WELLINGTON TRANSPORT ANALYTICAL TOOLS

PREPARED FOR GREATER WELLINGTON REGIONAL COUNCIL

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1. Introduction

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

1.1 Project Objectives

The project objectives can be distilled to:

- Improve user confidence in the Analytical Tools;
- Produce a high quality, fit for purpose product;
- Update the primary Tools and make them as simple as possible and transparent, while maintaining flexibility for future changes;
- Fix identified weaknesses; and
- Plug identified functionality gaps by developing and implementing new modules.

1.2 Project Staging and Status

The project was initially organised into three sequential stages, which encompassed:

- Stage 1 – fix specified weaknesses and develop new modules to embed specific additional functionality into the Wellington Transport Strategy Model (the demand model, WTSM). Review the current WTSM and determine if a full rebuild of the underlying equations is necessary. This process was to run in parallel with the collection of Household Travel Survey (HTS) data, which is the primary source of travel information and underpins strategic model development. Update the Wellington Public Transport Model (WPTM);
- Stage 2 – if required, rebuild the primary Analytical Tool which forecasts travel demand throughout the Region; and
- Stage 3 – incorporate income segmentation and PT crowding. During the Scoping Workshop, it was requested that PT crowding be addressed as part of Stage 2.

The new road assignment model (Wellington Traffic Assignment Model, WTAM) was planned to be developed in Stage 1 but has been shifted to Stage 2. This is due to a new EMME intersection modelling tool and the desire to incorporate this functionality, as well as significantly more observed data – the combination of which is envisaged to produce a better product.

With PT crowding moved to Stage 2, the only remaining element in Stage 3 was income segmentation. This has therefore also been moved to Stage 2 for efficiency reasons.

Stage 1 was completed later than anticipated in August 2021. This was partly due to high profile competing project demands, but primarily the impact of the Covid-19 pandemic which put New Zealand into an extended lockdown and significantly changed typical travel patterns in 2020. This meant the collection of observed travel behaviour data through the Household Travel Survey was prematurely stopped leading to a smaller sample than initially envisaged, and alternative representative travel pattern data sources were sought. The data obtained is documented in a separate technical note as part of this series.

At the end of Stage 1, an interim 2018 version of the WTSM was completed. This included 2018 inputs (land use data, economic parameters, network, etc), included some new sub-models and functionality, but retained the same zoning and form as previous versions.

The interim 2018 version of WTSM validated somewhat worse than the 2013 version (see Technical Note 16). The key issues were population increases producing trip making in excess of observed which the model was unable to replicate, and revised or added functionality pushing the model out of its calibrated range. This demonstrated the need to rebuild the demand model.

The components to be developed in Stage 2 of the project, which commenced in August 2021, are documented in this technical note.

1.3 Purpose of this Report

This technical note documents the functionality and specification for the rebuilt primary demand model (WTSM) and the new road assignment model (WTAM), which are the main deliverables of Stage 2.

This report is organised to document:

- Summary of the models in the analytical framework
- Sub-models and inputs developed in Stage 1 to be included in the new analytical framework
- Functionality and form of the new WTSM demand model
- Functionality and form of the new WTAM road assignment model

2. The Analytical Tools

The full suite of the Wellington Regional Analytical Tools for transport planning is shown below. The different components have specific capability and functionality and hence are applied at different stages of the transport planning process.

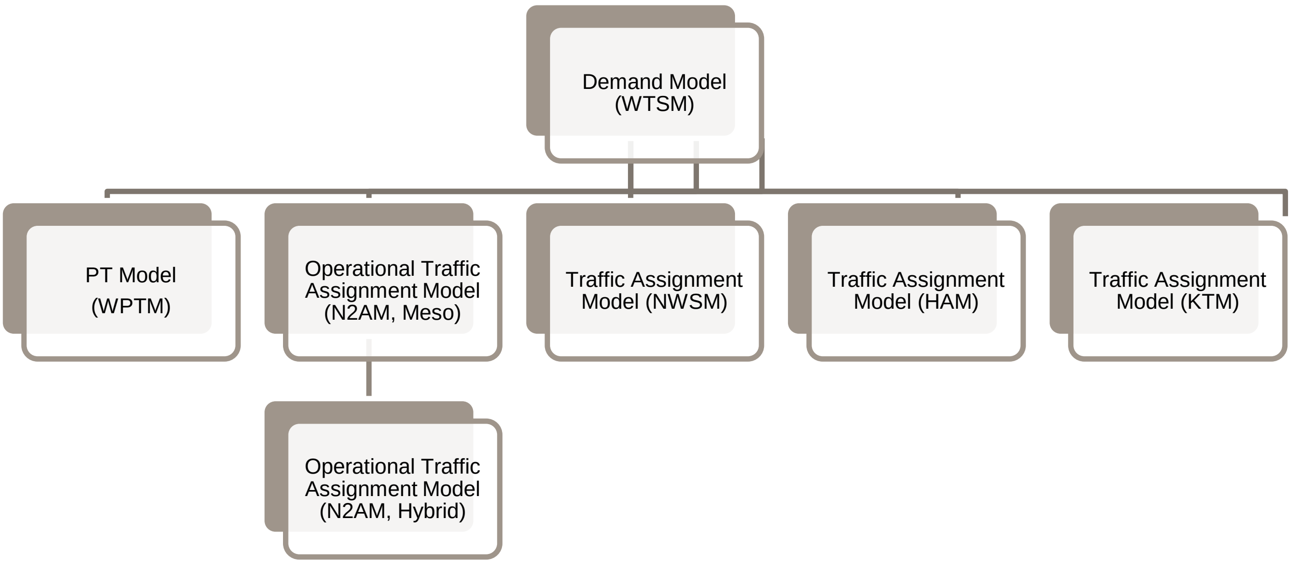

Figure 2-1: Wellington Regional Analytical Tools

The requirement of these tools is to provide a reliable basis for:

- Making informed investment decisions;
- Evaluating transport strategies;
- Evaluating the impact of transport interventions, including road and public transport improvements;
- Provide a mechanism to assess the impact of changes on mode share, including walking and cycling; and
- Providing travel demand for lower-tiered transport models.

The tools should reflect observed behaviour in the base year to an appropriate level of accuracy. They should be capable of forecasting future year conditions given specified inputs, and should enable (potentially through "what if" testing) the assessment of emerging trends.

A short description of the models illustrated in Figure 2-1 is provided in the following sections.

2.1 Demand Model

The overarching tool is the demand model, WTSM which is the primary tool used by for strategic transport demand analysis. It is used to investigate infrastructure investment options, public transport provision, transport policy and land use scenarios.

WTSM is a multi-modal four step strategic transportation model that applies calibrated travel behaviour to produce travel by mode based on input assumptions on the transport network, population and related demographics, policies (such as travel demand management initiatives, parking costs, fuel prices, etc), and other metrics. WTSM currently accounts for traditional motorised travel on the road network (private vehicles and light/heavy commercial vehicles), and people using public transport (rail, bus, ferry and the cable car). Bicycle and walk trips are not explicitly represented at present but are accounted for simply as a proportion of either car or PT (which varies by trip purpose).

A diagram of the current WTSM framework is shown below.

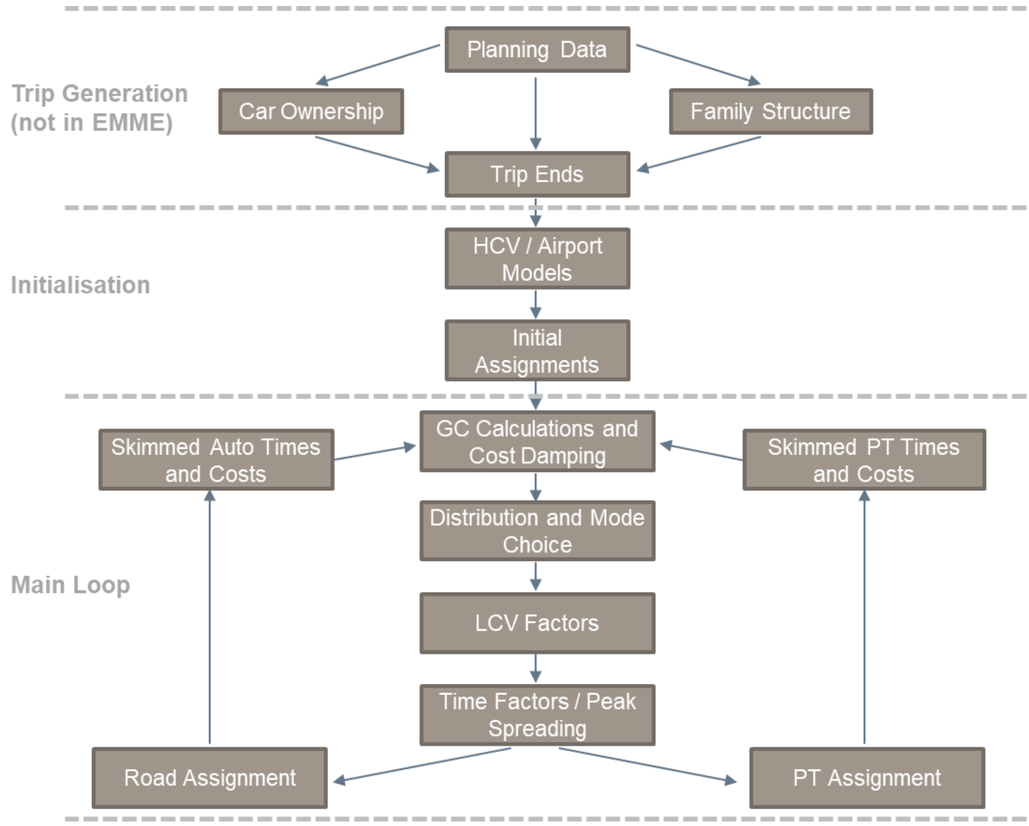

Figure 2-2: WTSM Schematic[1]

The model estimates demand for an average weekday. Prior to assignment, this daily demand is broken down into representative time periods: a two-hour AM peak (7-9am), a two-hour interpeak (two hours average of 9am-4pm), and a two-hour PM peak (4pm-6pm). The evening and overnight periods are not represented. These demand matrices are subsequently assigned to the road and public transport networks.

The primary purpose of the WTSM is to estimate travel demand by mode for medium to long-term horizons (i.e. 10, 20, 30 years beyond the base year). It produces first order estimates of transport system performance including travel distances and congested travel times, enabling high-level quantification of indicative benefits for strategic-level interventions. The model is appropriately strategic with 225 internal zones.

This generation of WTSM was first created in 1996 when the model was converted into the current EMME software platform. The WTSM was then fully calibrated and validated using a Household Travel Survey for

[1] Trip generation in WTSM currently carried out in Excel. The remainder of the model is implemented in EMME.

the base year of 2001. Since then, it was revalidated to the years 2006, 2011 and 2013. The years 2001, 2006 and 2013 coincided with the National Census. The 2011 revalidation should also have coincided with Census, but because of the Canterbury earthquakes, the 2011 Census was postponed to 2013. The 2011 review continued, however, to support a high-profile project, followed by a check in 2013 when Census data was available.

WTSM is now 18 years old, and as demonstrated through Stage 1 of this project needs to be recalibrated to more up-to-date travel patterns.

2.2 Public Transport Model

The Wellington Public Transport Model (WPTM) equips the Region with enhanced capability for public transport planning. WPTM recalculates sub-mode choice (undertaken previously in WTSM) and then route choice for public transport trips using more refined processes. It has an incremental mechanism to estimate future travel patterns by pivoting from observed base year public transport travel based on changes forecast by the WTSM. The model was developed with greater level of zonal resolution, with 780 internal zones to capture walk-in versus ride-in access mode catchments.

A diagram of the model process is shown below.

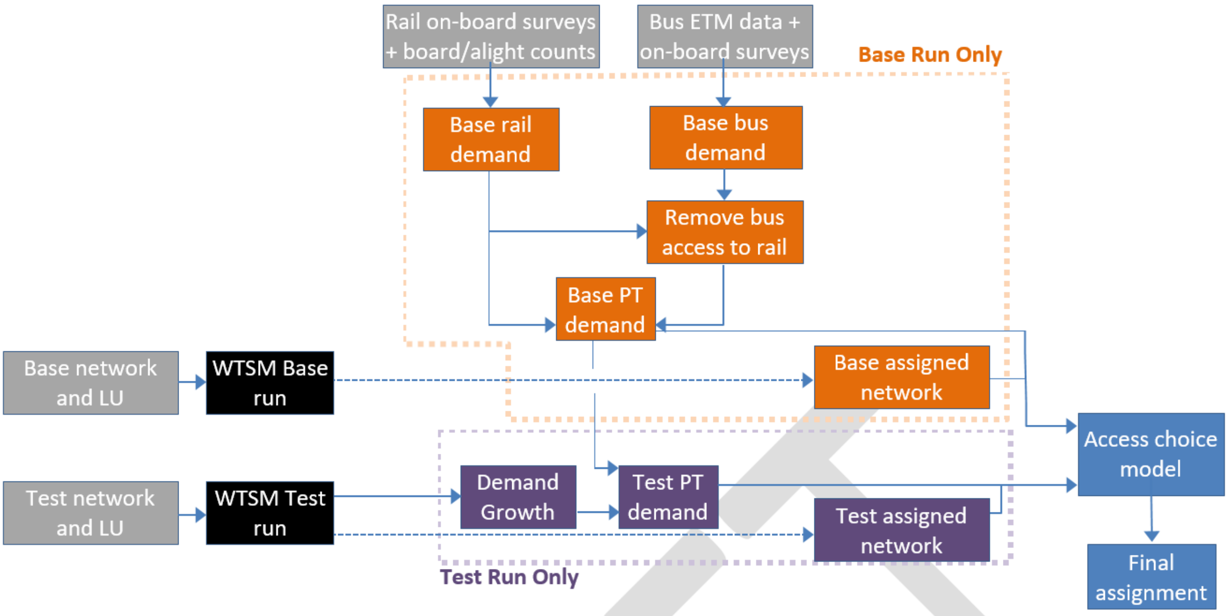

Figure 2-3: WPTM Schematic

WPTM has two-hour AM peak (7-9am) and two-hour interpeak assignments (2-hour average of 9am-3am) that were developed from comprehensive observed data. A two-hour PM peak assignment (4-6pm) was later developed as a factored transpose of the morning period. In Stage 1 of this project, a representative PM peak model was developed using observed PM peak demand.

Obtaining reasonable public transport trip matrices from a mode choice model embedded in a strategic model can be extremely challenging. The purpose of the WPTM is to produce a more refined estimate of public transport (PT) patronage by mode and route using observed PT matrices and a pivoting approach. Public transport system performance and benefits of PT interventions can be better estimated using this approach. It is noted that bus travel times are a function of the WTSM forecast of congested travel times on roads, which are strategic in nature (i.e. turning delays at intersections and bottlenecks are reflected simply).

WPTM (AM and interpeak periods models) was developed as part of the 2011 update and was calibrated and validated to 2011. The demands were developed from observed data – including rail and bus origin-destination interview surveys. The observed matrix was modified in 2013, applying minor sector-based factoring to reflect 2013 demand. In 2016, the PM peak period was added by transposing the AM peak demands with factoring of the outputs to better reflect observed patterns.

As part of Stage 1 of this project, the WPTM has been updated to 2018, including a full rebuild of bus matrices for all three time periods based on bus electronic ticketing data, and an increase in number of internal zones, with the upgraded zone system to be consistent with the new WTSM and WTAM.

2.3 Traffic Assignment Models

Alongside the WPTM are a series of traffic assignment models covering different geographic areas of the Region, as shown in Figure 2-1. These models produce more refined estimates of vehicle route choice with smaller zones and have a more detailed calculation of congested travel times taking intersection delays and cumulative queues explicitly into account. They have a base year vehicle demand matrix derived initially from WTSM and then adjusted and improved using observed data. Their respective base years vary depending on when and why the models were originally developed. These models all focus on vehicles, so while buses are represented as part of the traffic flow, people on the buses are not considered. Forecast vehicle demand is produced by applying the changes forecast by WTSM between the base and future years using a pivot approach based on their respective calibrated base year demand matrices .

Each of these models was developed for the purpose of producing a more robust estimate of travel benefits (congested vehicle travel times and travel distances) for a specific scheme. Given their large scale, however, they have subsequently been applied to evaluate other projects (after appropriate checks and updates were undertaken).

The newest of the suite is the Ngauranga to Airport (N2A) operational traffic model. Taking advantage of modern software functionality, this model assesses the build-up and dissipation of traffic throughout the congested peak periods. There is an AM peak (6-10am), an interpeak (10am-2pm), and a PM peak (3-7pm) model. Only the middle two-hours of each of the three periods were validated, with the first and last hour a warm-up and cool-down periods typical with simulation modelling.

3. Stage 1 - Updated Model Components/Inputs

Decisions on the new model, as well as sub-models/inputs updated or developed in Stage 1 and data collected are summarised in this section.

3.1 New Model Form

In the scoping workshop at the start of the project, the new model form was discussed, particularly whether it should remain a traditional trip-based model or evolve into a tour-based model. The collation of data to enable an informed decision to be made is documented in Technical Note 6.

A tour-based model requires comprehensive Household Travel Survey (HTS) data. The Covid-19 pandemic put New Zealand into an extensive lockdown in 2020 such that all data collection was interrupted before the Household Travel Survey could be completed, leading to a smaller sample than initially envisaged.

Uncertainty over the timelines to build a new tour-based model, in part due to a lack of essential travel pattern data, meant the decision was made to retain a trip-based model. This decision was re-enforced by Waka Kotahi indicating New Zealand major centre model rebuilds would be more frequent, meaning there was less needed to futureproof the model for the next 20 years.

3.2 New Sub-Models

3.2.1 Airport Model

A new airport passenger land access module has been developed as part of WTSM and is documented in Technical Note 10. This will be incorporated in the new model framework.

The outputs will be reconfirmed as appropriate when it is integrated with the new WTSM demand model.

3.2.2 Ferry Passenger Model

A new ferry terminals passenger access module to WTSM has been developed and is documented in Technical Note 14. This will be incorporated in the new model framework.

The outputs will be reconfirmed as appropriate when it is integrated with the new demand model.

3.2.3 HCV Model

An updated heavy commercial vehicle model has been produced and is documented in Technical Note 11. This is a trip-based predictive 3-stage model (generation, distribution, assignment). This will be incorporated in the new model framework.

The 2018 validation of the model will need to be confirmed when it is integrated with the new WTSM demand model.

3.2.4 WPTM

The Wellington Public Transport Model (WPTM) was updated to March 2018 and validated in Stage 1, which is documented in Technical Note 15.

The 2018 WPTM outputs will be rechecked following the completion of the new model framework.

3.3 2018 Inputs

3.3.1 Zoning

WTSM has 225 internal zones developed from Census meshblocks which is considered coarse by modern standards. It also has 3 additional zones representing the two road externals in the north and the Port.

A new zone system was developed in Stage 1 based on Census statistical area 1 (SA1) units which resulted in 819 zones (internal and external) comprised of:

- 813 internal zones
- 1 zone for each of the two road externals in the north (State Highway 1 and 2)
- 1 zone for the Centreport container terminal
- 1 zone for each of the Interislander and Bluebridge ferry terminals
- 1 zone for the Airport

This is documented in Technical Note 3 and is referred to as the "820 zone system" albeit that there are only 819 zones allocated at present (the 820th zone will be included as a dummy in the interim).

The WPTM had 780 zones, a subset of the 225 internal meshblock-based zoning. The WPTM was converted to the 820 system in Stage 1.In addition, both WTSM and WPTM include 50 additional "dummy" zones to represent park-and-ride and kiss-and-ride at rail stations. These were however not considered as zones in this document for the sake of clarity.

The new demand model and the WTAM will be developed using the 820 zone system. This will mean that that the key strategic models within the model framework will have consistent zoning.

3.3.2 2018 Household Travel Survey

Household Travel Survey data for the Greater Wellington Region was obtained from the annual rolling surveys carried out by the Ministry of Transport, for the years 2015 to 2019. In addition, a "boost" sample was to be collected in 2019-2020 to increase the total sample available specifically for this project. This extra collection was interrupted half-way in March 2020 because of the impact of Covid-19 and following lockdown. While the resulting sample is smaller than would typically be required for the development of a strategic transport model, it will still represent one of the main sources of data to rebuild the WTSM.

The resulting dataset therefore ranges from 2015 to 2020 but is referred to as '2018 HTS' in the remainder of this document for simplicity, as it will be used to update WTSM to a 2018 base year.

Analysis of this dataset will be reported separately.

3.3.3 Mobile Phone Data

Trip patterns from anonymised mobile device location data were obtained from Qrious, a mobile phone operator data analytics branch. Data for the month of March 2018 could not be used due to too much variability in the dataset, and data for the month of October 2018 was used instead.

Trip matrices were produced for all weekday time periods to be covered in the new model (as well as for a Saturday 11am-2pm, but this data will not be used in this project) and using the same 820-zone system as the models. Demand was split into home-based and non-home-based purposes, but not disaggregated into modes although the functionality to separate walk trips from other modes was added.

Analysis of this dataset will be reported separately.

3.3.4 2018 Network Development

The road and public transport networks were updated from 2013 to 2018 in Stage 1 of the project.

Centroid connectors for both the 225 and 820 zone systems were produced, the former for the interim 2018 version of WTSM.

3.3.5 2018 Land Use

The following 2018 land use data was sourced, processed, and tabulated in the 820 zone system:

- Land use (population, households, employment – all by type). This data was all factored to represent the mid-year "Estimated Resident Population" definition
- School roll, including primary, secondary and tertiary

Census journey-to-work and journey-to-education data was available at the more aggregate statistical area 2 (SA2) level. This was processed and allocated to sectors.

Sources and processing of the land use data is documented in Technical Note 12.

It is anticipated that more disaggregate land use data (such as labour force, households with children, etc and cross tabulations) will be required for the updated demand model. This will be specified, requested, processed, and documented as part of this Stage 2 work.

3.3.6 2018 Traffic Counts, Travel Times, and PT Patronage

2018 traffic counts, travel times and a range of public transport patronage indicators were collated and processed. These are documented in Technical Note 4, and the Addendum to Technical Note 4.

It was found around the CBD that 2018 counts were lower than expected. In some locations, the 2018 counts were lower than 2013, but in all cases, traffic levels had returned to expected trends around 2019. Alternative data sources were checked to ensure there were no processing errors, which was not the case.

Rather than fit the new model to these low counts with 2018 seemingly being an outlier, an amended count dataset will be produced, likely based on an average of surveyed years, and will be separately documented.

Public transport patronage data included bus electronic ticketing machine data, rail automated door counts and high (guard) counts, CBD cordon counts and high-level patronage data obtained from Metlink and GWRC.

3.3.7 2018 Economic Parameters

Economic and other model input parameters were updated for the current version of WTSM and are documented in Technical Note 9. This will need to be revisited for the new model, although the source data has been collated.

3.3.8 2018 Parking Charges

Parking supply and charges were collated for 2020. These were aggregated into sectors and allocated to WTSM trip purposes. This was achieved using Household Travel Survey data, and in the absence of up-to-date data, the 2001 HTS was used.

The aggregation of parking supply and charges to the new model trip purposes will be produced using the 2018 HTS in Stage 2. The data and calculation method will not be changed – just the trip purposes and the proportions which will be refreshed using up-to-date HTS data.

"Terminal times" reflecting time from an origin to a parked vehicle, and from a parked vehicle to the final destination were estimated using the 2001 HTS. These are very broad and will be retained for the new model.

Parking related inputs and calculations are documented in Technical Note 7.

3.4 Other changes

3.4.1 Improved Delay Representation

A review of modelled compared with observed travel times was undertaken as it had been indicated that the model performed poorly. This did not appear to be the case. However, a change in the volume-delay functions (VDF) applied to produce congested travel times on motorways was recommended, moving from the Akcelik curve to the Modified Davidson curve.

This is incorporated within the 2018 network and will be applied in the updated model. This is documented in Technical Note 5.

Further refinement of intersection modelling was investigated, leading to an ongoing evaluation of the new EMME "Junction Capacity Assignment Tool". This functionality will be specified in this technical note in terms of the new model functionality.

3.4.2 Park and Ride

Changes were introduced to the interim version of WTSM to improve the representation of park-and-ride (P&R) and to enable charging for parking spaces at P&R. The analysis and changes are documented in Technical Note 13.

The implementation of this functionality is only applicable in the current model which is based on 'p-connectors' and so will not be carried forward into the new model. The data analysis can, however, be used.

Park-and-ride will be incorporated in the new model but included explicitly as a mode, which is documented in this technical note.

3.4.3 Public Transport Assignment

As part of work carried out in parallel for the Let's Get Wellington Moving project, a number of changes were carried out in the PT assignment of WTSM, including:

- Implementation of the new EMME 'journey levels' functionality, to enable a better representation of varying costs and penalties for transfers vs initial boardings (e.g. integrated ticketing), or between various modes.
- Functionalities to apply in-vehicle time perception factors for both modes or links, or a combination of the two.

While it is anticipated that the PT assignment will be reworked as part of Stage 2, these improvements will be included in the next version of the model.

3.4.4 Time Periods

The duration of the commuting time periods in the current model have been extended to reflect travel patterns. In the new model, the time periods will be:

Table 3-1: New Model Time Period Definition

Period	Hours
AM	6-9am
Interpeak (IP)	Average hour between 9am-3pm
PM	3-6pm
Overnight (ON)	6pm-6am

This is documented in Technical Note 2.

4. Development of Observed Base Year Demands

Prior to building the new demand model, the first stage will be preparing the observed base year demands.

4.1 Household Travel Survey

This will involve checking and likely re-expanding the 2018 Household Travel Survey (HTS) Data. Expansion will consider:

- Households by broad (sector) geographic location
- Number of households by occupants (i.e., one person households, two person, etc), by broad geographic location
- Households by income and vehicle availability by broad (sector) geographic location

Checks will primarily involve assigning the car vehicle and PT person trips demands from the HTS and comparing to observed data. This will determine if there is any geographic bias or under-reporting in the dataset. Traditionally, for paper-based surveys, under-reporting can be as much as 40% in the interpeak period. This is not expected in this HTS which used a GPS tracker and prompted recall methodology, which is expected to significantly reduce under-reporting.

If geographic bias is discovered, we will:

- Revisit the expansion factors, and check any household, population, or population by age group variations within expansion sectors that need to be further addressed.
- Revisit the expansion factors, considering the work locations of employed persons and update the expansion factors if required.

If significant under-reporting is discovered, we will:

- Determine if simple adjustments can be applied (by trip purpose and sector) to improve the fit to observed.
- If simple adjustments are feasible, these will be applied.
- Alternatively, the model development approach will focus on increased reliance on the mobile phone data. Potentially, an error correction matrix may need to be introduced in the demand model – this is not considered good practice and will be a last resort if the relatively modest HTS sample and mobile phone data are not representative.

Sample rates by category and trip purpose will be calculated. The categories are likely to include vehicle availability or income band verses persons by age group (aggregated from the 18 Census categories into five or six groups). If there is no sample in some categories, the number of groups will be reduced. If there is still no sample in some categories, national HTS will be collated and applied for the trip production model. This is discussed further in Section 5.4.

For the trip attraction model, the 2018 HTS will need to be applied to provide local context.

For the mode/destination choice and time period models, low sample in the HTS can be supplemented with mobile phone data described in the next section.

The potential for using the 2001 household travel survey that was carried out for the development of the original WTSM will also be investigated. While initial analysis has shown that some trip patterns show changes between the 2018 and 2001 datasets, it may still be possible to reuse the 2001 HTS to supplement the 2018 data for parts of the model calibration, such as trip distribution. Check of statistical significances of these differences will be carried out, with the 2001 data potentially adjusted if it is found to be usable.

4.2 Mobile Phone Data

The mobile phone origin-destination data is segregated by:

- Time period
- Home versus non home-based
- All person trips which are modal agnostic, although there is an indicative flag for walk/cycle active mode trips
- Expansion has been undertaken by the supplier, Qrious, who have access to the raw data which cannot be released due for confidentiality reasons

The processing for the mobile phone data will include:

- Disaggregating the data by mode into person-in-cars, public transport, and active modes. Persons-in-cars will then be divided into drivers (i.e. vehicles) and passengers. Both levels of disaggregation will be produced using sector-based proportions from the expanded 2018 HTS.
- Assign the four peak period vehicle and public transport persons matrices in the current demand mode at 820 zones. Compare modelled with observed and determine if the data is representative. If there are any issues, the split into mode will be revisited in the first instance.
- It is expected that the Qrious data will be representative as comparison with the current WTSM, initial expanded 2018 HTS, and observed metrics (traffic counts and public transport line loadings) has already been undertaken at a high-level.

5. New Demand Model

This section documents the functionality for the rebuilt trip-based 4-stage demand model.

Some decisions cannot be made at this point in time as they depend on data availability or trends/relationships found in the travel pattern data. As such, the preferred functionality is documented along with the decision-making process.

5.1 Model Form

The model will be a trip-based 4-stage model. Background and references are documented in Section 3.1 of this technical note.

5.1.1 Model Structure

The model structure is illustrated below.

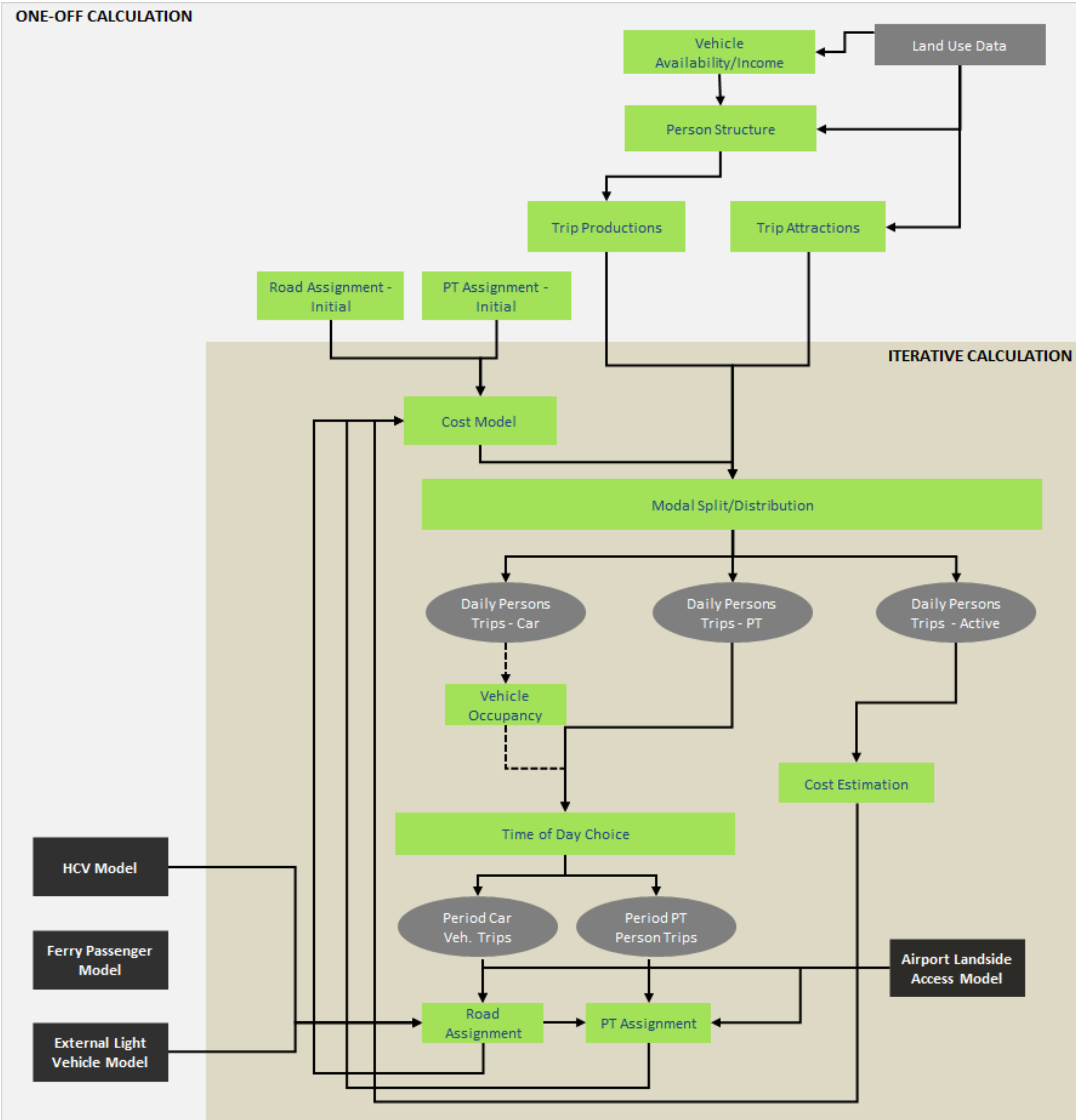

Figure 5-1: Demand Model Structure

The model will include the following components which are described in detail in subsequent sections:

- Vehicle Availability/Income and Person/Family Structure Models – allocation of people into different categories with distinctive trip making patterns.
- Trip End Models – including trip productions and trip attractions. This will be implemented for average weekday daily travel.
- Distribution/Modal Choice Model – which may be implemented as two distinct steps or as a composite estimation. This will be implemented for daily travel in production-attraction format.
- Vehicle Occupancy Model – converting persons in vehicles to vehicles. This may not be required if the mode choice model can distinguish vehicle drivers and passengers. If a separate model is required, this will be implemented either for daily travel or by time period depending on analysis of the household travel survey data. If this is a peak period calculation, the vehicle occupancy model will follow the time of day choice model.

- Time of Day Choice Model – conversion of daily trips to peak periods. This will be calculated for vehicles (or persons in cars, if vehicle occupancy by purpose is found to change throughout the day) and public transport. This will include conversion of production-attraction format demands into origin-destination matrices. There will be four peak periods: AM, interpeak (IP), PM, and overnight (ON). These will sum to daily/24 hours negating any adjustment/factoring to produce daily flows.
- Light Commercial Vehicle Model – there is no data to develop this model. The issues and solution are described in Section 5.9.
- Heavy Commercial Vehicle Model – the predictive three stage model for medium and heavy commercial vehicles which was developed in stage 1 of the project will be implemented. As the distribution uses distance, the outputs do not vary based on the congested assignment. Hence this model is estimated once (i.e not iteratively) in the initialisation sequence.
- Ferry passenger model – the new ferry terminals passenger access model, that was developed in stage 1 of the project will be implemented. This model is also estimated once in the initialisation sequence.
- External Light Vehicle Model – estimation of light vehicle through trips (external-external) and those with one end inside the study area and the other outside (internal-external and external-internal). This model is likely to be estimated once, as internal destinations are less likely to be cost-responsive. This will be confirmed during the model build. Heavy vehicle external trips are included in the heavy commercial vehicle model.
- Airport model – the new land access model, that was developed in stage 1 of the project will be implemented. This model includes a modal choice element and therefore is iteratively recalculated within the demand model.
- Trip Assignment Model – assignment of peak period vehicle and public transport trips to the network.

5.1.2 Trip Purpose

The demand will be segmented by trip purpose. The number of trip purposes will be determined based on analysis of the household travel survey data and consideration of the different travel behaviour, with the aim that any one purpose should not have a significantly larger demand than others.

It is expected that there will be six to eight trip purposes.

The trip purposes are likely to include:

- Home-based work
- Home-based education. This will be defined as any trip to education, and will include the person attending the education facility and any accompanying people (for example, school drop off/pick up)
- At least one other home-based category that could relate to shopping, social/recreation, etc.
- Home-based other
- Employer business. Included as there will be different cost sensitivity. This could be separated in home-based and non-home-based depending on the number of trips.
- Non-home based other

5.1.3 Base Year

The model will represent the base year of 2018 aligned with the national Census.

The demand model will represent March, with collated traffic counts seasonally adjusted to approximate the month of March.

The WPTM has also been amended to represent March average weekday conditions, providing consistency between the modelling tools.

5.1.4 Data Sources by Model

The expected primary observed data sources to develop each model component are summarised below.

Table 5-1: Model Component and Key Data Source

Model	Data Sources
Vehicle Availability/Income Model	Census and HTS (Wellington or national)
Person/Family Model	Census and HTS (Wellington or national)
Trip Production Model	HTS (Wellington or national)
Trip Attraction Model	HTS (Wellington), land use data
Cost Model	Assignments and externally calculated parameters
Modal/Destination Choice Model	HTS (Wellington); mobile phone data may be used for destination choice
Time of Day Choice Model	HTS (Wellington) and mobile phone data
Light Commercial Vehicle Model	No data
External Light Trip Model	HTS (Wellington) and mobile phone data Traffic counts
Road Pricing Response Tool	Ideally Stated Preference data, but may need to use Income segmentation from Census and HTS (Wellington)
Wellington Traffic Assignment Model (WTAM)	Mobile phone data

5.2 Vehicle Availability/Income Model

The approach to estimating trip ends is a category model. A category model has two dimensions which divide households/people into different groups where their behaviour is expected to differ. "Behaviour" includes daily trip rates and modal and destination choice, with mode and destination likely to be sensitive to vehicle availability or income. Daily trips in each category are fixed and do not change over time for each trip purpose.

Vehicle availability or income will be the first dimension of the two-dimensional category model.

The first step in developing the vehicle availability model will be to analysis the 2018 HTS to determine if there is a relationship between daily trip making by purpose and vehicle availability or income. Preliminary analysis of the initial expanded 2018 HTS indicated that there were lower trip rates for persons with an annual income of less than $50,000 but above that, there was a less clear relationship between income and propensity to travel. It is expected that a similar relationship will be found for vehicle availability, with the pattern differing mostly for a vehicle available compared with no-vehicle available.

Part of the decision of using vehicle availability or income as predictors will be the ability to robustly project the future year inputs to the model. This will be discussed with GWRC before a model is locked in, but it is considered more likely that vehicle availability will be a more robust metric to predict.

As discussed in Section 5.4, we plan to apply person-based (rather than household-based) trip rates as this takes account of people's place in the lifecycle and hence travel choices (such as school aged, working aged, etc). Hence the vehicle availability/income model will distribute persons into categories. Vehicle availability and income are, however, household commodities. For example, a couple with one car may each consider that they have one vehicle available. To enable the total number of vehicles to be aggregated and checked, we need to calculate vehicle availability on a household basis and then convert this to persons for the trip production model.

The process will be:

- Calculate total vehicle availability over the study area using international saturation rates for vehicles per person.
- Either calculate average vehicles per household for each zone, or if this is not possible, this will be an input to the model.
- From the average vehicles per household for each zone, calculate the number of households with zero, one, two, or three vehicles available. The vehicle groupings will change, however, there needs to be sufficient disaggregation to check the total study area number of vehicles.
- Calculate proportions of households in each vehicle availability group.

We will fit regression models to determine if the average vehicle availability per household can be calculated (rather than input). Predictors could include household size, geographic location/accessibility, average household income, number of adults, number of children, etc. While disposable income may be a strong predictor for vehicle availability, it will likely be difficult to forecast. If a predictive model cannot be robustly estimated, then average vehicle availability per household for each zone will be an input to the model. The base year data will be sourced from Census. Forecast years will require judgement but can be sensitivity tested.

Once the average vehicle availability per household is produced, vehicle allocation curves will be applied. These will convert an average zonal vehicle availability to numbers of households with zero, one, two, three plus vehicles. The source data to fit these curves is Census. An example of vehicle availability curves produced for Dunedin is shown below.

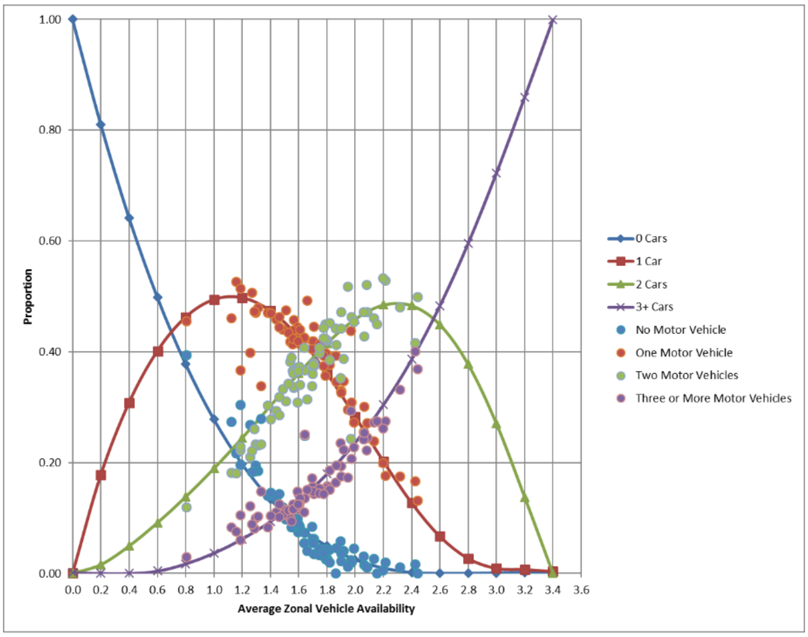

Figure 5-2: Example of Vehicle Availability Category Curves

5.3 Person/Family Structure Model

This forms the second dimension of the two-dimensional category model.

Persons will be allocated into categories where their trip making patterns are distinct. This will be identified by analysis of the 2018 HTS data for the Greater Wellington region.

Research has demonstrated that an appropriate categorisation is likely to be persons by age group, which has shown a relationship to daily trip rates by purpose. Adopted age bands must align with Census categories. Census age groups and potential age bands for the model is shown below.

Table 5-2: Potential Age Band Grouping

Census Age Groups	Potential Model Age Bands	Life Cycle
Persons Aged 0-4 Years	0-4 Years	Infant
Persons Aged 5-9 Years	5-14 Years	Primary School Aged
Persons Aged 10-14 Years		
Persons Aged 15-19 Years	15-19 Years	Secondary School/University/Young Worker Aged
Persons Aged 20-24 Years	20-29 Years	University/Working Aged
Persons Aged 25-29 Years		
Persons Aged 30-34 Years	30-64 Years	Working/Family Aged
Persons Aged 35-39 Years		
Persons Aged 40-44 Years		

Census Age Groups	Potential Model Age Bands	Life Cycle
Persons Aged 45-49 Years		
Persons Aged 50-54 Years		
Persons Aged 55-59 Years		
Persons Aged 60-64 Years		
Persons Aged 65-69 Years	65-85+	Retirement Aged
Persons Aged 70-74 Years		
Persons Aged 75-79 Years		
Persons Aged 80-84 Years		
Persons Aged 85 Years and Over		

Persons by age band for each model zone will be an input to the model. The base year data will be from the Census. Forecast year data is best calculated externally to the model, using cohort population modelling (i.e., considering birth/death and migration rates).

The final step is estimating the number of persons in each vehicle availability group and age band by model zone. This will be produced by multiplying the proportions in each vehicle availability group and each age band, and multiplying this figure by the total population for each zone. This distributes the population into age band and vehicle availability categories in preparation for the trip production model described in the next section.

5.4 Trip Production Model

The trip production model will apply fixed trip rates by purpose to the category model. The two dimensions of the category model which were described above will be:

- Vehicle availability (zero, one or one plus, two or two plus, three plus) or income band (in the order of five to six bands)
- Person or family structure. This could involve population by age band, or by family type (such as single person, couple without children, family with children, retirement-aged adults, etc)

The dimensions will depend on identifying relationships to trip making by purpose in the household travel survey data. The selection of the model dimensions will also consider the ease and representativeness of forecasting the input land use, which will be determined in consultation with GWRC.

Trip rates will be calculated from the household travel survey data for each category. These will be person-based (not household-based) trip rates.

We will actively avoid including zone-specific adjustment factors. Any adjustment factors required will be on a geographic sector basis.

For non-home-based trip purposes, a trip production model will be estimated and applied to control the total volume of trips.

Sample sizes will be checked. If there is insufficient sample for Wellington in the 2018 HTS, we would consider combining trip purposes. After that, national data from Auckland and Christchurch may also be used. Variation in trip rates will be checked prior to including different geographic areas.

Trip rates by category and purpose will be reviewed for the wider CBD compared with the overall study area to determine if there is any difference in trip making in the inner city. This will be subject to there being sufficient sample size for the CBD (by trip purpose and category).

The output will be daily trip productions (i.e. trip ends at the household zones) by trip purpose for each zone and each vehicle availability/income group retained. The retention of vehicle availability/income segmentation will depend on the requirements of the mode and destination choice model.

5.5 Trip Attraction Model

Trip attraction equations for each trip purpose will be developed using linear regression techniques. Explanatory variables, which are the input to the process, will include employment by type and school places by type. Weighted trip data from the HTS will be aggregated by (likely) SA2 sector to align with total attraction expandatory variables.

For non-home-based (NHB) trip purposes, linear regression will be applied to predict the zonal trip origins as well as the zonal trip attractions/destinations.

The total trip attractions by purpose (and the zonal trip origins for NHB purposes) will be factored to the total trip productions. This reflects greater confidence in the land use projections for population (productions) rather than employment (attractions).

The output from the trip attraction model will be the total daily trip attractions by trip purpose for each zone

5.6 Cost Model

The generalised cost of travel will be calculated for each origin-destination zone pairs separately per mode and trip purpose to feed into the distribution and mode choice models. The general approach will be similar to the current WTSM and standard 4-step models, with costs expressed in generalised minutes and monetary values converted into time units through the use of values of time.

Network skims carried out post-assignment will be used to extract costs, times, distances and other metrics between each OD pair. Economic input parameters currently used in the 2018 interim WTSM (e.g. value of time, vehicle operating costs, PT fares, etc) are detailed in 'TN9 – Model Input Parameters' but will be reviewed for the new version of the model. In particular, the current deflation of all costs to 2001 $ currently applied will not be carried over, with all costs expressed in 2018 $.

This section presents the calculations for generalised costs for each mode.

5.6.1 Private Vehicles

The formulation to calculate generalised costs for private vehicles for each purpose is expected to be as follows:

$$GC_p^{car} = Time + \frac{(Distance * VOC_p + Parking_p + Toll)}{VoT_p} + parkTermTime + parkSupplyCap$$

Where:

GC^{car}:	generalised costs for private vehicles
p:	trip purpose
VOC:	vehicle operating costs
VoT_p:	value of time for purpose p
parkTermTime:	parking terminal time

parkSupplyCap: additional time reflecting demand exceeding supply in the previous iteration when the 'parking constraint' switch is turned on

The following comments can be made:

- Parking cost calculations in the current WTSM have been revised as detailed in 'TN7 – Parking' and it is planned that these new calculations will be applied in the new version of the model, following refinements based on the new HTS. These costs are currently only calculated for the wider Wellington CBD. Parking costs outside of the wider CBD will not be calculated or incorporated, although calculations will be implemented in a way that enables parking costs for other areas to be specified at a later date.
- Parking terminal times represent the access time between a parked vehicles and ultimate trip destination (origin for outbound trips). They were not originally included in WTSM and have been added as part of Stage 1 (also detailed in TN7), although they were ultimately not activated as they led to the model becoming uncalibrated. These terminal times will be included in the new version of WTSM, based on the new HTS.
- There is currently no road tolling in the Wellington region but the WTSM allows for toll costs to be applied by link and this functionality will be included in the new version of the model. There is a strong potential for new types of road user charges to be implemented in the future, for example with the emergence of electric vehicles leading to a reduction in fuel tax revenue. It is important that their impact can be evaluated in the model and alternatives such as distance-based charges

will also be investigated. It is noted that this will be approximate in the absence of robust value of travel time savings data.

- An additional component will be added to the generalised costs and the model iteratively adjusted to represent parking capacity constraint. This is detailed in section 5.13.
- Costs per vehicle will then need to be converted into cost per person. In the case where simple vehicle occupancies are applied to convert person trips to vehicles, the same occupancy factors could be used to convert vehicle costs to person costs. Alternative approaches will however be investigated, especially regarding distribution of toll and congestion charging costs between driver and passengers.

5.6.2 Public Transport – Non-car Access

Calculations for public transport users generalised costs will account for improvements made to the EMME PT assignment since WTSM was developed, as well as added functionalities that have been implemented in the model since. In particular, 'journey levels' in the assignment will allow for a much better and easier representation of varying costs and penalties for transfers versus initial boardings, or between different modes.

The planned calculation for each purpose is as follows:

$$GC_p^{PT} = \left(IVT * p_{mode}^{ivt} * p_{link}^{ivt}\right) + \left(AuxT * p^{AuxT}\right) + \left(WaitT * p^{WaitT}\right) + \left(BoardT * n^{boardings}\right) + \left(n^{Transfers} * P^{Transfers}\right) + \frac{Fare}{VoT_p} + parkSupplyCap$$

Where:

GC^{PT}:	generalised costs for PT users
p:	trip purpose
IVT:	in-vehicle time
p^{IVT}_{mode}:	in-vehicle time perception factor per mode
p^{IVT}_{link}:	in-vehicle time perception factor per link
AuxT:	auxiliary time
p^{AuxT}:	perception factor on auxiliary time (currently 2)
WaitT:	waiting time (as a function of service headway, currently 0.25 * headway)
p^{WaitT}:	perception factor on waiting time (currently 2)
$n^{Boardings}$:	number of boardings
BoardT:	boarding time
$n^{Transfers}$:	number of transfers
$P^{Transfers}$:	transfer penalty
VoT_p:	value of time for purpose p
parkSupplyCap:	additional time reflecting demand exceeding supply in the previous iteration when the 'parking constraint' switch is turned on

The following comments can be made:

- In-vehicle time factors was only applied by mode in the current WTSM. A functionality was recently added to also specify these factors by link in order to reflect varying levels of services for different sections of a route (e.g., mass rapid transit running with traffic vs running smoothly on a segregated track). This will be included in the new model.
- An additional factor applying to in-vehicle time (and potentially boarding) will be added to represent crowding and vehicle capacity constraint. This is detailed in section 5.12.
- Values for waiting time factors, boarding times, interchange penalties and the various perception factors will be reviewed and compared against international practices. Values from the WPTM could potentially be applied for consistency between the two models.
- The introduction of journey levels will allow applying transfer penalties to actual transfers, whereas the current WTSM applies a blanket 10 minute penalty to all boardings.
- PT fares for input to the generalised costs in the current WTSM are not skimmed from the assignment but estimated through matrix calculations, based on skims of number of fare zones

travelled and boardings for each OD, to which the Metlink zone structure is applied. The main reason for this is that the assignment did not allow capturing the difference between boardings and transfers and applied a simple 10 minute proxy for fares for all trips. While this approach was generally satisfactory, it however resulted in a disconnect between the fares calculated in generalised costs and fare applied in the assignment. Journey levels allow more detail to be captured and the opportunity to directly skim the fares from the assignment will be investigated.

5.6.3 Public Transport – Car Access

For car access to public transport, i.e. park-and-ride and kiss-and-ride, the same generalised cost calculations will apply but the auxiliary time will be replaced with times and costs associated with the car leg of the trip, and the ability to specify parking costs will be added for park-and-ride.

The suggested generalised cost for the car leg of the trip is identical to the car generalised cost equation shown in section 5.6.1, with the following adjustments:

- In this case, parking costs will represent the cost of parking at park-and-ride sites (currently free), and apply only to park-and-ride trips. For sites with both formal and informal parking capacity, a weighted average parking cost would be calculated with zero cost for the informal parking spaces and the specified charge for the formal spaces. Sites with significant availability of informal parking spaces will therefore dilute the impact of adding parking charging.
- For kiss-and-ride trips, an adjustment factor may need to be applied on vehicle operating costs to account for the fact that the PT user is not the one directly incurring the cost.
- Parking terminal times may be applied to represent time between parked car and walking to the stop or rail station.
- An additional component will be added to the generalised costs for park-and-ride to represent parking capacity constraint. This is detailed in section 5.13.

5.6.4 Active Modes

Work recently carried out separate to this project to split active mode demand in the current WTSM will be used as a starting point to estimate generalised costs for walking and cycling. Expected formulations include times skimmed from the network (with a speed of 4kph for walk and 12kph for cycling) and accounting for intersection delays, as well (for cycle only) link gradient and negative perception factors for high speed arterials and rural links.

These formulations will be re-examined using more recent household travel survey and observed counts.

5.6.5 Heavy Commercial Vehicles

The formulation to calculate generalised costs for heavy commercial vehicles is as follows:

$$GC^{HCV} = VOC^{HCV} * Distance$$

Where:

GC^{HCV}:	generalised costs for heavy commercial vehicles
VOC:	vehicle operating costs

Time is excluded from the generalised costs to avoid small changes in travel times resulting in unrealistic redistribution effects. Excluding time means in application, that small changes in travel times will not result in businesses effectively relocating.

Tolls or charging for heavy vehicles will be incorporated in the assignment. As a result, any HCV tolls/charging will not result in businesses relocating, but will impact route choice.

5.7 Mode Split / Distribution Model

5.7.1 Model Structure

The distribution and mode choice models will be calibrated for 24hr demand, in production/attraction format. The main source of data for the calibration will be the household travel survey, potentially supplemented with mobile device location matrices.

Separate models will be developed for each demand segment, by purpose and depending on the segmentation adopted, including car availability or income.

One of the most important decision relating to these models will be the hierarchy of destination versus mode choice i.e. distribution occurring before, after or combined with modal choice.

The recommended approach is generally for mode choice to come before distribution as it has a lower sensitivity, to avoid small changes in generalised costs leading to comparatively large changes in demand by mode. The current WTSM applies this hierarchy except for Home-Based Work demand which has a combined model.

During technical workshops with GWRC, it was noted that the preferred order would be to have distribution occur before mode choice, the main reason being that this would allow running 'what-if' type of analysis, with adjustments to the mode choice without impacting trip distribution (if rerunning final loop only). The outcome of the calibration process and sensitivity of the model with this order will be compared against distribution post or combined with mode choice and discussed before a decision is made.

5.7.2 Distribution

The main choice for the distribution model will be the use of either a gravity model or a logit model. Both gravity and logit approaches have pros and cons. A gravity model is likely to be a simpler approach to fit and implement, but potentially result in trips being more "self-contained" within the various Wellington region's catchments given the fragmented nature of the regional urban areas. As a result, sector-based adjustments might be needed, as is the case in the current model which is based on gravity models. A logit model would likely perform better but will be more complex to calibrate, especially due to the small HTS sample.

Again, this choice will be made based on calibration results for both approaches.

Distribution models will be estimated through the use of either specialised statistical software, or custom scripts developed in-house.

5.7.3 Modal Choice

The mode choice model will convert total demand (either trip ends or trip matrices depending if it occurs before/combined or after the trip distribution) into demand by mode. The model choice model in the current WTSM is a binomial logit model which splits the demand into car and public transport. Active mode demand is included with either of these modes depending on the demand segment, and is later removed using fixed distance-based factors. For public transport, the choice between bus and rail, as well as between car access and non-car access to PT occurs through the assignment. For cars, there is no predictive split into drivers and passengers, people trips being converted into car trips by applying fixed vehicle occupancy factors, with a range of factors per demand segment, purpose and origin-destination sectors.

The suggested approach for the rebuilt WTSM is to use a multinomial logit model as follows:

- The main split between car and public transport will be retained, but active modes demand will be included in the mode choice at the same level.
- The form of the mode choice model for public transport, including the number of levels and "nesting" of the various sub-modes will be determined through testing and analysis of the HTS:
    - The choice between bus and rail in the current WTSM is carried out post mode choice model and through the assignment instead. Including this split as part of the mode choice model itself will be considered. While both modes tend to service different catchment with limited competition, including them in the model would allow for more control in terms of costs representation which would be important to improve representation of costs such as park-and-ride charges or capacity constraints.
    - Choice between car and non-car access to PT will also be included in the model, likely nested at a lower level after the bus/rail split, although this will be decided through calibration. If possible, park-and-ride will be further split from kiss-and-ride (in the same nest as car / non-car or below) to allow representing the impact of parking capacity constraints (see section 5.13).
- For cars, it is suggested that the conversion of car person trips into vehicle trips is still done through the use of vehicle occupancy factors. These will vary by trip purpose and geographically by sector-to-sector. While not within scope, we will consider whether single occupancy vehicles (SOV) and high occupancy vehicles (HOV) can be simply incorporated.

- For active modes, demand could be further split into walk and cycle, either through the use of simple distance-based factoring or through applying the logit model recently developed separately from this project.
- Ferry and cable cars are also represented in both WTSM and WPTM, but represent a much smaller share of public transport demand. They may be retained in the new model but will be combined with bus and rail demand. Likewise, new public transport modes to be evaluated in forecasting such as mass rapid transit will be part of the same public transport demand. In the case that bus and rail are separated through a logit model and not through assignment, it is recommended that rapid transit is treated as part of bus demand, with different speed and perception factors applied to these services.

While the ultimate model form will be decided based on calibration and may differ per demand segment, the following figure illustrates the mode choice model as described in this section, including post model processes for active modes and car occupancy.

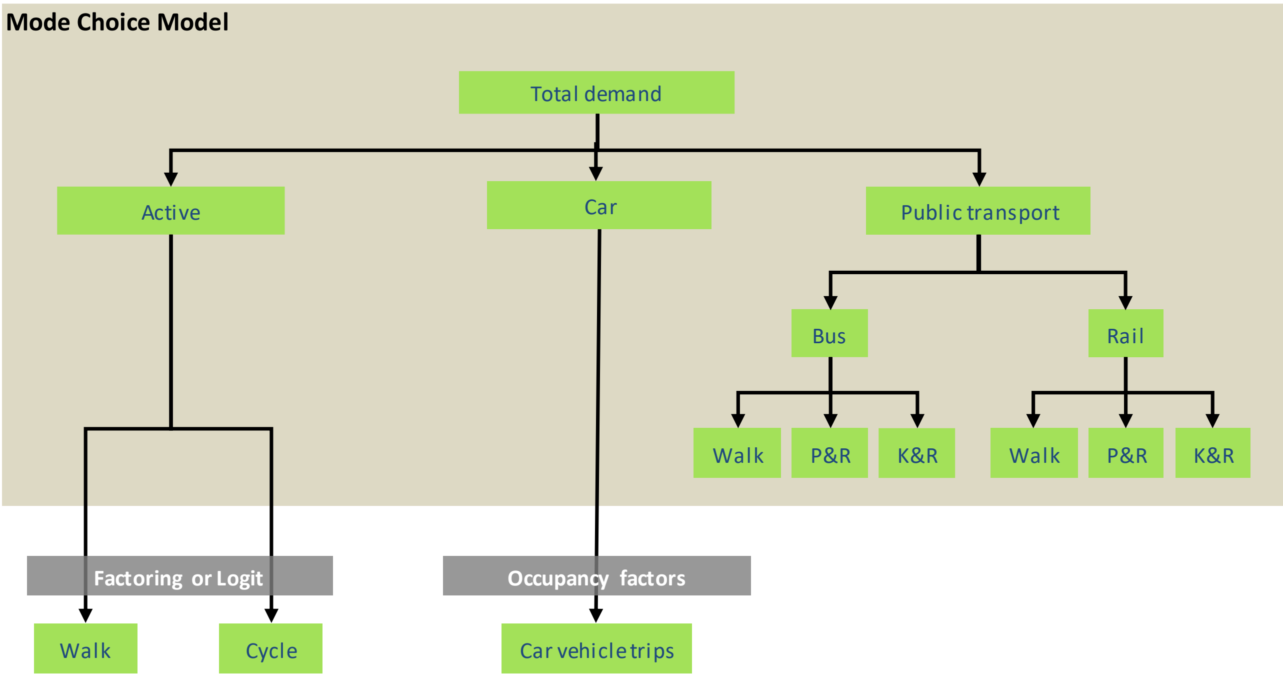

Figure 5-3: Mode choice model

5.7.4 Treatment of Generalised Costs

Generalised costs will be passed up from one level to the one higher up as composite costs, for example 'car access' and 'non-car access' to PT combined into a single 'PT' generalised cost. This will be done using the standard logsum formulation.

Generalised costs will be calculated for each model time period, and then aggregated to 24-hour for input into the mode choice and distribution models. The methodology for this will ultimately depend on how trips are split from 24-hour to modelled periods. If simple factors are used, the same factors will be used to convert period costs to 24-hour costs.

5.7.5 Car Access to PT

As described earlier, car access to public transport (park-and-ride and kiss-and-ride) will be included directly in the mode choice model, resulting in the p-connectors used currently in WTSM being discarded.

Car access to PT is mostly an option for rail users, with very few bus users travelling by car on the first leg. Each rail station park-and-ride is currently represented by a separate zone centroid in the model. This limits flexibility to test new rail stations and associated parking, as well as future park-and-ride to bus or new rapid transit modes.

EMME now allows using standard nodes (as opposed to zone centroids) for park-and-ride/kiss-and-ride calculations. This functionality will be investigated and if deemed suitable will be used in the model. The WPTM however will still use the current approach for current rail stations represented through their own centroid, so the methodology adopted will need to be compatible with the current approach, i.e. with park-and-ride being represented through both zone centroids or standard nodes. There is a possibility that it will be found to be incompatible with the operation of the WPTM, in which case the current approach will have to applied.

The car access leg to public transport will be added to the private vehicle matrices for the vehicle assignment in WTSM in order for these trips to be represented on the network.

Finally, the implementation of charges and capacity constraints for park-and-ride adopted in WTSM will be tested for implementation in WPTM. This would ensure consistency between the two models, but again it might prove to be incompatible with current operation of the WPTM.

5.7.6 Active Modes

As discussed earlier in this section, it is planned that active modes will now be directly included in the mode choice model. A WTSM sub-module to split active modes demand in the current model into walk and cycle has recently been developed separately from this project. This module will be investigated and if suitable will be used as a starting point to produce walk and cycle demand separately, and calculate their respective generalised costs.

An alternative, simpler approach would be to use distance-based factors to split the two modes.

The active mode sub-module includes a functionality to allow manually “enforcing” changes in active modes demand caused by factors that cannot be replicated by the model (e.g. improved facilities, changes in behaviour, or uptake in new modes such as e-bikes). This functionality will be retained, and coupled with changes in parameters used in generalised costs calculations will allow for testing of a range of scenarios (e.g. an increase speed to account for ‘what if’ testing for the use of electric scooters), and how they impact on overall mode share and trip distribution.

5.8 Time-of-Day-Choice

5.8.1 Macro time period choice

It is not planned to incorporate a logit time-of-day choice model, instead, daily matrices will be factored to the four peak periods by applying fixed proportions on a geographic sector-to-sector basis.

Car vehicle and public transport person trips will be processed into four time periods.

It is not envisaged that active mode trips, including walking and cycling, will be converted to peak period. These demands will remain at a daily level. If the functionality is subsequently required, when more data becomes available, it would be possible to produce approximate peak period active mode demands.

This process will also convert the daily production-attraction demands into peak period origin-destination demands suitable for assignment to the network.

If trip retiming (AM and PM peak periods to interpeak and overnight) is to be incorporated, the current WTSM procedure will be reinstated.

The output of this model will be car vehicle and public transport person peak period demand matrices in origin-destination format.

5.8.2 Representative travel times within each period

For strategic models that typically reflect longer time periods (e.g., two, three, or six hours in duration), the mechanism to produce representative travel times for each peak period needs to be determined. It is worth noting that the purpose of ‘representative’ travel times is to sufficiently inform the mode and destination choice calculations, rather than reproducing observed on an hourly basis which is best suited to more detailed tools in the modelling hierarchy.

Options are listed below in the context that demand and delay are not linear, so that half the demand will not result in half the delay.

- Model the average hour across the period.
- Model the ‘busiest’ or peak hour in the period. Because of the size of the study area, this will not relate to a single specified hour, such as 8-9am.
- Model both the peak hour and the remaining shoulder period. The ‘shoulder’ is defined as peak period less the peak hour demand and would then be modelled as an average. It would not

relate to any specific time of the day, and in fact will represent both the time before and after the peak hour.

Methods to divide the demand into peak hour and shoulder periods include:

- Fixed proportions on a broad sector-to-sector basis reflecting distances travelled. This is the simplest and most transparent approach but is insensitive to changing congestion throughout the peak period.
- Develop a predictive model of the choice, likely through a logit calculation, based on relativity of travel times in the peak hour and shoulder periods. This would necessitate assignment of both the peak and shoulder demands.

As specified in the previous section, fixed proportions are proposed for the macro time of day choice. While micro time of day choice could be explicitly modelled, it is more appropriate for a lower tiered model in the hierarchy which includes profiling over the period. Hence predictive modelling the choice of peak hour versus shoulder period is not proposed and fixed proportions will be used as well for micro time of day choice.

Modelling both the peak hour and the shoulder period will produce the most representative travel times but will be at the expense of almost doubling the assignment run times. Given that minimising run times is a key objective, the improved representativeness does not appear to meet project objectives.

In light of this, the following is proposed:

- For the interpeak and overnight periods, an average (or duration representative of when people are travelling) of the peak period will be assigned to produce travel times for the generalised costs. For the 12 hour overnight period in particular, one twelfth will not represent when most people are travelling and a reduced number of hours may be adopted for the divisor instead. This reflects expected lower levels of congestion and is a necessary simplification/compromise for a strategic model.
- For the AM and PM peak periods, a peak hour demand will be produced and assigned by applying fixed sector-to-sector proportions of the whole period. This will reflect mode and destination choice for the busiest part of the peak period.

Peak hour proportions of the peak period will be calculated for vehicles and public transport from the 2018 HTS data.

The peak hour demands will not be validated explicitly. The demand model validation will focus on peak periods.

The peak hour will not represent any actual hour of the day – it will be the busiest hour in each area. As an example, in Sydney, there is a four hour morning peak model and they look at the two busiest hours to determine the peak. The same approach will be adopted for Wellington albeit considering the busiest hour to estimate congested travel times.

In forecasting, it may be required to 'damp' the proportion of demand in the peak hour if convergence issues eventuate. Consideration will be given whether the current peak spreading module can be repurposed for micro time of day choice adjustment, however, this will likely require the peak hour and shoulder periods to both be assigned (i.e. it relies on cost differential) which will have significant run time implications. Other options will be considered during the model development process.

Options to mitigate any long run time issues that arise are to:

- Relax the convergence criteria during interim model iterations and increase for the final assignment only.
- Only assign the AM and interpeak periods during the model iterations, and calculate the daily generalised cost based on these two periods (i.e. excluding the PM and overnight periods).

5.9 Light Commercial Vehicles

LCVs are notoriously difficult to model, because there is no clear definition, and it is complex and expensive to obtain observed data.

An LCV could be defined as a vehicle type (e.g., utes and vans) or more appropriately, include their trip purpose (i.e., any light vehicle undertaking commercial trips). There will be a very small sample of LCV trips in the HTS and so there is no observed travel pattern data. In the scoping workshop at the beginning of

Stage 1, it was decided that LCV travel pattern data would not be collected, and simple assumptions should be made in the model.

5.9.1 2001 Model Process

For the 2001 build of the WTSM, LCVs were defined as "utes and vans" (i.e., not considering the commercial trip purpose). The technical notes report this was due to commercial utes/vans trips being under-represented in the HTS. So WTSM forecasts combined "light vehicles" (cars plus utes/vans) using the traditional 4-step model. This means that any difference in travel patterns for LCVs are not replicated – their travel patterns are the same as other light vehicles. Light vehicles are then split into cars and LCVs (defined as utes/vans) using fixed proportions which vary by trip purpose. There is an under-reporting factor applied to LCVs, although reporting states that the under-reporting factor for LCVs in the base year (2001) was set to one, which seems to contradict the under-reporting. The LCV under-reporting factor now has a different value in WTSM, which may have been a validation change at some point. There is also an additional growth factor which is applied to LCVs for forecasting. The additional growth factor is to reflect the fact that ute/van commercial trips may grow at a different rate to car trips.

The 2001-bsaed process is illustrated below.

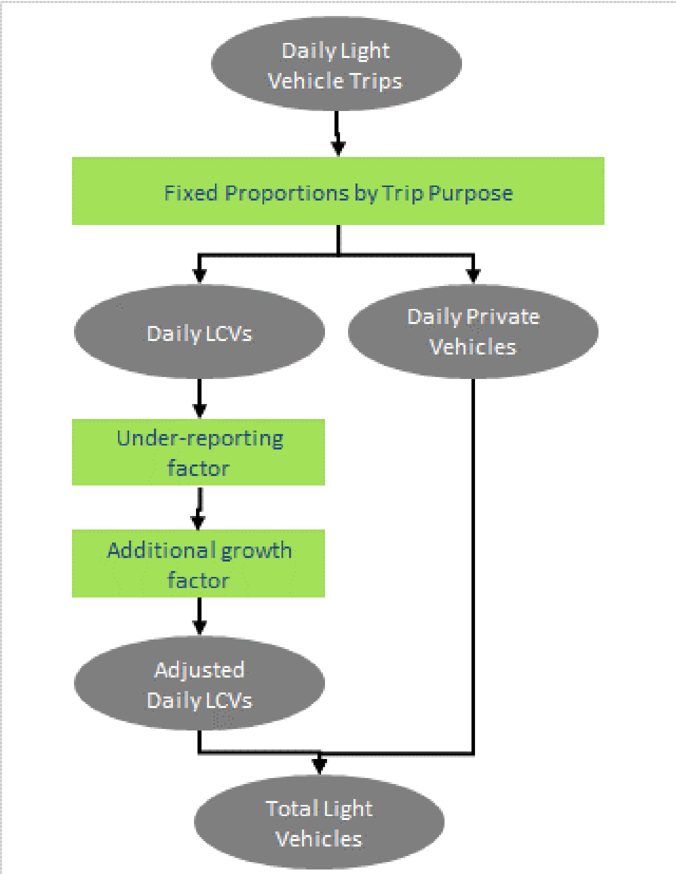

Figure 5-4: 2001-Based LCV Treatment

5.9.2 2018 Model Process

The treatment of LCVs for the new demand model will be similar due to the lack of observed data. A placeholder will be included for a predictive LCV model, which can estimate representative OD patterns.

In the interim, modelled light vehicle flows must replicate total volumes crossing screenlines, so the light vehicles forecast by the person-based demand model will again forecast private vehicle combined with LCV trips.

The process, which is illustrated below, will be:

- Forecast daily light vehicle (private vehicle plus light commercial vehicle) trips in the demand model as a single matrix.

- Subtract a placeholder matrix for the LCV daily demand. Until a predictive LCV model is developed, this placeholder LCV demand matrix will be zero.
- Combine the private vehicle matrix with the LCV matrix for the separate model for assignment.

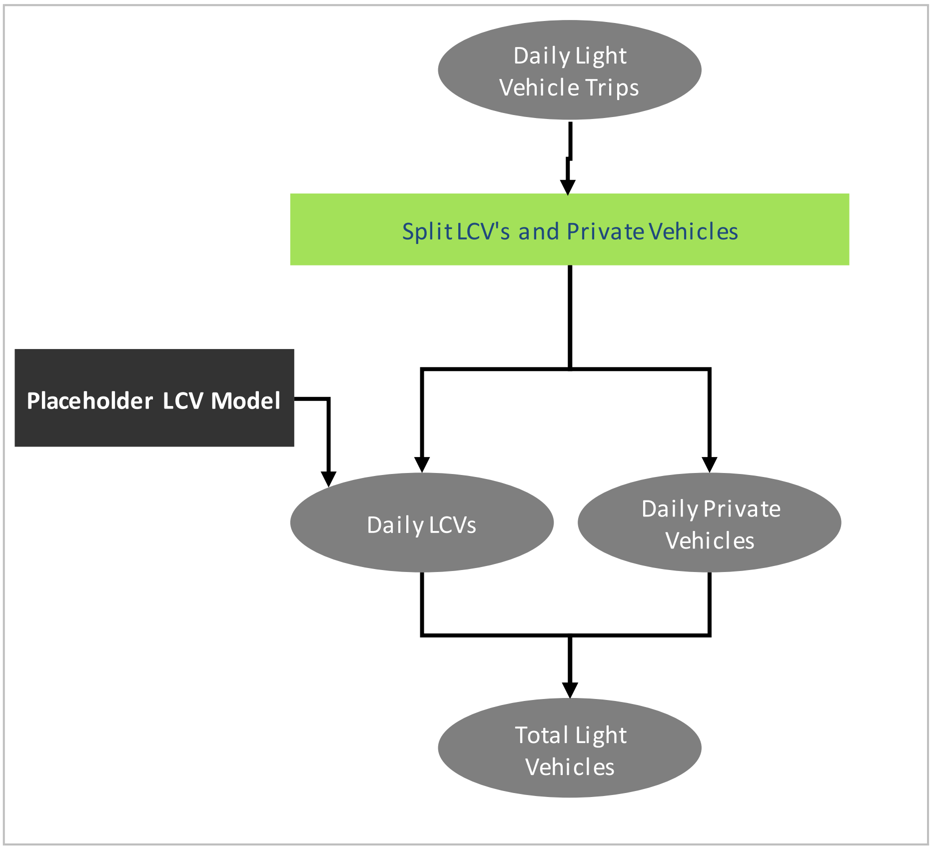

Figure 5-5: 2018-Based LCV Treatment

The output of this stage will be a matrix to total light vehicles (private and light commercial) for assignment.

5.10 External Light Vehicle Trips

External light vehicle trips will be forecast for State Highway (SH) 1 and SH2 in the north of the study area. This will include trips with one end outside of the study area and one end inside the study area (external-internal and internal-external).

Because of Wellington's geographic location with the two main roads into the region being SH1 and SH2, both to the north and separated by the Tararua range, the amount of "through" trips (with both ends outside the study area) is negligible. Vehicle trips between the ferry terminal and outside the region are technically through trips however, and these have been modelled in the Ferry Passenger Model. The vehicle flows forecast to leave the study area via SH1 or SH2 in the Ferry Passenger will be subtracted from the observed traffic counts. The remainder will be considered external/internal and vice versa.

The Airport Land-Side Access Model assumes all demand is within the study area, which was due to a lack of observed travel pattern data and professional judgement that any demand from outside the study area would be negligible.

The external trip end of external-internal trips will be the traffic count for the base year and average growth per annum for future years estimated from trend analysis of traffic counts.

The internal trip end of the external-internal trips will be estimated by applying linear regression techniques – the same as the attraction model discussed in Section 5.5. Daily trips will be estimated. Vehicle, rather than person, trips will also be estimated. A vehicle occupancy may be applied to produce an estimate of external light vehicle-person trips if this improves consistency of the matrices.

The output of this model will be a matrix of daily external light vehicle trips.

5.11 Road Assignment

5.11.1 Approach

The current model has a single user class assignment (private vehicles and HCVs combined) during the iterative mode/destination/route choice calculation, with a multi-class assignment in the final iteration. The weakness of a single user class assignment is that a single value of time and vehicle operating cost is required. Given the relatively small proportion of HCV's, this limitation is unlikely to have a significant impact on results. In the updated demand model, traffic is to be modelled in units of PCU's. This makes a single user class assignment slightly more difficult to interpret.

As minimising run times is a key objective, options for the updated model include:

- Use a multi-user class assignment with more relaxed convergence criteria for interim iterations, with tighter criteria for the final assignment.
- If the above produces long run times or instability issues, then default to a single user class assignment during the iterative calculations and a multi-user class assignment for the final assignment.

The assignment type is discussed in the next section.

Vehicle access legs to PT (kiss and ride and park and ride) will be added to the forecast private vehicle demand for assignment. Because the model form will be trip-based and not tour-based, the kiss and ride access leg will not be linked to the next trip, which is the vehicle continuing to its final destination. Over time, it will therefore be possible for different growth to apply to the trip from an origin to the station (kiss and ride) compared with the vehicle continuing to its end destination.

The assignment will be in units of PCUs (passenger carrying units). Forecast heavy vehicles will be multiplied by an input PCU factor. Bus preloads will also be incorporated based on input specified headways and routes. These will also be converted to PCUs using an input PCU factor. PCU factors for HCVs and buses are expected to be between two and three. In Australia, an average value of 2.4 is used for trucks which is based on 2.0 for medium and 4.0 for long vehicles. The 2.4 average value will be adopted for HCV's.

5.11.2 Congested Capacity and Delay Calculation

Congested travel times on roads (links) are calculated by applying Akcelik volume-delay curves. This will be continued, albeit using the Modified Davidson curves for motorways as documented in TN 5 – Improve Delay Representation'.

Intersection capacities are currently calculated on an approach basis and the following points are noted:

- At signalised intersections, each arm is assumed to run in a dedicated phase. This does not reflect reality well and is likely to underestimate capacity (and overestimate delay) where there are strong north-south or east-west flows.
- At priority intersections, right turns from major arms are assumed to be unopposed, and all turns from minor arms (left, through and right) have a single approach-based average capacity applied.
- In the CBD, modelling intersection capacity led to instability and extended run times, the capacity calculation is therefore switched off, and fixed input capacities are used instead.

An Akcelik curve is then applied to calculate the approach-based intersection delay. This means links with an intersection modelled at one end have a two-part Akcelik curve applied.

Intersection approach capacities are recalculated at specific intervals, controlled by a function, within the equilibrium traffic assignment. The process is: traffic flows are assigned for X iterations; capacities are recalculated; the assignment continues for Y iterations; capacities are recalculated; the assignment continues; etc. This process increases run times as the assignment convergence worsens each time capacities are recalculated. Intersection capacities are damped, taking an average of the current and previous values.

The rationale for this approach was, according to the documentation, approach-based intersection modelling is appropriate for a strategic demand model with 225 zones where the flows at intersections will unlikely be representative due to the coarse zoning.

For the new demand model, intersections will be modelled by adopting the new Junction Capacity Assignment Tool (JCAT). JCAT enables turn-based rather than approach-based capacities and delays to be modelled. Points to note include:

- Extra input attributes are required. These have already been coded and some initial testing undertaken.
- Intersection capacity and delay algorithms would be based on the US Highway Capacity (HCM) manual. This would mean New Zealand give way intersections will need to be modelled as two-way stops.
- At signalised intersections, cycle and green times are calculated by JCAT based on opposing traffic flows. This will mean some loss of control, but negates the need to estimate and input cycle and green times, particularly for future years.

It is possible that the demand model may not converge with full turn-based intersection modelling. In this occurs, it may be necessary to revert to the approach-based capacity and delay formulae in the current model.

For calculation of delay at intersections, JCAT used a Bureau of Public Roads (BPR) curve rather than an Akcelik curve for the congestion-based delay element. We will test replacing this with an Akcelik curve and review the calculated delays and the impact on model stability.

For both link and intersection delays, a 'peaking' calculation is incorporated in the current model based on input peak factors that vary by peak period and link type. This was added because, according to documentation, an average flow input to the volume-delay functions does not produce the average delay. For links without an intersection at the end, the peaking calculation is applied to the link, otherwise the peaking calculation is only applied to the intersection part of the Akcelik curve.

It is planned that the 'peaking' calculation is discarded for the new demand model. If found necessary, a similar process can be re-introduced.

5.12 PT Assignment and Crowding

5.12.1 Assignment approach

The PT assignment in the current WTSM was developed with a number of processes and simplifications to get around limitations of EMME software at the time, particularly regarding representations of transfers. Transit time functions were recalculated as part of the development of the WPTM and are shared in both models, but these were found to lead to unrealistic results for scenario testing, with new bus lanes or bus only links leading on occasions to slower speeds than with the current network.

The assignment will be redeveloped to account for new EMME functionalities such as journey levels, which negate the use of the current workarounds, and transit time functions for buses will be revised if sufficient and suitable bus travel time data can be sourced. Rail travel times are based on scheduled times and this is not suggested to be changed.

The new perceptions factors which have been recently added (e.g. link in-vehicle time perception) will be included in the new scripts, which will also be set up in a way that ensures ease of changing the factors or applying additional ones for scenario testing with minimal intervention.

The various demand segments by purpose are currently aggregated into a single public transport demand for each time period before assignment in WTSM. The new model will have PT demand disaggregated by purpose but also by access to PT. The decision to either aggregate them before assignment or assign them separately with different parameters will be made during the course of the project.

Finally, EMME includes a number of PT assignment algorithms, including Standard, Extended, or Capacited assignments. The current WTSM uses Extended Assignment as it allows for more post-assignment strategy-based analysis. It is likely that the new model will use either Extended or Capacited to represent PT crowding (see section 5.12.2 below).

5.12.2 PT crowding

A significant new functionality will be the addition of the representation of public transport crowding, to account for its impact on destination, mode and route choice, as well as reflect the benefits from higher frequencies or new vehicles and modes with higher capacity.

Crowding factors will be introduced in the travel functions with level of discomfort leading to increasing perception factors for in-vehicle times, and potentially boarding times, to represent vehicles being over-capacity and not stopping to pick up passengers. Parameters for these functions will be based on a review of best practice in New Zealand and internationally, in particular, the London model.

As noted in the previous section, EMME has introduced a Capacitated PT assignment specifically for the representation of crowding, however the Extended assignment can also be adopted if using custom functions that integrate the extra costs associated with crowding. Both tools will be evaluated to understand their respective pros and cons before a decision is made as to which one is the most suitable.

Crowding functionalities will be implemented in a way that enables turning it on or off. This will be dependent, however, on the calibrated/validated base year not being overly negatively affected if crowding is turned on or off. Different approaches are possible regarding the introduction of PT crowding in the model structure, which will all have a different impact on demand, but also on convergence and model run times:

- Run the PT assignment with crowding turned on only for the final assignment once the model has converged. While this option would have no impact on convergence and only a minimal one on run times, it would only improve the representation of route choice and have no effect on distribution and modal choice. It is therefore not recommended.
- Run the PT assignment with crowding within each demand loop, but the crowding penalties are recalculated only once per loop, with no convergence of the assignment itself within the loop. This would likely have a moderate effect on run times and convergence. This approach has recently been implemented in the Auckland Macro Strategy Model (MSM).
- Run the PT assignment with crowding within each demand loop, with iteration of the crowded PT assignment until it converges within the loop. This would have a more marked impact on run times due to more PT assignments being run, but the impact on overall demand convergence is less clear.

Either options 2 or 3 are therefore recommended, with the choice of the most appropriate option being decided during testing.

5.13 Parking Capacity Constraint

The key aspects to consider in order to determine the best approach to constrain vehicle demand to parking capacity include:

- Availability of supply data, including formal and informal parking spaces.
- The availability of observed arrival and departure profiles for types of parking facilities, the difference between the profiles being the parking capacity at each point in time.
- Some vehicle trips to a destination do not terminate there (i.e., park). Some will be drop off/pick up.

Supply data will be an input to the model. This will be by broad geographic sector and will include formal and informal supply. The formal parking supply has been collated for 2018/20 in the wider CBD and at park and ride sites. No data on informal supply could be sourced, and so inputs to the model for informal supply will require judgement. Similarly, future year input supply will also require judgement.

Supply data has already been allocated to trip purpose using the 2001 HTS and this will be updated using the 2018 HTS if there is sufficient sample. If the sample in the 2018 HTS is too small, the calculation from the 2001 HTS will be retained.

There is no data on arrival and departure profiles to work out, for example, the parking capacity at 10am. As such, the parking capacity at each time of the day cannot be calculated. Instead, a simple approach must be used. This will be based on average duration of stay calculated by trip purpose from the 2018 HTS.

The morning commuter peak is when parking supply issues are most likely to occur, as well as the interpeak when shopping and other recreational trips occur. So the AM peak (6-9am) and the interpeak (9am-3pm) will be considered in this simple calculation – a total of 9 hours over which the average duration of stay will be applied.

The equation to calculate parking capacity is shown below.

$$Parking\ Capacity\ =\ No\ of\ Spaces * \frac{No.of\ AM\&IP\ hrs}{Ave\ duration}$$

Where:

Parking Capacity:	number of spaces available from 6am to 3pm
No. of AM&IP hrs: hours	number of hours in the combined AM and interpeak periods, 9
Ave duration:	average duration of stay, in hours, for each peak period

The forecast vehicle demand (AM and interpeak combined) will be reduced by a global percentage to allow for the number of vehicles that do not park. This 'global' percentage will be calculated from the 2018 HTS for each trip purpose. As the number of parked vs continuing vehicles may vary significantly across the study area, the calculation will focus on the wider CBD where the issue of demand exceeding supply is most likely to become a problem in future years.

This simple parking capacity constraint module will be developed so that it can be switched on or off.

Its default will be off, which means parking demand may exceed supply. This reflects both the presence of informal parking spaces and uncertainty over the amount of formal parking supply that may be available in the future.

This module will be applied as a single process simultaneously to both parking for private vehicle trips (i.e., trips without a PT leg) and for parking at park and ride sites.

Capping demand to the input parking supply will be achieved by iteratively adding 'cost' (in units of minutes) to the generalised cost for private vehicle and PT trips (for park-and-ride capacity restraint) when demand exceeds supply.

Depending on the amount of parking supply specified, there is a strong possibility that the model may not converge. A maximum number of iterations will be specified, and output messaging will record the convergence status (i.e. maximum loops reached, or parking demand less than or equal to supply). In addition, it is likely that specifying a maximum percentage change in the generalised cost from the initial unconstrained value may be judicious. For example, doubling or tripling the generalised cost for private vehicle travel is questionable and suggests input elements to the model are not aligned (i.e., expected population growth and parking supply).

Where no parking supply is input, an infinity capacity will be assumed (i.e., no constraint).

The impact of constraining demand to parking supply in the CBD will be redistribution and change of mode (private vehicle to PT). However, the switch to PT will then be governed by the amount of park and ride parking supply. Overly constraining CBD parking supply and parking supply at park and ride sites will almost definitely result in the model failing to converge.

At this point, it is anticipated that turning off constraint for particular geographic areas will be controlled by not specifying input parking supply, which will be interpreted as infinite supply (i.e. no constraint). If parking constraint is to be tested for vehicle trips to the CBD, but not PT trips using park and ride, this can be accomplished by specifying an infinite supply for park and ride.

To enable parking supply constraint at park and ride sites, the model will need to be able to shift demand from park and ride to kiss and ride. To accomplish this, park and ride versus kiss and ride will need to be calculated in the modal choice model and not determined through PT assignment. If a PT sub-mode choice model cannot be estimated, it may not be possible to constrain parking supply for park and ride specifically. Any simplifications adopted, would effectively reduce all PT trips (i.e. kiss and ride and walk in) for stations where constraint was applied.

As with most models, there are limitations in this simple parking capacity constraint model which include:

- The new demand model will be trip-based and therefore does not connect inbound and outbound trips. So it will be possible to constrain an inbound car trip (with perhaps a change of mode), but the outbound/return trip is still by car even though the vehicle was at home. This is integral to a trip-based model and is not specific to parking constraint.
- With the smaller sample in the HTS and no parking survey data, there is minimal data on parking arrival and departure rates and the subsequent supply by time of day. Applying average duration of stay does not allow for the fact that, for example, parking spaces may all be fully occupied by 9am at the start of the interpeak.
- Demand versus capacity will be compared for the combined AM and interpeak periods, then if required, additional time added to the daily generalised cost. This will therefore also affect PM peak and overnight vehicle trips. The impact for the PM peak will somewhat reflect inbound AM peak vehicle trips being diverted.

The output of this module will be demands (private vehicle and PT), adjusted to reflect input parking supply.

6. Road Pricing Response Model

In the current model, road pricing (toll or cordon pricing) is represented through the use of average values of time. As a result there is no differentiation in demand response between trip purposes and households' income, which in reality both impact the Willingness to Pay (WtP) for the additional cost. This functionality will be incorporated in the new model through a 'road pricing' module.

The potential for weaving income segmentation and WtP through the model was considered but the resulting increase in complexity and run times was considered too great, especially given that this module is likely to be run infrequently for specific options. As a result this process will be a post-model run module, turned off by default but activated for scenarios that include such road pricing schemes. The process will be run as follows:

- Carry out a standard run of the model, including the congestion pricing which will be applied with standard values of time per mode and trip purpose. This will allow capturing the overall effect of the additional charges simplistically.
- Final demand matrices will then be segmented to account for income levels by zone, (likely segmented into low, medium and high income) for each trip purpose and mode. For home-based purposes, this will be based on proportions from the zone where the household is located, with proportions to be sourced from Census data. For non-home based purposes (including employer business), overall averages will be applied.
- Calculate generalised costs for each demand segment, including their respective WtP through different values of time. The relationship between WtP/values of time and income will be based on a review of international best practice and analysis carried out for the Auckland MSM model.
- Run an incremental mode choice model using the new generalised cost matrices and demand matrices for each purpose and income segment. This type of model allows estimating the changes in demand resulting from modifying generalised costs for one mode. The incremental mode choice model will be run for 24 hour production-attraction person trip matrices.
- The matrices will then be converted to time period origin-destination trip matrices (and vehicle for road) using the same process as the overall model.
- Run a final assignment of the revised public transport and private vehicle demands. For the road assignment, this will be a multi-class assignment with all segments assigned separately with their respective value of time (some trip purposes may be grouped together is they have the same value of time, for example all non-work home-based trips). This will account for the impact of road pricing on route choice for each demand segment.

The cost skimming will be set up in a way that allows different types of road pricing including toll and cordon, but also distance-based pricing.

The road pricing module will therefore allow estimating the more detailed impact of road pricing on mode and route choice. The effect on redistribution of trips will only be captured through the main model processes and at a more aggregated level, and the effect on time period choice will not be represented. As mentioned previously the alternative would require income segmentation to be included throughout the model and is not considered appropriate for the envisaged use of this module, given the trade-off in complexity and run time. The same will apply for trips related to the airport, ferry terminals and park-and-ride sites, for which only the standard aggregated demand values of time will apply.

For forecasting, zonal proportions of households per income band will need to be specified. The module will also allow for changing relationships between WtP/values of time and income, likely through the use of easily accessible elasticity parameters.

7. WTSM Calibration and Validation Checks

The Transport Model Development Guidelines (TMDG) focuses on <u>assignment</u> calibration and validation; however, each step of the new demand model should be calibrated/validated individually. The checks that will be undertaken for the development of each model are listed in the following table, including the comparisons that will be undertaken between modelled and observed.

Table 7-1: Model Component and Calibration/Validation Checks

Model	Calibration/Validation Checks
Vehicle Availability Model	• Compare modelled to observed Census in total for each vehicle availability group. • Compare modelled to observed Census on a sector basis for each vehicle availability group.
Person/Family Model	• Person types are an input – no validation required • Compare categories of person types by household vehicle availability group against Census for the whole study area. • Compare categories of person types by household vehicle availability group against 2018 HTS for the CBD compared with the rest. This will depend on sufficient sample sizes in the 2018 HTS.
Trip Production Model	• Compare modelled trip productions by purpose against observed from the 2018 HTS in total and by sector. • Compare modelled trip productions by purpose for each vehicle availability group against observed from the 2018 HTS in total and by sector.
Trip Attraction Model	• Compare modelled trip attractions by purpose against observed from the 2018 HTS in total and by sector. This is a calibration check – there is no independent data for validation.
Modal Choice Model	• Compare modelled trips by mode and purpose against observed from the 2018 HTS in total and by sector. If mode choice follows distribution, this will be on a sector-to-sector basis. • If mode is before destination choice, check modelled trip end mode choice by vehicle availability group against observed from the 2018 HTS. This will depend on sufficient sample sizes in the HTS. • For vehicle occupancy, check modelled against observed from the CBD cordon survey.
Destination Choice Model	• Compare modelled trips by purpose against observed from the 2018 HTS and/or mobile phone data on a sector-to-sector basis. This will depend on sufficient sample size in the 2018 HTS • Compare modelled trips for HBW and HBED against observed Census Journey to work and Journey to Education by sector in terms of the distribution pattern. This is discussed further in section 8.7. • Check modelled average trip length by purpose against observed from either the 2018 HTS (sample size permitting) or mobile phone data
Time of Day Choice Model	• Compare modelled trips by mode (private vehicle and PT) for each of the four modelled time periods against observed from the 2018 HTS on a sector-to-sector basis • Compare modelled private vehicle trips for each of the four modelled time periods against observed screenline traffic counts on a broad sector-to-sector basis
External Light Trip Model	• Compare modelled trips to observed from either the 2018 HTS or mobile phone data (whichever has the largest sample) on an internal sector-basis.

8. WTSM Assignment Validation Criteria

The criteria to be used for assignment validation of the WTSM will be consistent with the Transport Model Development Guidelines (TMDG), developed by Waka Kotahi[2]. Under the TMDG definition, WTSM is a model of category A, or 'Regional'.

'TN4 – Data Analysis' details the data that will be used for the validation and how it has been processed.

8.1 Traffic counts and screenline

16 screenlines have been used for the validation of the current WTSM, including a total of 66 counts. These will be used for the validation of the new model, but data for an additional 12 screenlines and 41 counts was also collected and these will be used for validation. Description of the screenlines and traffic counts is included in TN4.

Validation criteria for traffic counts and screenlines is based on TMDG. The following table shows the criteria for the GEH statistics, used to compare observed and modelled counts. Guidelines for the use of the GEH statistics mention hourly volumes. The method employed in previous updates of WTSM was to divide the 2-hour observed and modelled flows by two to generate an "average hour" flow, and the same approach will be applied to convert volumes from the various modelled periods to hourly as well as traffic counts (i.e. consistency between modelled and observed in terms of the period average).

Table 8-1: Hourly GEH comparison criteria for WTSM road traffic count validation

GEH	% of screenlines (per direction)	% of traffic counts (per direction)
GEH <5	>60%	>65%
GEH <7.5	>75%	>75%
GEH <10	>90%	>85%
GEH <12	N/A	>95%

In addition to the GEH, the TMDG specifies the following criteria:

Screenline hourly count bands:

- >70% within 10%
- >80% within 15%

Link hourly counts bands:

- For links with volumes less 700 vph (vehicles per hour): >70% within 100vph
- For links with volumes between 700 and 2700 vph: >70% within 15%
- For links with volumes above 2700 vph: >70% within 400vph

Scatterplots of modelled vs observed for all traffic counts:

- R2 greater than 0.85
- Slope line of best fit between 0.9 and 1.1

RMSE (root mean squared error) for all counts:

- Acceptable: less than 30%
- Requires clarification: between 30% and 40%
- Unlikely to be appropriate: greater than 40%

Turning movements will not be validated, as this is not required or appropriate for a strategic model of category A.

Validation will be carried out separately for light vehicles, and medium and heavy vehicles combined. However light commercial vehicles will be combined with privates cars as observed data does not allow separate validation.

[2] https://www.nzta.govt.nz/assets/resources/transport-model-development-guidelines/docs/tmd.pdf

Validation will also be carried out for all time periods for the period as an average. For example, peak hours and shoulder periods will not be separately validated which would necessitate additional assignments and increase run times. This was discussed in section 5.8.

8.2 Private vehicle journey times

Journey times for private vehicles will be compared against observed on eight different routes (in both directions), as detailed in TN4.

The TMDG specifies the following criteria:

- 80% of routes within 15% or 1 minute (if higher)
- 85% of routes within 25% or 1.5 minute (if higher)

Modelled and observed times along each route will be plotted on an XY scatter graph. Traditionally these graphs show the mean observed travel times, along with the minimum and maximum. In this case however, due to the travel time data being sourced from GPS information, minimum and maximum times reflect minimums and maximums experienced at a particular point in time. Summing minimums/maximums over a route does not result in a minimum/maximum journey time experienced in reality. The 5th and 95th percentiles will therefore be used as an alternative.

8.3 Public transport patronage

Public transport assigned patronage will be validated using the same screenlines as traffic volumes, although some of these screenlines do not apply as they are not crossed by any public transport services.

The TMDG specifies criteria for the validation of public transport, as shown in the following table.

Table 8-2: Hourly GEH comparison criteria for WTSM public transport patronage validation

GEH	% of screenlines (per direction)	% of traffic counts (per direction)
GEH <5	>60%	>50%
GEH <7.5	>70%	>60%
GEH <10	>80%	>70%
GEH <12	>90%	>85%
Line of best fit	y=0.9x to 1.1x	y=0.85x to 1.15x
R^2	>0.85	>0.80

Unlike traffic counts, no observed public transport patronage is available across screenlines. A methodology was developed for the validation of the WPTM that will be used for the WTSM as well:

- For bus patronage, a tool was developed to extract volumes passing through each bus stop from electronic ticketing machine (ETM) data, which was then used to inform observed bus patronage at most count locations on the screenlines. For some locations (mostly locations on State Highway or on main arterials with no nearby bus stop), results could not easily be extracted from the ETM tool. For those, a "reference assignment" was carried out, with the bus matrices developed from ETM assigned onto the bus network only, representing a reliable proxy for observed bus volumes.
- For rail patronage, observed boardings and alightings from an extensive 2011 platform survey factored using Metlink patronage data per line will be used.
- Ferry and the cable car are much less significant in terms of patronage. For those, observed volumes from the Wellington CBD cordon will be used.

In addition to screenline validation a range of other observed metrics will be used for public transport validation:

- Metlink patronage data, by mode (and by line for rail)
- Rail high (or guard) counts showing patronage directly to/from Wellington station
- Observed patronage from the Wellington CBD cordon

For rail plots showing the loading profiles along each line (Johnsonville, Kapiti and Hutt Valley) will be produced, comparing observed and modelled boardings, alightings and volumes.

Finally, modal access to rail (including walk, park-and-ride and kiss-and-ride) will also be compared against observed data, including the 2011 surveys carried out for the development of the WPTM and a more recent survey carried out in 2017 for a park-and-ride study.

8.4 Public transport journey times

Initial analysis of the ETM data indicates that it is likely not to a reliable source of data for producing bus travel times. Real time information data from the bus operators will therefore be needed to produce data suitable for the mode validation. If this can be sourced, it will be used to validate bus travel times along strategic corridors using the same criteria as general traffic.

Rail and ferry travel times are currently based on timetable in WTSM, and it is recommended that the model use the same approach.

8.5 Active modes

The WTSM being a strategic model, it is not planned that active modes will be assigned and so validation at a similar level of detail to road and public transport modes will not be carried out. However observed pedestrian and cycle volumes through the Wellington CBD cordon will be used to ensure active mode volumes estimated by the model (in matrix form) to and from the CBD are a suitable representation of observed patterns.

8.6 Model convergence

The WTSM, as a 4-step model, iterates over a number of loops with trip distribution, modal choice and assignment being run in sequence for each iteration until the model converges to a stable outcome. The model convergence will be determined by undertaking a number of checks after each iteration. Suitable checks will be confirmed during the model development, but will be along the lines of the following:

- Demand: for demand matrices, either the root mean square error (RMSE) of matrices between the last and the previous iteration will be used, or a threshold such as 95% of matrix cells changing by less than 5%. Matrices for all main modes (car, public transport, active modes) and all time periods will need to match this criteria for convergence to be demonstrated.
- Assignment: total vehicle kilometres and vehicle-hours across the whole network changing by less than 0.1% between the last iteration and the previous one. Again this criteria will have to be met for all time periods.

The assignment itself also iterates until convergence is achieved within each loop. Due to the new JCAT assignment algorithm being likely to be used, which includes new intersection delay calculations, suitable convergence criteria will be discussed with the software developer and tested, aiming for the best compromise between model run-times and stability of output.

8.7 Journey to work / Journey to education

Census 'journey to work' and 'journey to education' data will be compared against modelled trip patterns for work and education related trips, looking at sector-based aggregated demand. While care must be taken in interpreting these results as the definition of journey to work/education in the census and home-based work/education modelled trips is different, it will however allow validating the representation of these trip purposes in terms of spatial distribution and modal choice.

8.8 Sensitivity tests

A number of sensitivity tests will be carried out to verify the elasticity of the model response to changes in travel costs assumptions and network level of service, including changes in:

- Private vehicle operating costs (e.g. changes in fuel costs, or decreases relating to uptake in electric vehicles)
- Private vehicle travel times
- Public transport fares
- Public transport in-vehicle times
- Public transport frequencies

- Active modes costs - perceived (e.g. better facilities) or actual (e.g. uptake in micro-mobility)
- Public transport vehicle capacity (for crowding)
- Capacity constraints for CBD parking and park-and-ride sites
- Adding parking charges at park-and-ride sites
- New park-and-ride sites, including for bus
- Congestion charges
- Convergence tests

Response from the model will be checked against industry standards, guidelines and common sense.

9. WTAM – Wellington Traffic Assignment Model

9.1 Approach

Features of the new traffic assignment model are:

- Refined zoning system of circa 820, consistent with the demand model and WPTM.
- Consistent network with the demand model.
- Turn-based intersection capacity calculations using the Junction Capacity Assignment Tool (JCAT), described in section 5.11.2.
- The base year private vehicle demands will be from mobile phone data, which will be processed to produce vehicle trips, separating modes and vehicle passengers as part of the demand model development.
- Models will be developed for the AM, interpeak and PM peak periods.
- Forecasts will use a 'pivot' style approach similar to WPTM, where changes are forecast by the demand model and then applied to the base year demands in WTAM.

Heavy commercial vehicles matrices produced by the demand model will be used directly.

Initial demand matrices for light vehicles (private cars plus light commercial vehicles) will be from the mobile phone data, noting this will include some HCVs that are unlikely to be identifiable and therefore cannot be removed. If necessary, matrix estimation of the base year light vehicle demands may be undertaken depending on the fit with observed traffic counts. The focus on adjusting the demands will be on light vehicles and greater tolerance allowed for any modelled versus observed discrepancies for the smaller volume of HCVs.

Ideally, for the AM and PM periods, there will be a peak hour assignment and a separate shoulder (or residual demand) assignment. This will depend on how well the mobile phone data represents observed and the amount of effort to bring the model into line. It may be necessary to compromise the separate peak hour and shoulder assignments in order to focus on producing better peak period demands. The interpeak period will be an average hour assignment.

9.2 Calibration and Validation Targets

The criteria to be used for validation of the WTAM will be based on category B in the TMDG, or 'Strategic Network' because of the large geographic coverage of the model.

9.2.1 Traffic counts and screenline

The validation targets for a category B model are listed below, noting these are based on the traffic flows being an hourly equivalent.

Table 9-1: Hourly GEH comparison criteria for WTAM road traffic count validation

GEH	% of screenlines (per direction)	% of traffic counts (per direction)
GEH <5	>75%	>80%
GEH <7.5	>85%	>85%
GEH <10	>95%	>90%
GEH <12	N/A	>95%

In addition to the GEH, the TMDG specifies the following criteria:

Screenline hourly count bands:

- >80% within 10%
- >90% within 15%

Link hourly counts bands:

- For links with volumes less 700 vph (vehicles per hour): >80% within 100vph
- For links with volumes between 700 and 2700 vph: >80% within 15%
- For links with volumes above 2700 vph: >80% within 400vph

Scatterplots of modelled vs observed for all traffic counts:

- R2 greater than 0.9
- Slope line of best fit between 0.9 and 1.1

RMSE (root mean squared error) for all counts:

- Acceptable: less than 25%
- Requires clarification: between 25% and 35%
- Unlikely to be appropriate: greater than 35%

Turning movements will not be validated for a strategic-level assignment model.

Validation will be carried out separately for light vehicles, and medium and heavy vehicles combined. However light commercial vehicles will be combined with private cars as observed data does not allow separate validation.

Validation will also be carried out separately for the peak hour and shoulder periods in the AM and PM peaks although the focus will be on validation of the peak period overall. Interpeak and overnight periods will be average hour assignments and validation.

9.2.2 Private vehicle journey times

Journey times for private vehicles will be compared against observed on eight different routes (in both directions), as detailed in TN4.

The TMDG specifies the following criteria:

- 85% of routes within 15% or 1 minute (if higher)
- 90% of routes within 25% or 1.5 minute (if higher)

Modelled and observed times along each route will be plotted on an XY scatter graph. Traditionally these graphs show the mean observed travel times, along with the minimum and maximum. In this case however, due to the travel time data being sourced from GPS information, minimum and maximum times reflect minimums and maximums experienced at a particular point in time. Summing minimums/maximums over a route does not result in a minimum/maximum journey time experienced in reality. The 5th and 95th percentiles will therefore be used as an alternative.

Appendix A Comments

A.1 Improvements

The following improvements to be delivered through the model update were informally identified by members of the Let's Get Wellington Moving (LGWM) project team. These identified improvements focus on weaknesses of the current model rather than the specification of the new model. Comments are tabulated below for the record.

No.	Comment
1	Further thought needs to be given to improved representation of shorter trips within CBD.
2	Improved representation of active travel trips (possibly relating to the short trips question)
3	We will need the ability to incorporate refined mode specific constants for PT (what if the model underestimates mode shift?). This might include any societal factors to encourage uptake of "less attractive" modes due to environmental considerations etc.
4	We want the flexibility to test things like alternative car ownership relationships, income changes, trip rates, mode choice.

A.2 Key Functionality Improvements

The following key functionality improvements were informally identified by members of the Let's Get Wellington Moving (LGWM) project team.

No.	Comment
1	Probably the most important aspect is the ability to test different land use implications. This will include sensitivity testing related to employment, land use characteristics, and trip making characteristics.
2	We would like to see a feedback loop between Aimsun and WTSM/WTAM – ideally decoupling the highway assignment from WTSM when required.
3	Emissions outputs will be increasingly important going forward.
4	Some lessons to be learnt in terms of quality of output production – building on Dan Jones work and the work that Will, Christoph and others have done for LGWM

Appendix B “What if” functionality to be included

While we understand flexibility is a key objective, we cannot provide functionality without specifying what needs to be incorporated. Hence in this section, the functionality sought for “what if” sensitivity testing is recorded along with how this will be achieved, and notes on implications, caveats, and other issues to be aware of.

No.	Functionality Sought	Functionality to be Included	Notes
	Reduction in working from the workplace, replaced by more working from home	Apply input factor to home-based work trips	Chained work trips (e.g. home, drop kids at school, work) cannot be identified in a trip-based model and therefore will not be adjusted. Application of different model types suggest increased working from home is accompanied by more other home-based trips. These have not been factored.
	Adjust vehicle availability	Apply input percentage factor to average vehicles per household on a zonal basis	This will change the propensity to travel on a zone-by zone basis. Note, reducing vehicle availability will not necessarily reduce car use. In the CBD, less vehicle availability could lead to reduced overall travel, including less walking, cycling and PT trips.
	Adjust trip rates	Production or attraction	Included through Working-from-Home adjustments
	Adjust mode split	Apply matrices containing generalised cost adjustment by mode, on a zonal basis. Likely additive as this will be easier to visualise the magnitude of change. Possibility of costs becoming negative or zero if a large negative cost (cost reduction) is input. This will be capped and a warning message written to output reporting.	This is for “what if” tests where considerable improvement/deterioration to one mode are expected which cannot be simply modelled.
	Mimic better cycle infrastructure, so adjust mode split	As above	As above

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