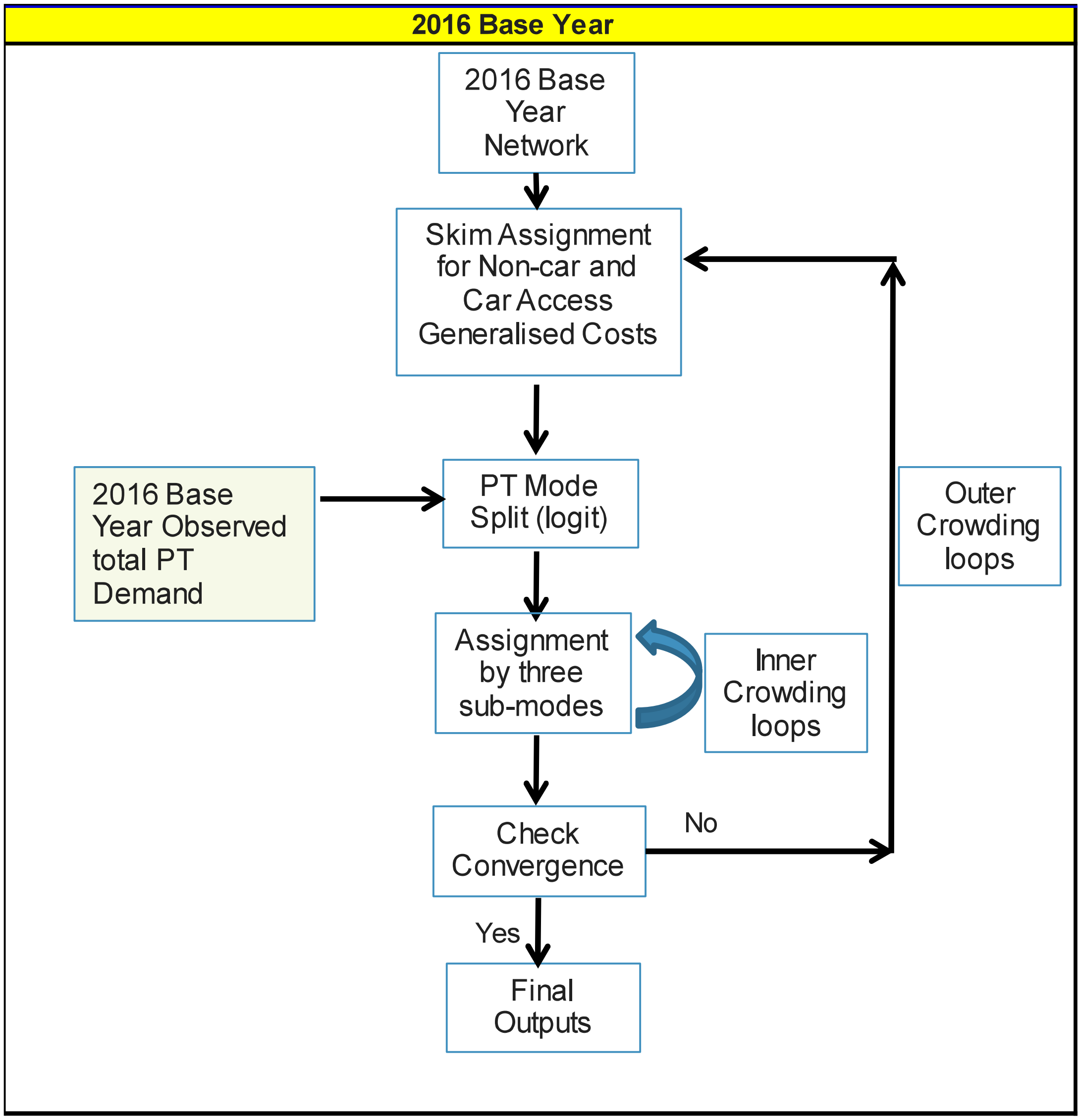


Figure 8-2 Structure of MPT 2016 Base Model

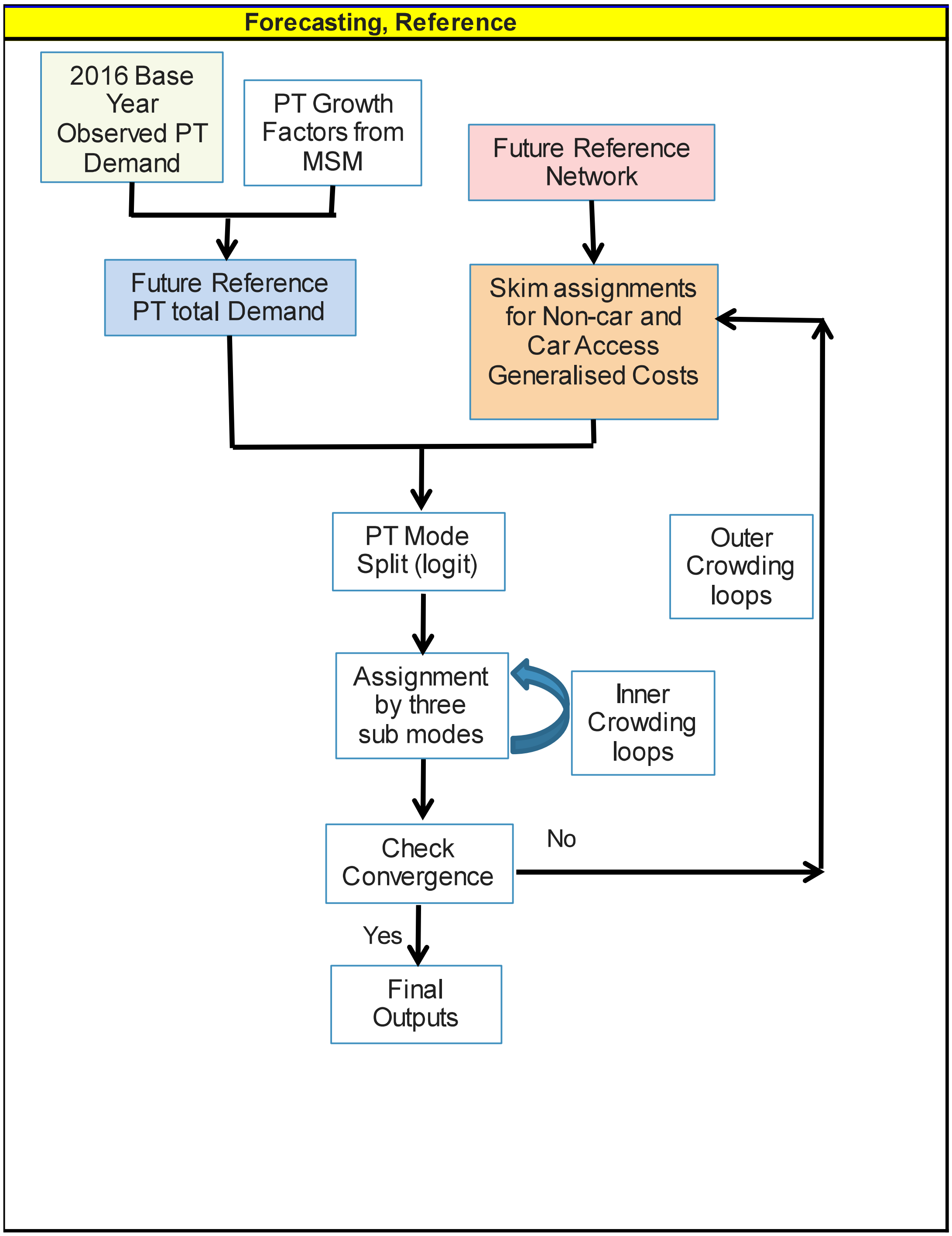


Figure 8-3 - Structure of MPT Future Reference Model