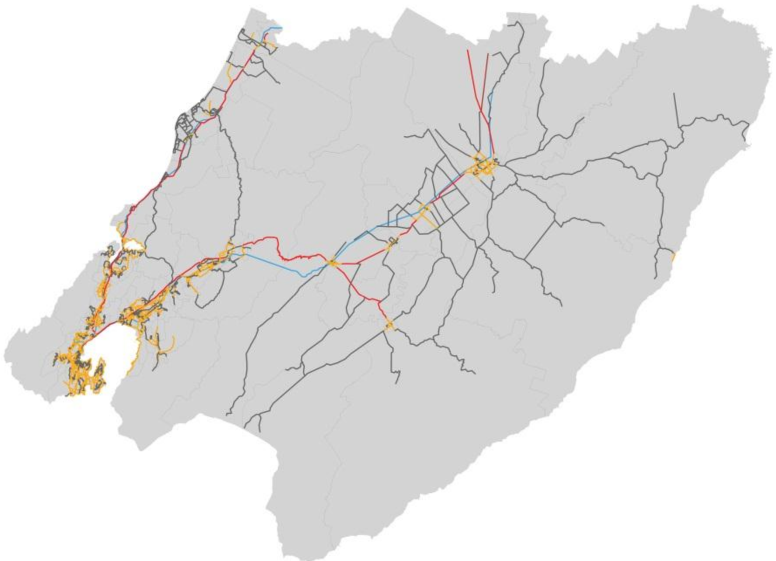
OPUS INTERNATIONAL CONSULTANTS AND ARUP

WELLINGTON TRANSPORT MODELS

Contract No C3079



TN1: Network Preparation

Date: December 2012

ARUP OPUS

Wellington Transport Models

TN1: Network Preparation

prepared for

Greater Wellington Regional Council

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John Bolland: ____________________________
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Contents

1 Introduction

1.1 Introduction

This technical note (TN) outlines the procedure used in preparing the networks for the 2011 Wellington Transportation Strategic Model (WTSM) update and the Wellington Public Transport Model (WPTM). Unlike the 2006 WTSM update, where the previous (2001) model network was used as a base for the update, a new network has been developed for the 2011 update.

This note covers:

- The goals driving the network development process (Section 1);
- The process of developing the new initial networks (Section 2);
- The process of refining those networks (Section 3);
- The process of developing the transit lines input files (Section 4);
- The process of developing transit time functions (Section 5);
- The research and development of bus and rail fare tables in WPTM (Section 6);
- Network changes made to WPTM (Section 7);
- A comparison between the old and new models (Section 8); and
- A summary of the team's findings with some concluding remarks (Section 9).

1.2 Project Driving Specifications for the Model Update Process

At the time of writing this technical note there were two major public transport studies underway in the region:

- Public Transport Spine Study; and
- Wellington City Bus Review.

The team are mindful that immediate uses of the WTSM system (in addition to public transport studies) include continuing investigations of the Wellington Roads of National Significance (RoNS). WTSM has been the main source of highway travel demands used in project highway assignment models around the region for a number of years. These roading projects include:

- Wellington Inner-City Transport Improvements;
- Aotea Quay to Ngauranga;
- Linden to MacKays (Transmission Gully);
- Kapiti Expressway; and
- Otaki to Levin.

1.3 Aims of the Network and Transit Service Coding

Two key goals were identified by Greater Wellington Regional Council (GWRC) for this project, the first being to develop a regional public transport model of sufficient detail that it can be used to provide more refined assessment of improvements and changes in PT services in the studies listed above. The team then translated this goal into two core aims:

1. Increase confidence that forecast demand using specific corridors and services are more accurate => *operational planning*; and

2. Increase confidence that forecast demand for public transport facilities such as bus stops or stations is more accurate => *asset management*.

The second goal of GWRC, in cooperation with NZTA, was to maintain or enhance WTSM's ability to provide regional demands into sub-regional NZTA project models. The team then translated that goal into three core aims:

1. An increased confidence in the mode splits being generated;
2. Better representation of the network through link curving, increased level of detail and other improvements; and
3. Improved modelling of intersections by loading of traffic at mid-point links as opposed to intersections.

The level to which this has been achieved is clearly illustrated with comparisons of network detail shown in Appendix A.

1.4 Data Availability for Achieving Aims

The network enhancement process was made possible by an increase in data availability and quality. Specifically:

- **Electronic Ticketing Machine (ETM) data**. Increase in the availability and quality of the ETM data made it possible to link passenger demand to specific transit stops. When combined with a more refined linking of the zone system to the model network the access leg of the Public Transport trip could also be more accurately modelled.
- **Electronic Timetable Data (ETD).** A new process has been developed to automatically generate transit line input files directly from Greater Wellington Regional Council electronic timetable datasets. Generating a new network with all stopping locations reduced the need for a cumbersome correspondence interface between these datasets and the model network and streamlined the process of updating transit lines.
- **Electronic Road Information Data (ERID)**. The traditional approach to public transport network coding was to take an existing highway assignment model and adapt transit lines to it. The approach was never entirely satisfactory from a public transport perspective as the highway network often contained very crude mid link detail. By "snapping" bus stops to a new highway network, all the benefits of a more refined public transport network are added while retaining the coding required for successful modelling of a highway network.

1.5 Cohesion between WTSM and WPTM

To ensure consistency across the project, both the WTSM and WPTM models are built on the same network. Figure 1-1 below outlines the differences between the WTSM and WPTM model networks, these differences are explained further in the following sections.

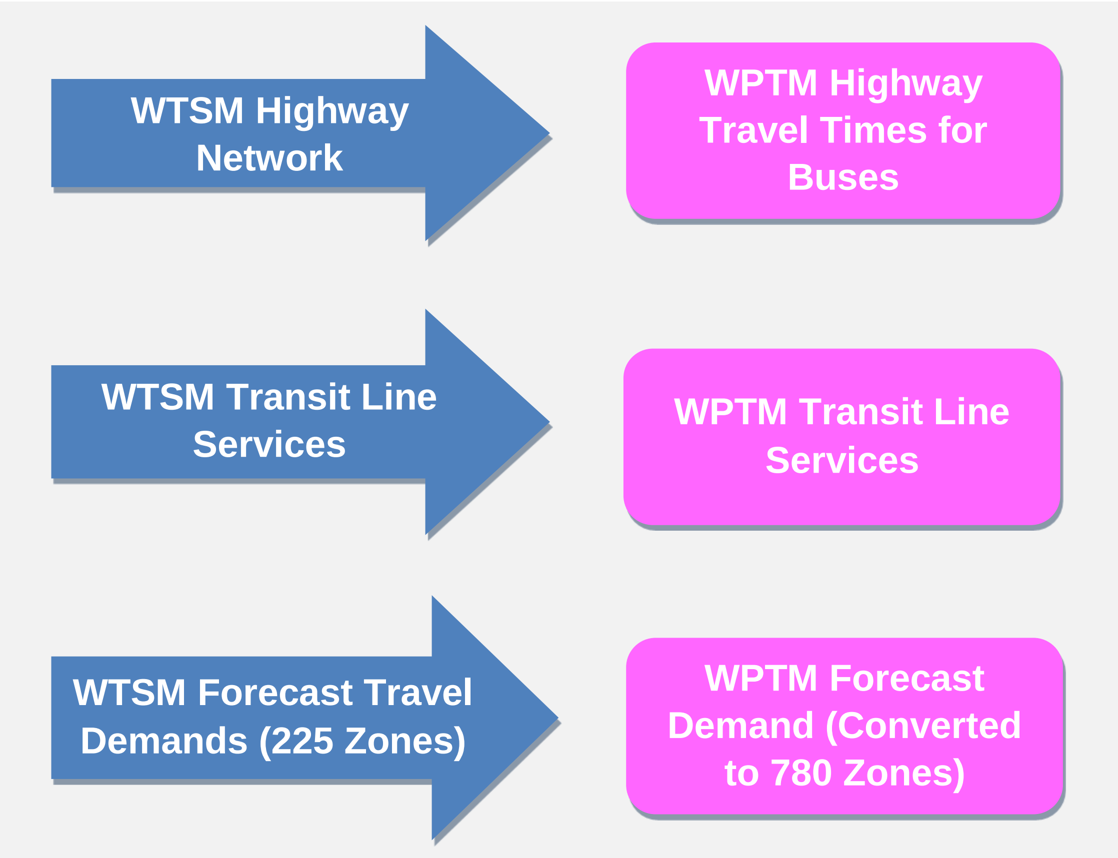


Figure 1-1: WTSM / WPTM Comparison

2 Initial Networks

2.1 Basic Principles

The updated WTSM network has been formed using road centreline GIS shape files and the information contained in the General Transit Feed Specification (GTFS) of the Wellington region. The GTFS contains information on all bus services and stop locations and is created from the Greater Wellington Regional Council (GWRC) Public Transport Database. This network information is duplicated in the WPTM model.

Figure 2-1 and Figure 2-2 show the differing overall network coverage of the previous 2006 model compared to the new 2011 models. Appendix A includes plots of the 2006 and 2011 networks at various locations throughout the region to display comparisons.

The first network produced using the above methodology contained over 24,000 nodes which is well above the upper limit of the GWRC's EMME licence size, as well as much more detail than is required in a strategic model. To reduce the number of nodes, roads were filtered out to leave only those that meet the following criteria in the class field:

- Arterial Rural;
- Major Rural;
- Medium Rural;
- Arterial Urban;
- Major Urban;
- Medium Urban; and
- Motorway.

This effectively removed all the minor roads and walkway tracks and resulted in approximately 6,500 nodes remaining in the network. The removal of minor roads however left a number of orphaned bus stops, where the bus route occurs on a minor road that has been filtered out. These roads, as not too great in number, were then re-added manually, as have the major walk links within the Wellington CBD.

Figure 2-3 below shows the initial number of nodes before the filtering process was applied. The resultant final nodes can be seen in Figure 2-4. Figure 2-5 shows the initial GIS nodes and Figure 2-6 shows the resultant Wellington city nodes after the filtering process has been applied.

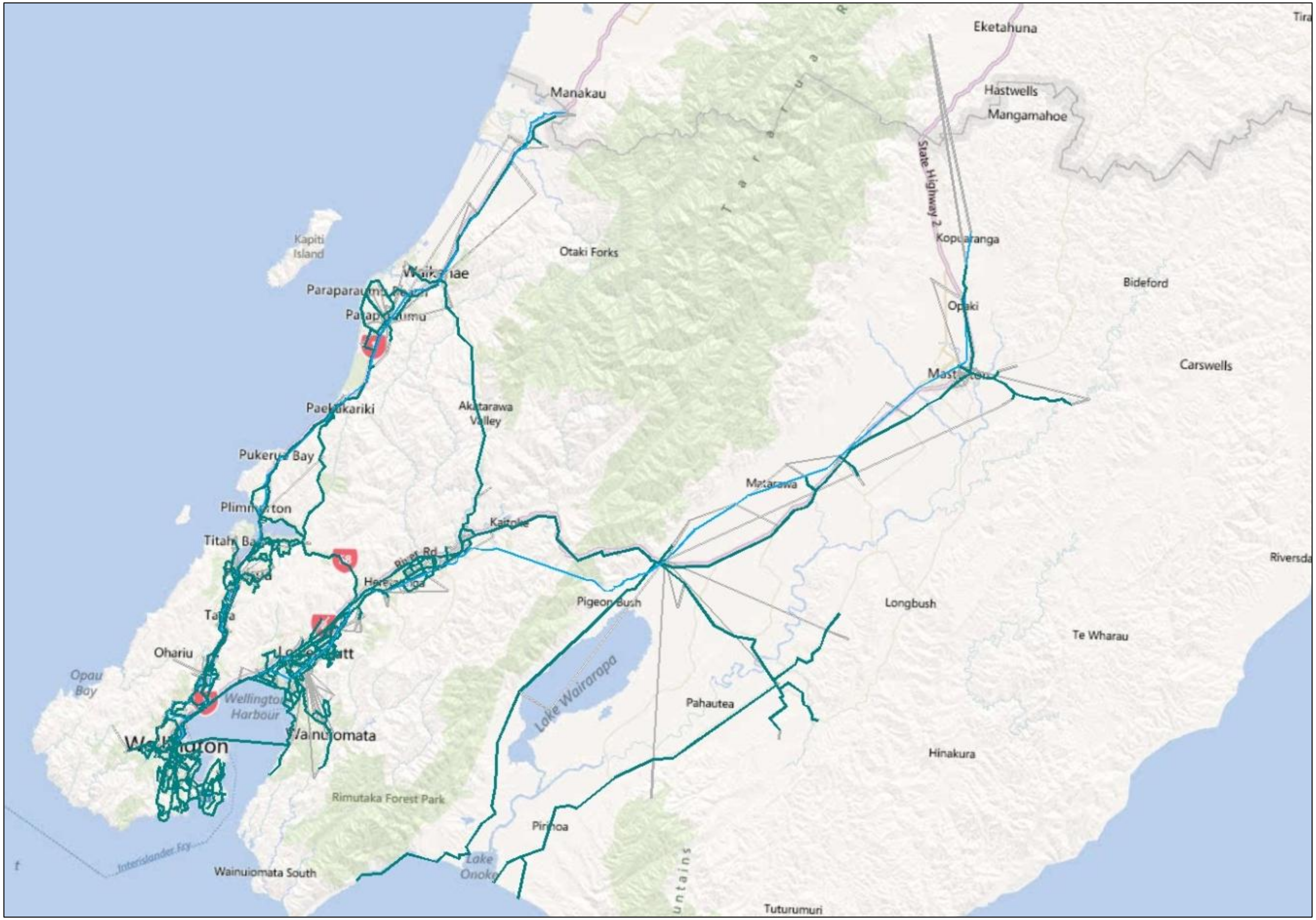


Figure 2-1: WTSM 2006 Network

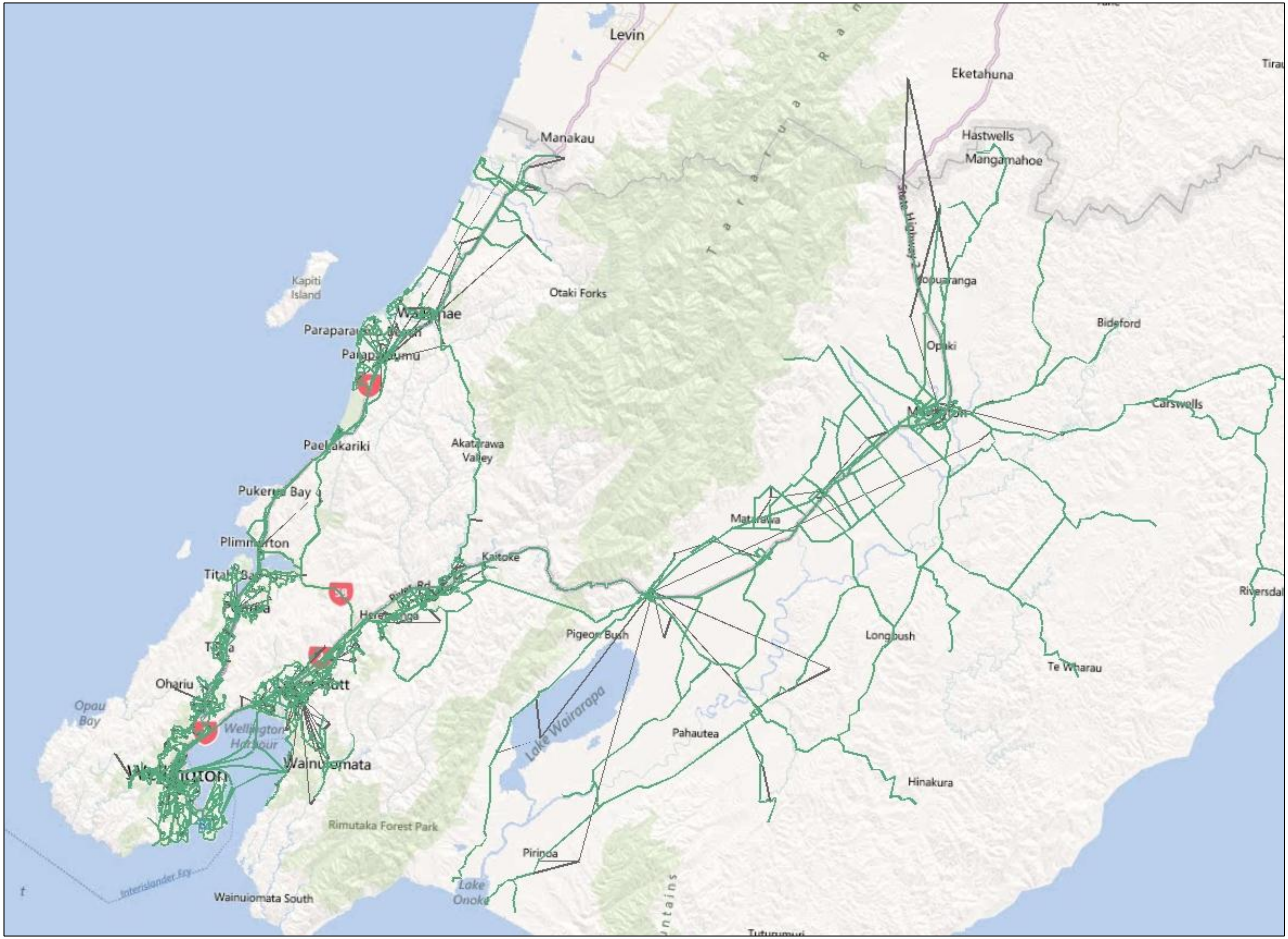


Figure 2-2: WTSM 2011 Network

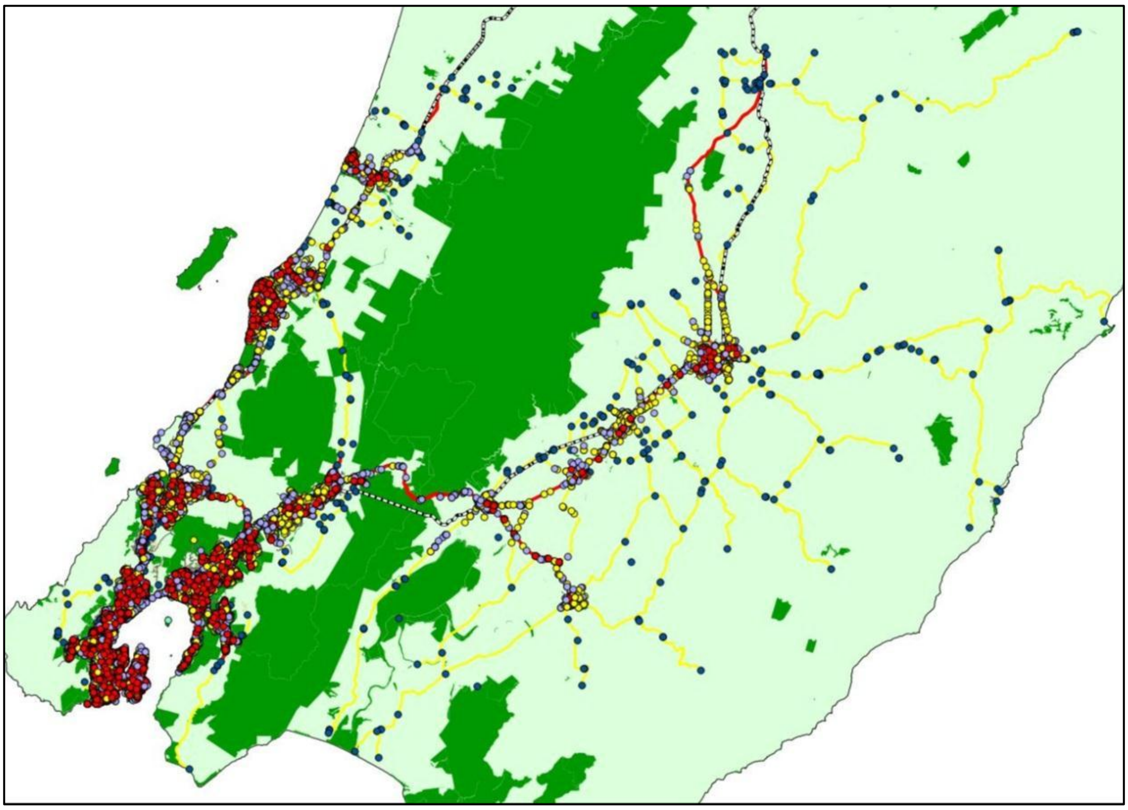


Figure 2-3: Initial GIS Nodes

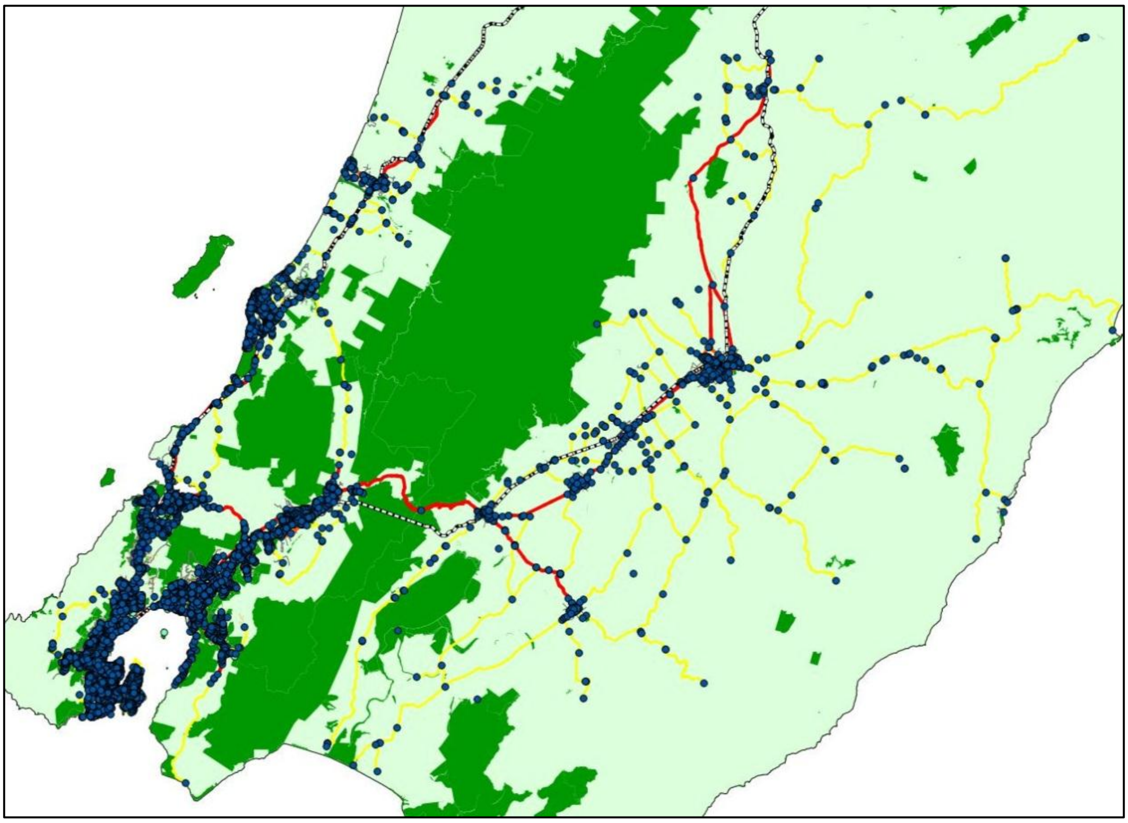


Figure 2-4: GIS Nodes after Filtering

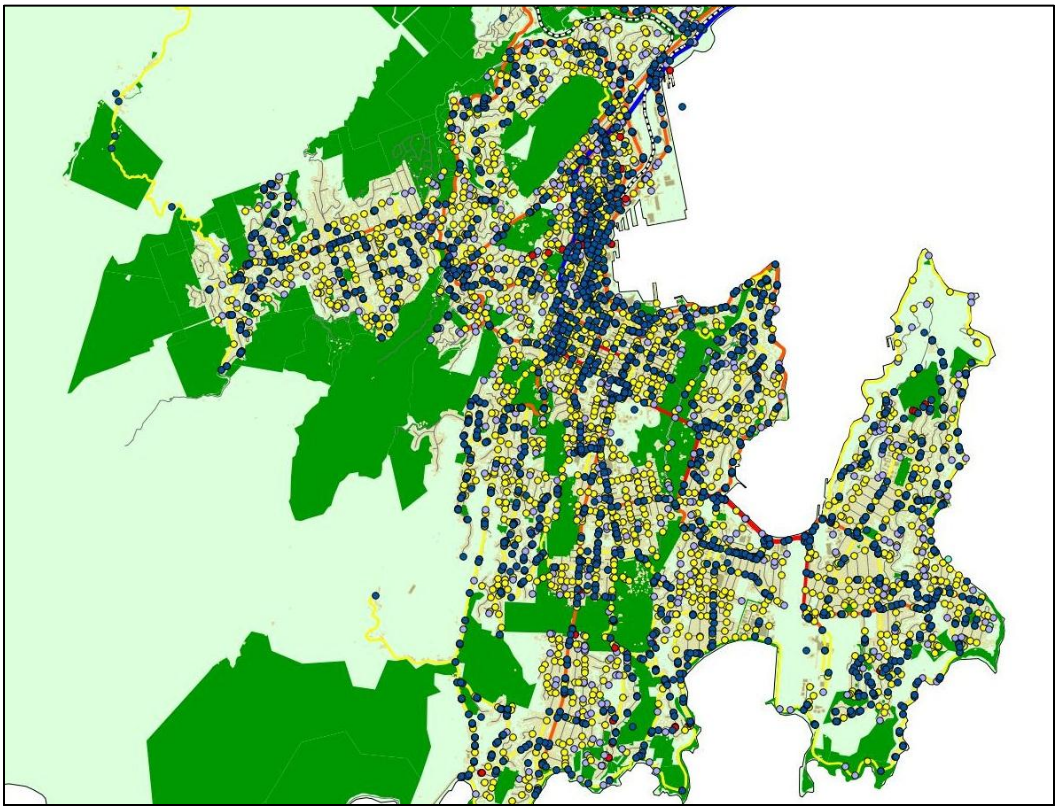


Figure 2-5: Wellington City Area All GIS Nodes

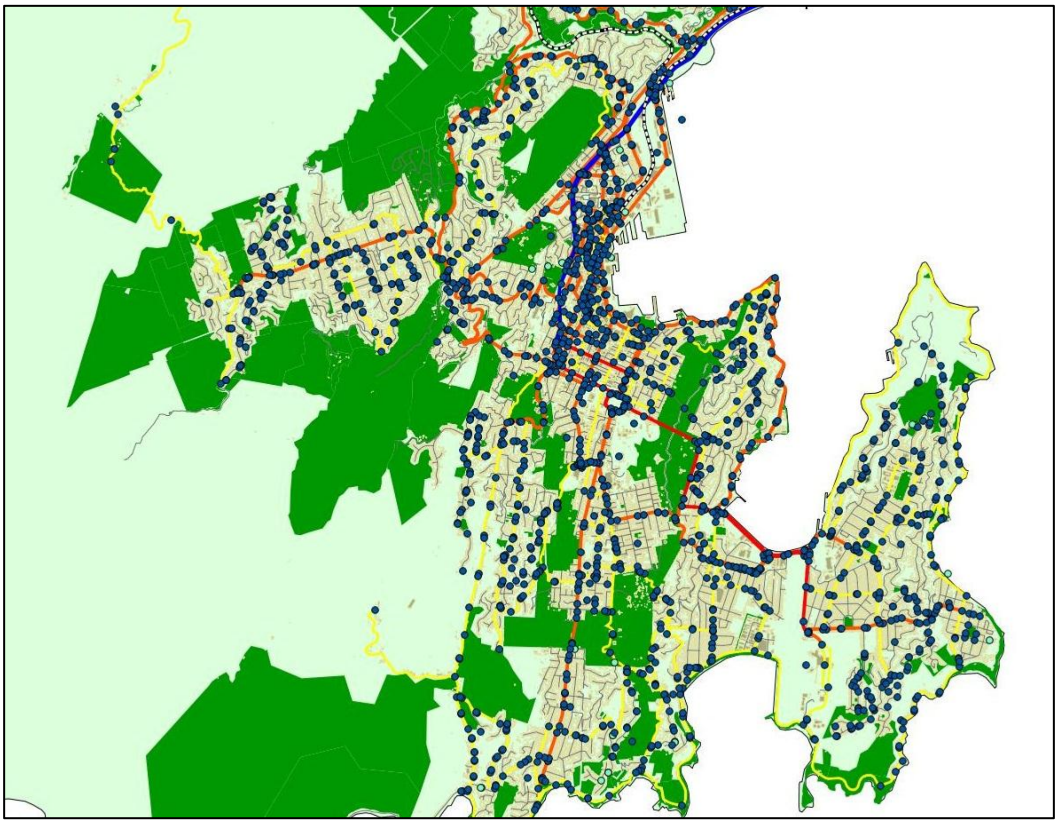


Figure 2-6: Wellington City Area GIS Nodes after Filtering

2.2 Node Numbering

The node digit limit has been increased from the 4 digits in the 2006 model to the maximum of 6 digits. This allows the node number to contain an increased level of detail.

The first node digit represents the territorial region in which the node is located as outline in the Table 2-1 below. An exception to this is centroids which, in WTSM, are all three digits numbering from 1 to 228. In WPTM centroid nodes have 4 digits, the first three are from the corresponding WTSM zone and the last digit is a sequential number (e.g. WTSM zone 54 is divided into 541, 542, 543 etc. in WPTM).

Table 2-1: Node Region Numbering

First Node digit	Node Location	Example
Blank	Rail Nodes	30015 is the Petone Rail Station node and is located at x1761041,y5435704
1	Wellington	100367 is a Wellington City node located at x1748520 y5427439
2	Lower Hutt	210677 is a Lower Hutt node located at x1759548,y5436146
3	Upper Hutt	311281 is a Upper Hutt node located at x1773021,y5445276
4	Porirua	423350 is a Porirua City node located at x1754636,y5444323
5	Kapiti	500017 is a Paraparaumu node located at x1754636,y5444323
7	South Wairarapa	700079 is a node located in Featherson township at x1795073,y5445886
8	Carterton	800090 is a Carterton node located at x1812572,y5455495
9	Masterton	922651 is a Masterton node located at x1823537,y5463017

Note that 6 is unused – previously this was Horowhenua which, due to the low number of nodes, is now included in the Kapiti Area.

The remaining 5 digits are allocated as follows:

- If the node is a bus stop, the last 5 digits are used by the General Transit Feed stop number. This is generally a five digit number between 10,000 and 40,000;
- If the node is not a bus stop then sequential numbering has been used, counting up from zero. As no area has over 10,000 nodes, there is no overlap with the stop node numbers;
- Rail nodes have been given 5 digit sequential numbering starting from 30,000 (note this won't overlap with any bus stop nodes as bus stop nodes have the region number in front). Rail node numbers, with some exception, generally decrease as the rail line heads north;
- Nodes included in scheme coding for option testing are to have the region prefix as per Table 2-1 above, followed by a sequential number starting from 50,000 for each region; and

- Centroids have retained the node numbers previously used in the 2006 model, this being the range from 1 to 1,000.

2.3 Bus Network

All bus stops are now coded in both models (WTSM and WPTM) as individual nodes, the co-ordinates of these new stop nodes coming from the General Transit Feed. This is a change from the 2006 model where all nodes were potential bus stopping locations (excluding express services). Refer to Section 4 for full details of the transit line coding.

2.4 Rail Network and Travel Time Function

The GTFS provided the rail station node locations. A correlation table was created to relate the new rail nodes numbers to those in the 2006 WTSM network and was used to include rail junction locations. As described earlier, rail station nodes are numbered sequentially beginning at 30,000. The rail correlation table is included in Appendix B.

It was decided early in the process that WPTM would benefit from the direct linking of rail travel time functions to the timetable times. This was driven by three main factors:

- More accurate timetable data coming through from the GTFS made it possible to model rail travel times more accurately in the base 2011;
- In the new assignment procedure adopted for the 2011 update (and documented in TN18) the in-vehicle perception factors can be entered explicitly in the assignment algorithm removing the need for the direct manipulation of the rail travel time functions; and
- To maintain consistency, and reduce the risk of producing different rail results between WTSM and WPTM, WTSM rail travel time functions follow suit.

In practice this meant that:

- Rail ttf11 was changed from *<(0.90*length*60/rail-speed)*1>* to us1 (where us1 was the timetable travel time function, based on the rail timetable representing the stop to stop time). The 0.90 related to an in-vehicle perception factor being applied in the base. As stated above, the in-vehicle perception factor no longer needs to be included in the ttfs;
- Rail ttf12-ttf13 were included in the 2001 and 2006 versions of WTSM as a way to model different in-vehicle perceptions factors to reflect the introduction of, among other things, the new Matangi rail carriages. Again, the in-vehicle perception factor no longer needs to be included in the ttfs; and
- Coding up rail services in the future involves coding us1 using rail speed attribute (@rlsp) as was used in the 2006 version model (but without the in-vehicle perception factor and subtracting estimated dwell time from us1).

Where ttf# are the travel time functions and us# is a specified user segement value.

2.5 Rail Access P-Connectors

Passengers can access rail stations by one of two ways, they can either:

- Access the rail station via the network i.e. walk or bus from destination to the rail station; or
- Access the rail station via P-connector to station.

P-connectors are included in the WTSM model to allow rail access, predominately by car (i.e. Park and Ride, where people drive to and park at the rail station and then use the rail) but also allows for access by other modes, such as the bus or walk modes.

In the 2001 WTSM, P-connectors linked directly into rail stations (Refer Figure 2-7 below); however in 2006 a second node was included at each rail station for P-connector access. This feature limits P-connector use only to those trips which actually use rail and was kept in the 2011 update as shown in Figure 2-8 below. Without this second node trips would use the P-connector to access zones near to the station. In the WPTM, instead of P-connectors, an additional Park and Ride node is included with vehicle and walk links for access as can be seen in Figure 2-8 below and as is detailed in Section 7.3. This Park and Ride node is present in WTSM but is not used.

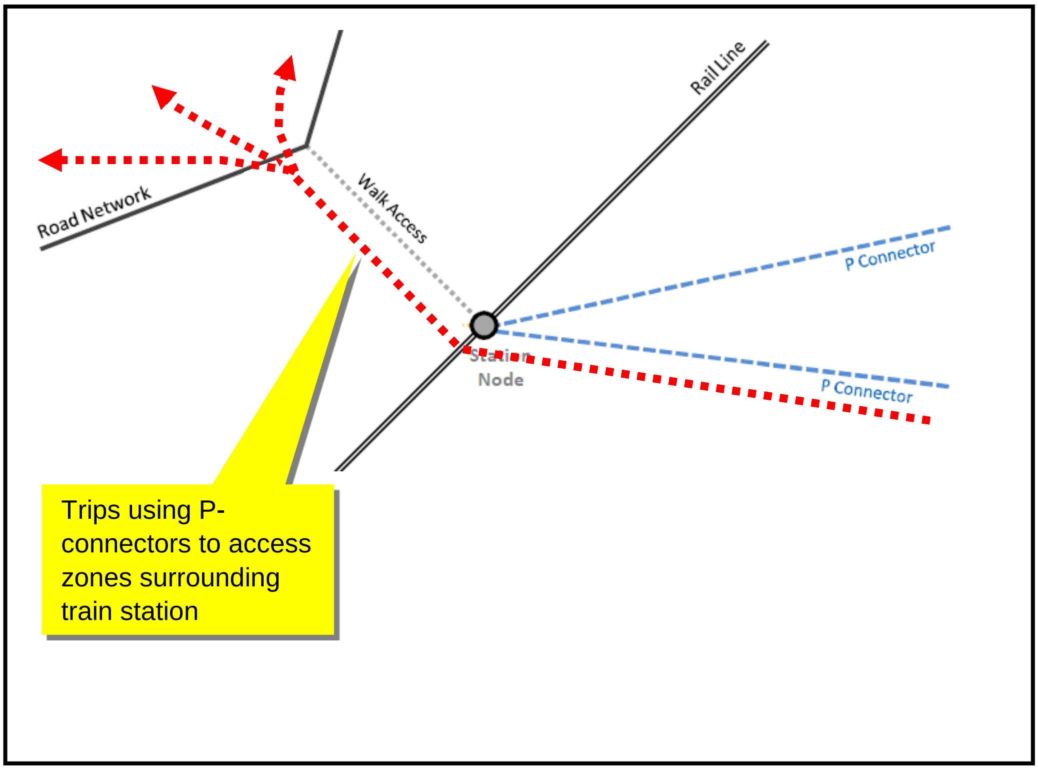


Figure 2-7: P-Connector Arrangement in the 2001 Model

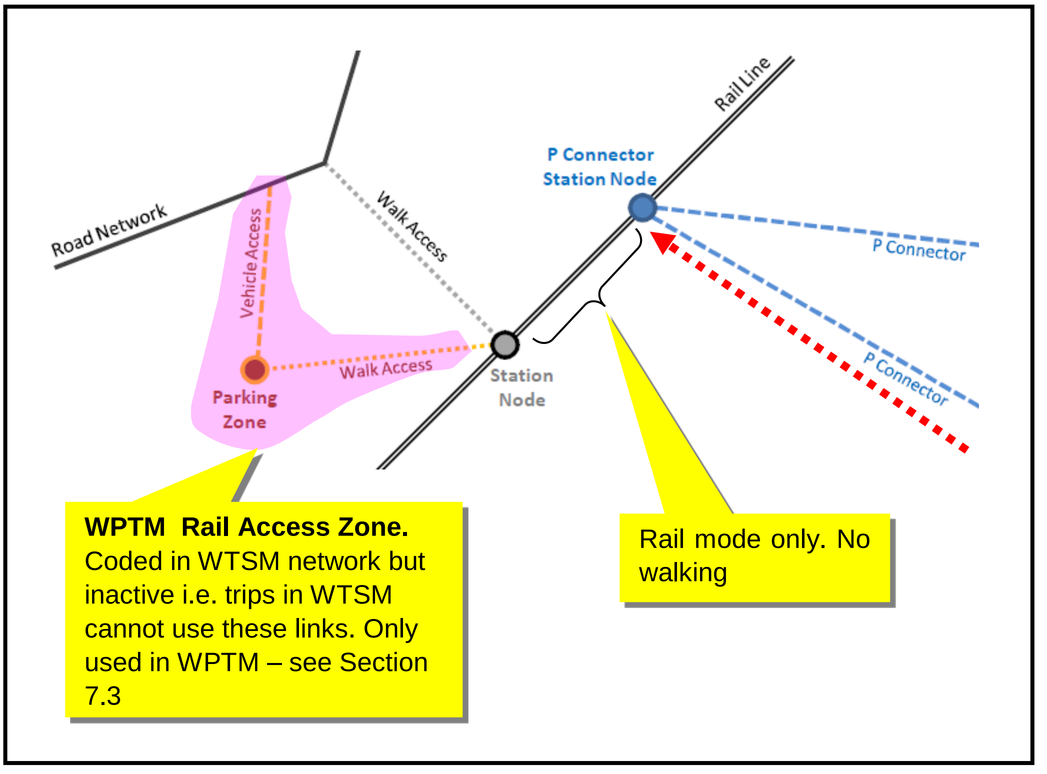


Figure 2-8: P-Connector Arrangement in the updated 2011 Model

As mentioned above, P-connector demand is made up in practice of park and ride car demand, public transport demand and walking demand. Car demand is extracted from the P-connectors and added to the car matrices using the following functions (which are illustrated in Figure 2-9):

- Where link length is less than 5km the function is:
  <P-connector demand> * <-0.0176*length^2+0.2027*length>
- Where the link length is greater than 5km the function is:
  <P-connector demand> * 0.6

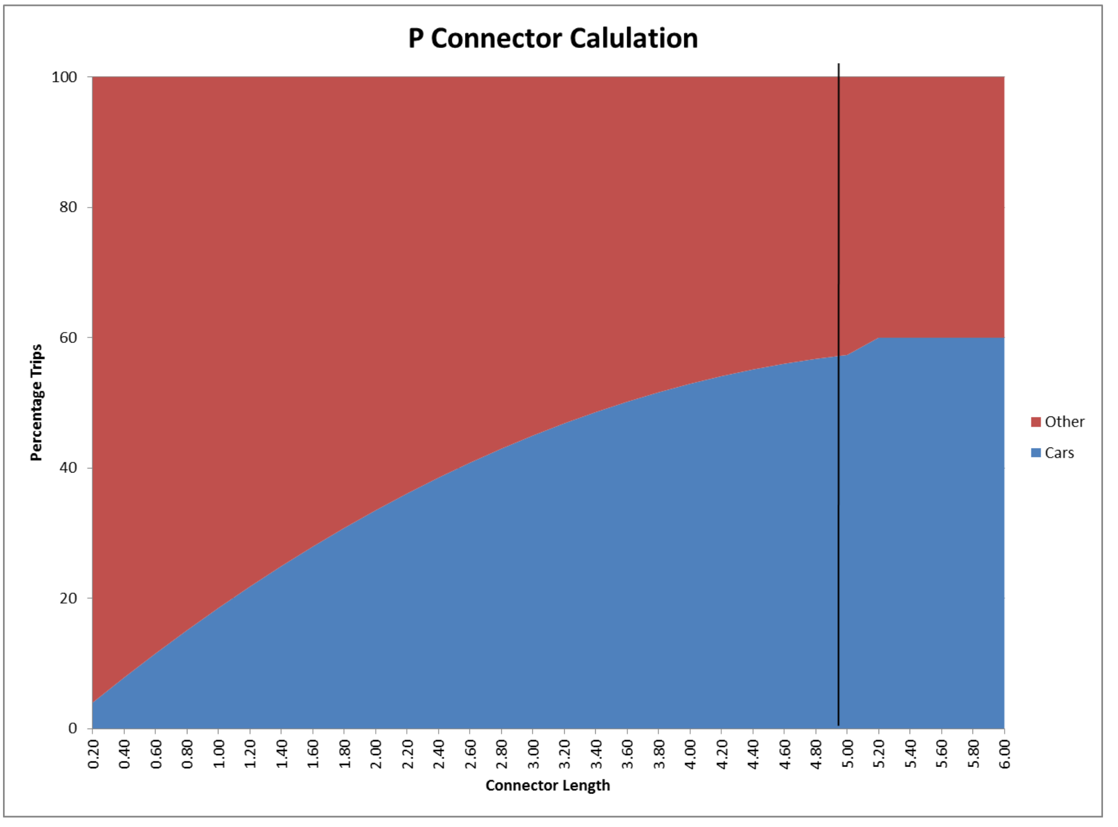


Figure 2-9: P-Connector Calculation Graph

2.6 Centroid Connectors

Zone centroids have generally been connected into the network in the same or a similar location as was used in the 2006 model. Locations vary in some locations due to differing node arrangements between the two models. Zone connectors have also been relocated; where the centroids were previously loading directly onto intersections in the 2006 model they have been repositioned to load onto the network at a more suitable mid-link node (i.e. a bus stop or similar). WPTM centroid coordinates were used for WTSM zones to maintain consistency (as discussed later in the document – WPTM centroid coordinates were adjusted to better reflect weight of activity in the zone). Using the rail node correlation table described above, the P-connector (rail access) locations were updated to the new rail node numbers.

2.7 Highway Network

The 2006 WTSM link and intersection coding regime has been retained and applied to the updated network. Initial link types were taken from the road centreline GIS file class attribute and related to those in the 2006 Model User Document tables which assign various attributes, such as free flow speed and capacity, based on link type.

The number of lanes also came from the road centreline shape file from the lanes attribute which gave the total number of lanes in both directions. In most cases this lanes number was simply halved for each direction, except for where the number of lanes an odd number, which indicates that there is a different number of lanes in each direction. These links were flagged and manually coded later inside the EMME network editor using aerial photography and local knowledge.

2.7.1 Link Types

The link type classification and default values used for coding the auto networks are shown in Table 2-2 below. These are based on the link type classifications used in the 2006 WTSM model. Link types were initially assigned to each link based on the class attribute in the GIS road centreline file. The link types and default parameters were reviewed during network coding, site-specific attributes being applied where necessary. The need for additional link type classifications was also highlighted during this process (using results from the travel time surveys and local knowledge) leading to the addition of types 20 to 22, refer Table 2-2 below. A map showing locations of these new link types is included in Appendix C.

Table 2-2: Link Type

No.	Description	Typical Free Auto Speed (kph)	Typical Capacity (vph)	Delay Parameter[1]
1	Centroid Connector	40	5,000	0.0
2	Centroid Connector – rail access	40	5,000	0.0
3	CBD/Shopping – medium friction	40	600	1.8
4	CBD/Shopping – low friction	45	800	1.6
5	Local	48	1,000	1.2
6	Collector (high friction/poor alignment)	50	1,100	1.2
7	Collector (low friction/good alignment)	52	1,250	1.0
8	Urban arterial – low speed	52	1,350	1.0
9	Urban arterial – medium speed	55	1,450	0.8
10	Expressway	95	1,800	0.8
11	Motorway	100	2,000	0.4
12	On ramp	70	1,800	0.6
13	Off ramp	70	1,800	0.6
14	Rural – restricted speed	70	1,400	1.4
15	Rural – unrestricted speed	100	1,400	1.4
16	Walk – Auxiliary Transit	-	-	-
17	Rail – Transit	-	-	-
18	Ferry – Transit	-	-	-
19	Bus with or without walk link	-	-	-
20*	Urban Traffic calming	25	600	1.8

21*	CBD/Shopping - high friction	30	600	1.8
22*	Rural State Highway	80	1,800	0.7

* New link types added in the 2011 update of WTSM
[1] Represents road friction which is used in delay calculations in the Akcelik speed-flow model

2.7.2 Vehicle Types

The 2011 WSTM update has adopted the same vehicle types as was used in the 2006 WTSM update as shown in Table 2-3 below.

Table 2-3: Vehicle Types

Type	Description	Seated Capacity	Total Capacity
1	Rail carriage	156	312
2	Bus	42	66
3	Ferryboat	200	300
4	Trolley	42	66
5	Superbus	42	66

Note that vehicle types 4 and 5, Trolley and Superbus, are not used in the 2011 model (but left in the model should they be required in option testing). All bus services are instead coded as vehicle type 2 – bus.

2.7.3 Modes

As with other model aspects, the modes used in the 2011 WTSM update has been based on those used in the 2006 update as shown below in Table 2-4.

Table 2-4: Modes

Mode	Type	Description
a	Auto	Car
h	Auxiliary Auto	Heavy Commercial Vehicle
r	Transit	Rail
b	Transit	Bus
f	Transit	Ferry
w	Auxiliary Transit	Walk with speed of 5kph
c	Auxiliary Transit	Centroid Connector with speed of 10kph
p	Auxiliary Transit	Rail Access Connector to Rail Station with speed of 15kph. Includes Park and Ride trips as well as some Public Transport access.

Neither the trolley nor superbus modes are used in the 2011 model. The decision to not use the trolley mode was made due to the fact that many services run a combination of diesel and trolley buses along the same service route. An example of this is service number 3 which runs between Karori and Lyall Bay via the Wellington CBD. The super bus mode was not utilised in the 2006 WTSM model so has not been used in the 2011 model either.

The Wellington Cable Car has been coded into the rail mode. This is consistent with the 2006 WTSM model.

2.7.4 Intersection Coding

WTSM 2011 has adopted the WTSM 2006 approach to coding intersections with the following attributes presented in Table 2-5 being specified.

Table 2-5: Intersection Coding Attributes

Attribute	Description
@int	Intersection type: 1 = Priority, 2 = Roundabout, 3 = Signals
@jcalc	Intersection Calculation Flag: 0=no, 1=yes
vdf	Delay Function: 16 = No Link Delay, 26 = Link Delay
@intln	Number of Intersection Approach Lanes
@intcp	Intersection Approach Capacity
@intmn	Intersection Minimum Time

As outlined in Figure 2-10 below, the @int attribute determines the intersection type. Where zero is entered, it is not an intersection, therefore no delay occurs. The @jcalc attribute determines where the intersection capacity is fixed or calculated. The volume delay function (vdf) attribute determines where the link has delay or not.

If the intersection capacity is fixed and the link has delay, the @intcp (intersection capacity) and @intmn (Intersection minimum time) attributes must be populated. If the intersection capacity is calculated, the @intln (intersection approach lanes) must be populated.

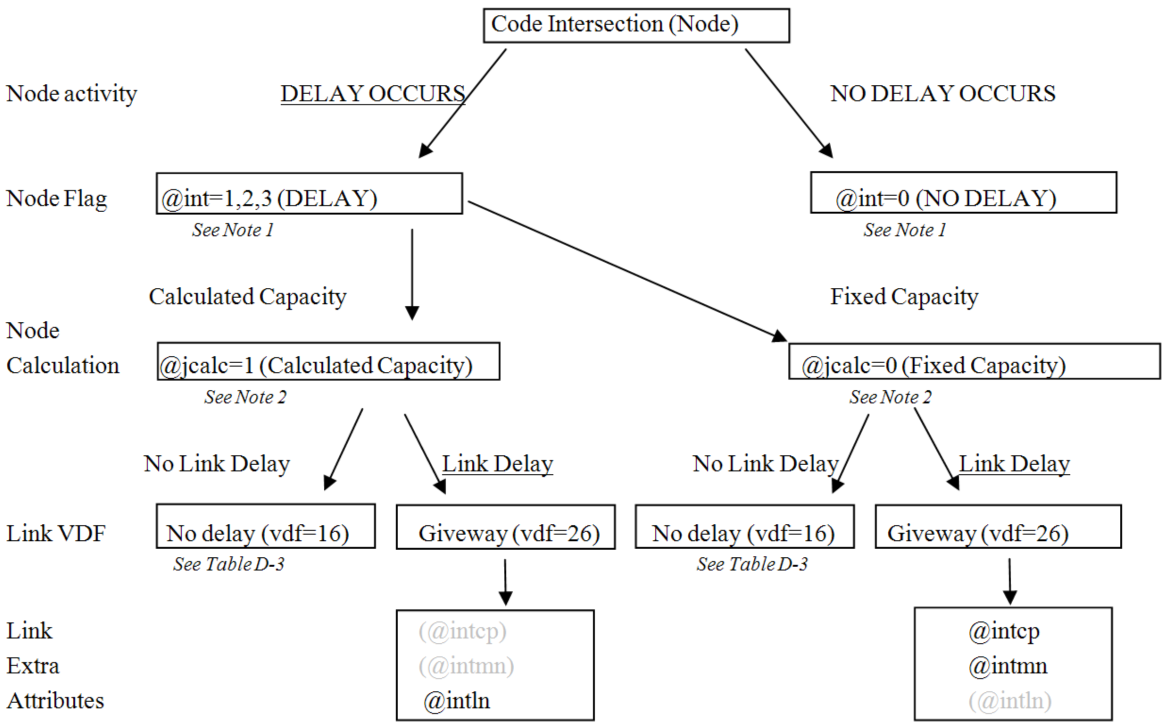


Figure 2-10: Intersection Coding Flow Chart

Image sourced from WTSM 06 Model User Manual

3 Highway Network Refinement

3.1 Link Shaping

Curvature has been added to the links using the EMME link vertices function throughout the network. This was done to both help calculate link distances as well as to improve the presentation of the network. Elevation has also been added to the node attributes using GIS to help calculate better link lengths.

3.2 Fixed Capacities

The majority of intersection capacities and delays in WTSM are calculated through successive iterations in the highway assignment. However, the WTSM User Manual suggested that this produced significant convergence issues and a potential resolution was to apply fixed capacities in dense urban networks with severe congestion.

In the 2006 WTSM version of the model the majority of these fixed capacity intersections were located in the Wellington CBD. The 2011 WTSM Update began with the same assumptions i.e. the first iteration of the update identified the same fixed capacity intersections as the 2006 model.

Whereas the 2006 version of the model manually calculated fixed capacities, the 2011 update took capacities from the Wellington Traffic Model (WTM) Saturn model, the idea being that these would take congestion and other network effects into account. A VBA macro was written to convert the Saturn outputs into EMME format based on intersection approach coordinates. Figure 3-1 below indicates the intersections where fixed capacity has been used.

The 2006 WTSM User Manual suggests a simple calculation be used to calculate the fixed capacity of an intersection:

$$Effective\ Lanes\ x\ 1800\ vph\ saturation\ flow\ x\ pecentage\ green\ time\ x\ 2\ hours$$

For the 2011 WTSM update we instead developed an automated procedure to introduce capacities modelled in Saturn for the Wellington Traffic Model (WTM) into the EMME model. This was utilised predominately in the Wellington CBD where the majority of fixed capacities have been specified.

The effect of fixed capacities in the Wellington CBD with regards to model convergence is unknown as they were already present in the 2006 WTSM.

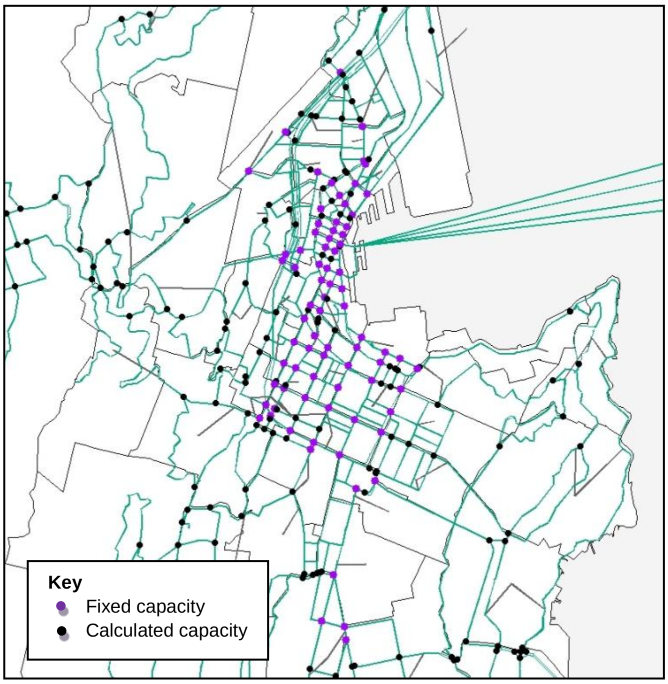


Figure 3-1: Location of Fixed Capacity Intersections

3.3 Additional Road Links for Compatibility with WPTM

As WPTM has a finer grained zone system than WTSM, some additional minor road and walk links (beyond those added to cater for bus routes) are required to provide a better representation of some elements of travel that impact on the modelling of public transport trips or competition between public transport access modes. These additional links have been fed back into WTSM and are included in both models to ensure consistency between the two models.

The network coding process was to record these network additions in a standalone macro file to transfer back the changes into the WTSM network.

3.4 Site-Specific Adjustments

Initial assignments in WTSM indicated significant levels of rat running due to the increased network detail. Many of these rat runs were considered implausible due to the steep and winding nature of the roads or other traffic restrictions (e.g. parking). To resolve the issue in a more comprehensive but less time consuming manner, a method was developed which included calculating curvature and gradients for the entire network.

All nodes in the network have been given an elevation attribute (@elev), which has been generated from GIS data. This elevation attribute has been used to calculate the link gradient and stored in additional attributes (@slope for raw gradient and @abslo for absolute gradient – i.e. negative gradient values made positive).

A further check was to compare the link lengths against the node to node distance. This was expressed as a ratio and stored in the new attribute @curat. The higher the curve ratio, the more winding the section of road is. A curve ratio of less than one indicated an error to be remedied.

Using these new attributes, links where speed adjustment was needed could be identified. Three filters were applied to identify those links with extreme conditions where speeds should be reduced.

Using this process reduced rat-running of traffic through minor routes.

3.4.1 Filter 1

The first filter applied the following conditions:

- First, removes connectors from the selection;
- Removes links with speeds of less than 45kph;
- Removes links that have a gradient of less than 5%;
- Identifies urban / CBD link types;
- Removes links of length greater than 300m; and
- Identifies only links which are not straight.

The results of filter 1 are shown in Figure 3-2. Links identified here have been reduced to have a 25kph link speed. The EMME formatted filter text used was as follows:

"not(isConnector) && @v0>45 && @abslo>0.05 && not(@curat<0.9>1.1) && type<8 && length<0.3 && not(@curat==0)"

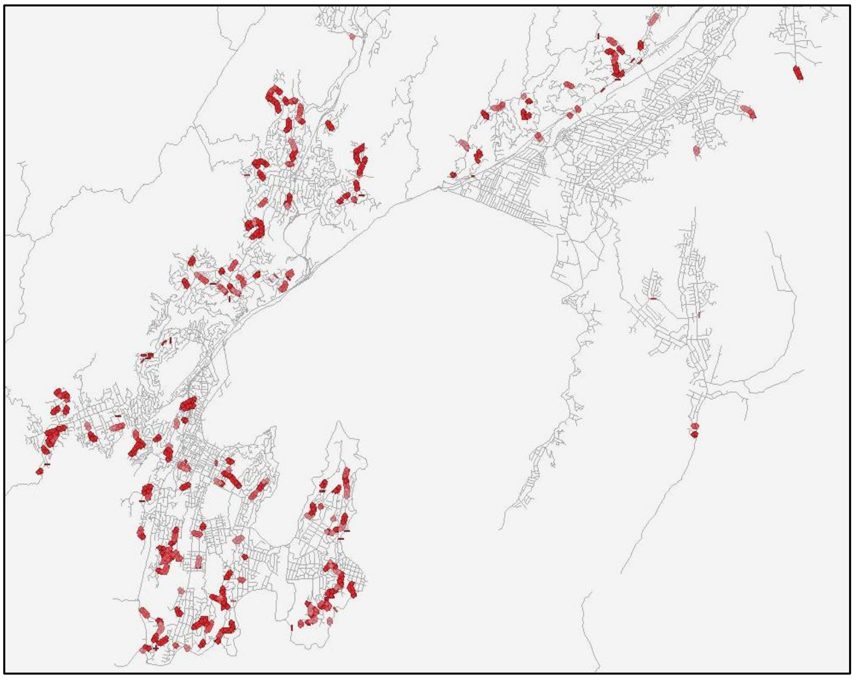


Figure 3-2: Links Identified by Filter 1

3.4.2 Filter 2

The second filter applied the same conditions as those listed for filter 1, with the exception of the link length now filtering those links under 300m long. The filter result was as shown in Figure 3-3. The links identified here had a link speed of 45kph applied to them. The text used to apply this EMME formatted filter was as follows:

"not(isConnector) && @v0>45 && @abslo>0.05 && not(@curat<0.9>1.1) && type<8 && length>0.3 && not(@curat==0)"

Figure 3-3: Links Identified by Filter 2

3.4.3 Filter 3

The third and final filter looked only at medium speed urban roads (link type 9). The other filter conditions were the same, except in this case no length restriction was applied. The links identified here have had speeds reduced to 45kph. The links identified after application of this filter are as shown in Figure 3-4. The EMME formatted filter text used is as follows:

"not(isConnector) && @v0>45 && @abslo>0.05 && not(@curat<0.9>1.1) && type==9 && not(@curat==0)"

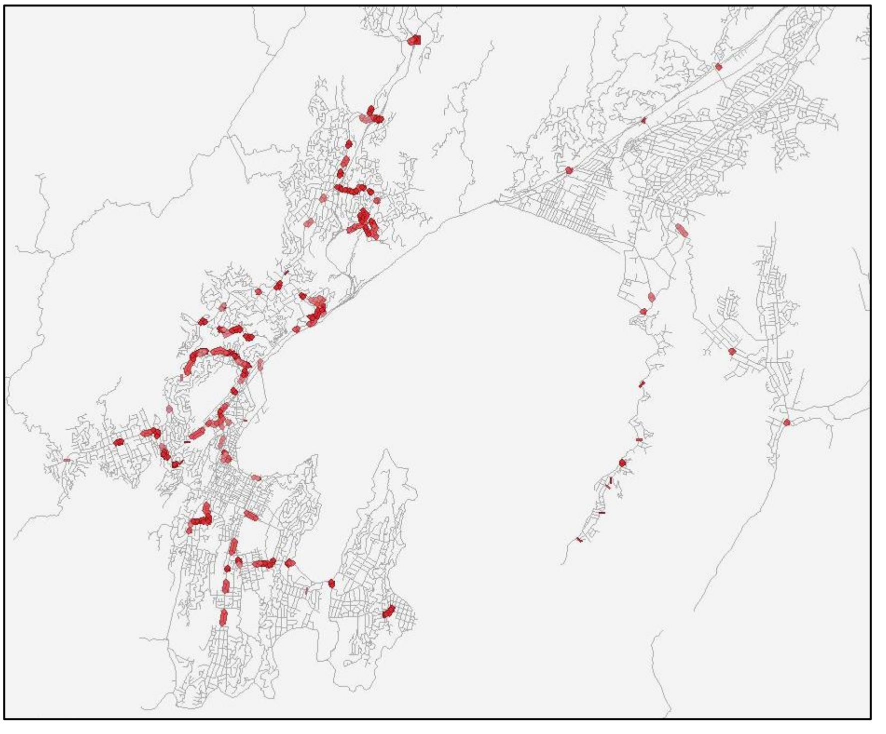


Figure 3-4: Links Identified by Filter 3

4 PT Services Coding

4.1 General Transit Feed Specification

Transit lines (for both bus and rail) were coded by converting General Transit Feed data provided by GWRC into an EMME transit batch-in file. This data uses a common format called General Transit Feed Specification (GTFS) to store public transport itineraries and schedule data, and is used by Public Transport organisations around the world to make their transit information available to web-based applications.

The main advantage of using this format was to eliminate the need to code the public transport services manually, thereby significantly reducing the time needed for this task and the potential for coding errors. Another advantage is that any future modification in public transport services could be easily and rapidly implemented in the model.

GTFS uses a number of standard comma-separated text files, each containing various layers of information. The files used in the GWRC transit data are as follows:

- **agency.txt** - Contains information about the operating agencies that provide the data;
- **stops.txt** - Contains information about individual locations where vehicles pick up or drop off passengers;
- **routes.txt** - Contains information about transit organization's routes. A route is a group of trips that are displayed to riders as a single service;
- **trips.txt** - Lists all of the individual trips of each route which occur throughout the day. A trip is a sequence of two or more stops that occurs at a specific time;
- **stop_times.txt** - Lists the times that a vehicle arrives at and departs from individual stops for each trip;
- **calendar.txt** - Defines dates for service IDs using a weekly schedule. Specify when service starts and ends, as well as days of the week where service is available; and
- **calendar_dates.txt** - Lists exceptions for the service IDs defined in the calendar.txt file.

4.2 General Transit Feed to EMME Conversion

In order to convert General Transit Feed into an EMME transit batch-in file, an innovative program was developed, using the C# programming language.

A key focus behind the development of the General to EMME (G2E) convertor was flexibility. As can be seen in Figure 4-1, a range of parameters can be specified for the output file.

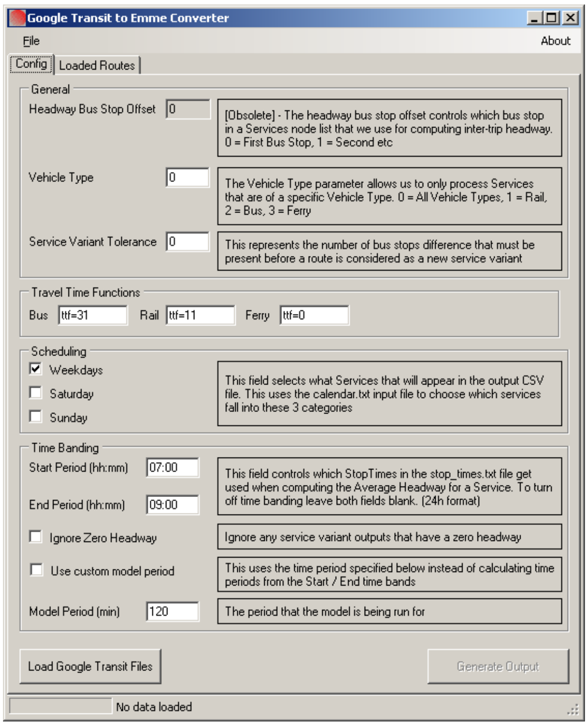


Figure 4-1: General Transit to EMME Converter interface

This program reads in the GTFS text files and processes them to create a single batch-in file in EMME format, containing detailed transit data for the modelled period, including all service itineraries, stopping patterns and headways.

A number of issues arose during the development of the converter program, mainly due to inconsistencies within the coding hierarchy of the transit database. Transit lines in GTFS are coded using the following hierarchy:

- **Route:** all trips with the same origin and destination and sharing generally similar characteristics in terms of itineraries and stopping patterns (e.g. Go Wellington Bus No.2);
- **Service:** trips are grouped in the same route but with variations in stopping pattern, itinerary, fare, etc. (e.g. inbound and outbound services to and from Wellington CBD, express services, services with extra stops at schools at certain times); and
- **Trip:** a single occurrence of a service (e.g. Go Wellington Bus No.2 inbound starting at 06:30).

Using this convention, it was thought that all trips with the same route and service numbers would be identical, except for the time at which they occur. However, testing of the initial output transit files in EMME showed that the database contains another layer of variance, with some trips having the same route and service numbers but still showing some variation. Conversely, some trips having a different service number appear to be perfectly identical.

This was taken into account in the development of the program, with all trips being given an identifier reflecting the route, the service and the variation they belong to. Trips with the same identifier were then grouped together in a service variation and the headway for this group was calculated based on the number of trips occurring during the modelled period.

4.3 Headway Calculation

Headway calculation for a given service variation is based on the number of complete trips occurring within the specified time period, a complete trip being where the whole trip takes place within the time period. Fringe services (trips which partially occur outside the specified time period) are also allowed for by calculating the proportion of stops within the time period and including this into the total headway calculation. This approach is illustrated below as Figure 4-2 which gives a visual representation of these fringe services.

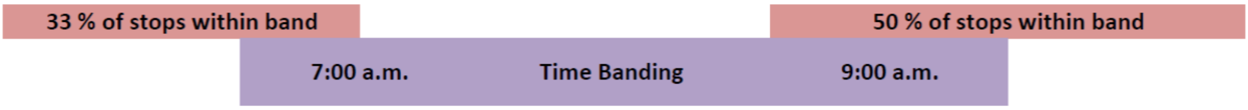


Figure 4-2: Treatment of Fringe Services

In the rare instance where the only trip of a service occurs partially within the time period, the maximum headway (total period) time is applied. An example of this is the Kapiti Commuter (service 289) where the southbound service begins at 5:40am in Waikanae and ends at 7:20am at Courtenay Place. This Kapiti service has been given a headway value of 120 minutes, the length of the AM period.

4.4 Transit Line Path Interpolation

A drawback of using the General Transit Feed data was the fact that it only contains information on stops and not on the actual itinerary between stops. This was solved by using the EMME path interpolation functionality, which calculates the shortest path between bus stops (described in more detail below).

Although bus travel times in WTSM / WPTM are modelled based on road congestion, timetable information from the General Transit feed data is retained in a transit segment attribute (tus1) to help calibrate in-vehicle transit journey times.

The resulting transit data produced by the Converter is in the following format:

```
a 001O02 b 2 0 25 'Wellington - Island Bay' 0 2 40
 path=yes
 110360 dwt=#0 ttf=2
 110351 tdwt=+0 tus1=1
 110350 tdwt=+0 tus1=0
 110349 tdwt=+0 tus1=1
 110329 tdwt=+0 tus1=1
 110331 tdwt=+0 tus1=2
 123336 tdwt=+0 tus1=2
```

The EMME path interpolation is carried out by calculating the shortest path based on the length attribute. Generally this approach is acceptable; however it does cause issues where the stops are far apart i.e. this can happen when the shortest path according to length is not necessarily the fastest route. A procedure was developed to temporarily replace the length attribute with the auto travel time attribute (timau) from an assigned network prior to the transit line batch-in. This way EMME is calculating the fastest path between stops and not the shortest. Overall this produced much better results.

4.5 Transit Line Header Information

Using the data contained within the GTFS, the convertor specifies the line name for the transit line. The convention adopted for the six allocated digits is as shown in Table 4-1.

Table 4-1: Transit Line Header Conventions

Parameter	Description
Line Name	Six characters describing the transit line. • First three characters are the service number (e.g. 001 for service one or WRL for Wellington Rail Line) • Fourth character indicates whether the service is inbound or outbound (as defined in the GTFS). This is based on the CBD or, where this is inappropriate the nearest rail station. • Last two characters are numerical and sequential, starting from one. This is so service variants can be batched into the model. For example the line name “045O01” indicates that this is service 45, the service is heading outbound from the CBD and that it is the first of the outbound 45 services in the EMME transit line batch-in file.
Mode	b, r, f
Veh	Vehicle Type – 1 = rail/cable car, 2 = bus, 3 = ferry
Hdwy	Service headway in minutes. Generated from the GTFS as described above.
Speed	Default speed is 25kph (used only on transit lines where TTF=0)
Description	Transit line description – generated from the GTFS routes file.
ttf	Travel time function – ttf=11 for rail and ttf=31 for bus. Ferry has no travel time function in the model so uses ttf=0.
tdwt	Dwell time: Rail = 0.8 min at stations and is located on the first station node approached by a service; = zero (+0.00) for the section station node; = no stopping (#0.00) between stations (i.e. at rail junction nodes). Bus = zero (+0.00) at bus stop nodes (last 5 digits of node between 10,000 and 40,000), and no stopping (#0.00) elsewhere.
lay	Layover time = 5 min at the end of services.
tus1	Segment attribute used to store average stop to stop time for the service as per the timetable data.

4.6 Bus Frequency / Headway Validation

To verify that the transit line generation process bus frequencies were checked against two sources:

- Independent data: The GWRC Wellington city public transport cordon; and
- Dependent data used to verify the process was working correctly: Timetable data from the Metlink website. The Metlink website made it possible to extract services passing specific stops.

Comparisons of the resulting transit line frequency calculations compared against the two sources above are tabulated in Appendix D.

4.7 Transit Line Refinement

The transit line files have been refined throughout the network preparation process; Figure 4-3 shows an outline of the refinement process. As outlined previously, the initial transit lines for the modelled periods were produced by the G2E convertor. Analysis of the outputs from the final version of the G2E convertor showed that the convertor was, while giving the correct total number of services, producing a large number of service variants. This wouldn't have any effect on model assignment but to simplify analysis and future coding of PT services, the transit line files were consolidated. Refer to Section 7.4 for details and examples of the consolidation process. The final step in the transit line refinement process was to, following the resolution the P-connector debate outlined in Section 2.5, include a second rail node for rail access.

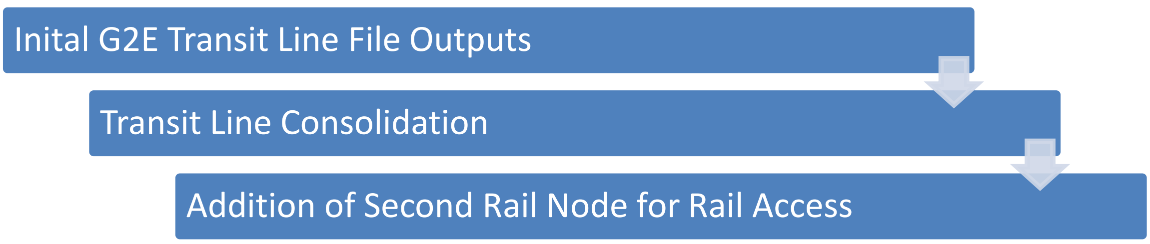


Figure 4-3: Transit Line File Progression

5 Transit Times Analysis

5.1 Overview

The transit times for rail, cable car and ferry are 'hard coded' in both WTSM and WPTM according to the published timetable. The actual performance of these modes is understood to largely match the timetable, although some unreliability is inevitable. This 'hard coding' approach would be possible for bus but this would limit the model in two ways (1) it is known from ETM data that buses frequently fail to adhere to timetables, particularly in peak periods and (2) increasing highway congestion in future years is expected to affect bus run times. Based on these arguments, an approach was selected that seeks to replicate actual (not the timetabled) bus run times in the base year, and using the WTSM highway (car) times as an explanatory variable. This enables the model to capture the impact of increasing or reducing congestion in future years as Wellington grows and as the highway network changes.

5.2 Approach

The purpose of this analysis is to understand what determines bus travel time and to develop functions to represent this in WPTM.

At an early stage in the project, two possible approaches were determined for the WPTM bus travel time functions:

- Method 1: hard-code the bus times in base WPTM to the timetables, with adjustment to ensure that run times align with actual performance. In future years or option testing, where highway congestion is changing, the run times would be adjusted in proportion to changes in highway run times from WTSM.
- Method 2: develop a function to estimate bus times in WPTM from the modelled car running times from WTSM plus allowances for dwell time at stops. This function must be calibrated. Where buses are segregated, a fixed speed would be applied. In future years or option testing, bus times are automatically updated as highway congestion levels change.

Method 1 has the advantage that bus times in the base year can be replicated with a minimum of modelling error but has the disadvantage that if a new bus route is designed that is unrelated to the base bus routes; there are no base bus times available to use or to factor. This would make the model less easy to maintain.

Method 2 implies potentially greater modelling error in the base (than Method 1) but would be more straightforward to apply in future years and option cases. Initial results from calibration of the functions showed that base modelling error was not severe; therefore a decision was made, with support of the steering group, to follow Method 2. This also has the benefit of being somewhat more familiar in the Wellington setting as this is the approach currently used in WTSM.

For rail, cable car and ferry, which are mostly reliable and unaffected by interactions with cars, the transit times will be hard-coded to match the timetables. In future years, it will be the modelling analyst's responsibility to determine what changes are required to the base timetable for these modes.

5.3 Transit Time Data Sources

5.3.1 ETM Bus Matrices

Bus stopping times can be deduced from the ETM (electronic ticketing machine) database. There are some differences between Go Wellington and Mana bus company ETM data that have an influence on the extraction of transit times.

For Go Wellington, when a passenger tags on and tags off, the system records the board stop, board time, alight stop and alight time measured to the second. Thus the travel time between these two stops can be calculated. The data can therefore provide times between stops where passengers have undertaken the journey, and for the main movements of interest, the data is rich.

For Mana, only the board stop and boarding times were recorded, not alight stop or time. However it was possible to link each record to a particular service. So for example, if passengers boarded at both the first stop and second stop, the time between these stops could be calculated. Once again, the travel times between all stops are not known, but a rich sample is available between the main stops of interest.

5.3.2 Metlink Wellington Timetables

As part of WTSM route file creation process (from the General Transit Feed), average times from the current bus timetable were extracted and written to an EMME segment attribute (us1), which records timing points. The approximate times for each individual link traversed can then be determined by interpolation.

5.3.3 WTSM congested highway times

The WTSM link variable timau contains forecast car running times, including junction delay (where junctions are modelled), for each link. Another attribute, v0, provides free-flow speed, which is useful for links where there is no timau value available, e.g. bus-only roads.

5.4 Transit Times Investigation

5.4.1 Segments

A set of representative 'segments' were selected for analysis. These were chosen to represent the key movements where bus passenger flows are high and as a result the ETM data is plentiful such as Karori to the CBD and Kilbirnie to the CBD via the bus tunnel. Figure 5-1 and Figure 5-2 show the chosen segments. A full list of the segments is included in the Table 5-1. They cover approximately 38% of route kilometres in the AM period, and 49% in the IP period.

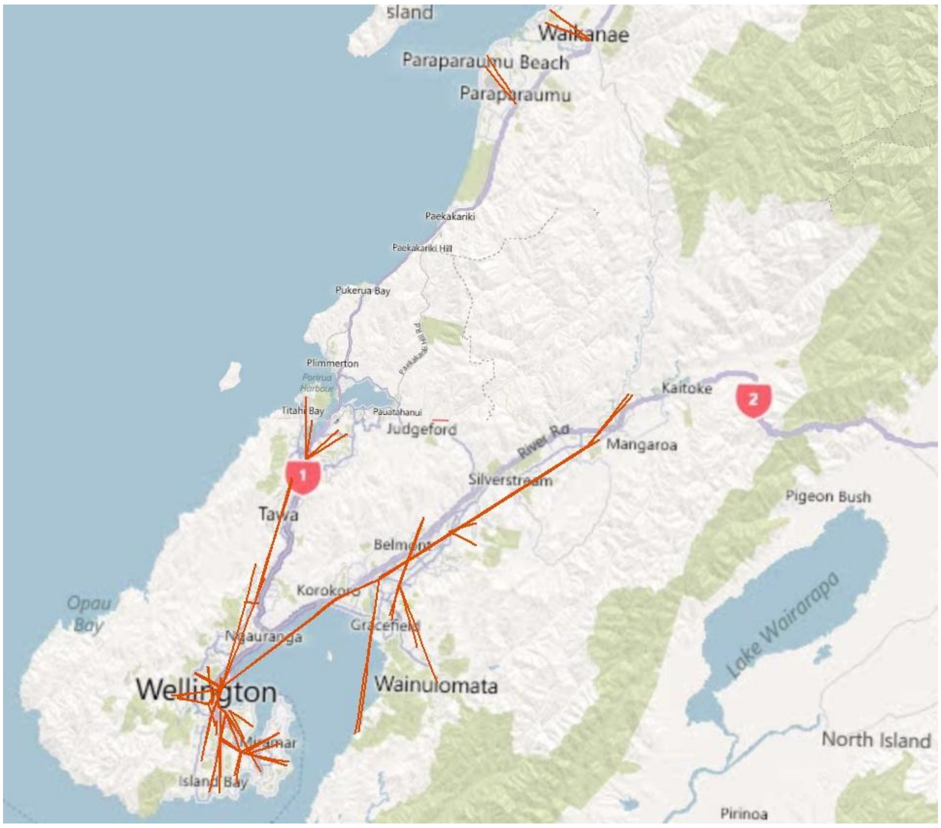


Figure 5-1: Travel Time Segments Overview

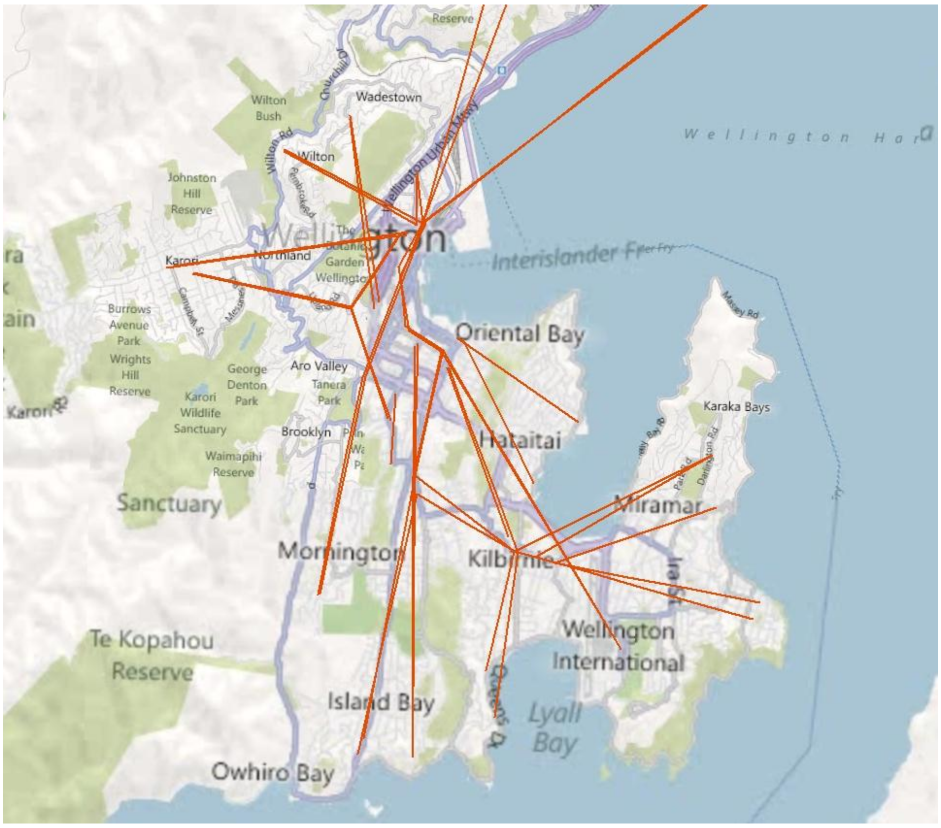


Figure 5-2: Travel Time Segments, Wellington CBD

Table 5-1: List of Segments

Start Stop	End Stop	Location	Routes
5000	5515	Golden Mile (Courtenay Pl - Cuba St)	MANY
5515	5010	Golden Mile (Cuba St - Panama St)	MANY
5010	5016	Golden Mile (Panama St - Wellington Stn)	MANY
7135	7018	Island Bay - Hospital	1
7017	5000	Hospital - Courtenay Pl	1,3,22,23,43,44
7241	7027	Miramar - Kilbirnie	2,18
7223	7212	Kilbirnie - Courtenay Pl via Hataitai Tunnel	2,6,24,25,91
7338	7026	Lyall Bay - Kilbirnie	3,6
7026	7018	Kilbirnie - Hospital	3,11,18,43,44
5015	5326	Lambton Quay - Karori Mall	3
7730	7712	Kingston - Webb St	7
7712	5016	Webb St - Wellington Stn	7,8
7017	7910	Hospital - Taranaki St	10,11
7041	7028	Seatoun - Kilbirnie	11
5111	5114	Wellington Stn - Molesworth St	14
5111	5133	Wellington Stn - Wilton	14
5911	5915	The Terrace - Vic Uni	5,6,7,17,20,22,23,24,25,43
5915	5308	Vic Uni Kelburn - Vic Uni Karori	18
7914	5915	Massey Uni - Vic Uni Kelburn	18,47
6913	6747	Massey Uni - Newtown	21
4934	4914	Mairangi Rd - The Terrace	22,23
6017	7955	Hospital - Houghton Bay	22
7270	7028	Miramar - Kilbirnie	24
3056	3252	Johnsonville West - Johnsonville	53
3220	5500	Churton Park - Wellington Stn	54
8857	8115	Eastbourne - Lower Hutt	83
8115	8002	Lower Hutt - Petone	83,91
8002	5500	Petone - Thorndon Quay	83
8584	8115	Upper Hutt - Lower Hutt	110
5516	7399	Courtenay Pl - Airport	91
8604	8580	Emerald Hill - Upper Hutt	110
8375	8252	Stokes Valley - Taita	120
8178	8165	Gracefield - Waterloo	121
8219	8165	Kelson - Waterloo	150
8910	8140	Wainuiomata - Waterloo	170
3948	3250	Kenepuru Hospital - Johnsonville	97,210,211
2821	2003	Titahi Bay - Porirua	220
2003	2136	Porirua - Ascot Park	220
1152	1192	Paraparaumu Beach - Paraparaumu	262
1616	1596	Waikanae Beach - Waikanae Stn	280,289
7551	7512	Evans Bay - Courtenay Pl	24

Start Stop	End Stop	Location	Routes
5513	5516	Golden Mile (Cuba St - Courtenay Pl)	MANY
5508	5513	Golden Mile (Panama St - Cuba St)	MANY
6000	5508	Golden Mile (Wellington Stn - Panama St)	MANY
6017	6134	Hospital - Island Bay	1
5516	6017	Courtenay Pl - Hospital	1,3,14,22,23,43,44
6224	7241	Kilbirnie - Miramar	2
6212	6224	Courtenay Pl - Kilbirnie via Hataitai Tunnel	2,20,91
6026	6336	Kilbirnie - Lyall Bay	3
6017	6026	Hospital - Kilbirnie	3,11,14,18,43,44
4327	5502	Karori Mall - Lambton Quay	3
6712	6730	Webb St - Kingston	7
6001	6712	Wellington Stn - Webb St	7,8
6910	6017	Taranaki St - Hospital	10,11
6026	6042	Kilbirnie - Seatoun	11
4114	5500	Molesworth St - Wellington Stn	14
4133	5500	Wilton - Wellington Stn	14
4915	4911	Vic Uni Kelburn - The Terrace	17,20,22,23
4308	4915	Vic Uni Karori - Vic Uni Kelburn	18
4915	6914	Vic Uni Kelburn - Massey Uni	18,47
5914	5934	The Terrace - Mairangi Rd	22,23
7955	7017	Houghton Bay - Hospital	22
5016	3208	Wellington Stn - Johnsonville	54,211
8115	9856	Lower Hutt - Eastbourne	83
9002	9113	Petone - Lower Hutt	83,91,110,130,154
5016	9002	Thorndon Quay - Petone	83
9115	9580	Lower Hutt - Upper Hutt	91,110
7399	5000	Airport - Courtenay PL	91
9580	9602	Upper Hutt - Emerald Hill	110
9251	9377	Taita - Stokes Valley	120
9165	9779	Waterloo - Seaview	121
9165	9219	Waterloo - Kelson	150
9140	9959	Waterloo - Wainuiomata	160
3000	3926	Johnsonville - Porirua	210
2001	2846	Porirua - Titahi Bay	220
2130	2001	Ascot Park - Porirua	220
1000	1148	Paraparaumu - Paraparaumu Beach	262
1501	1560	Waikanae Stn - Waikanae Beach	280
6512	6546	Courtenay Pl - Evans Bay	24

Each segment is traversed by one or multiple bus routes. A further selection criterion was to cover a variety of conditions, for example segments that run through the CBD, suburbs and freeways. The reverse direction for each segment was also investigated where possible.

5.4.2 Average Bus Run Time

Our first step was to gain an understanding of how accurately the bus timetables reflect what actually happens, as recorded in the ETM data. Figure 5-3 and Figure 5-4 compare the timetabled times with the average ETM times for all segments.

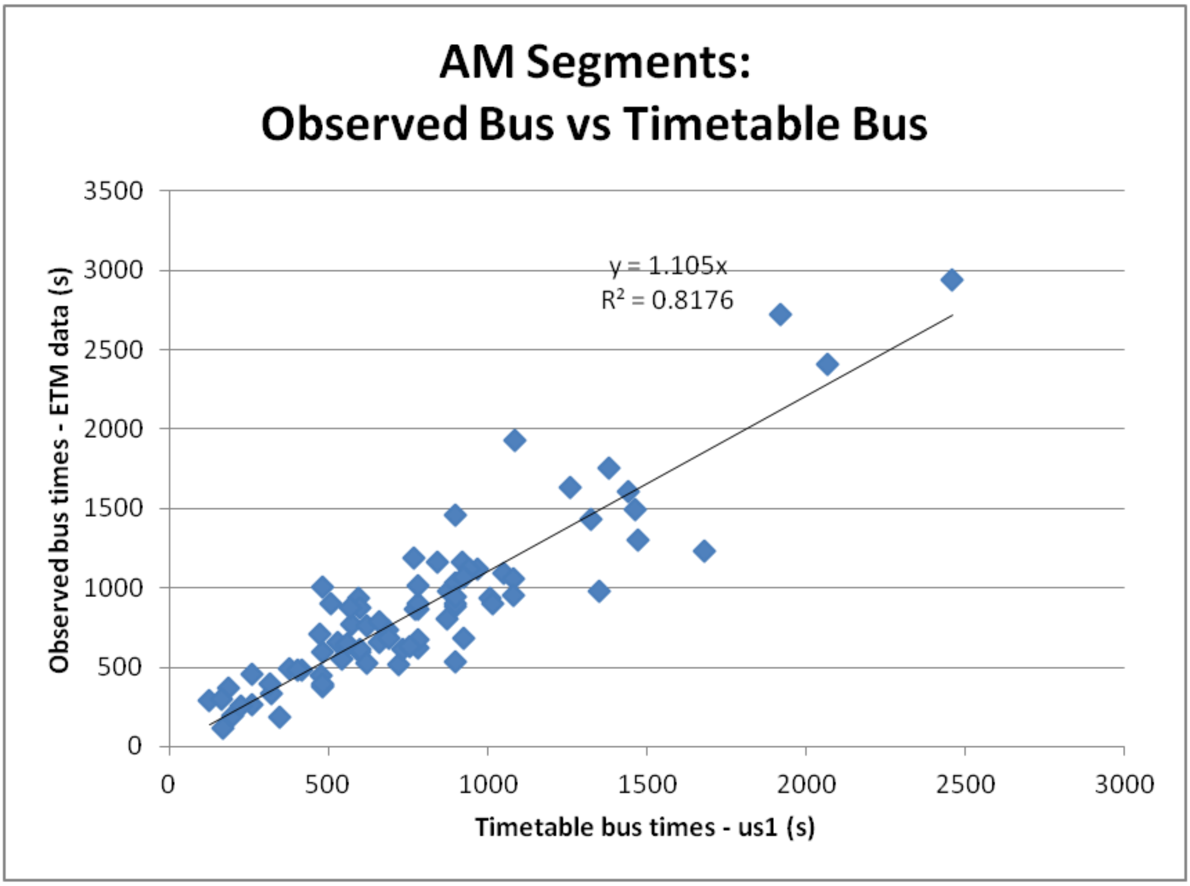


Figure 5-3: AM Segments, Observed Bus vs. Timetable Bus

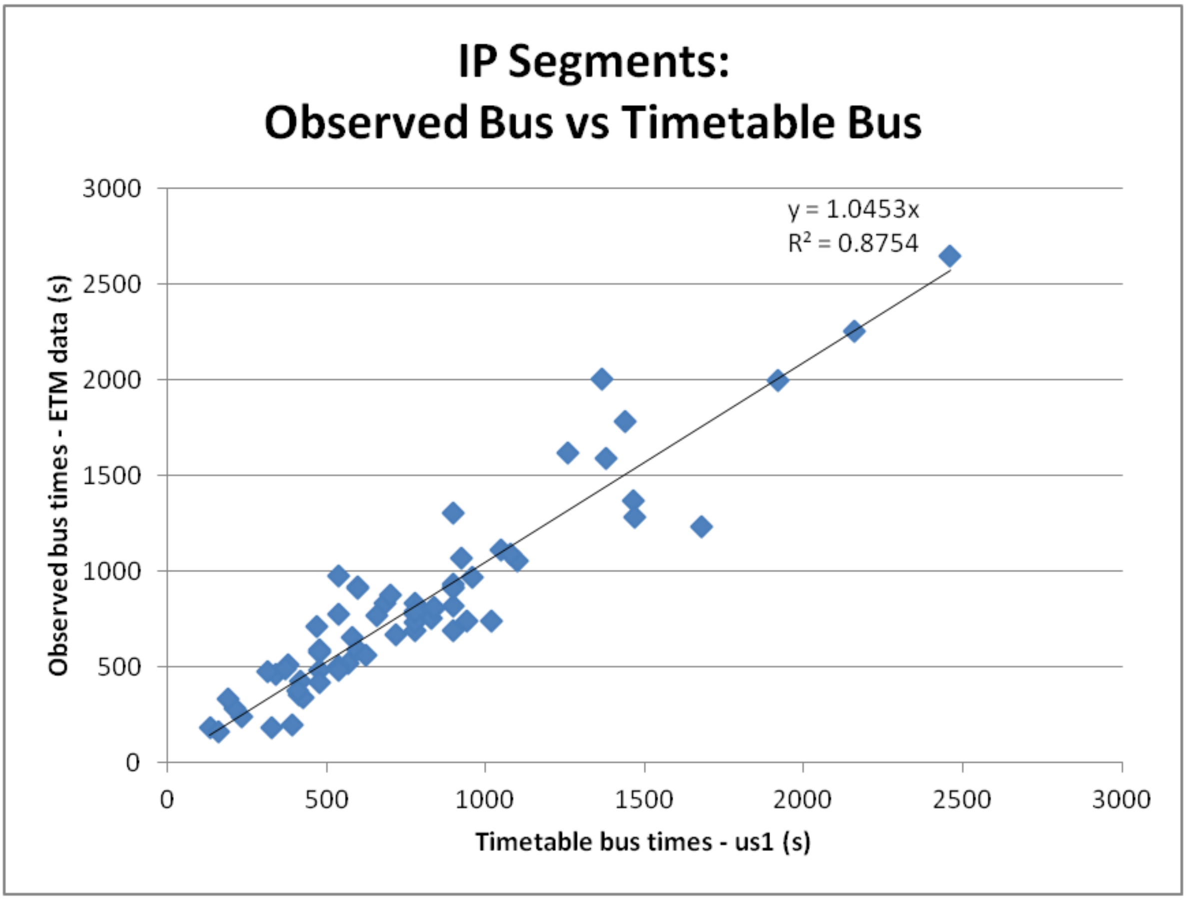


Figure 5-4: IP Segments, Observed Bus vs. Timetable Bus

The above figures show that the times recorded by the ETM system are, on average, 11% longer than the timetabled times in the AM period, and around 5% longer in the IP period. This is unsurprising, as timetables normally represent the minimum run times, not average times. For modelling purposes, we need to represent average conditions, and therefore the ETM times will be our main guide, rather than the timetables.

Several patterns were observed in the data. During the AM peak, times on inbound segments (towards CBD) were 22% longer than timetabled and outbound were 4% shorter. This is because the inbound direction is the more congested and has more passengers in the morning. Differences were also observed in relation to location. Buses took around 30% longer than timetabled in the Golden Mile and the CBD, 9% longer in areas surrounding the CBD and around 5% longer in suburban areas. Again, all as would be expected.

5.4.3 Comparison against modelled car times

To assess the viability of linking bus times in WPTM to highway times from WTSM, the bus observed times were compared to modelled car times from WTSM (see Figure 5-5 and Figure 5-6).

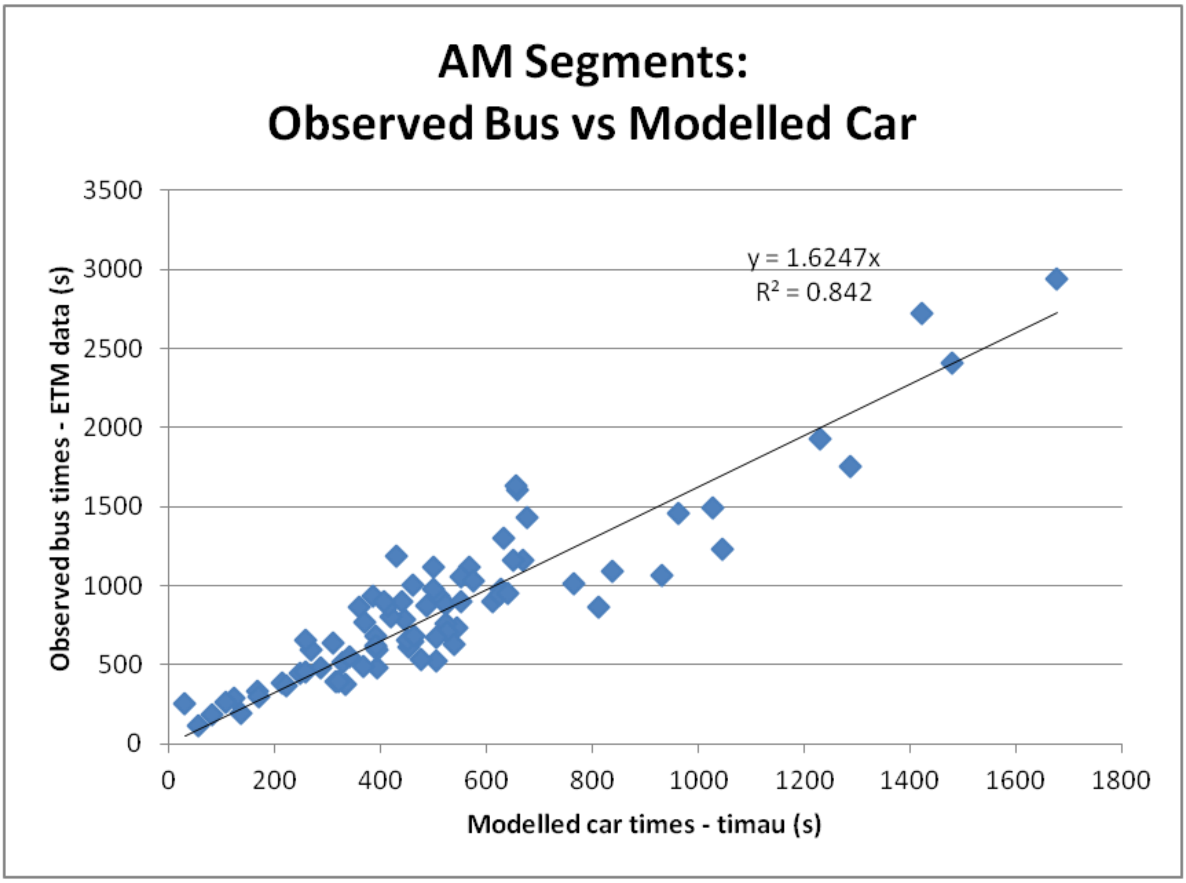


Figure 5-5: AM Segments, Observed Bus vs. Modelled Car

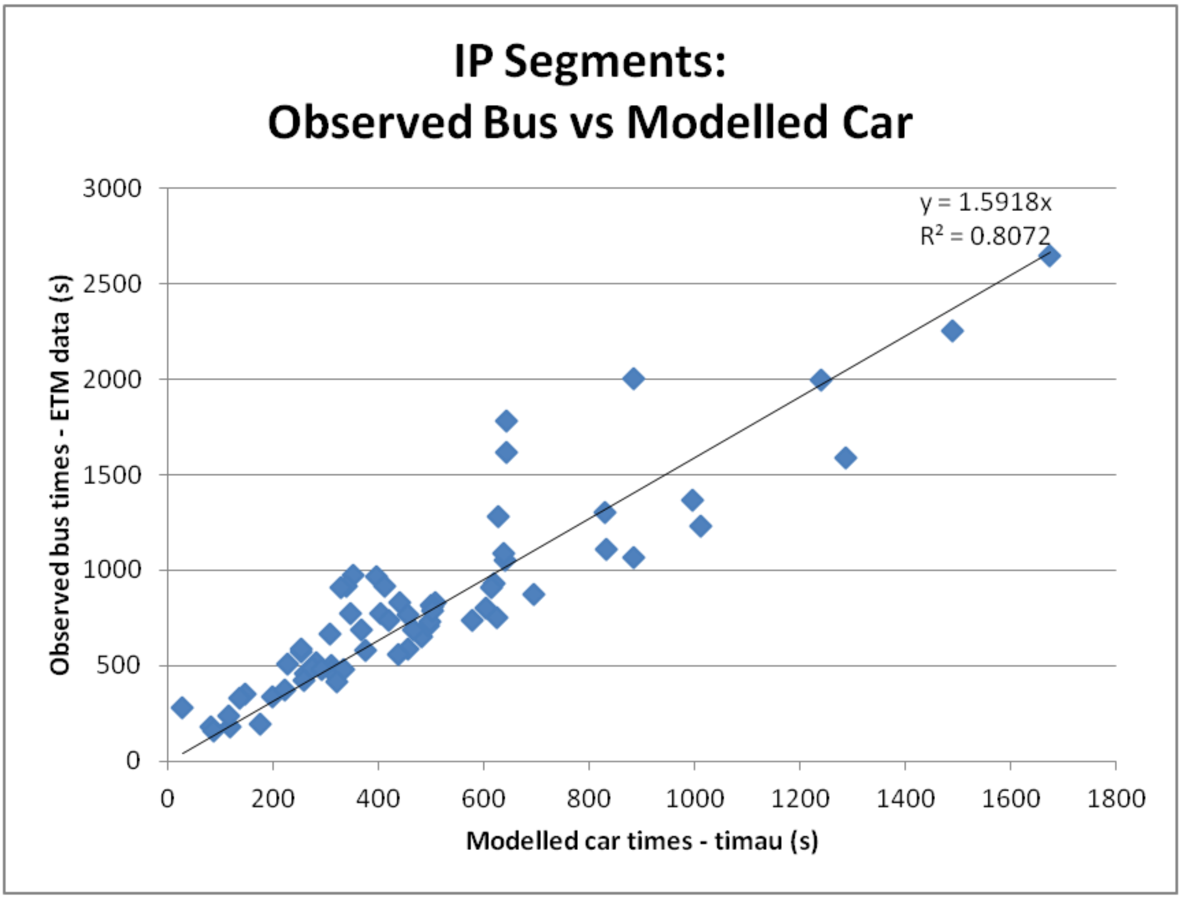


Figure 5-6: IP Segments, Observed Bus vs. Modelled Car

These figures show that buses take around 60% more time than the modelled WTSM car time on the selected segments in both AM and IP periods. The graphs have a linear trend, suggesting it is valid to relate bus run times to the modelled car times. It should be noted that the modelled car times take no account of stop dwell times that a bus would experience. These will need to be added when developing the function.

5.5 Transit Times Calibration

5.5.1 Introduction

A function was created to relate the WTSM times to the observed bus times. The most important variable in this function was timau, car travel time. Timau is the equilibrium car travel time from WTSM on each link, including any turn delay at the downstream end of link, in minutes. Initially a global uplift factor on timau was developed. However, this tended to overestimate the bus times on congested links where buses and cars are both queuing. To overcome this, the function was adapted so that for heavily congested roads (volume-capacity ratio > 0.9) bus time would be equal to car time. This is appropriate as all vehicles would travel at the same speed in such conditions, ignoring the effect of bus stops, which is accounted for separately.

The number of bus stops was also included as an explanatory variable, split into CBD and non-CBD to allow for the different boarding and alighting volumes and hence stopping time.

There are some bus-only links where cars do not travel and therefore no timau value is available from WTSM. To deal with this free-flow speed (v0) along these links was used to calculate a free-flow time to input into the function, which could be reduced by a factor if necessary.

For highway links with bus lanes, a free-flow speed was calculated and reduced by a factor, with the condition added that speed on a bus lane link is no slower than it would be running in the adjacent general purpose lane.

The full function is shown below. Calibration and validation of the coefficient A-I is described in the following sections.

Bus time (minutes) = A * (timau on normal roads)

+ 1 * (timau on congested roads)
+ B * (length/v0 on CBD bus only lanes)
+ C * (length/v0 on non-CBD bus only lanes)
+ D * (length/v0 on CBD bus lanes approaching junction)
+ E * (length/v0 on non-CBD bus lanes approaching junction)
+ F * (length/v0 on CBD bus lanes no junction)
+ G * (length/v0 on non-CBD bus lanes no junction)
+ H * (CBD stops)
+ I * (non-CBD stops)

5.5.2 Estimation

There are not many bus lanes or bus-only roads in the Wellington network, and they are concentrated in the CBD. Therefore, these links were calibrated first, by directly comparing the observed times with modelled, and trialling reasonable values. It was necessary to apply a different factor depending on whether the links were in the CBD or not, as these areas had very different characteristics. The CBD was defined as Metlink fare-zones 0 and 1. The final coefficients are shown in Table 5-2 below. The term '(length/v0)' refers to time calculated from the free-flow speed coded in WTSM. More details of the Golden Mile travel time can be seen in Section 5.6.2 of this note.

Table 5-2: Bus travel time function coefficients

	Condition	AM	IP	Calculation
B	bus only lanes, in CBD	3	3	* (length/v0)
C	bus only lanes, out of CBD	1.25	1.25	* (length/v0)
D	bus lanes, approaching junction, CBD	3.5	3.25	* (length/v0) OR normal roads calc
E	bus lanes, approaching junction, non-CBD	2	1.5	* (length/v0) OR normal roads calc
F	bus lanes, no junction, in CBD	3	3	* (length/v0) OR normal roads calc
G	bus lanes, no junction, non-CBD	2	1.5	* (length/v0) OR normal roads calc

The next step was to determine the coefficients for timau, CBD bus stops, and non-CBD bus stops. These were obtained firstly by manual minimisation of the sum of squares, then by a formal multiple regression analysis. Initially, this was carried out on several different samples - AM / IP, Segments / Routes / Golden Mile and intercept=0 / intercept>0. The Golden Mile sample contained only segments from the Golden Mile, and was judged to be too small to give an accurate representation. The routes sampled consisted of ETM times for entire routes from start to finish, or the longest movement with sufficient records. The segments and routes samples gave similar results, but the segments sample was larger, so this was used for subsequent calibrations. The calibration process was carried out several times, as updated car times were received from WTSM.

For the Inter peak period, the regression analysis gave a timau coefficient of below one, meaning buses would travel faster than cars, which is not reasonable. So this was set at one, and the stop times were calibrated.

The final coefficients for AM and IP are shown in Table 5-3 and Table 5-5, along with standard error values, t-statistics and P-values. The dependent variable is bus travel time in seconds.

The regression statistics shown in Table 5-4 and Table 5-6 give an indication of the goodness-of-fit. A t-statistic value above 1.96 indicates a level of significance greater than 95%.

Table 5-3: Coefficients Obtained from Regression (AM segments)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0	#N/A	#N/A	#N/A
#CBD stops	0.4052	10.07	2.42	0.02
#non-CBD stops	0.1785	3.82	2.80	0.01
timau on non-bus lanes (s)	1.29	0.11	12.17	0.00

Table 5-4: Regression Statistics (AM segments)

Regression Statistics	
Multiple R	0.98
R Square	0.96
Adjusted R Square	0.95
Standard Error	196
Observations	85

Table 5-5: Coefficients Obtained from Regression (IP segments)

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0	#N/A	#N/A	#N/A
#CBD stops	0.5003	8.61	3.49	0.00
#non-CBD stops	0.3473	1.71	12.19	0.00

Table 5-6: Regression Statistics (IP segments)

Regression Statistics	
Multiple R	0.85
R Square	0.72
Adjusted R Square	0.70
Standard Error	213
Observations	74

The coefficients in Table 5-3 above indicate that in the AM peak, buses take on average 29% longer along links than cars, and dwell for an average of 11s (0.1785 minutes) outside the CBD and 24s (0.4052 minutes) in the CBD. The IP dwell times in the CBD are greater than in the AM peak (dwell times are generally determined by the boarders, who take more time to process than the alighters, and there are more bus boarders in the CBD in the IP than in the AM peak).

The bus run times for segments predicted by the calibrated functions are compared against the observed average times from the ETM data in Figure 5-7 and Figure 5-8.

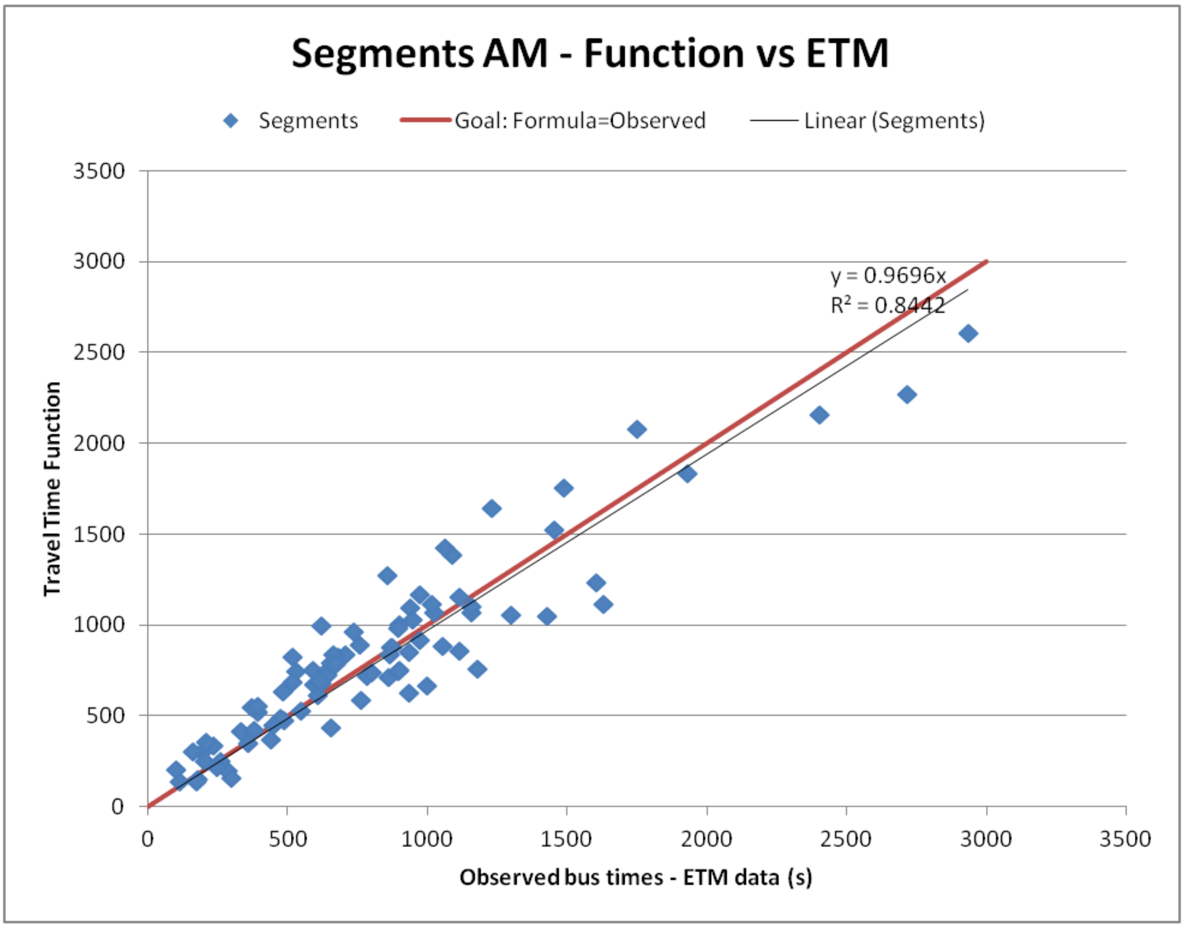


Figure 5-7: AM Segments, Function vs. Observed Bus

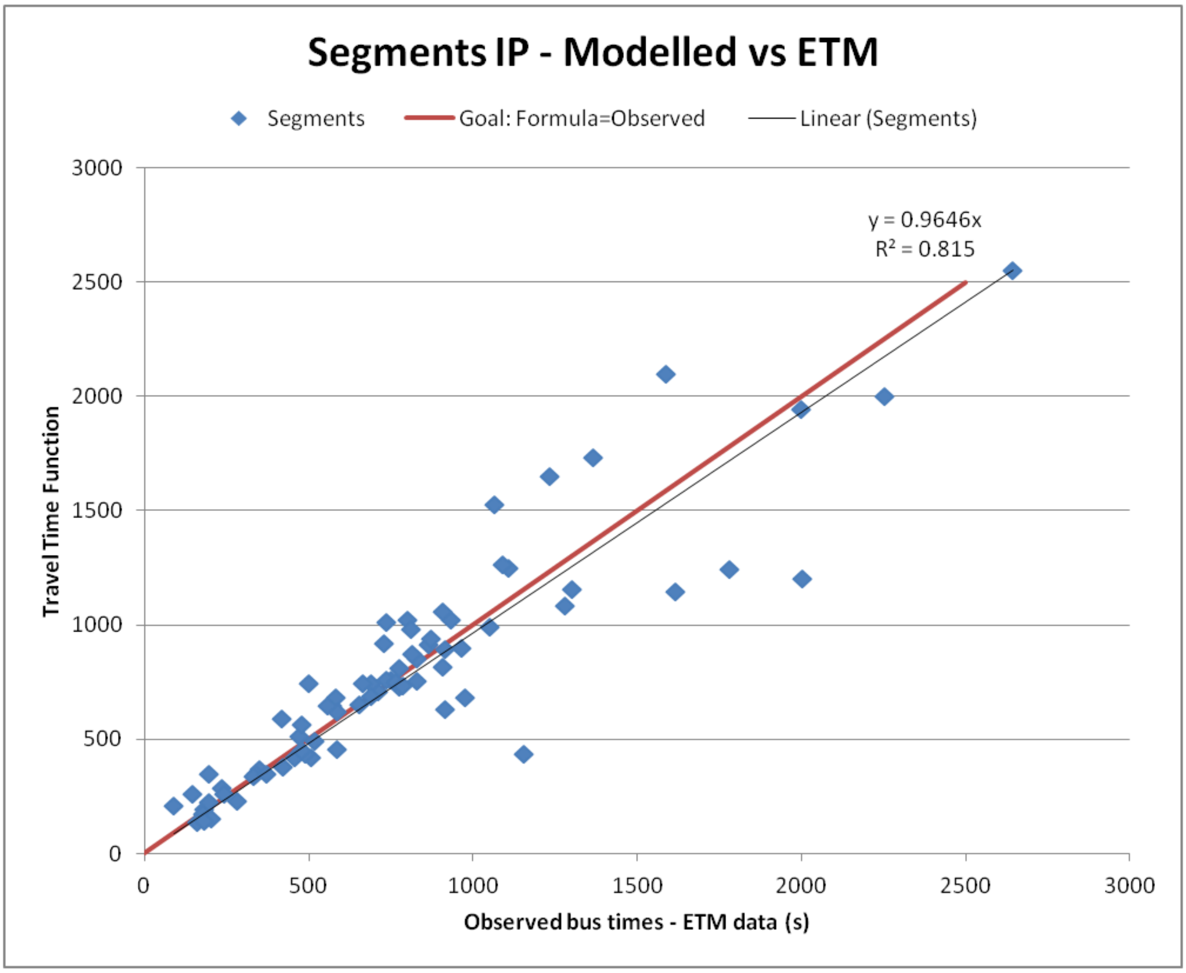


Figure 5-8: IP Segments, Function vs. Observed Bus

5.6 Validation of Bus Travel Times

5.6.1 Introduction

The functions were calibrated on segment data (i.e. discrete sections of network such as Karori to Wellington Station, using all data for all routes). The validity of the functions are judged in reference to performance on:

- Golden Mile run times;
- Route level end-to-end run times; and
- Independent data from on-bus GPS location.

5.6.2 Golden Mile and Hospital

The Hospital to Wellington Station section, including the Golden Mile, is an important part of the Wellington public transport network. It contains both bus lanes and bus-only roads. Figure 5-9 and Figure 5-10 show the average ETM travel time vs. the modelled time from WPTM for this section of road in each direction.

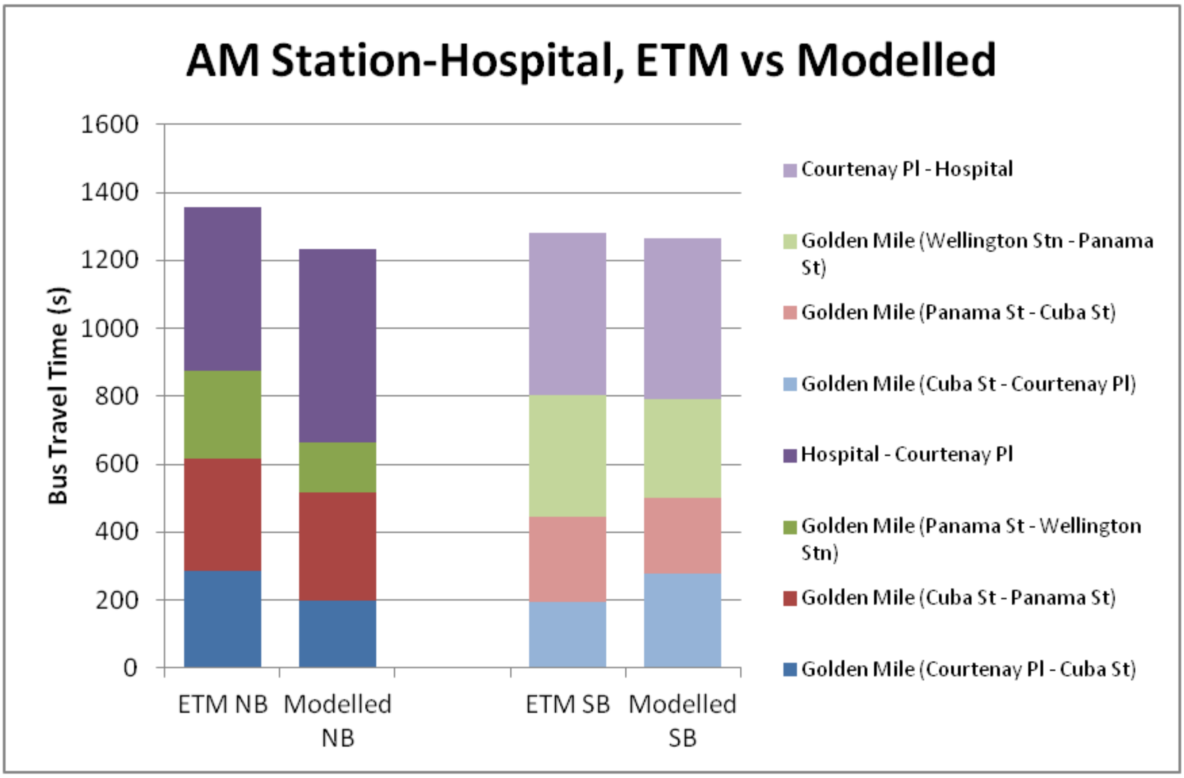


Figure 5-9: AM Hospital-Station, ETM vs. Modelled

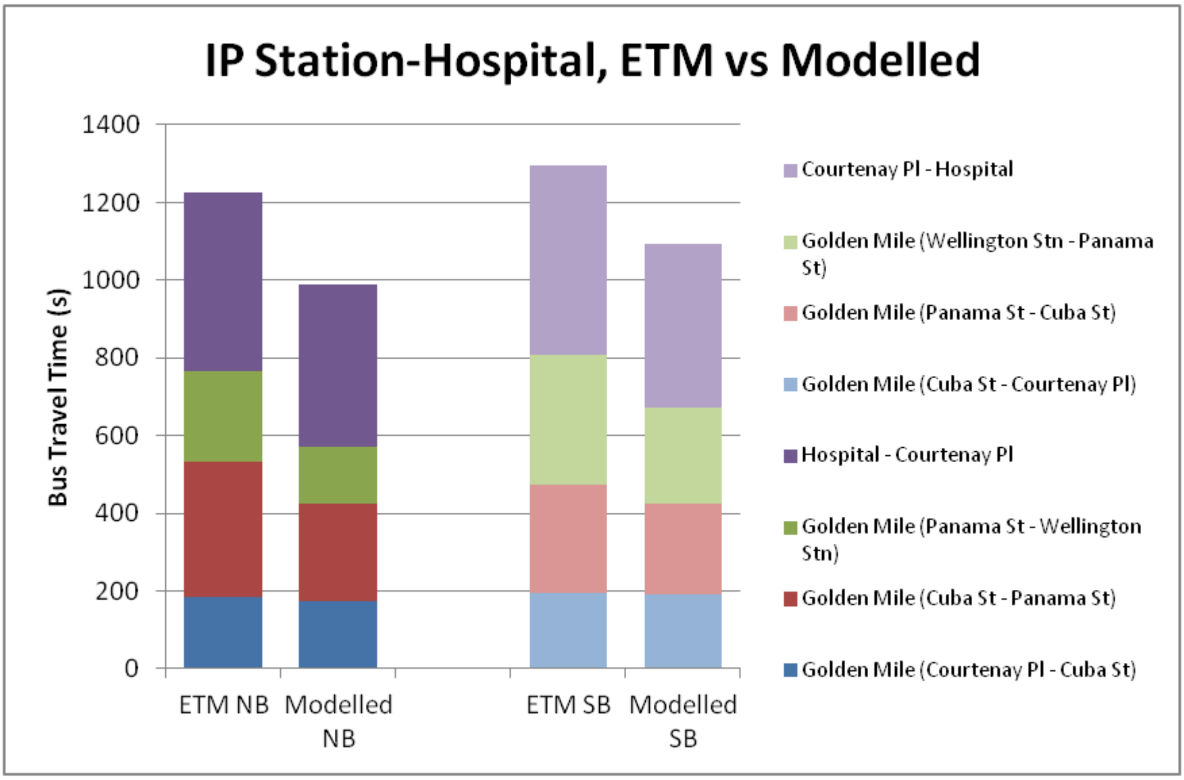


Figure 5-10: IP Station-Hospital, ETM vs. Modelled

As part of the Central Area Bus Operational Review, carried out by Opus in 2009, bus travel times along the Golden Mile were surveyed. This provides another source of observed data, although it should be noted that the route travelled was slightly longer and slower than it is today (in the region of Manners Mall).

The graphs below (Figure 5-11 and Figure 5-12) compare the observed and modelled bus travel times, for the section between Courtenay Place and Molesworth St. The dark blue bars represent mean observed travel time, and the light blue bars represent the mean plus or minus two standard deviations, a passenger's journey should be in this range 95% of the time. The red bars show the average travel time based on the ETM data, and the green bars show the modelled time from WPTM, using the transit time function.

It can be seen that the modelled time matches well in the AM southbound, but is too short in the northbound direction, and in the IP period. This could not be investigated further within the timeframe. It may be that simplified modelling does not fully reflect bus congestion. The large number of buses on the Golden Mile may mean they have difficulty pulling in and out of stops. However further investigation would be needed.

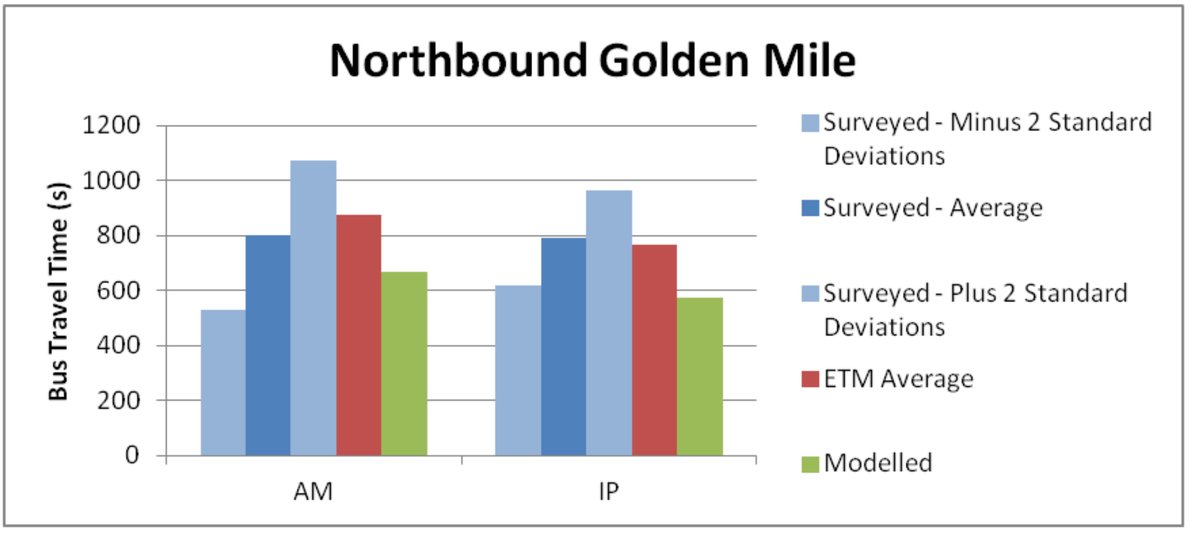


Figure 5-11: Golden Mile Survey Data Comparison, Northbound

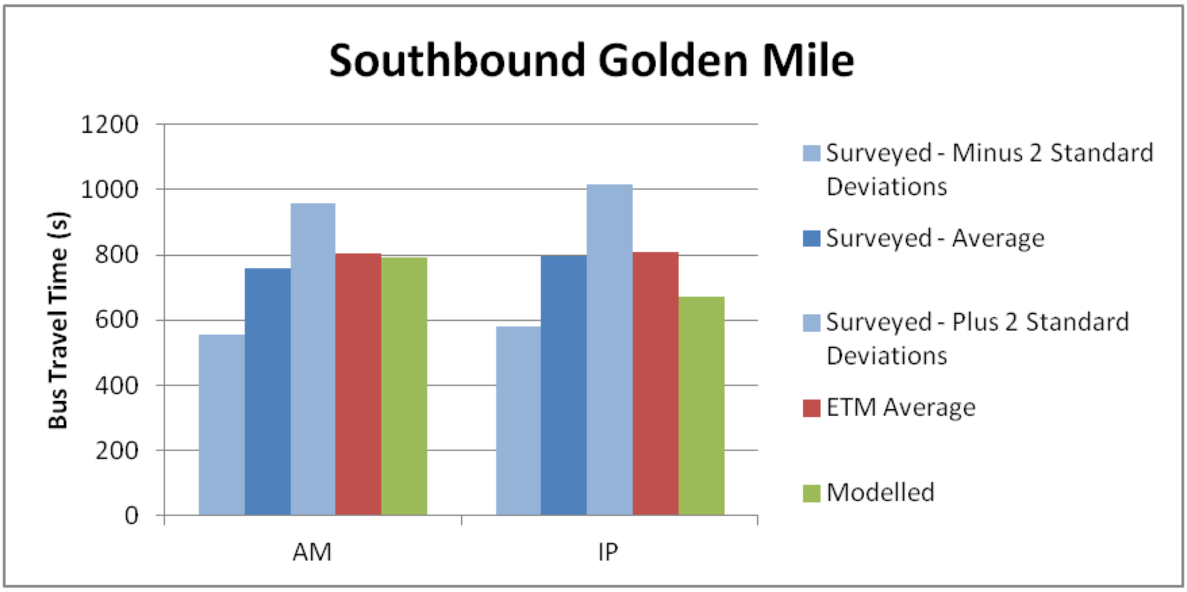


Figure 5-12: Golden Mile Survey Data Comparison, Southbound

5.6.3 Full Routes

The performance of the functions was compared against full route run times extracted from ETM data. The routes included in the on-board surveys were selected as the sample. These provide a good cross-section of environments in which buses operate across the network. Figure 5-13 and Figure 5-14 show the route times observed vs. the times returned by the calibrated function. This demonstrates that the chosen coefficients give acceptable results for full routes, as well as segments.

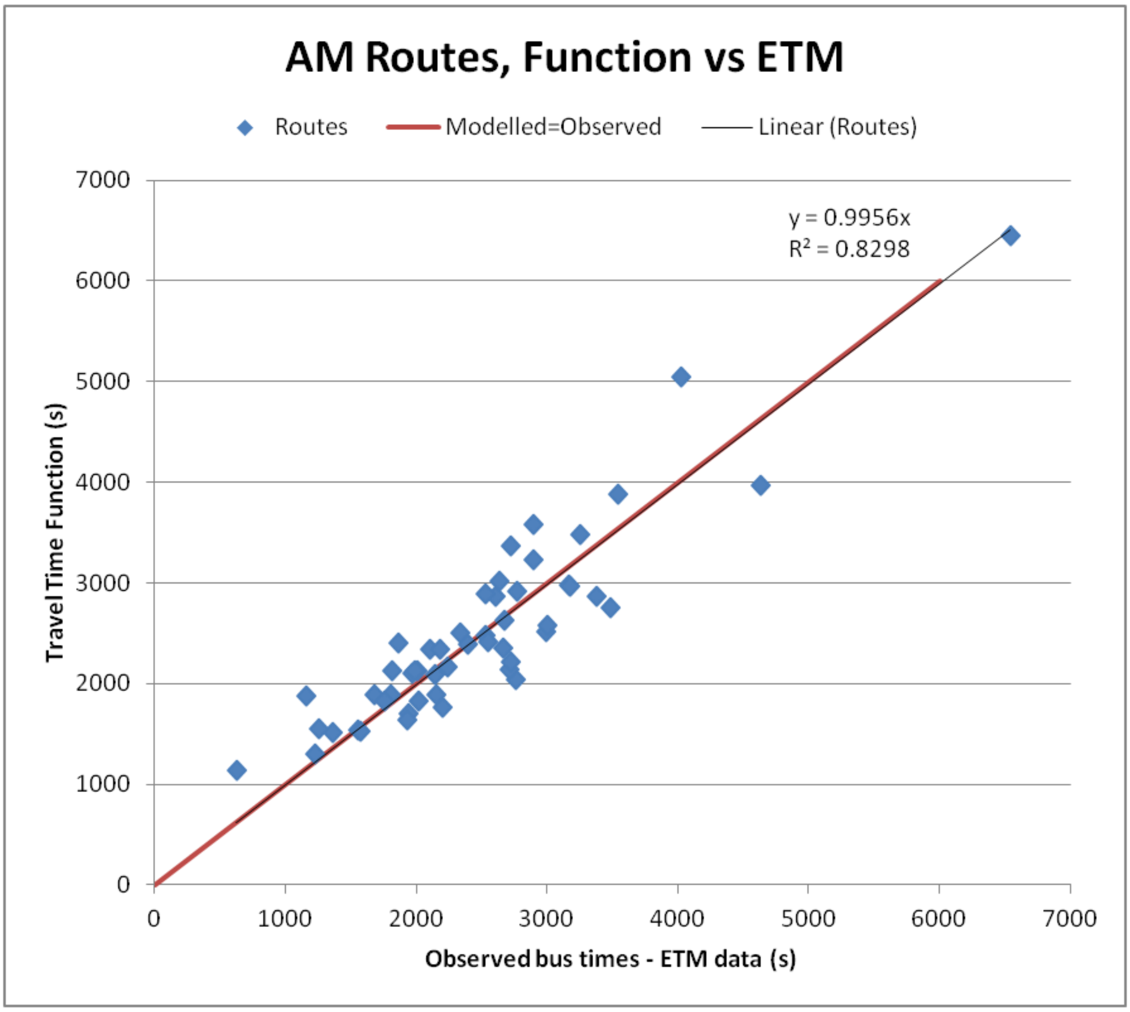


Figure 5-13: AM Routes, Function vs. Observed Bus

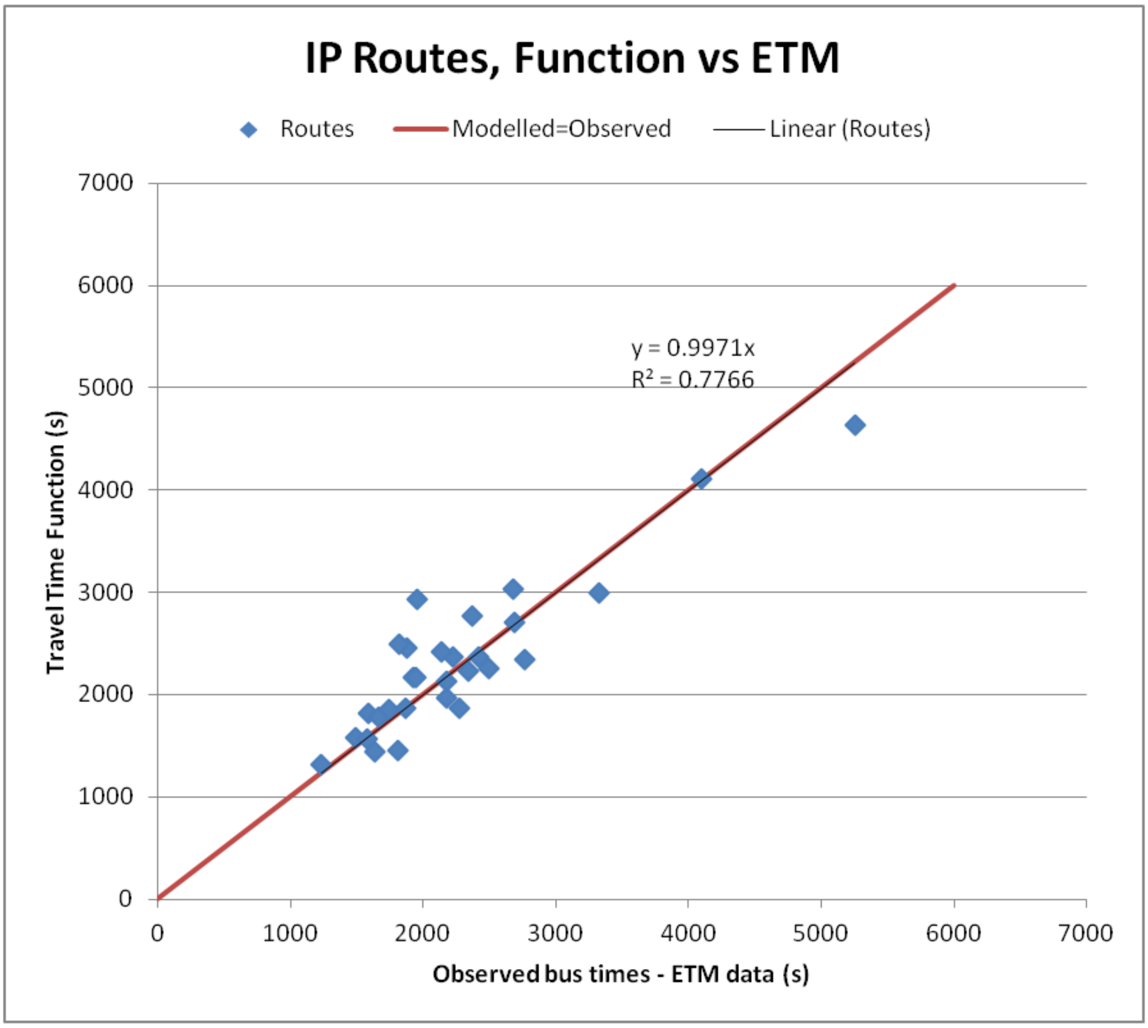


Figure 5-14: IP Routes, Function vs. Observed Bus

Where data for an entire route (terminus to terminus) was not available from the ETM data, the longest movement with sufficient ETM records was used.

5.6.4 Comparison Against RTI Data

RTI (real-time information) data was obtained from GWRC for Go Wellington Routes 1 and 2 in the AM and IP periods, and Route 3 in the AM peak only. These are the routes with highest patronage in Wellington. This data provided scheduled and actual performance at each stop along the route for all weekdays in September 2011. The plots show the timetable time, average actual time, one standard deviation either side of this average ('Min Actual' and 'Max Actual') and the modelled time from WPTM. It should be noted that these are not distance-time graphs (as in reality bus stops are not equally spaced), meaning the slope does not represent speed.

The modelled time corresponds reasonably well with the actual time. It is not always within one standard deviation of the actual time however the general pattern aligns well. In most cases, the modelled time represents the actual time as well as, or better than, the timetabled time.

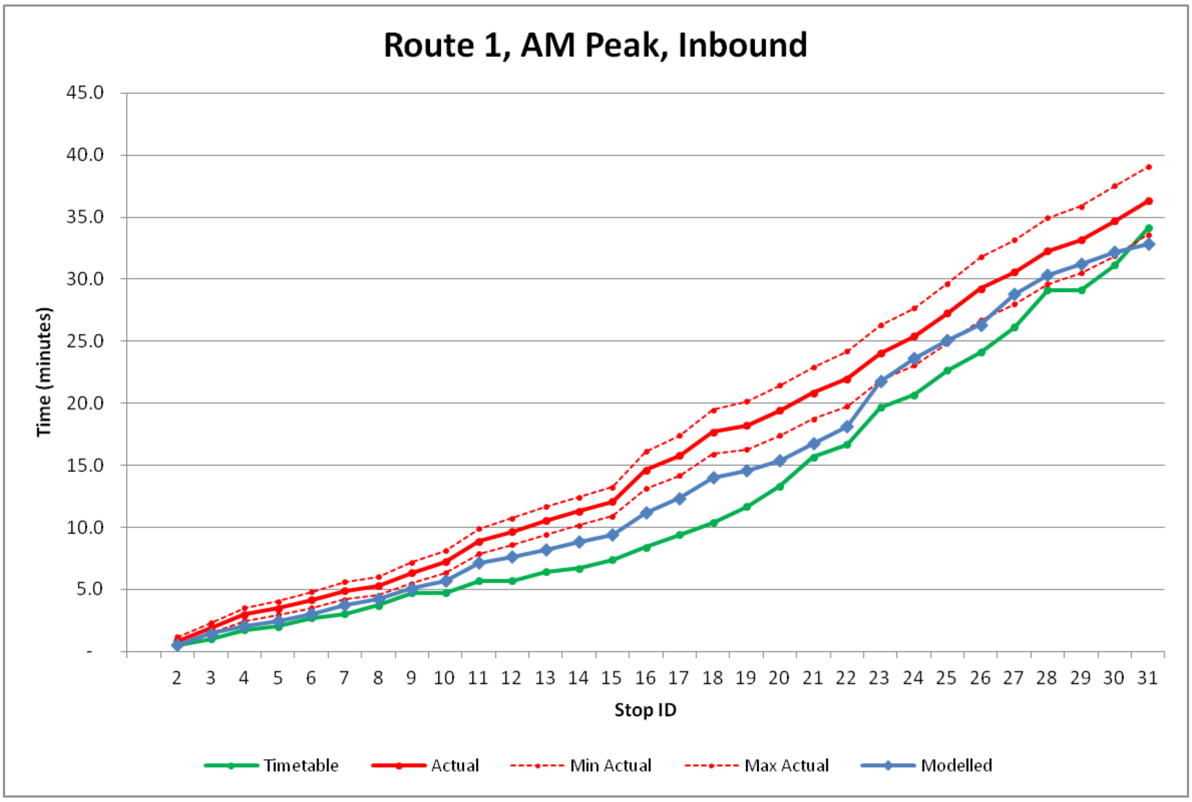


Figure 5-15: RTI Comparison, Route 1, AM Inbound

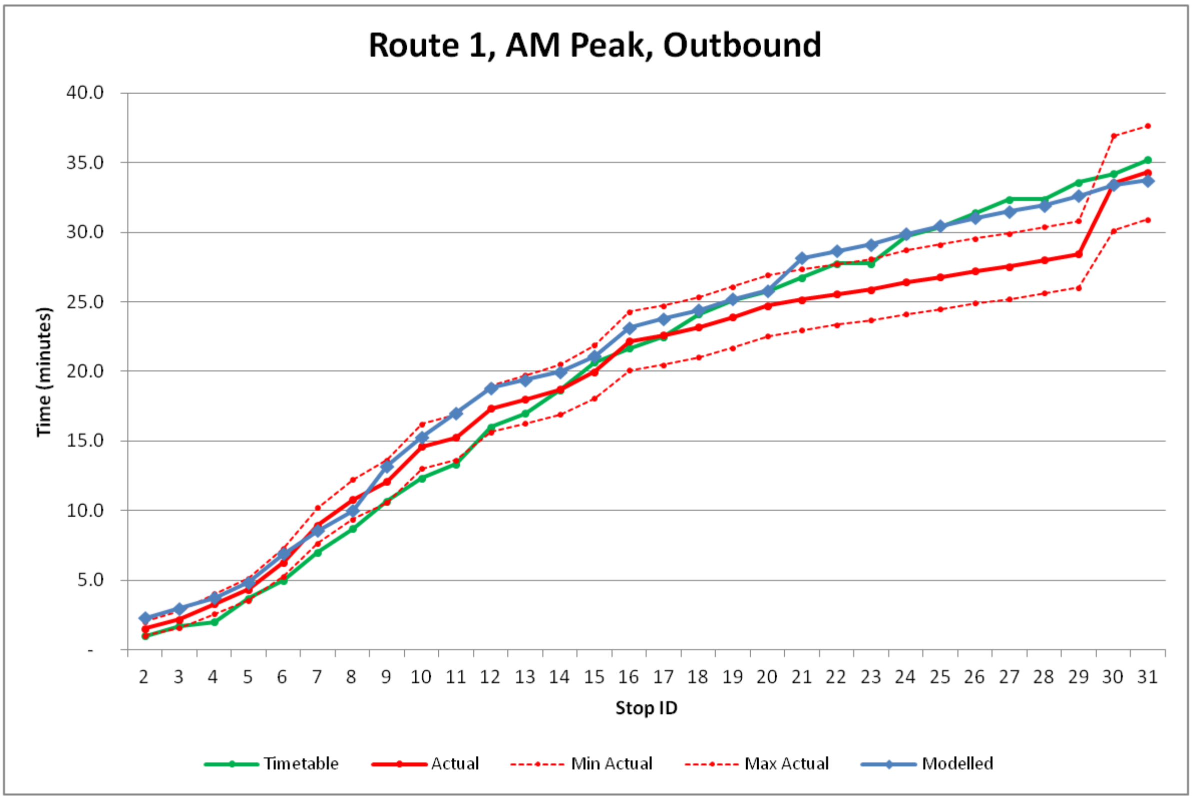


Figure 5-16: RTI Comparison, Route 1, AM Outbound

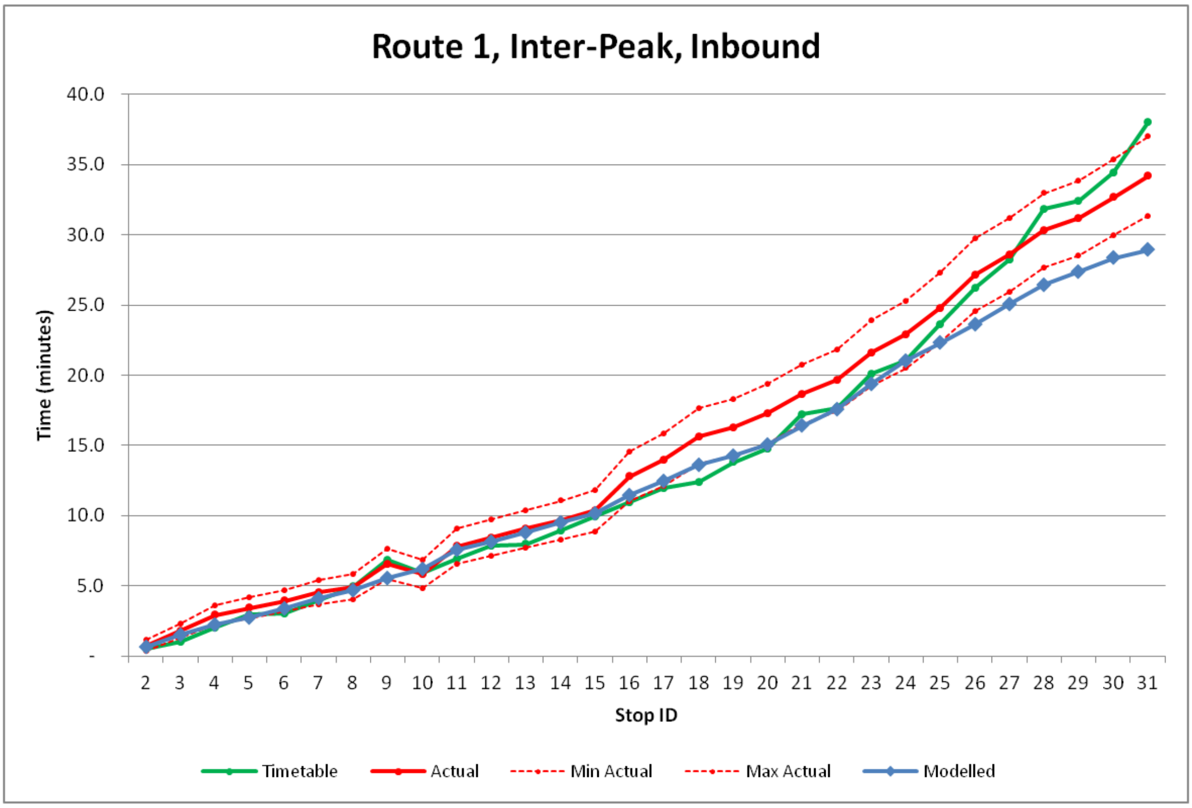


Figure 5-17: RTI Comparison, Route 1, IP Inbound

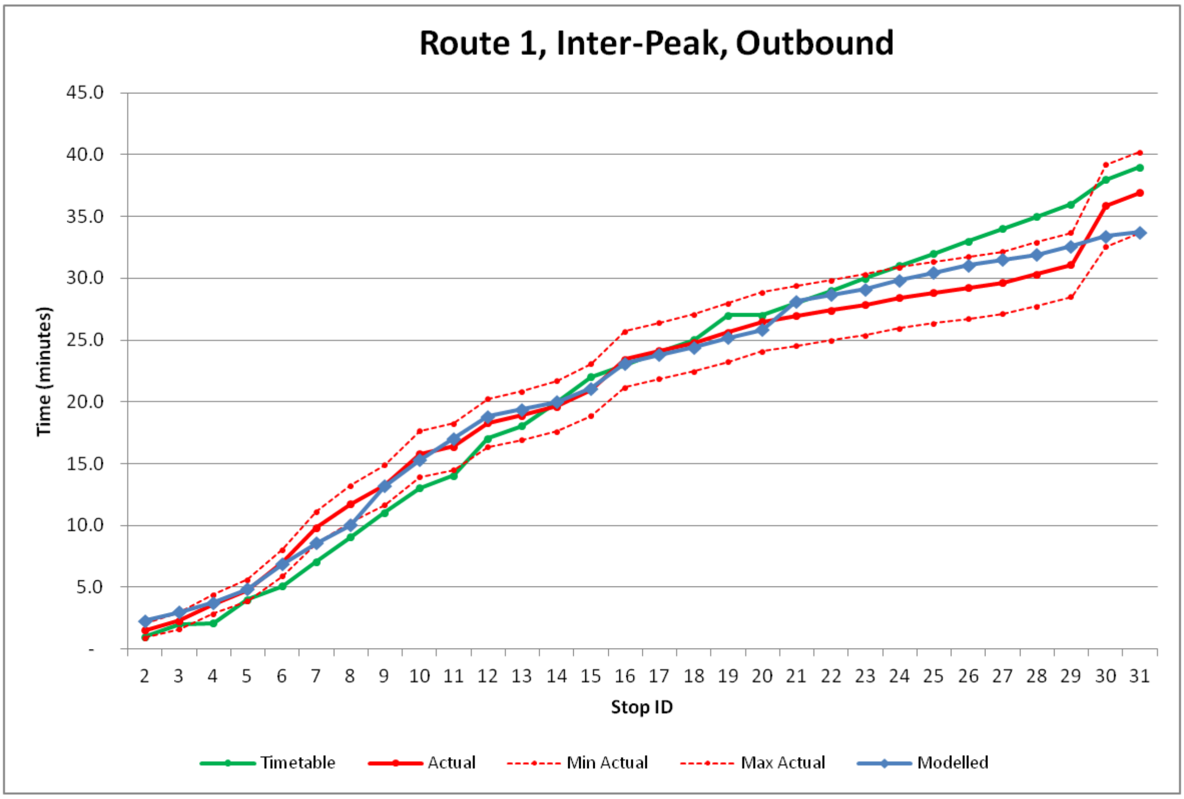


Figure 5-18: RTI Comparison, Route 1, IP Outbound

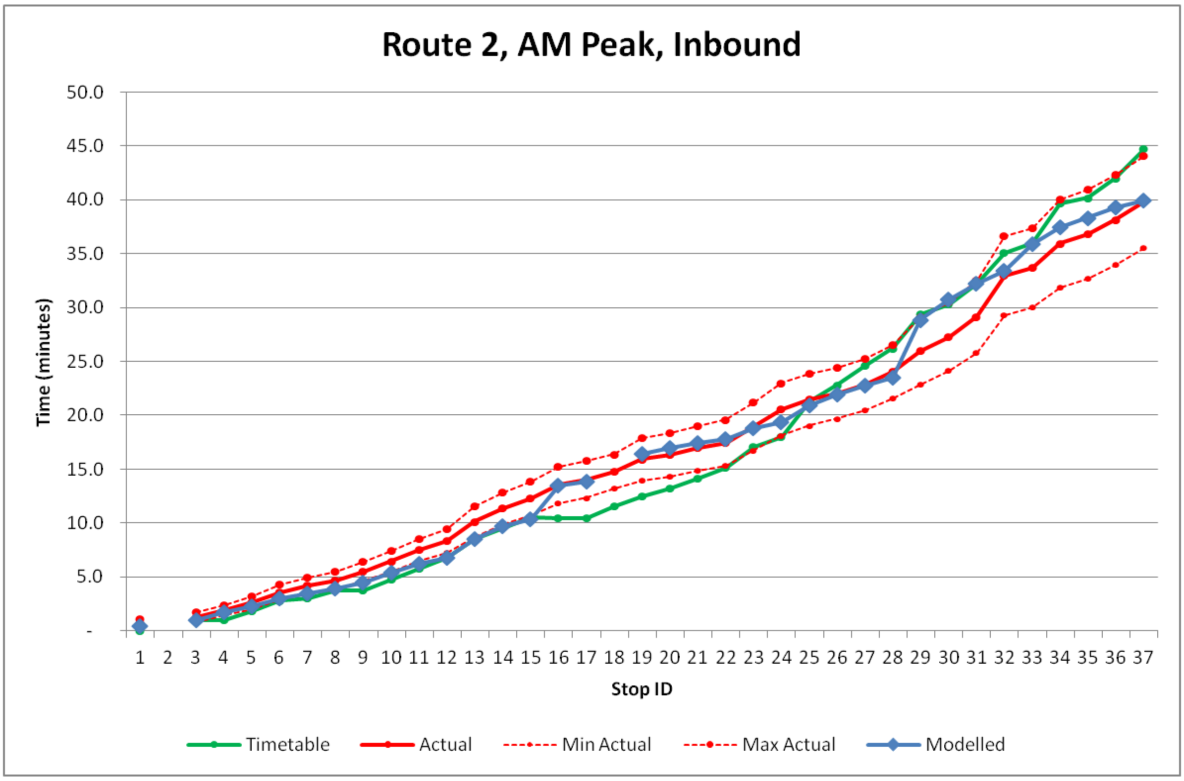


Figure 5-19: RTI Comparison, Route 2, AM Inbound

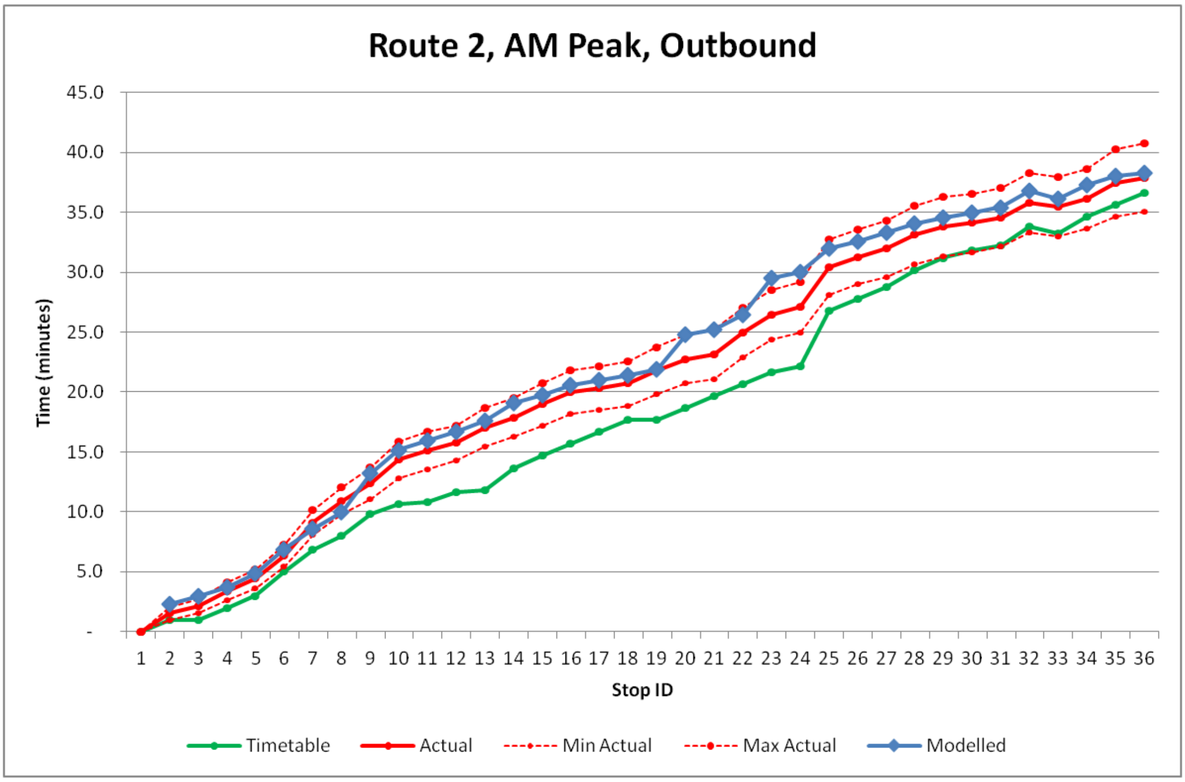


Figure 5-20: RTI Comparison, Route 2, AM Outbound

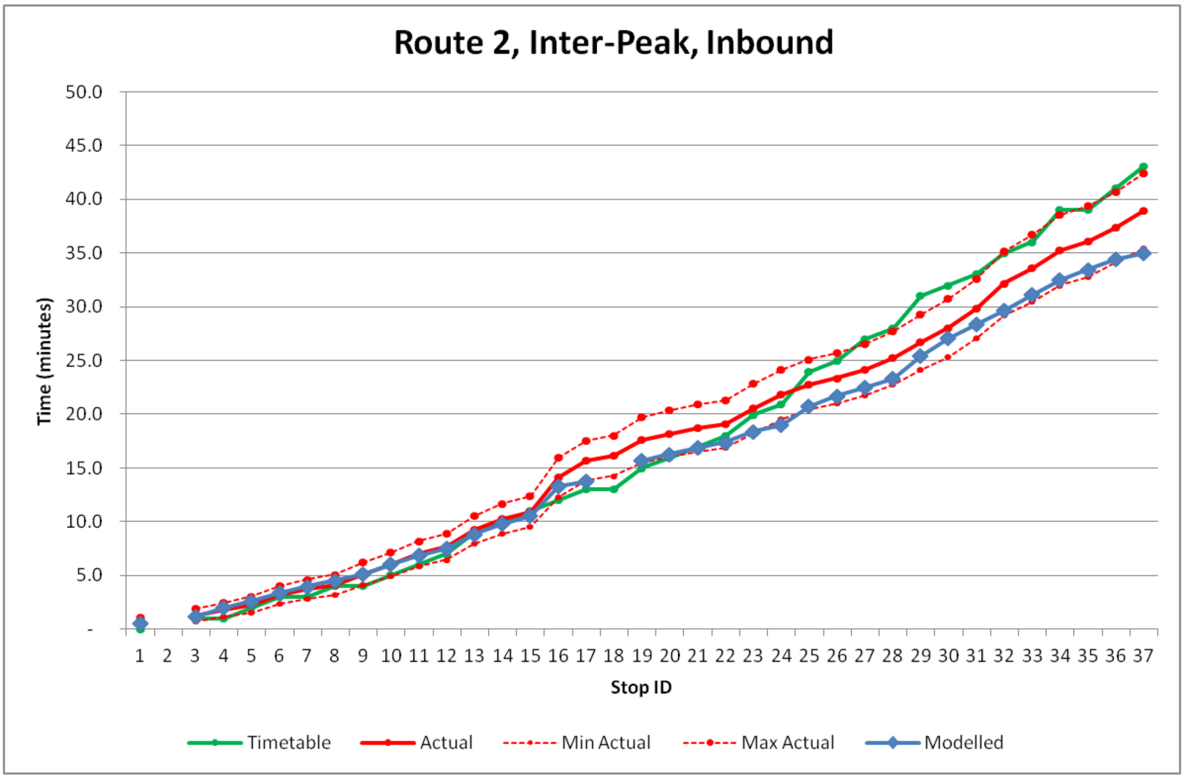


Figure 5-21: RTI Comparison, Route 2, IP Inbound

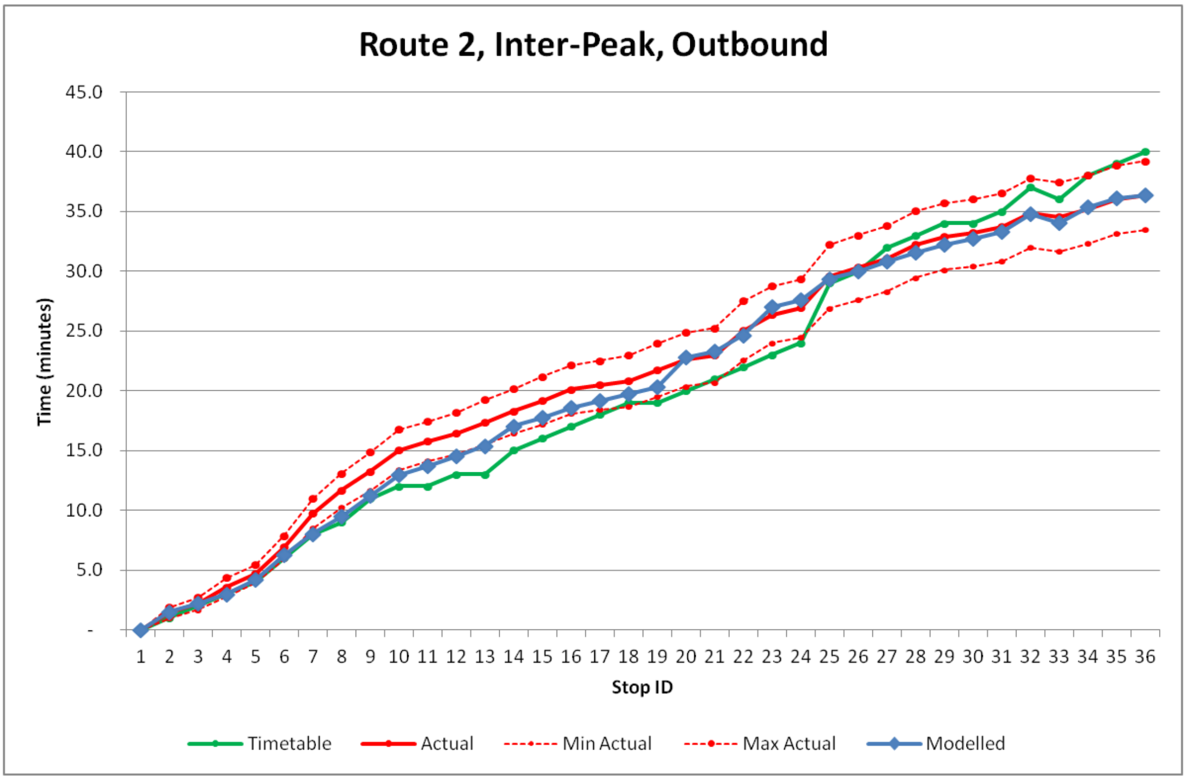


Figure 5-22: RTI Comparison, Route 2, IP Outbound

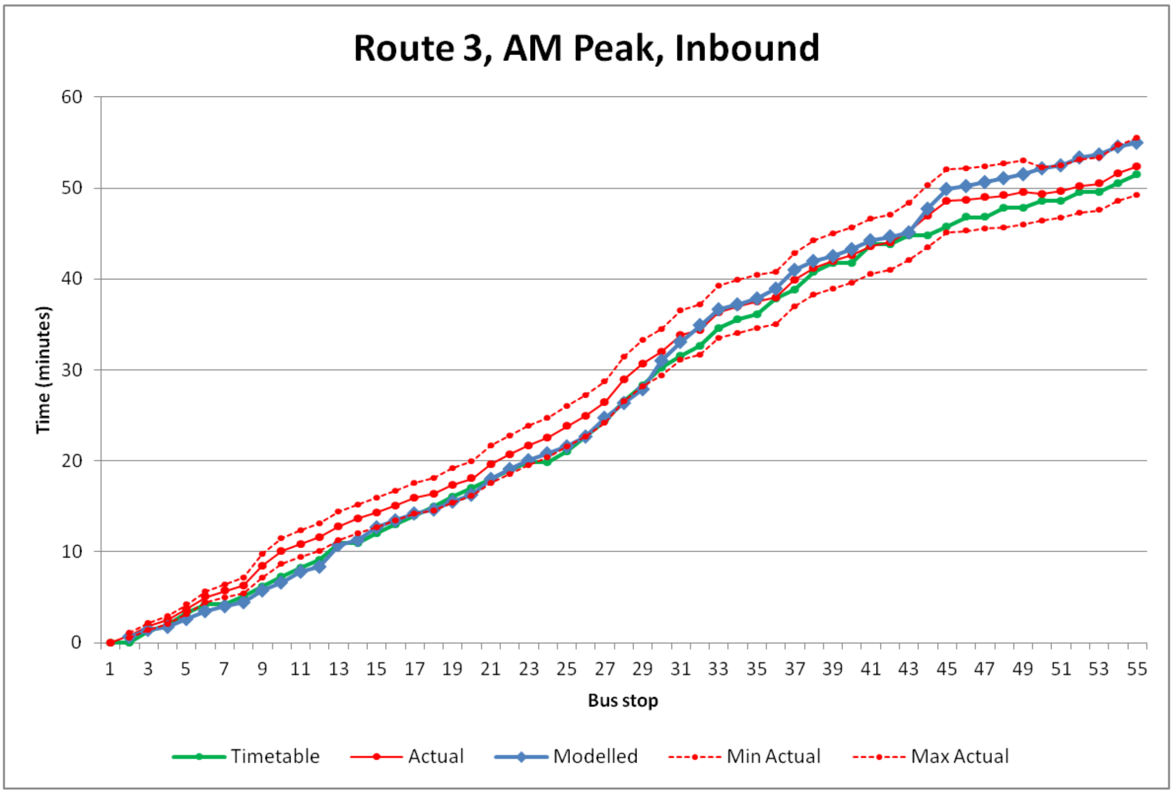


Figure 5-23: RTI Comparison, Route 3, AM Inbound

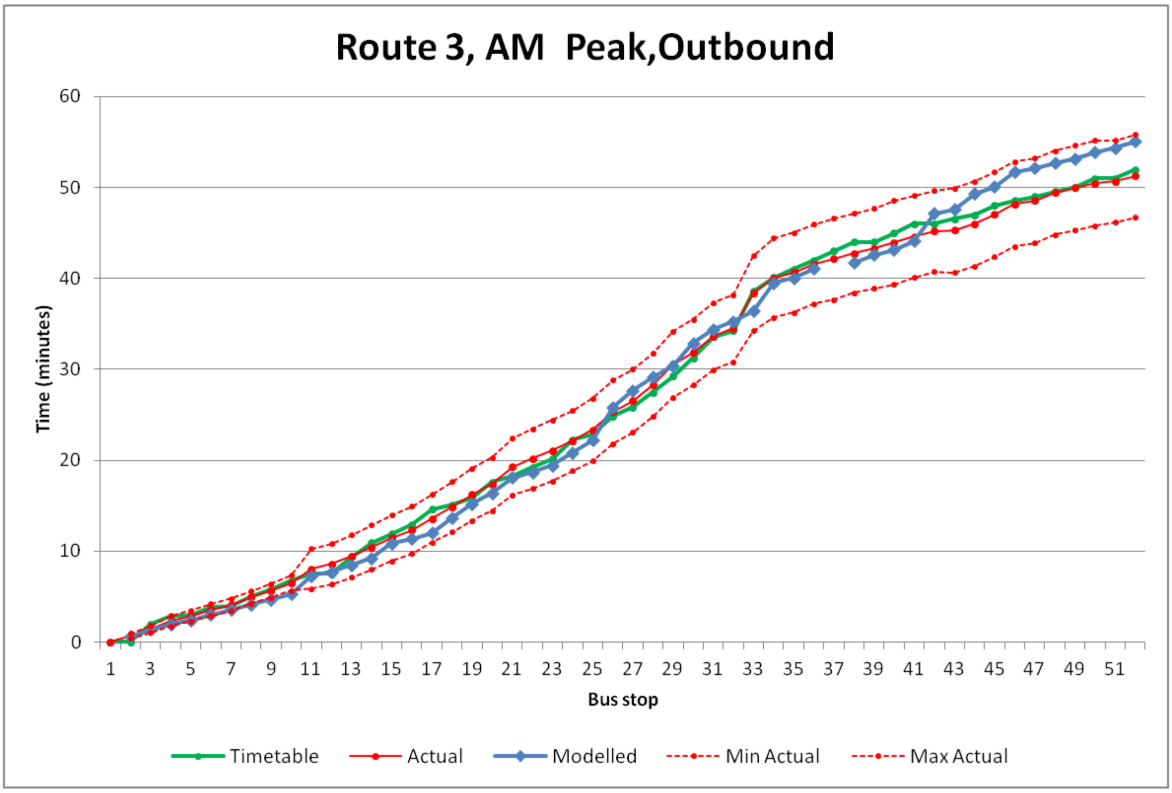


Figure 5-24: RTI Comparison, Route 3, AM Outbound

5.7 Implementation in EMME

The bus transit time function that is used in WPTM is shown below, and summarised in Table 5-7, CBD stops are defined as those within the Metlink fare-zones 0 or 1.

Bus time (minutes) = A * (timau on normal roads)

+ 1 * (timau on congested roads)
+ B * (length/v0 on CBD bus only lanes)
+ C * (length/v0 on non-CBD bus only lanes)
+ D * (length/v0 on CBD bus lanes approaching junction)
+ E * (length/v0 on non-CBD bus lanes approaching junction)
+ F * (length/v0 on CBD bus lanes no junction)
+ G * (length/v0 on non-CBD bus lanes no junction)
+ H * (CBD stops)
+ I * (non-CBD stops)

Table 5-7: Function Parameters

	Condition	AM	IP	Calculation
A	normal roads	1.29	1	* timau
-	normal roads with congestion	1	1	* timau
B	bus only lanes, in CBD	3	3	* (length/v0)
C	bus only lanes, out of CBD	1.25	1.25	* (length/v0)
D	bus lanes, approaching junction, CBD	3.5	3.25	* (length/v0) OR normal roads calc
E	bus lanes, approaching junction, non-CBD	2	1.5	* (length/v0) OR normal roads calc
F	bus lanes, no junction, in CBD	3	3	* (length/v0) OR normal roads calc
G	bus lanes, no junction, non-CBD	2	1.5	* (length/v0) OR normal roads calc
H	CBD stop time	0.405	0.5	* # stops
I	non-CBD stop time	0.178	0.347	* # stops

6 WPTM Fare Analysis

As part of the Wellington Transport Model commission, the project team were asked to undertake analysis of bus and rail fares within the Greater Wellington region and develop a methodology for replicating the costs incurred that can be used within the WPTM.

Sub-sections 6.1 to 6.6 report on the current fare system operating in Greater Wellington and the derivation of average fare tables by mode, time-period and user class (i.e. Adult or Child).

Sub-sections 6.7 and onwards are focused on reporting the development of a fare methodology that can be applied within the Emme environment to replicate as accurately as possible the fare tables developed in the preceding sub-sections.

It should be noted that the fare methodology developed and described from Section 6.7 onwards is applicable to the WPTM only. It has been documented in this TN as it is a network-based approach rather than the matrix-based approach as used in WTSM and reported in TN15.

6.1 Fare System

Greater Wellington has employed a zonal based fare structure since November 2008. Prior to this date single fares were specified on a route by route basis, with the fare broadly corresponding to the distance travelled. This change from a distance-based to a zonal-based fare structure was an attempt to simplify the fare structure and introduce commonality across the various operators who run services within the Greater Wellington region.

There are 14 zones that lie within the Greater Wellington region, covering both the bus and rail networks. The zone system is generally linear in nature from the Wairarapa, Hutt Valley and Kapiti Coast towards Wellington. An exception to this rule is Zones 2 and 3 that form concentric rings around Zone 1 (Wellington CBD). Within Wellington CBD there is also a sub fare-zone that covers the Lambton Quay / Manners Street / Courtenay Place corridor and is referred to as the city section. Fares within this sub-zone, sometimes referred to as Zone 0, are slightly cheaper than fares within Zone 1. The zone system is displayed in Figure 6-1 below:

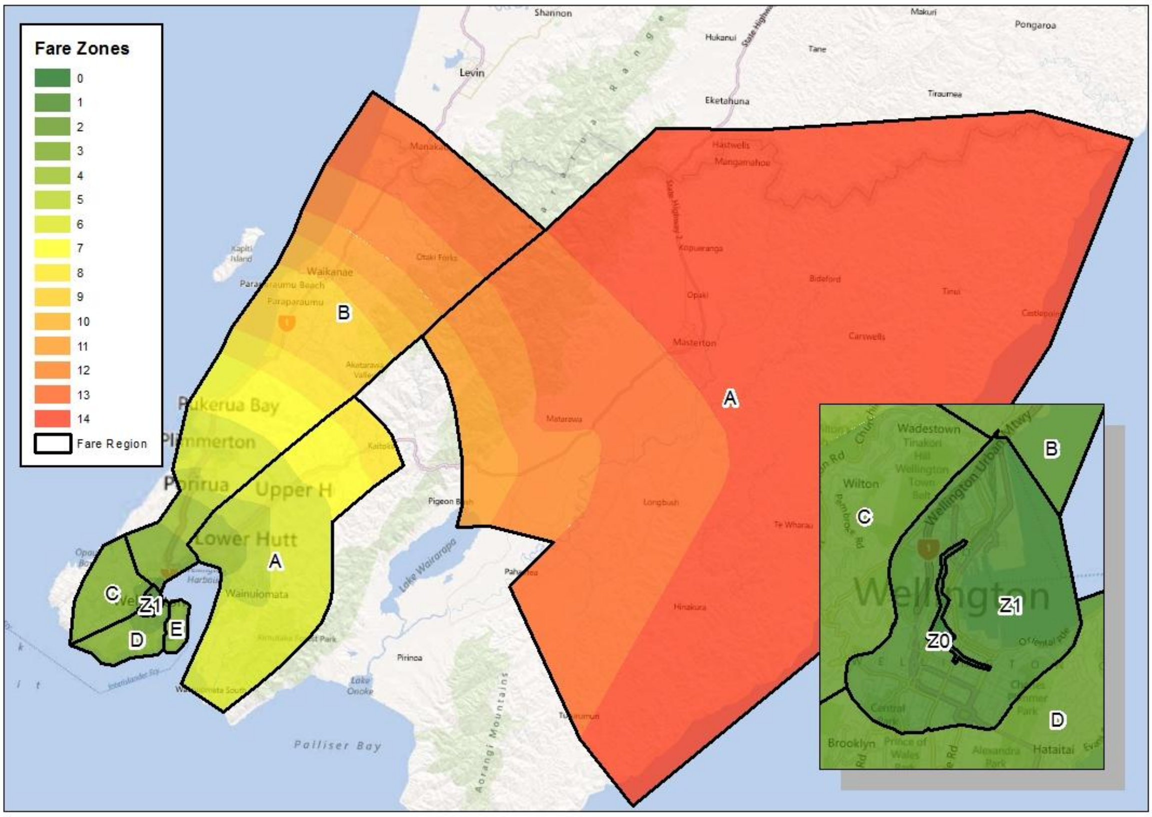


Figure 6-1: Wellington Fare-Zone Regions

The fare is calculated according to the number of zone boundaries crossed (also known as stages). For example, a trip from Masterton to Wellington (Zone 14 to Zone 1) crosses 13 fare-zone boundaries and is therefore considered to be a 14 zone fare as the starting fare-zone is considered as a fare-zone on its own.

An exception to this calculation occurs for trips that are undertaken within zones 1-3 of the Wellington area. Under Go Wellington policy trips undertaken within zones 1-3 are capped to 3 stages of travel even though the trip may cross more than 3 fare-zone boundaries. For example, a trip from Karori (Zone 3) to Miramar (Zone 3), whilst appearing to be within the same fare-zone, will actually cross 4 fare-zone boundaries, but under Go Wellington policy is ‘capped’ at a 3 zone fare.

Due to the topography of Wellington City and the clustering of jobs in the CBD (Zones 1 to 3), nearly all services, including through services, converge on Wellington CBD. Anyone wanting to make a journey such as the example given above would have to travel through the CBD as there are virtually no orbital public transport services.

6.2 Current Bus Fares

Table 6-1 below shows the zonal bus fares, taken from the Metlink website on 20th January 2012. These fares were last updated on 1st November 2011. It is important to note that the fares relate to services with ‘standard’ fares and exclude services such as the Airport Flyer and Commuter buses.

The fares differ by user class (adult / child) and method of payment (stored value card / 'snapper' or cash).

Table 6-1: Adult and Child Bus Fares

	Adult		Child	
Stages / Fare-Zones	**Cash**	**10-trip & stored value card – per trip**	**Cash**	**10-trip & stored value card – per trip**
City Section	$2.00	$1.50	$1.50	$1.10
1	$2.00	$1.60	$1.50	$1.20
2	$3.50	$2.58	$2.00	$1.50
3	$4.50	$3.44	$2.50	$1.80
4	$5.00	$3.86	$3.00	$2.20
5	$6.00	$4.72	$3.50	$2.60
6	$7.50	$6.00	$4.00	$3.00
7	$8.50	$6.80	$4.50	$3.45
8	$9.50	$7.60	$5.00	$3.86
9	$11.00	$8.58	$5.50	$4.29
10	$12.00	$9.44	$6.50	$4.72
11	$13.50	$10.80	$7.00	$5.45
12	$14.50	$11.60	$7.50	$5.88
13	$16.50	$12.80	$8.50	$6.40
14	$17.50	$13.64	$9.00	$6.82

Table 6-2 shows the number of recorded trips, by time period and aggregated ticket type, taken from the weekday ETM data that spans 35 days in February and March 2011. This data is used for all the subsequent bus analysis that is presented in this note. There are a plethora of different daily and monthly tickets available, such as GetAbout Pass, Go Wellington 30 Day Pass, Metlink Explorer and Hutt Plus, to name a few. However these have been grouped together in the table and it can be seen that they comprise a small percentage of total ticket sales.

Table 6-2: Ticket Type by Time Period

Ticket Type	**AM Peak (7am-9am)**		**Inter Peak (9am-3pm)**	
Purse (stored value card)	503,403	74%	338,331	42%
Cash	115,808	17%	188,291	24%
Monthly	55,110	8%	182,899	23%
Free	3,146	0%	49,056	6%
Term	1,747	0%	37,639	5%
Daily	421	0%	1,808	0%
TenTrip	259	0%	275	0%
Total	**679,894**	**100%**	**798,299**	**100%**

In the Inter peak period, 24% of all tickets sold are free. This reflects the popularity and high usage of the SuperGold Card which provides free travel to passengers over 65 years of age.

The fares presented in Table 6-1 above are the standard fares that are used within the Greater Wellington Region. Across all services (excluding the Airport Flyer), cash or stored value card (labelled as purse in the table) is the chosen method of payment for over 90% of all trips.

There are a handful of services that have non-standard fares that have been excluded from the analysis presented in Table 6-1. These services are presented in Table 6-3 below, together with the number of combined AM and Inter-peak recorded trips and the percentage of non-standard ticket sales that they constitute.

Table 6-3: Routes with Non-Standard Fares

Number	Route	Count	% of Total
80	Wainuiomata Commuter	4,925	9%
90	Stokes Valley Commuter	142	0%
91	Airport Flyer	47,959	89%
92	Runcimann Commuter Bus	53	0%
93	Runcimann Commuter Bus	567	1%
97	Weltec Bus	0	0%
98	Runcimann Commuter Bus	15	0%
99	Runcimann Commuter Bus	2	0%
300	Whetapua Cemetery	0	0%
Total		**53,663**	**100%**

Looking at the data in Table 6-3, it is apparent that that majority of non-standard services are either not captured by the ETM data (due to lying outside of the modelled time periods) or have very low levels of demand. The Airport Flyer accounts for around 90% of all non-standard fares – as a percentage of all AM and IP records (1.48 million records), Airport Flyer records (48k) comprise around 3%.

6.3 Current Rail Fares

The current rail fare system is shown in Table 6-4 below. Rail fares are largely the same as bus fares, the only difference being that there are a number of additional fare products available for rail, such as ten-trip tickets, term passes and special off-peak rail fares.

Table 6-4: Current Rail Fares

	Adult				Child			
Stages / Fare-Zones	**Cash**	**10 trip and Snapper**	**Off-peak cash**	**Monthly**	**Cash**	**10 trip and Snapper**	**Monthly train**	**School term ticket**
City Section	$2.00	$1.50	–	–	$1.50	$1.10	–	–
1	$2.00	$1.60	$2.00	$48.00	$1.50	$1.20	$36.00	$94.50
2	$3.50	$2.58	$3.00	$77.40	$2.00	$1.50	$45.00	$110.00

	Adult				Child			
Stages / Fare-Zones	**Cash**	**10 trip and Snapper**	**Off-peak cash**	**Monthly**	**Cash**	**10 trip and Snapper**	**Monthly train**	**School term ticket**
3	$4.50	$3.44	$3.50	$103.20	$2.50	$1.80	$54.00	$134.00
4	$5.00	$3.86	$4.00	$115.80	$3.00	$2.20	$66.00	$161.00
5	$6.00	$4.72	$4.50	$141.60	$3.50	$2.60	$78.00	$193.00
6	$7.50	$6.00	$6.00	$180.00	$4.00	$3.00	$90.00	$225.00
7	$8.50	$6.80	$6.50	$204.00	$4.50	$3.45	$103.50	$258.00
8	$9.50	$7.60	$7.50	$228.00	$5.00	$3.86	$115.80	$290.00
9	$11.00	$8.58	$8.00	$257.40	$5.50	$4.29	$128.70	$322.00
10	$12.00	$9.44	$9.50	$283.20	$6.50	$4.72	$141.60	$354.00
11	$13.50	$10.80	–	$324.00	$7.00	$5.45	$163.50	$410.00
12	$14.50	$11.60	–	$348.00	$7.50	$5.88	$176.40	$441.00
13	$16.50	$12.80	–	$384.00	$8.50	$6.40	$192.00	$480.00
14	$17.50	$13.64	–	$409.20	$9.00	$6.82	$204.60	$512.00

6.4 Derivation of Modelled Bus Fares

In order to help represent bus fares within WPTM, an average fare is required for each stage length. This fare is calculated by taking the fare (by stage length) for each of the following fare products and weighting according to the percentage of total ticket sales that each individual fare product constitutes:

The fare products are as follows (listed in descending order of popularity):

- Snapper (E-purse);
- Cash;
- Free – SuperGold Card (over 65's) and other free passes (NZ Bus staff);
- Daily tickets;
- Monthly tickets; and
- Ten trip tickets.

Table 6-5 and Table 6-6 below show the number of records by ticket type and stage, together with the percentage contribution of each ticket type / stage length combination to:

- The number of records in that ticket type; and
- The overall number of records.

The analysis presented in this note covers adult tickets. Similar analysis has been undertaken for child tickets. The tables only go up to 8 stages of travel as there are almost no trips covering more than 8 stages.

Table 6-5: No of Records by Ticket Type, AM Peak, Adult

	City	1 Stage	2 Stage	3 Stage	4 Stage	5 Stage	6 Stage	7 Stage	8 Stage	Total
Snapper	23,804	65,176	142,286	131,617	14,981	3,249	2,819	131	2	384,065
% Ticket Type	6.2%	17.0%	37.0%	34.3%	3.9%	0.8%	0.7%	0.0%	0.0%	100.0%
% Total	4.7%	13.0%	28.3%	26.2%	3.0%	0.6%	0.6%	0.0%	0.0%	76.3%
Cash	8,105	20,319	26,268	14,931	2,071	548	318	-	3	72,563
% Ticket Type	11.2%	28.0%	36.2%	20.6%	2.9%	0.8%	0.4%	0.0%	0.0%	100.0%
% Total	1.6%	4.0%	5.2%	3.0%	0.4%	0.1%	0.1%	0.0%	0.0%	14.4%
Monthly	1,312	5,888	10,808	21,916	1,463	1,147	1,079	254	5	43,872
% Ticket Type	3.0%	13.4%	24.6%	50.0%	3.3%	2.6%	2.5%	0.6%	0.0%	100.0%
% Total	0.3%	1.2%	2.1%	4.4%	0.3%	0.2%	0.2%	0.1%	0.0%	8.7%
Free	32	229	314	261	15	4	2	127	984	1,968
% Ticket Type	1.6%	11.6%	16.0%	13.3%	0.8%	0.2%	0.1%	6.5%	50.0%	100.0%
% Total	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.2%	0.4%
Ten Trip	1	179	41	8	-	-	-	-	-	229
% Ticket Type	0.4%	78.2%	17.9%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
% Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Daily	17	37	106	126	25	1	7	-	-	319
% Ticket Type	5.3%	11.6%	33.2%	39.5%	7.8%	0.3%	2.2%	0.0%	0.0%	100.0%
% Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Term	-	-	-	-	-	-	-	-	-	-
% Ticket Type										
% Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	33,271	91,828	179,823	168,859	18,555	4,949	4,225	512	994	503,106
% of Total	7%	18%	36%	34%	4%	1%	1%	0%	0%	100%

Table 6-6: No of Records by Ticket Type, Inter Peak, Adult

	City	1 Stage	2 Stage	3 Stage	4 Stage	5 Stage	6 Stage	7 Stage	8 Stage	Total
Snapper	31,349	80,151	93,436	48,808	9,844	941	1,320	14	1	265,864
% Ticket Type	11.8%	30.1%	35.1%	18.4%	3.7%	0.4%	0.5%	0.0%	0.0%	100.0%
% Total	5.4%	13.8%	16.1%	8.4%	1.7%	0.2%	0.2%	0.0%	0.0%	45.9%
Cash	13,840	41,636	47,300	16,737	3,551	373	332	2	6	123,777
% Ticket Type	11.2%	33.6%	38.2%	13.5%	2.9%	0.3%	0.3%	0.0%	0.0%	100.0%
% Total	2.4%	7.2%	8.2%	2.9%	0.6%	0.1%	0.1%	0.0%	0.0%	21.4%
Free	17,635	34,129	37,111	25,266	5,344	591	1,055	2	6	121,139
% Ticket Type	14.6%	28.2%	30.6%	20.9%	4.4%	0.5%	0.9%	0.0%	0.0%	100.0%
% Total	3.0%	5.9%	6.4%	4.4%	0.9%	0.1%	0.2%	0.0%	0.0%	20.9%
Monthly	5,155	8,943	11,663	10,153	1,000	145	282	49	7	37,397
% Ticket Type	13.8%	23.9%	31.2%	27.1%	2.7%	0.4%	0.8%	0.1%	0.0%	100.0%
% Total	0.9%	1.5%	2.0%	1.8%	0.2%	0.0%	0.0%	0.0%	0.0%	6.5%
Daily	3,706	4,957	7,851	8,827	3,086	103	573	1	6	29,110
% Ticket Type	12.7%	17.0%	27.0%	30.3%	10.6%	0.4%	2.0%	0.0%	0.0%	100.0%
% Total	0.6%	0.9%	1.4%	1.5%	0.5%	0.0%	0.1%	0.0%	0.0%	5.0%
Ten Trip	5	1,469	130	37	-	-	-	-	-	1,641
% Ticket Type	0.3%	89.5%	7.9%	2.3%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
% Total	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Term	-	-	-	-	-	-	-	-	-	-
% Ticket Type										
% Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	71,690	171,285	197,491	109,828	22,825	2,153	3,562	68	26	578,928
% of Total	12%	30%	34%	19%	4%	0%	1%	0%	0%	100%

The fare by stage length for cash, snapper, SuperGold card and ten-trip tickets were obtained from the Metlink website.

For daily and monthly fares, many different fare products are used, making it difficult to obtain an ‘average’ daily / monthly fare. A simplified process was used to calculate an average daily / monthly fare (outlined for monthly records only) using all daily records:

- Identify all different monthly records that feature in the ETM data and segment by time period and user class (adult and child);
- Obtain the cost of these monthly records from the Metlink website;
- For each different type of monthly record, multiply the cost by the % of total monthly tickets that are attributable to this category; and

- Aggregate these weighted monthly fares, in order to obtain an average monthly fare across all ticket products.

The next step was to convert the average monthly or daily fare into an average fare per trip, regardless of the number of stages travelled.

Some monthly passes have a unique ID, meaning that usage of these tickets can be tracked through time. Analysis of this data shows that, on average, each monthly pass is used 1.31 times every weekday. It has also been assumed that each monthly pass will be used 1.31 times every weekend. When combined this results in each monthly pass being used 31 times.

Similar analysis performed on the daily ticket data shows that these tickets are used, on average, 3.11 times each day.

If the average monthly and daily fares are divided through by the average number of trips made with these tickets during their period of validity, this results in an average fare per stage as follows:

- Average Monthly Fare - $142; Average No of Trips per month – 31: Average Fare per trip - $4.60; and
- Average Daily Fare - $9.50; Average No of Trips per day – 3.11: Average Fare per trip - $3.14.

Whilst a number of approximations have been used in order to calculate these fares, it is important to bear in mind that monthly and daily tickets comprise a relatively small percentage (8.7% and 0.5% respectively) of overall trips on the network. Therefore their contribution towards the average fares presented in this note will be small, with ‘snapper’ and ‘cash’ sales having the greatest impact on average fares.

Table 6-7 and Table 6-8 below shows the average fare by ticket type and stage length for AM peak and Inter peak adult trips respectively. It should be noted that the ‘adult’ category includes ‘senior’ trips.

The overall average fare is obtained by weighting the average fare by ticket type by the percentage of total tickets that each fare comprises. For example, the average fare for a 3 stage Snapper ticket, $3.40, would be multiplied by 26.2% (the percentage of overall records that are classified as ‘3 stage Snapper’).

Table 6-7: AM Peak Average Fare (given in $) by Stage Length and Aggregate ticket Type

	City Zone	1 Stage	2 Stage	3 Stage	4 Stage	5 Stage	6 Stage	7 Stage	8 Stage
Snapper	1.5	1.6	2.6	3.4	3.9	4.7	6.0	6.8	7.6
Cash	2.0	2.0	3.5	4.5	5.0	6.0	7.5	8.5	9.5
Free	-	-	-	-	-	-	-	-	-
Ten Trip	1.5	1.6	2.6	3.4	3.9	4.7	6.0	6.8	7.6
Daily	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Monthly	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Term	-	-	-	-	-	-	-	-	-
Weighted Average	1.7	1.9	2.8	3.7	4.0	4.8	5.7	5.3	6.7

Table 6-8: Inter Peak Average Fare (given in $) by Stage Length and Aggregate ticket Type

	City Zone	1 Stage	2 Stage	3 Stage	4 Stage	5 Stage	6 Stage	7 Stage	8 Stage
Snapper	1.5	1.6	2.6	3.4	3.9	4.7	6.0	6.8	7.6
Cash	2.0	2.0	3.5	4.5	5.0	6.0	7.5	8.5	9.5
Free	-	-	-	-	-	-	-	-	-
Ten Trip	1.5	1.6	2.6	3.4	3.9	4.7	6.0	6.8	7.6
Daily	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Monthly	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Term	-	-	-	-	-	-	-	-	-
Average	1.5	1.6	2.5	2.9	3.1	3.6	3.8	5.0	4.4

When aggregated across all fare-zones, the average adult bus fare across the whole network is $2.98 in the AM peak and $2.20 in the Inter peak. The average fare in the AM peak is higher because there will be more long distance (commute) trips in the AM peak compared to the Inter peak, where trips will predominantly be shorter distance shopping or leisure trips. Supergold card fares (free) have also been included in the analysis and, given that there is a higher proportion of travellers using this card in the Inter-peak period compared to the AM peak period, it further supresses the average Inter-peak fare.

Figure 6-2 below plots the average fare by stage length, time period and user class. When analysed alongside Figure 6-3 it shows that average fare increases in a broadly linear fashion for trips between 1 and 5 fare stages in length (the majority of all trips).

For trips greater than 6 stages length (around 5%) of all demand, this relationship appears to breakdown. Whilst analysis of this data shows that the reason for this apparent trend is a greater percentage of monthly tickets within the 6 and 7 stage length bracket compared to the 1 to 5 stage bracket (which in itself is not surprising), it is hard to draw meaningful conclusions due to the lack of data covering these longer distances trips.

Therefore the relationship between fare and stage length for trips of 1 to 5 stages in length be taken, extrapolated and applied to the (relatively few) bus trips that are greater than 6 stages in length.

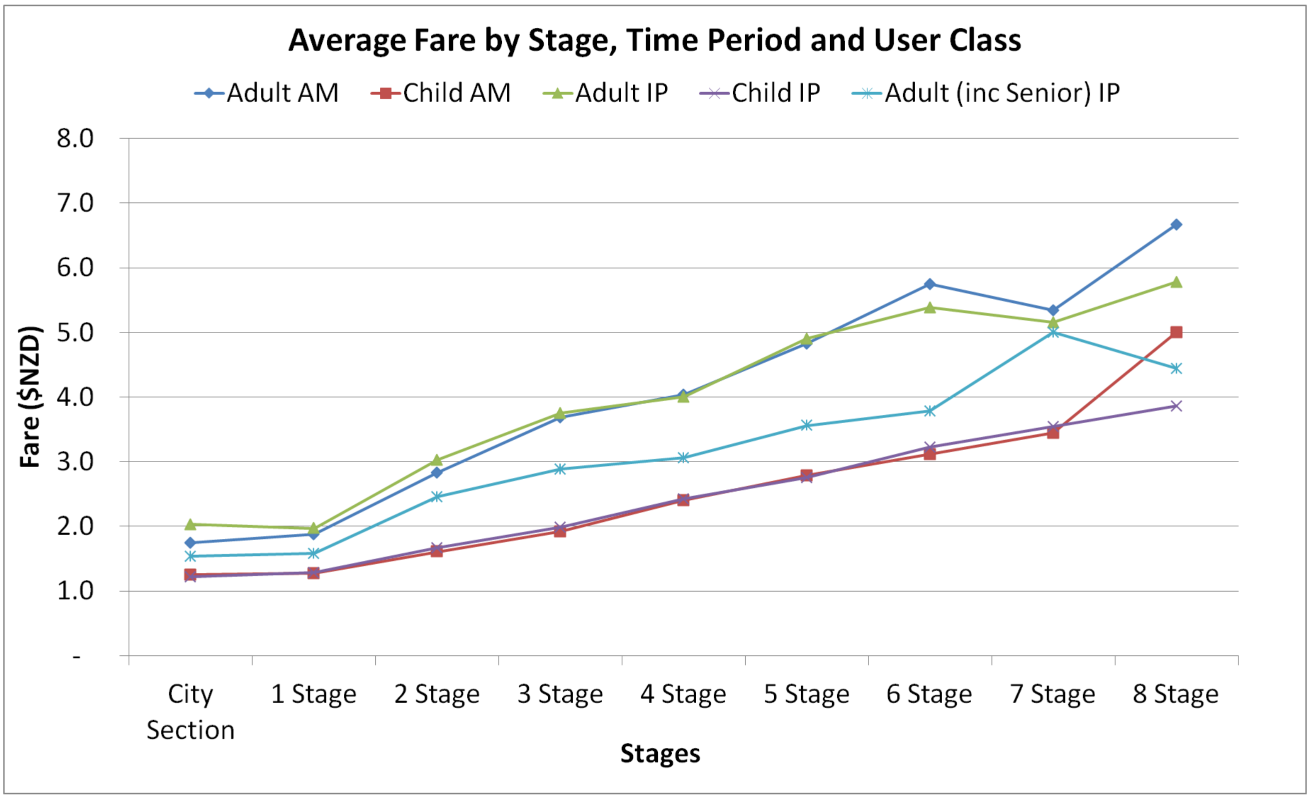


Figure 6-2: Average Fare by Stage, Time Period and User Class

6.5 Airport Flyer

As mentioned in Section 6.2 a number of services use non-standard fares (listed in Table 6-3). In an ideal situation we would want to accurately represent the fare tables for each of these services – in reality this is not practical for a number of reasons:

- There is no available independent patronage data at a service specific level – therefore the validation of patronage for standard and non-standard services along the same corridor / within the same area cannot be undertaken;
- For some of the services there are relatively few trips, making it hard to accurately derive fare relationships from such a limited data set; and
- Many of these non-standard services are infrequent, have low levels of patronage and serve small markets. Therefore not deriving specific fare tables for these non-standard services won't affect the robustness of WPTM and its ability to be used for any future forecasting work that might be undertaken.

In our view the time taken to accurately model these unique fare tables would heavily outweigh the benefits for all services apart from Route 91, the Airport Flyer. This service has a high frequency (15 minutes) and serves a distinct market compared to other services in the network, catering for passengers between the Airport / Wellington CBD and Hutt Valley. This niche market, combined with some unique service characteristics (limited stops, leather seats, Wi-Fi) means that this service is aimed at a different type of passenger to standard bus services and is priced accordingly. This is a premium product which may be applicable to other routes in future.

The method of deriving bus fares outlined in Section 6.4 was applied to the Airport Flyer ticket data. Due to this being a relatively small data set, the resulting average fares showed no discernable pattern. Indeed there were some instances where the average fare for a particular stage was actually lower than that for the preceding stage. Whilst this could be plausible, for example due to higher snapper / monthly ticket usage in one fare-zone compared to another, with such a small data set it is hard to make many meaningful conclusions.

Therefore the preferred method for creating the Airport Flyer fare tables was to take the standard fares presented in Table 6-7 and

Table 6-8 and apply the relative difference between the standard and Airport Flyer cash fare to the average bus fare. Table 6-9 shows the standard fare, the Airport Flyer fare and the resulting uplift factor. Note that the Airport Flyer fare structure is designed to attract longer distance travellers (i.e. from the Airport / Hutt Valley to Wellington CBD) and dissuade shorter distance travellers from using the service.

Table 6-9: Airport Flyer Fare Tables and Multiplicative Uplift Factor

	Adult Fares ($)			Child Fares ($)		
	Average AM Fare	Average AM Flyer Fare	Flyer Uplift Factor	Average AM Fare	Average AM Flyer Fare	Flyer Uplift Factor
City Section	1.7	4.9	2.9	1.3	3.3	2.5
1	1.9	4.8	2.8	1.3	3.0	2.3
2	2.8	5.4	2.0	1.6	3.4	2.1
3	3.4	5.8	1.7	1.9	3.8	2.0
4	3.9	7.0	1.8	2.4	4.3	1.8
5	4.3	6.9	1.6	2.8	4.8	1.7
6	5.2	7.3	1.4	3.1	5.0	1.6
7	3.9	5.5	1.4	3.5	5.3	1.5
8	5.6	7.3	1.3	5.0	7.5	1.5

6.6 Derivation of Rail Fares

The process of deriving a set of average rail fares is similar to that outlined above for the derivation of average bus fares. The main differences when deriving the rail fares are as follows:

- Ten-trip tickets are unique to the rail network;
- The rail surveys undertaken for the model development study did not adequately capture child demand, as the surveyors were instructed not to survey children who appeared to be less than 15 years of age. The limited data from the surveys regarding concessionary and term time fares has been used to estimate average child fares across the network. Whilst this lack of accurate data is an undoubted limitation of this process there is little further data available from which child fares could be estimated; and
- Whilst bus fares are the same throughout the day, there is a specific off-peak rail ticket product for travel between 9am and 3.30pm.

The rail ticket products are as follows:

- Monthly tickets
- Ten trip ticket
- Cash
- Concessionary tickets (child only)
- Term tickets (child only)
- Free – SuperGold card (over 65s)

As mentioned above, the same principles used when deriving average bus fares were used for calculating average rail fares. In order to convert the monthly fare into an average fare per trip, the monthly cost was divided by 37 (as opposed to a figure of 31 that was used during the derivation of the average bus fares). The rationale behind this is that monthly tickets are more popular for rail than bus, accounting for over 50% of ticket sales in the AM peak. Most of these passengers will be commuters, who will travel regularly. Assuming that there are 22 weekdays per month, that people are away from work 15% of the time (due to annual leave, sickness, working away from home) and that monthly tickets are not used at the weekend results in monthly tickets being used for, on average, 37 journeys per calendar month.

Table 6-10 and Table 6-11 below show the number of trips by ticket type and stage, together with the percentage contribution of each ticket type / stage length combination to:

- The number of records in that ticket type; and
- The overall number of records.

Table 6-10: AM Peak Rail Trips by Ticket Type and Stage Length

	Stages														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Monthly	239	149	958	2162	650	546	341	58	183	108	163	48	100	104	5809
% Ticket Type	4%	3%	16%	37%	11%	9%	6%	1%	3%	2%	3%	1%	2%	2%	100%
% Total	2%	1%	9%	20%	6%	5%	3%	1%	2%	1%	1%	0%	1%	1%	53%
Ten trip	124	133	411	1449	811	480	221	79	155	124	115	34	71	73	4279
% Ticket Type	3%	3%	10%	34%	19%	11%	5%	2%	4%	3%	3%	1%	2%	2%	100%
% Total	1%	1%	4%	13%	7%	4%	2%	1%	1%	1%	1%	0%	1%	1%	39%
Cash	26	28	88	185	183	76	40	6	35	18	20	6	12	13	735
% Ticket Type	4%	4%	12%	25%	25%	10%	6%	1%	5%	2%	3%	1%	2%	2%	100%
% Total	0%	0%	1%	2%	2%	1%	0%	0%	0%	0%	0%	0%	0%	0%	7%
Concession	19	0	54	2	2	0	0	0	0	0	3	1	2	2	86
% Ticket Type	22%	0%	62%	3%	2%	1%	0%	0%	0%	0%	4%	1%	2%	2%	100%
% Total	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Term	2	3	3	30	33	6	9	2	15	0	3	1	2	2	112
% Ticket Type	1%	3%	3%	27%	29%	5%	8%	1%	14%	0%	3%	1%	2%	2%	100%
% Total	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Gold Card	0	1	0	7	2	6	0	0	15	0	1	0	1	1	35
% Ticket Type	0%	4%	1%	19%	6%	18%	0%	0%	44%	0%	3%	1%	2%	2%	100%
% Total	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	410	315	1514	3835	1681	1114	611	144	403	252	305	90	187	194	11055
% Total	4%	3%	14%	35%	15%	10%	6%	1%	4%	2%	3%	1%	2%	2%	100%

Table 6-11: IP Rail Trips by Ticket Type and Stage Length

	Stages														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Month	54	38	60	100	68	17	7	1	9	14	-	-	-	-	367
% Ticket Type	15%	10%	16%	27%	18%	5%	2%	0%	3%	4%	0%	0%	0%	0%	100%
% Total	4%	3%	4%	7%	5%	1%	0%	0%	1%	1%	0%	0%	0%	0%	25%
Ten trip	79	66	96	167	103	27	32	1	14	11	-	-	-	-	597
% Ticket Type	13%	11%	16%	28%	17%	4%	5%	0%	2%	2%	0%	0%	0%	0%	100%
% Total	6%	5%	7%	12%	7%	2%	2%	0%	1%	1%	0%	0%	0%	0%	41%
Cash	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% Ticket Type	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% Total	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Concession	42	19	62	54	30	10	10	1	6	2	-	-	-	-	237
% Ticket Type	18%	8%	26%	23%	13%	4%	4%	0%	2%	1%	0%	0%	0%	0%	100%
% Total	3%	1%	4%	4%	2%	1%	1%	0%	0%	0%	0%	0%	0%	0%	16%
Term	0	1	1	1	2	0	0	0	0	0	-	-	-	-	5
% Ticket Type	4%	23%	13%	15%	37%	2%	1%	4%	0%	1%	0%	0%	0%	0%	100%
% Total	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Gold Card	11	40	34	53	44	11	14	1	8	20	-	-	-	-	235
% Ticket Type	5%	17%	14%	23%	19%	5%	6%	0%	3%	8%	0%	0%	0%	0%	100%
% Total	1%	3%	2%	4%	3%	1%	1%	0%	1%	1%	0%	0%	0%	0%	16%
Total	186	163	252	376	246	65	62	5	37	47	-	-	-	-	1,440
% Total	13%	11%	18%	26%	17%	5%	4%	0%	3%	3%	0%	0%	0%	0%	100%

Table 6-12 and Table 6-13 below show the average rail fares for the AM peak and Inter peak. Figure 6-3 presents a graphical plot of average fare by number of fare stages travelled. The tables show that the relationship in the AM peak between fare and distance travelled is generally linear, with fare increasing with distance for both adult and child user classes. Child fares (concessions and term passes) are on average around half the price of the equivalent adult full fare. In the Inter peak there is also a broadly linear relationship between fare and distance travelled, with the exception of 10 stage fares that appear to be cheaper than 9 stage fares. The relationship between average rail fare and number of stages travelled will be taken for trips between 1 and 8 stages in length and extrapolated to cover trips greater than 8 stages in length

Table 6-12: AM Peak Average Rail Fare

	Stages													
Ticket Type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Ten trip	1.6	2.6	3.4	3.9	4.7	6.0	6.8	7.6	8.6	9.4	10.8	11.6	12.8	13.6
Cash	2.0	3.5	4.5	5.0	6.0	7.5	8.5	9.5	11.0	12.0	13.5	14.5	16.5	17.5
Concession	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.5	7.0	7.5	8.5	9.0
Month	0.8	1.3	1.7	1.9	2.4	3.0	3.4	3.8	4.3	4.7	5.4	5.8	6.4	6.8
Term	0.9	1.1	1.3	1.6	1.9	2.3	2.6	2.9	3.2	3.5	4.1	4.4	4.8	5.1
Gold Card	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average Fare - Adult	**1.4**	**2.3**	**2.9**	**3.4**	**4.4**	**5.3**	**6.0**	**6.9**	**7.4**	**8.6**	**9.5**	**10.2**	**11.3**	**12.0**
Average Fare - Child	**1.5**	**1.1**	**2.4**	**1.7**	**2.0**	**2.4**	**2.7**	**3.2**	**3.2**	**5.0**	**5.5**	**5.9**	**6.6**	**7.0**

Table 6-13: Inter Peak Average Rail Fare

	Stages													
Ticket Type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Ten trip	1.6	2.6	3.4	3.9	4.7	6.0	6.8	7.6	8.6	9.4	10.8	11.6	12.8	13.6
Cash	2.0	3.0	3.5	4.0	4.5	6.0	6.5	7.5	8.0	9.5	–	–	–	–
Concession	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.5	7.0	7.5	8.5	9.0
Month	1.6	2.6	3.4	3.9	4.7	6.0	6.8	7.6	8.6	9.4	10.8	11.6	12.8	13.6
Term	0.9	1.1	1.3	1.6	1.9	2.3	2.6	2.9	3.2	3.5	4.1	4.4	4.8	5.1
Gold Card	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average Fare - Adult	**1.6**	**2.0**	**2.8**	**3.2**	**3.6**	**4.7**	**4.9**	**5.7**	**6.2**	**5.3**	**-**	**-**	**-**	**-**
Average Fare - Child	**0.9**	**1.1**	**1.3**	**1.6**	**1.9**	**2.3**	**2.6**	**2.9**	**3.2**	**3.5**	**-**	**-**	**-**	**-**

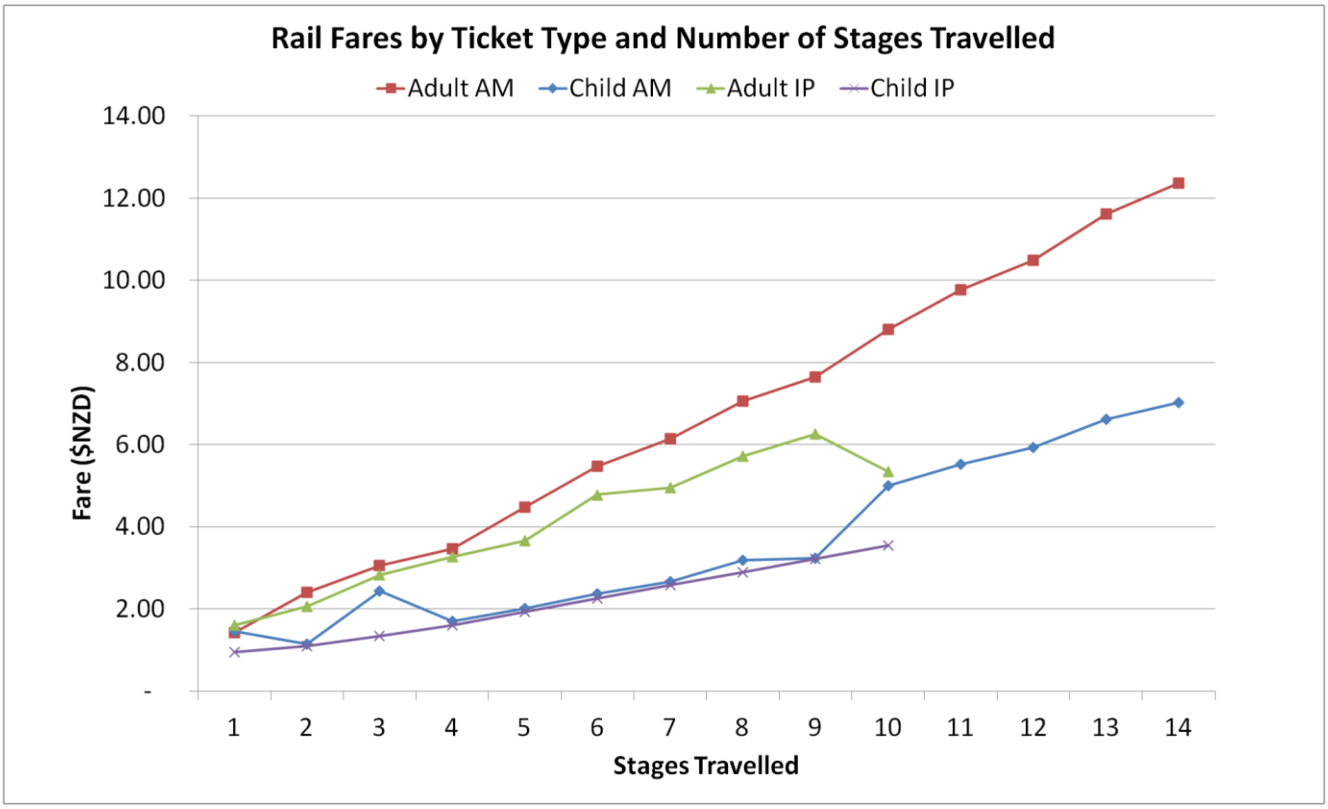


Figure 6-3: Rail Fares by Ticket Type and Number of Stages Travelled

6.7 Initial Implementation in EMME

In WTSM, the average fare from origin to destination across all PT modes is added to the generalised costs used for trip distribution and mode choice. However, the fare has no influence on PT sub-mode choice or route selected. In WPTM, it is desirable for fare to influence sub-mode and route choice so that premium priced services such as Airport Flyer can be properly modelled.

Based on the information presented in this technical note, a composite approach was followed in WPTM to create AM Peak and Inter peak (Adult and Child) fare tables for both bus and rail modes:

- To create bus fare tables the observed relationship between average fare and stage length has been taken for trips between 1 and 6 stages in length. This relationship has been linearly extrapolated to cover trips greater than 6 stages in length;
- The Airport Flyer fare tables have been created from the standard bus fare tables, with uplift factors used as outlined in Table 6-14;
- Rail fares have been created by taking the observed relationship between average fare and stage length for trips between 1 and 8 fare stages in length. This relationship has been linearly extrapolated to cover trips greater than 8 fare stages in length; and
- All ‘City Stage’ trips cost the same as 1 stage trips.

The extrapolated relationship between fare and distance travelled has only been used for stage lengths where there are a low number of direct observations, principally bus trips greater than 6 stages in length and rail trips greater than 8 stages in length. Less than 5% of overall bus and rail demand is covered by this extrapolated relationship.

Table 6-14 and Table 6-15 below show the average fares for bus and rail respectively, with red signifying a direct relationship and green signifying an extrapolated relationship. Figure 6-4 and Figure 6-5 show the relationship between average fare and number of stages travelled

Table 6-14: Average Bus Fares

	City	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Avg
AM Peak Adult - Bus	1.89	1.89	2.84	3.70	4.05	4.86	5.78	6.44	7.17	7.91	8.65	9.39	10.13	10.87	11.60	**2.99**
AM Peak Adult - Flyer	5.48	5.29	5.69	6.29	7.30	7.77	8.09	9.01	9.33	10.29	10.38	11.27	12.15	13.04	13.93	**7.28**
Inter Peak Adult - Bus	1.57	1.57	2.44	2.87	3.06	3.55	3.77	4.33	4.74	5.16	5.57	5.99	6.40	6.82	7.23	**2.19**
Inter Peak Adult - Flyer	4.54	4.39	4.88	4.88	5.50	5.67	5.28	6.06	6.16	6.70	6.69	7.18	7.68	8.18	8.68	**5.36**
AM Peak Chid - Bus	1.28	1.28	1.61	1.93	2.40	2.79	3.11	3.51	3.89	4.26	4.64	5.02	5.39	5.77	6.15	**1.58**
AM Peak Child - Flyer	3.19	2.94	3.38	3.85	4.33	4.75	4.98	5.26	5.83	5.97	6.50	7.02	7.55	8.08	8.61	**4.48**
Inter Peak Child - Bus	1.29	1.29	1.67	1.98	2.42	2.75	3.23	3.56	3.95	4.33	4.71	5.09	5.48	5.86	6.24	**1.61**
Inter Peak Child - Flyer	3.23	2.97	3.50	3.97	4.36	4.68	5.17	5.34	5.92	6.06	6.60	7.13	7.67	8.20	8.74	**4.37**

Table 6-15: Average Rail Fares

	City	1	2	3	4	5	6	7	8	9	10	11	12	13	Avg
AM Peak Adult	1.43	2.40	3.05	3.47	4.48	5.48	6.14	7.05	7.75	8.54	9.33	10.12	10.91	11.70	**4.62**
Inter Peak Adult	1.61	2.06	2.83	3.26	3.67	4.78	4.94	5.71	6.28	6.88	7.47	8.07	8.66	9.26	**3.25**
AM Peak Child	1.46	1.15	2.44	1.70	2.01	2.38	2.67	3.19	3.26	3.52	3.78	4.04	4.30	4.56	**2.34**
Inter Peak Child	0.95	1.10	1.34	1.61	1.93	2.25	2.58	2.90	3.18	3.48	3.78	4.09	4.39	4.70	**1.64**

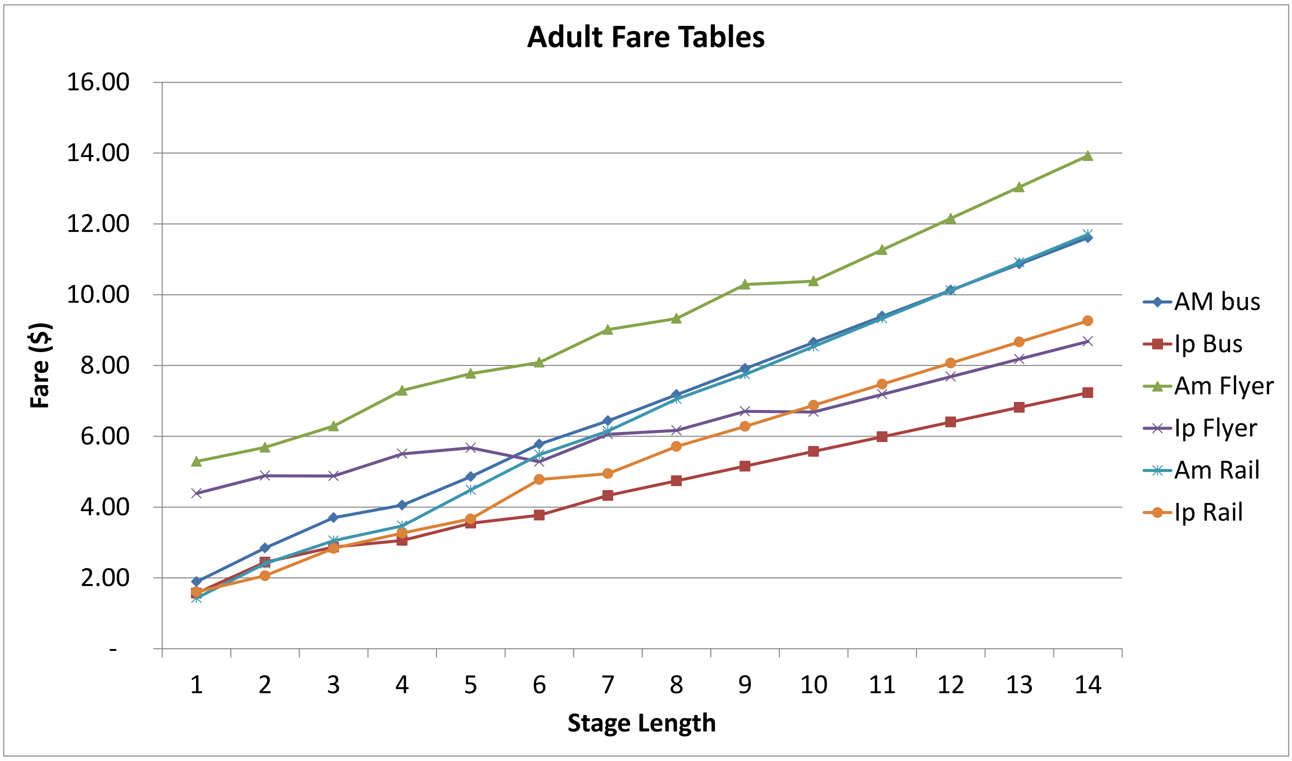


Figure 6-4: Final Adult Fare Tables

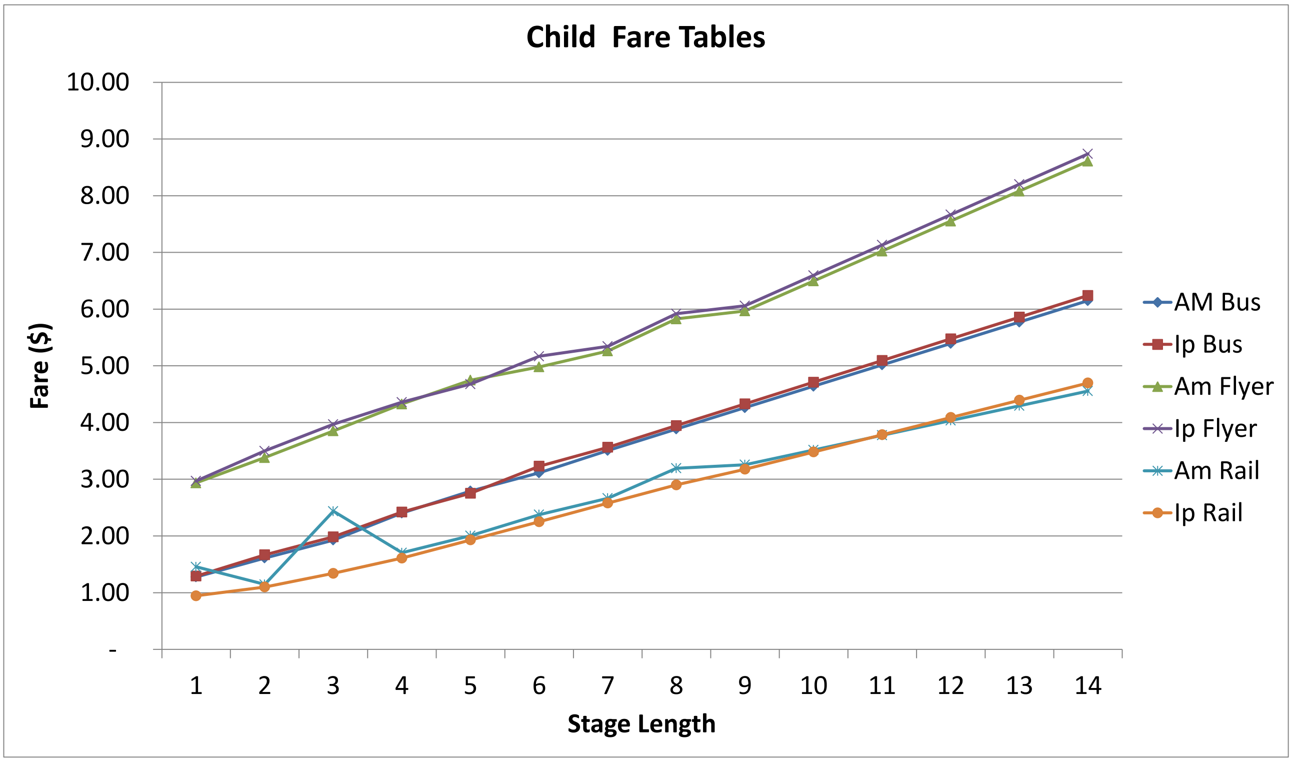


Figure 6-5: Final Child Fare Tables

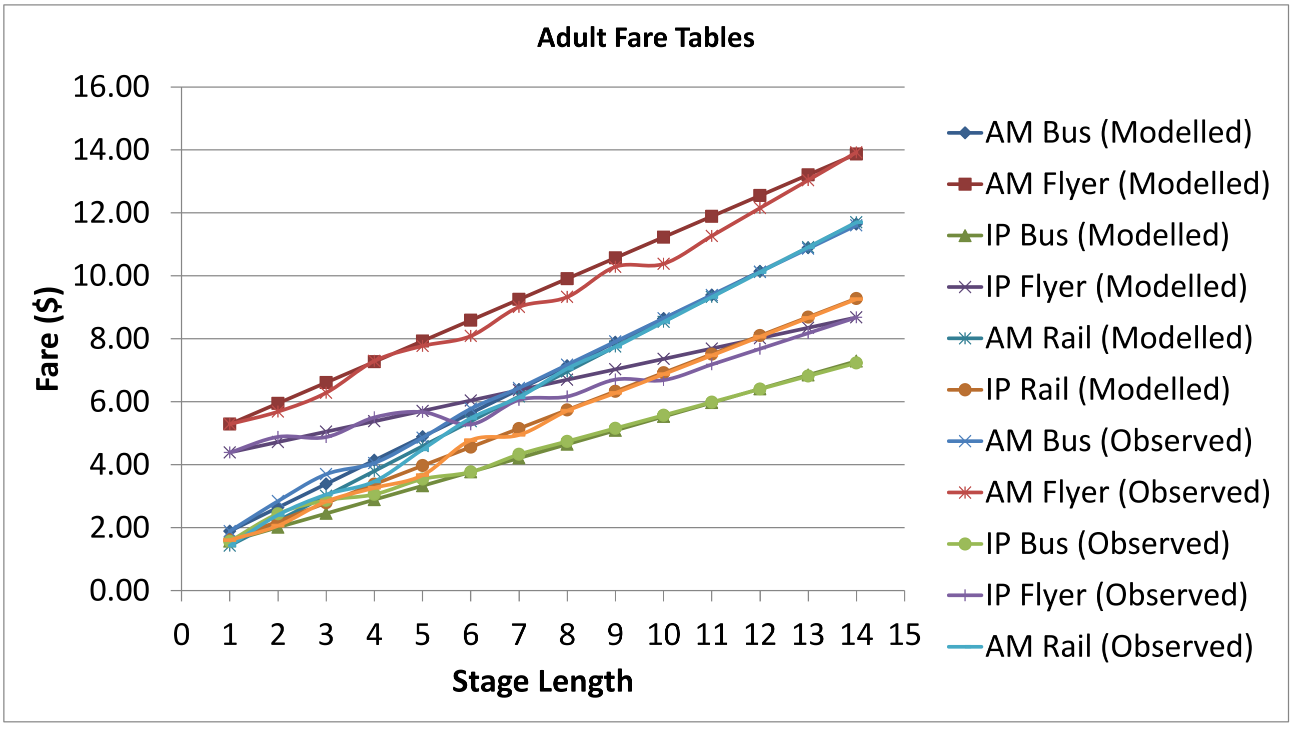


Figure 6-6: Final Adult Fare Tables (Observed vs. Modelled)

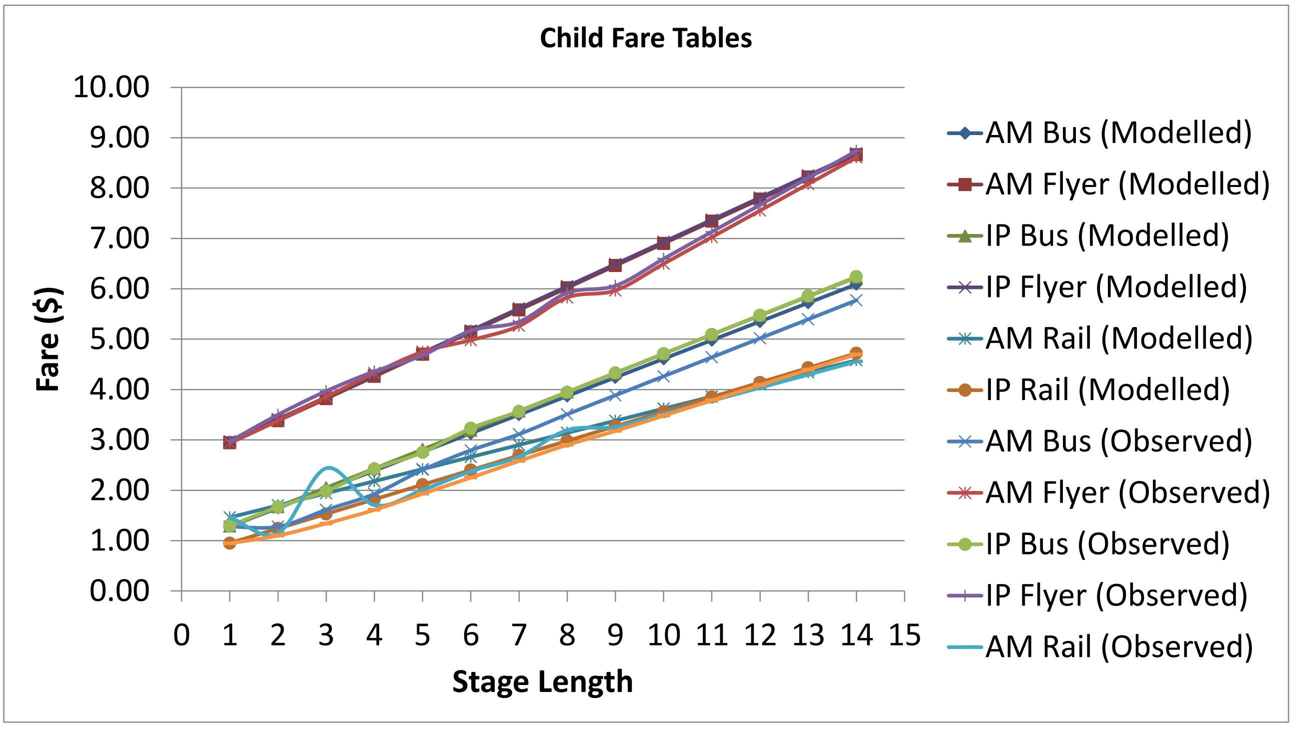


Figure 6-7: Final Child Fare Tables (Observed vs. Modelled)

Overall the relationship between the average fare across all modes, time periods and user classes appears reasonable and plausible:

- AM peak bus fares are higher than Inter peak bus fares, due to longer trip lengths (and therefore more fare boundaries crossed) and a significant number of SuperGold (free) card users in the Inter peak;
- Child bus fares are around 50% lower than adult bus fares;
- The average airport flyer fare is around 3 times the value of the average standard bus fare, due to higher base fares and a longer average stage length;
- Average rail fares are around 50% greater than average bus fares, due to a greater average stage length (most rail fares are 4 to 6 stages in length) combined with a lower percentage of gold card users on rail services relative to bus services.

In WPTM, the fares can be applied through a 'flag fall' fare plus an additional fare increment for each fare-zone boundary crossing. Table 6-16 shows each fare expressed in the format:

- $y = ax + c$

where:

- y = average fare
- x = number of stages travelled minus 1,
- a = incremental increase in fare by stage travelled,
- c = flagfall fare

The maximum fare, for a 14 stage trip, is also tabulated. Given that the relationships presented in Figure 6-4 and Figure 6-5 are broadly linear, a flagfall fare plus incremental fare is a reasonable method by which fares can be represented.

Table 6-16: Average Bus Fares

	Flag Fall (c)	Incremental Fare (a)	Max Fare	Average
Bus				
AM Peak Adult - Bus	1.89	0.75	11.6	**2.99**
AM Peak Adult - Flyer	5.29	0.66	13.93	**7.28**
Inter Peak Adult - Bus	1.57	0.44	7.23	**2.19**
Inter Peak Adult - Flyer	4.39	0.33	8.68	**5.36**
AM Peak Chid - Bus	1.28	0.37	6.15	**1.58**
AM Peak Child - Flyer	2.94	0.44	8.61	**4.48**
Inter Peak Child - Bus	1.29	0.38	6.24	**1.61**
Inter Peak Child - Flyer	2.97	0.44	8.74	**4.37**
AM Peak - Bus	1.68	0.67	10.45	**2.71**
AM Peak - Flyer	5.13	0.57	12.52	**7.02**
Inter Peak - Bus	1.54	0.44	7.21	**2.14**
Inter Peak - Flyer	4.36	0.23	7.36	**5.33**

	Flag Fall (c)	Incremental Fare (a)	Max Fare	Average
Rail				
AM Peak Adult	1.43	0.79	11.7	**4.62**
Inter Peak Adult	1.61	0.59	9.26	**3.25**
AM Peak Child	1.46	0.24	4.56	**2.34**
Inter Peak Child	0.95	0.29	4.7	**1.64**
AM Peak	1.43	0.78	11.61	**4.58**
Inter Peak	1.60	0.58	9.12	**3.25**

Table 6-17 shows the average fare by mode for the AM peak, Inter peak and whole day. The whole day figure has been estimated by assuming that all AM peak demand can be transposed to account for the PM peak and assuming that the Inter peak 2hr demand can be multiplied by 5 to account for both the Inter peak period (9am to 4pm) and off-peak period (6pm to 7am).

Table 6-17: Average Fare

Mode	Average Fare by Mode and Time Period		
	Total	Peak	Off-peak
Rail	$4.36	$4.58	$3.25
Bus	$2.62	$2.80	$2.27
Ferry	$8.39	$8.39	
Total	$3.18	$3.47	$2.45

The calculated average AM bus fare equates to an actual fare midway between a 2 to 3 stage 'Snapper' fare whilst the average rail fare equates to a fare midway between a 4 to 5 stage journey paid for with either a monthly ticket of a ten-trip card. Two or three stage bus trips account for around 69% of all bus trips and four to five stage rail trips account for 50% of all trips using this mode. A similar pattern can be seen in the Inter peak, with the average fare equivalent to the most popular trip length. It is therefore re-assuring that the average fare lies within acceptable bounds.

The inclusion of SuperGold cards to derive average fares for use in WPTM should be noted when undertaking revenue calculations using outputs from the model. This is particularly important if in any future scenario the proportion and/or distribution of passengers using SuperGold cards were to change, which would imply that the average fares would need to be recalculated (see Section 6.10).

The lower average fares resulting from the inclusion of the SuperGold cards in the analysis will also impact the passengers' cost perceptions of a trip. However, as the modelling of fares in WPTM is not so much concerned with fares driving mode choice (i.e. PV vs. PT) but the difference in fare between competing PT modes (i.e. Rail vs. Bus vs. Ferry etc…) it is not considered to be an issue. This holds true as long as the proportion of SuperGold card users is roughly equal between the main modes (bus and rail) within the given modelled period.

6.8 Revised Implementation in EMME

The approach outlined in Section 6.7 above is the theoretical best approach for implementing bus, rail and ferry fares in WPTM. The idea of a flagfall fare and an additional charge for each fare-zone boundary crossed means that the modelled fare system is more or less identical to the actual public transport fare system in Greater Wellington.

When implementing this approach in EMME, however, a potential deficiency in the approach was identified, relating to so-called 'through trips' across Wellington (described in Section 6.1).

There are a number of Go Wellington routes within Zones 1 to 3 that cross the CBD and can therefore be categorised as 'through' routes. *e.g. Route 3, from Karori into the City Centre then out towards Lyall Bay.*

Route 3 (Figure 6-8) crosses 2 fare-zone boundaries between Karori and the CBD, then a further 2 between the CBD and Lyall Bay. Using the method outlined in Section 6.7 above this would equate to a 4 zone fare. In reality, Go Wellington fares within Wellington City are capped at a 3 zone fare i.e. it costs the same to travel from Karori to the CBD as it does to travel from Karori to Lyall Bay.

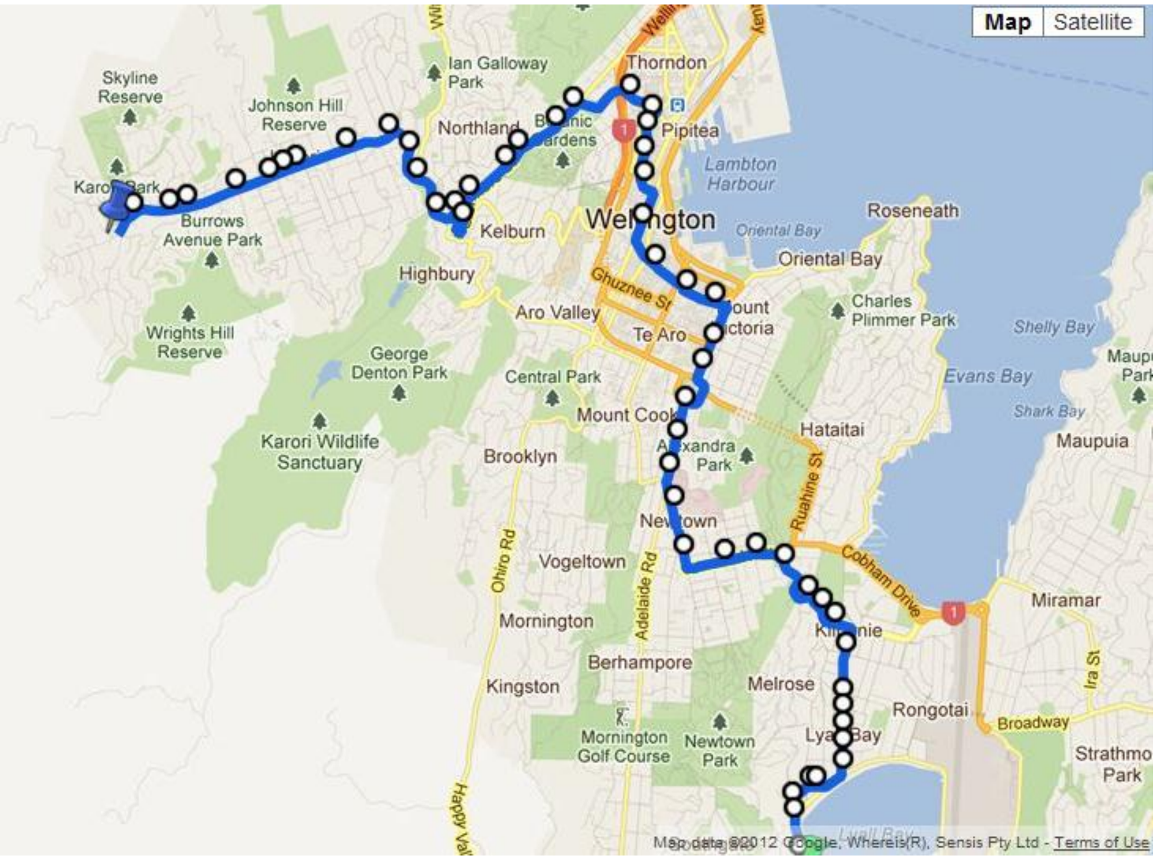


Figure 6-8: Route 3 Schematic

There are two possible approaches for dealing with this issue:

- Implement the methodology as outlined in Section 6.7, quantifying the percentage of trips (from the ETM data) that can be classified as through trips and will thus have to be dealt with separately external to the WPTM if, for example, total fare revenues were to be extracted from the model (Fare Approach 1); and
- Implement a modified fare structure, whereby only the difference in fares between modes is required, using the bus fare as the 'base fare' (Approach 2). For example, if the bus and rail flagfall fares were $1.00 and $2.00 respectively and the additional fare for each boundary crossed were $0.40 for bus and $0.60 for rail, then the modified rail fare would be $1.00 flagfall and $0.20 per boundary crossing. This enables the influence of fare on the rail vs. bus choice to be captured.

6.8.1 Analysis for Fare Approach 1

Figure 6-9 below shows the area within which the majority of Go Wellington services operate, together with a rough indication of the fare-zone boundaries. In order to quantify the number of 'through' trips using the network, the area was split into 6 sectors as follows:

- Sector Z: CBD (Fare-zone 1);
- Sector B: Johnsonville area;
- Sector C: Karori area;
- Sector D: Island Bay / Southern Suburbs area;
- Sector E: Miramar; and
- Rest of region.

Apart from trips between Miramar (E) and Kilbirnie (D) that have been discounted from this analysis and not classified as through trips, any trips between other sectors should require travel through the CBD. Therefore this sector system will enable these trips to be isolated.

'Snapper' data, the most accurate subset of data from the ETM records, was extracted for all routes operated by Go Wellington and processed according to the sector system detailed above to determine the number of through trips as a percentage of the total number of trips.

As can be seen from Table 6-18, less than 1% of trips in the AM peak can be considered 'through' trips. Of those through trips, the majority come from Johnsonville and Karori.

Table 6-18: AM Peak Through Trips

	Thru	Non-Thru	Thru %
Trips	3,620	405,212	0.89%
From CBD (Z)		84,571	0.00%
From Johnsonville Area (B)	1,765	24,021	6.84%
From Karori Area (C)	1,215	63,744	1.87%
From Island Bay / Southern Suburbs (D)	566	131,057	0.43%
From Miramar (E)	74	34,660	0.21%
From Rest of Region		67,159	0

Table 6-19: Inter Peak Through Trips

	Thru	Non-Thru	Thru %
Trips	4,920	272,549	1.77%
From CBD (Z)	-	140,565	0.00%
From Johnsonville Area (B)	1,689	3,751	31.05%
From Karori Area (C)	2,324	23,503	9.00%
From Island Bay / Southern Suburbs (D)	849	49,369	1.69%
From Miramar (E)	59	8,739	0.66%
From Rest of Region	-	46,623	0

Looking at

Table 6-19, the number of through trips as a percentage of total trips is slightly higher in the Inter peak at 2%. Over 30% of Go Wellington trips associated with the Johnsonville sector are designated through trips, with 9% of trips associated with Karori also being categorised as through trips.

More detailed analysis of the ETM data shows that, reassuringly, most through trips are undertaken on the following through services:

- Route 3 – Karori to Lyall Bay;
- Route 18 – Campus Connection;
- Route 21 – Wrights Hill to Vogeltown;
- Route 22 – Mairangi to Southgate / Houghton Bay;
- Route 23 – Mairangi to Southgate / Houghton Bay;
- Route 43 – Khandallah to Strathmore; and
- Route 44 – Khandallah to Strathmore.

The large number of apparent through trips between Johnsonville and Karori (and vice versa) is due to people taking Service 47 (Newtown to Johnsonville) which does travel between these two areas whilst largely avoiding Wellington CBD. Therefore if these trips were removed, the actual number of true through trips would be even lower.

Therefore from this piece of analysis we can conclude that the number of through trips using the Go Wellington network is very small, such that if the fare structure proposed in Section 6.7 were to be implemented in WPTM the number of trips for which the fare would be incorrectly calculated would be very low and as a consequence could not be categorised as a deficiency of the model.

However in future, there may be growth in cross-city trips as PT serves to major trip attractors on the fringes such as the Hospital and Victoria University continue to develop. Hence, a fare methodology with greater flexibility in accounting for this possibility would be preferred.

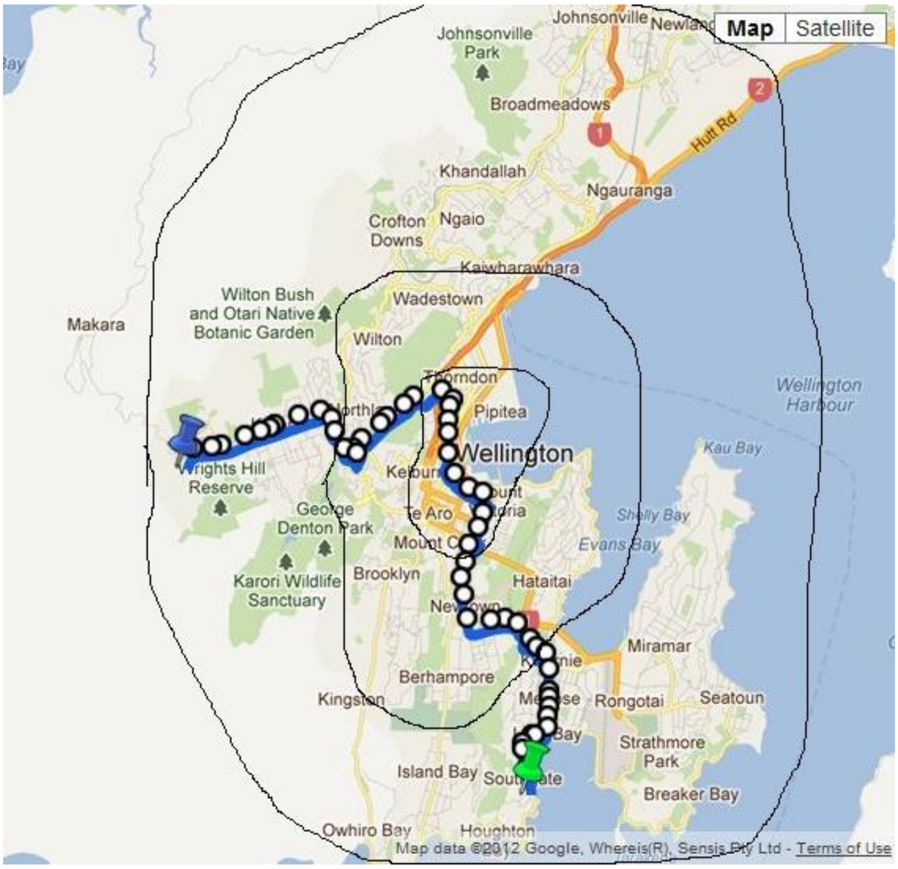


Figure 6-9: Fare-Zones 1 to 3

6.8.2 Analysis for Fare Approach 2

The second method that is proposed for taking account of through trips involves implementing a modified fare structure, with each fare component expressed in one of two possible ways as shown under the sub-headings below. In order to implement these methods, some slight revisions have been made to both the flagfall and boundary crossing elements of the fares, mainly to ensure that the bus crossing charge component is lower than the rail and airport flyer crossing charges components for each user class.

<u>Method 2A</u>

- bus flagfall = bus flagfall minus minimum flagfall (= 0 by design);
- bus boundary crossing charge = bus boundary crossing charge minus minimum boundary crossing charge (= 0 by design);
- airbus flagfall = airbus flagfall minus minimum flagfall;
- airbus boundary crossing charge = airbus boundary crossing charge minus minimum boundary crossing charge;
- rail flagfall = rail flagfall minus minimum flagfall; and
- rail boundary crossing charge = rail boundary crossing charge minus minimum boundary crossing charge.

<u>Method 2B</u>

- bus flagfall = bus flagfall;
- bus boundary crossing charge = bus boundary crossing charge minus minimum boundary crossing charge (= 0 by design);
- airbus flagfall = airbus flagfall;
- airbus boundary crossing charge = airbus boundary crossing charge minus minimum boundary crossing charge;
- rail flagfall = rail flagfall; and
- rail boundary crossing charge = rail boundary crossing charge minus minimum boundary crossing charge.

Whilst the modified rail fare structure shown in Method 2A and Method 2B above is not required to solve the issue relating to through trips (unless a situation would arise where cross-city rail services would be implemented), the rail fare structure must follow that for all other modes as the fare costs are seen as relative differences between modes.

6.8.3 Summary

A summary of the fare flagfall and crossing values for the different proposed approaches is given in Table 6-20 below and shows the following:

- Previous fare (from Section 6.7);
- Modified fare (re-based to ensure that the bus crossing charge component is lower than the rail and airport flyer crossing charges components for each user class);
- Method 2A (preferred); and
- Method 2B.

It can be seen that the changes between the previous fare flagfall and boundary crossing values are small and will not materially affect the fare relationships.

Table 6-20: Summary of Fare Structure

	Previous Flagfall	Previous Boundary	Modified Flagfall	Modified Boundary	Flagfall 2A	Boundary 2A	Flagfall 2B	Boundary 2B
AM Adult								
Bus	1.89	0.75	1.89	0.75	-	-	1.89	-
Flyer	5.29	0.66	5.04	0.75	3.15	-	5.04	-
Rail	1.89	0.75	1.89	0.75	-	0.01	1.89	0.01
IP Adult								
Bus	1.57	0.44	1.57	0.44	-	-	1.57	-
Flyer	4.39	0.33	4.07	0.44	2.50	-	4.07	-
Rail	1.96	0.56	1.96	0.56	0.39	0.13	1.96	0.13
AM Child								
Bus	1.28	0.37	1.28	0.37	0.28	-	1.28	-
Flyer	2.94	0.44	3.12	0.37	2.13	-	3.12	-
Rail	1.28	0.28	0.99	0.37	-	-	0.99	-
IP Child								
Bus	1.29	0.38	1.29	0.38	0.39	-	1.29	-
Flyer	2.97	0.44	3.16	0.38	2.26	-	3.16	-
Rail	1.29	0.25	0.90	0.38	-	-	0.90	-
AM Combined								
AM Bus	1.68	0.67	1.68	0.67	-	-	1.68	-
Am Flyer	5.13	0.57	4.81	0.67	3.13	-	4.81	-
Am Rail	1.86	0.75	1.86	0.75	0.18	0.08	1.86	0.08
IP Combined								
AM Bus	1.54	0.44	1.54	0.44	-	-	1.54	-
Am Flyer	4.36	0.23	3.74	0.44	2.21	-	3.74	-
Am Rail	1.96	0.55	1.96	0.55	0.42	0.11	1.96	0.11

In terms of modelling fares in WPTM, EMME is not so much concerned with absolute fares but the difference in fare between competing modes and hence the relative attractiveness of the various modes.

Using this modified method the through trips would not be an issue (as the standard bus boundary crossing charge could be zero) yet the difference in attractiveness between modes would be captured.

A potential limitation of this approach is that it is unclear what impact zero bus fares might have on people's decision to potentially walk further to the next fare-zone to catch a cheaper / quicker / more frequent bus (as opposed to getting on at the nearest stop to their initial origin) or potentially walk to their final destination as opposed to taking the bus.

Boarding and transfer penalties, roughly equivalent to the perceived (monetary and time based) cost of boarding and transferring between services, would be calibrated and applied in order to achieve the required level of validation. The advantage of this method, however, is that transfer penalties could be modified or removed should integrated ticketing be tested using WPTM in the future.

6.9 Chosen Approach

Sections 6.8.1 and 6.8.2 have described two approaches to modelling fares in WPTM that would deal with 'through trips' within the model.

The first approach (Section 6.8.1) showed that maintaining the fare methodology described in Section 6.7 would be acceptable in the base years as the number of through trips is very low. Hence, dealing with the through trips external to the WPTM (or in this case not accounting for them at all) would be not be an issue as the differences would be immaterial.

However in future, there may be growth in cross-city trips as PT serves to major trip attractors on the fringes such as the Hospital and Victoria University continue to develop. For this reason, two possible to account for the through trips in Emme were considered in Section 6.8.2. Following initial testing of Method 2A and 2B in Emme, it was decided that **Method 2A** should be implemented.

6.10 Compatibility with Future Year Schemes

It is important that any fare system can be accurately modified in the future to account for any or all of the following:

- Fare increases – both across the board and specific to certain ticket types;
- The removal of certain ticket types;
- Changes to the number of fare zones or fare-zone boundaries;
- The implementation of an integrated public transport ticketing system; and
- The introduction of a new modes and associated updated fare structure.

The ability of the proposed fare system to deal with these interventions is dealt with in this section.

Fare Increases

The relative difference in fares would need to be recalculated only if the fare changes varied by operator. Otherwise WTSM would deal with fare increases, resulting in a different PT mode share dependent on whether the fare increases were greater than any change in vehicle operating costs.

Different Ticket Products

Average fares would be recalculated by mode should ticket products be withdrawn (or introduced), differences between bus and rail fares would be updated and the fare structure updated accordingly.

Changes to Fare-Zone Boundaries

The fare relationships would remain unchanged as it would be too onerous to go back and update these from first principles to take account of fare-zone boundary changes. The boundary crossing points would be modified and the model would be run. The actual fare (as opposed to modelled fare) could be calculated and revenues compared against revenue from the existing fare system.

Integrated Ticketing

An integrated ticketing system is proposed for Greater Wellington region in the medium term and is likely to be one of the schemes tested with the new model. The ability to successfully model and quantify the impact of integrated ticketing has challenged public transport modellers all across the world. Using **Method 2A** as outlined above, integrated ticketing could be modelled by using a proxy method of removing any transfer penalties or boarding penalties for a second boarding. Precise fare revenues could be calculated using a more complex method, assigning different fares depending on whether a trip is the first, second or subsequent leg of a PT journey. Alternatively, and more accurately, free transfers can be allowed through minor alterations to the network coding at key bus stops where interchanging is expected to be focused.

New Modes

New modes can be modelled provided a fare structure is known and can be linked (relatively) to the existing fare structure. Whilst outside of the scope of this analysis on fares, IVT coefficients, boarding penalties and transfer penalties for any new mode would have to be estimated in order to provide meaningful and robust patronage forecast.

7 WPTM Preparation

7.1 WPTM Network Details

This section documents the edits / modifications undertaken on the base WTSM network to make the network better suit the requirements of the WPTM.

Where necessary, to ensure consistency between WTSM and WPTM, changes made in the latter have been fed back into WTSM. Where this is the case, automated procedures (macros) have been set up to undertake the transfer of information. The node numbering and extra attributes have been described below:

- **Node / Zone Numbering**: There are no differences in the node numbers between the WTSM and WPTM networks. Zone numbers however are different as there are a greater number of zones in WPTM than in WTSM. Zone centroids are numbered between 1 and 1000, the additional WPTM centroid numbers following on from the WTSM numbers.
- **Extra attributes**: To facilitate easier calculations and data processing along with detailed PT assignment procedures in WPTM, additional attributes have been added to the network. The additional attributes are listed Table 7-1 below. Further details on the extra attributes are given in the following sub-sections.

Table 7-1: Additional Attributes in WPTM Model

Short Name	Long Name	Type
General network and data attributes		
@timau	Auto time from WTSM assignment	Link
@ntype	Node type	Node
@fzone	Fare-zone	Link
@fzbdy	Fare-zone boundary number	Link
@fzbdx	Fare-zone boundary tag	Link
@wtvdf	WTSM volume-delay function number	Link
@vc	WTSM volume-capacity ratio	Link
Assignment specific attributes		
@hdwy	Effective headway	Transit Line
@nbt	Node boarding times	Node
@lbt	Line boarding times	Transit Line
@ivtf	In-vehicle time perception factor	Transit Line
@brdpf	Boarding costs (fare flagfall)	Transit Line

- **@timau**: This attribute is used to store the auto time values from the WTSM assignment.
- **@ntype**: The node type is defined to enable ease of selection of various types of nodes which will assist in EMME processes. The node number types are designated as shown in Table 7-2 below.

Table 7-2: Node Type Definition

Node Type Number	Node Type
1	Regular node
2	Rail platform node
3	Bus stop node
4	Ferry stop node
5	Cable car stop node
9	Centroid/zone

- **@fzone**: This attribute contains the value of the fare-zone that the model link is within as based on the GWRC's fare-zone boundary definition. It is applied to all links in the network with the exception of zone connectors. Where the link is on a zone crossing, the zone number in which the i-node is located in is given. This attribute is primarily used to constrain network calculations to particular fare-zones e.g. inside the CBD (@fzone=0,1) or outside of the CBD (@fzone>=2) . Values of @fzone range from 0 to 14.
- **@fzbdy**: This is similar to @fzone but is only coded on the links actually crossing the fare-zone boundaries. If a link crosses multiple fare-zone boundaries, the highest fare-zone is taken as the @fzbdy value. It is primarily used in the calculation of incremental fare-zone crossing component of fare costs. Values of @fzbdy range from 1 to 14.
- **@fzbdx**: The @fzbdx is similar to @fzbdy in that it is only coded in the links actually crossing the fare-zone boundaries, but, rather than coding the fare-zone, the value assigned to @fzbdx is the number of fare-zones a given link crosses. This attribute is also primarily for the calculation of the incremental fare-zone crossing component of fare costs but is needed to account for long links in the network that cross multiple fare boundaries.
- **@wtvdf**: This attribute is used to store the volume-delay function values from the WTSM and is used to differentiate the calculation of bus times on links approaching a junction with or without delay. Possible values of @wtvdf is either 16 (no delay at junction) or 26 (additional junction delay).
- **@vc**: This attribute is used to store the calculated volume-capacity ratio based on values from the WTSM assignment. The calculation used is as follows:

  @vc = (@cars+@hcv)/(2*@q*lanes)

  Where:

@cars	= number of cars on the network link
@hcv	= number of heavy commercial vehicles on network link
@q	= theoretical capacity of the network link in vehicles / hour / lane

- **@hdwy, @nbt, @lbt, @ivtf, @brdpf**: These attributes are all included in the WPTM as they are all required for storing of public transport assignment parameters.

7.2 WPTM Zone Connections

To maintain consistency between the two models, where there is a 1:1 correspondence between WTSM and WPTM zones the connection of the model zones to the surrounding road network has been kept the same in both models. Generally this is not the case as WPTM has a much greater refinement in its zone system which subdivides the WTSM zones. Where there are additional WPTM zones, the zones have been connected to reasonable access points on the surrounding network.

7.3 Rail Station Zone / Node Connections

Greater detail is required around rail station nodes in WPTM than in WTSM due to the processes developed for the mode access choice model. As the choice model uses some elements of WTSM cost skims (or the WTSM loaded network link travel times to specific network points), the network detail around rail station nodes also needed to be coded in WTSM.

Figure 7-1 below shows an example of the level of detail and the coding required for a typical rail station. The figure shows the WPTM network superimposed on an aerial photo, with the network link colours representing the following:

- Grey = general road network links
- Red = P&R/K&R access links
- Yellow = rail line
- Green = walk access links

The key node numbers to note in this example are node 30012 (station platform node), node 30112 (station entrance node) and node 30212 (station zone).

The link between the station entrance node and the station platform has been added so that summaries of total flows to and from the station can be easily extracted from the network links. This is done by producing plots of transit and auxiliary transit volumes.

WPTM is an access choice mode; public transport users can choose to use park and ride sites during trip assignment, therefore the WPTM network doesn't require P-connectors. Refer to TN9 for further details.

Figure 7-1: Example of Network Connections at Rail Stations (Waterloo Station)

7.4 Transit Line Consolidation

In analysing the transit lines a number of service variants were identified which are only one or two stops different from each other but under the same service number. This is the case where, say, service 81 carries onto Wellington College once in the morning peak, when otherwise this service would turn around. To simplify analysis of the results it was decided that these minor route variants should be combined with the main service route. It should be noted that this consolidation had no effect on the actual public transport patronage modelled, who see total headways in the model assignment and not individual services.

Initially the approach was to incorporate this feature into the GTFS converter procedures as described in Section 4. However, determining how the converter will choose which route to maintain proved complex, so this consolidation became a manual exercise. Figure 7-2 below illustrates the amount of variation in individual services. For example, before consolidation 32 services had 4 variants and after the consolidation only 20 services had 4 variants. Some variant ranges can be seen to have increased, this is due to reductions in the higher variant ranges. For example, the reduction in the number of services with 4 variants has caused the number of services with 2 variants to increase.

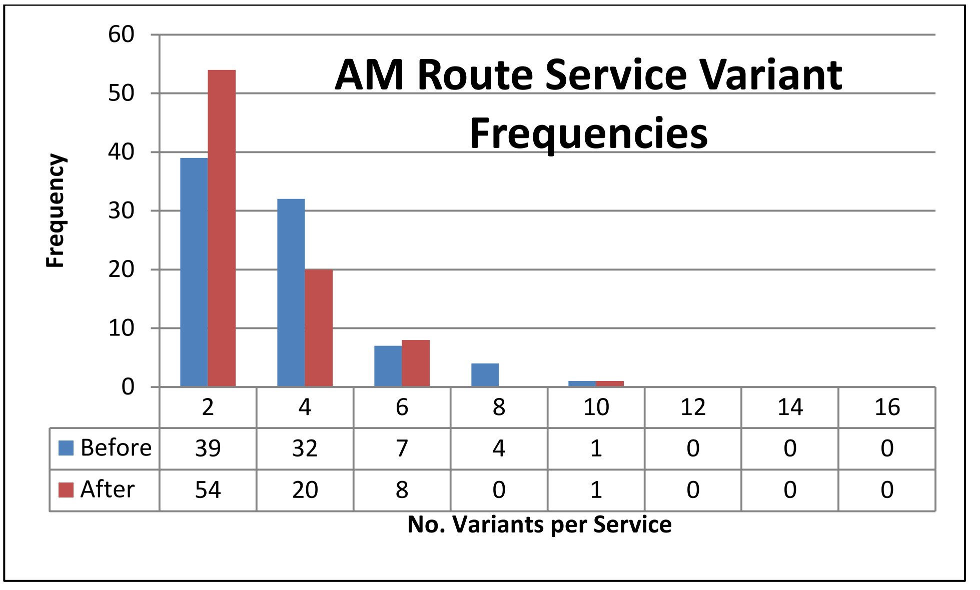


Figure 7-2: Route Service Variants

8 Previous Model Comparison

8.1 Summary Statistics

This section builds on earlier network comparisons between 2006 and 2011 WTSM models. Table 8-1 below summarises the model characteristics and shows the extensive changes made in the update of WTSM and the development of the WPTM.

The number of links and nodes in the model has greatly increased as a result of the update. This is due to the vast amount of network detail now included in the model. Likewise the increase in highway link length and number of intersections is due to the additional network detail.

The increase in the number of bus stops is due to the fact that the model now includes every bus stop in the Wellington region, as per the Wellington GTFS, whereas previously bus stops where approximated.

The greater level of transit line detail has led to an increase in the total length of PT routes as well as an increase in the number of bus services. Interestingly the number of rail services has decreased; this is likely to be due to the transit line service consolidation being carried out.

The number of zones remains unchanged between the 2006 and 2011 WTSM models; the number of WPTM zones however is greater as the WPTM zone structure is finer than those in WTSM.

Table 8-1: Network Comparison

	2006 WTSM	2011 WTSM / WPTM
Number of links	4,897	13,749
Number of nodes	1,792	5,714
Number of bus stop nodes	1,059	2,895
Number of train station nodes	49	50
Total number of zones	228*	228* / 780
Total length of highway links	3,138	5,227
Total length of railway links	377	393
Total length of PT routes	7,874	11,884
Total number of bus services	415	619
Total number of rail services	68	63
Number of intersections	405	1,259

* made up of 3 external zones and 225 internal zones

9 Conclusion

To summarise, the 2011 update has resulted in a much better definition and representation of the Wellington regional network and public transport services.

Network coding has largely followed guidance and parameters as set out in the 2006 model user manual with the following improvements having been introduced:

- **Zone system –** The WPTM model contains 780 zones, an increase over those allowed for in WTSM;
- **Network and transit line detail –** Increased detail has been included as part of this update; and
- **Extra link types and retired modes –** Extra link types have been included to account for the increased network detail now in the models. Unused vehicle modes have also been removed.

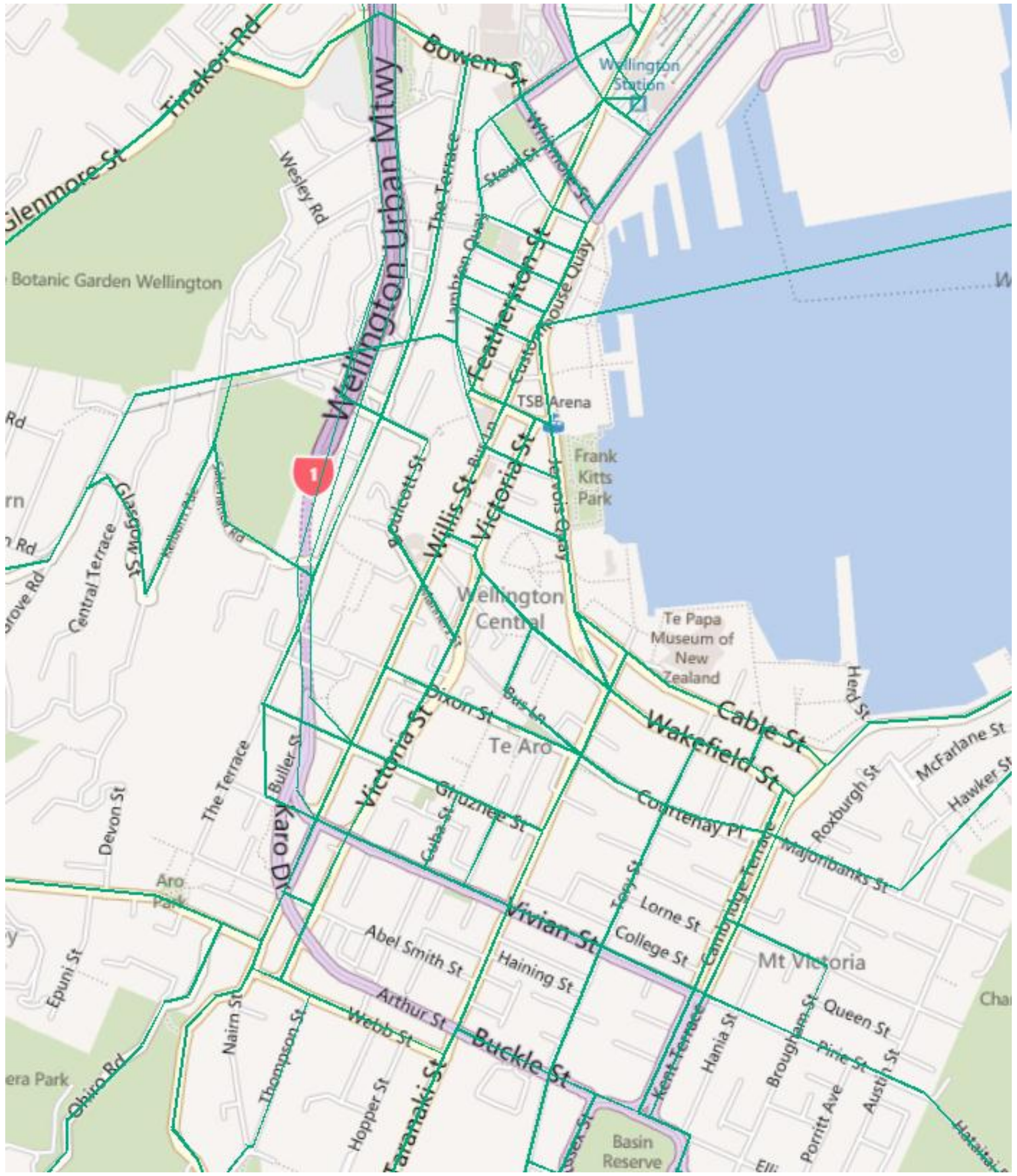
Having consistency between the WTSM and WPTM network helps to reduce the amount of dual coding work while the extra model detail helps GWRC modellers make best use of the Electronic Ticketing Machine (ETM) data i.e. the ETM data contains information by transit stop ID enabling observed records to be tied directly to nodes in the model network (whereas previously this relationship was a crude approximation).

Therefore it can be said with confidence that:

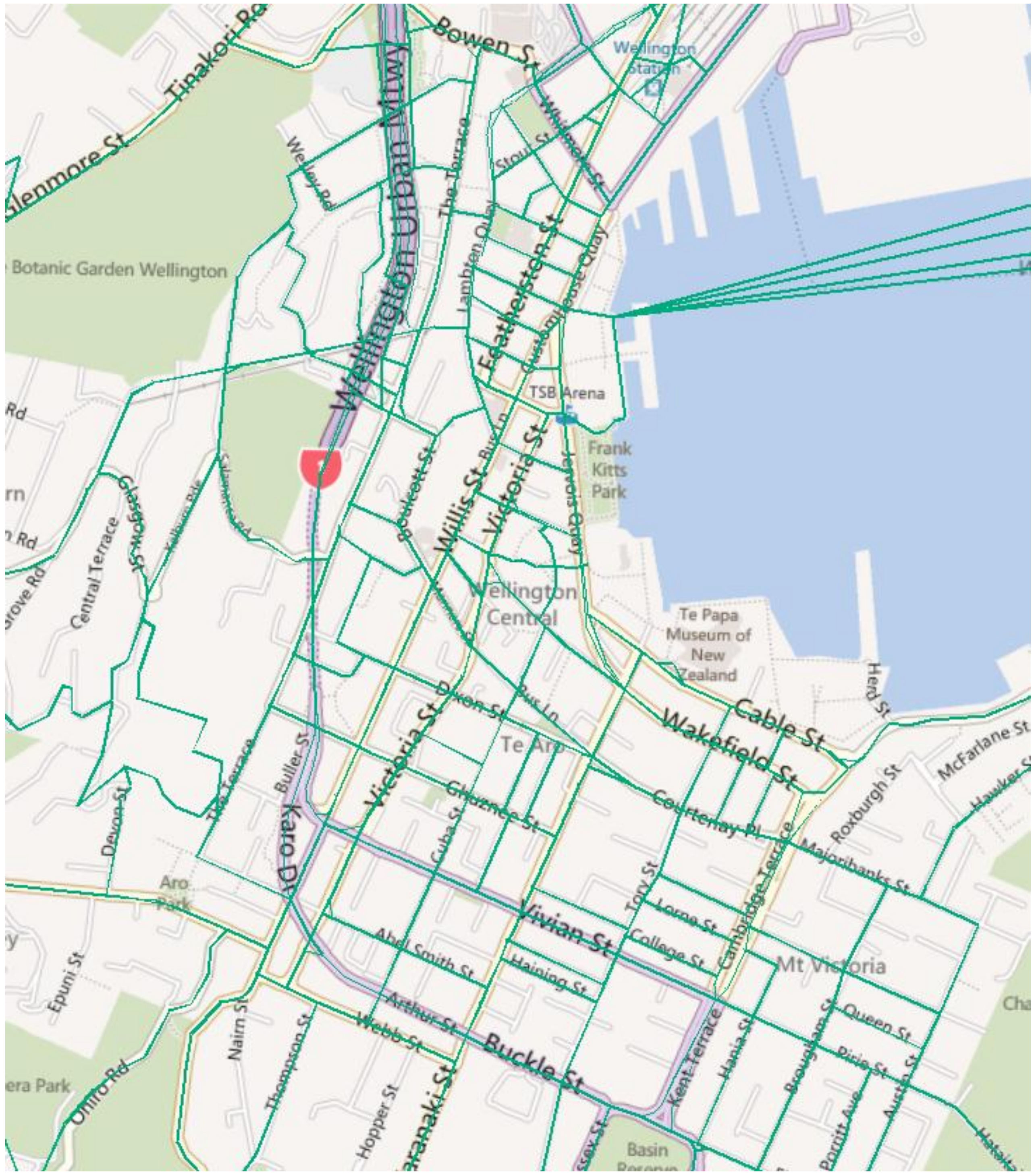
> The combination of the increase in network detail, service detail, and zone detail has moved the public transport model from one that can be used to help make strategic or policy decisions to one that can be used to help make *operational* and *management* decisions concerning the Wellington public transport services and infrastructure.

The success of the statement above will be shown in outcomes from not only the model validation technical notes (TN18 and TN19) but documentation of the sensitivity tests (TN22) and forecasts (TN20) which document more completely the full range of functionality the enhanced networks and services offer GWRC analysts.

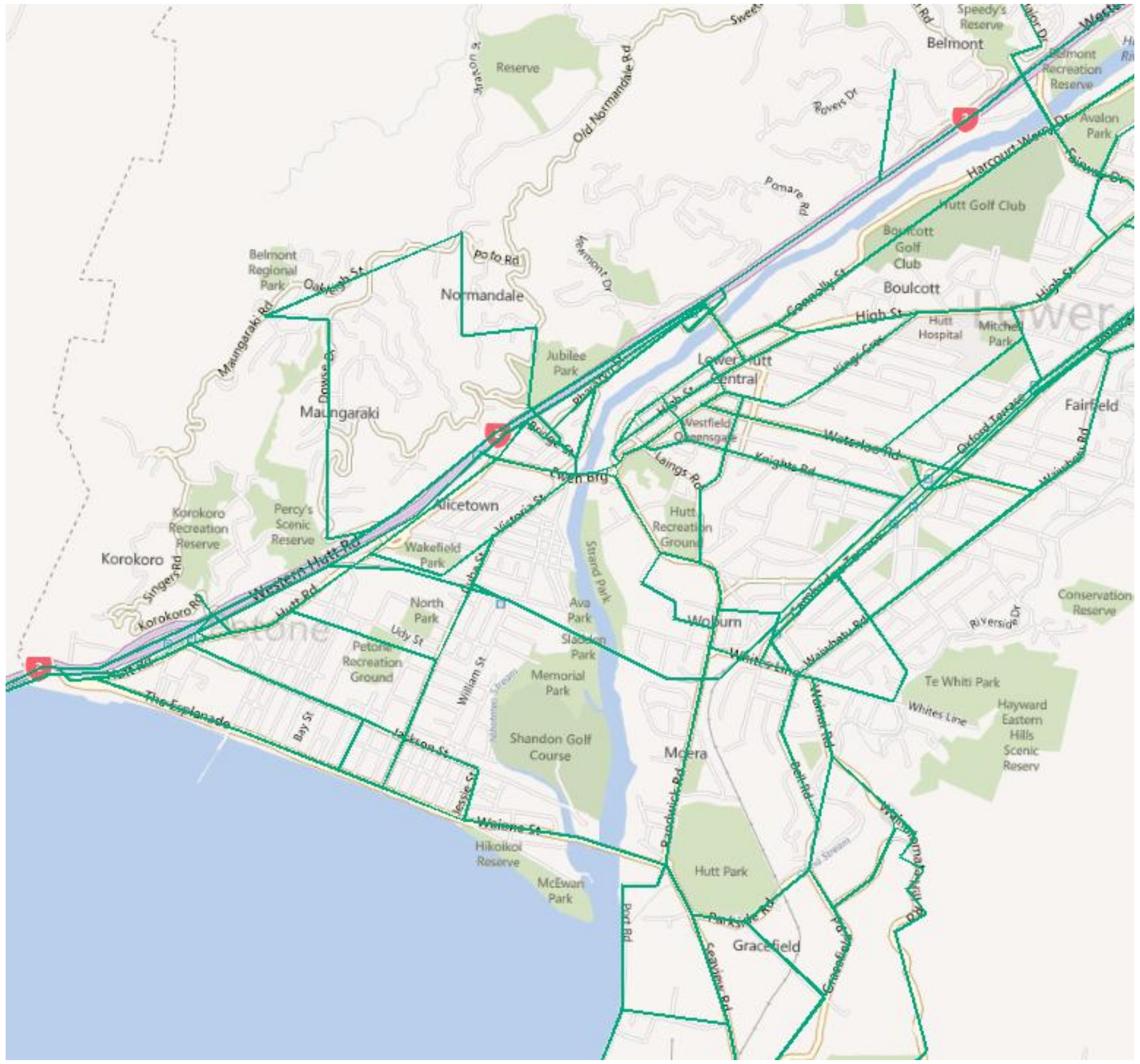
APPENDIX A – Comparison Plots of WTSM 2006 and 2011



2006 Model Wellington CBD

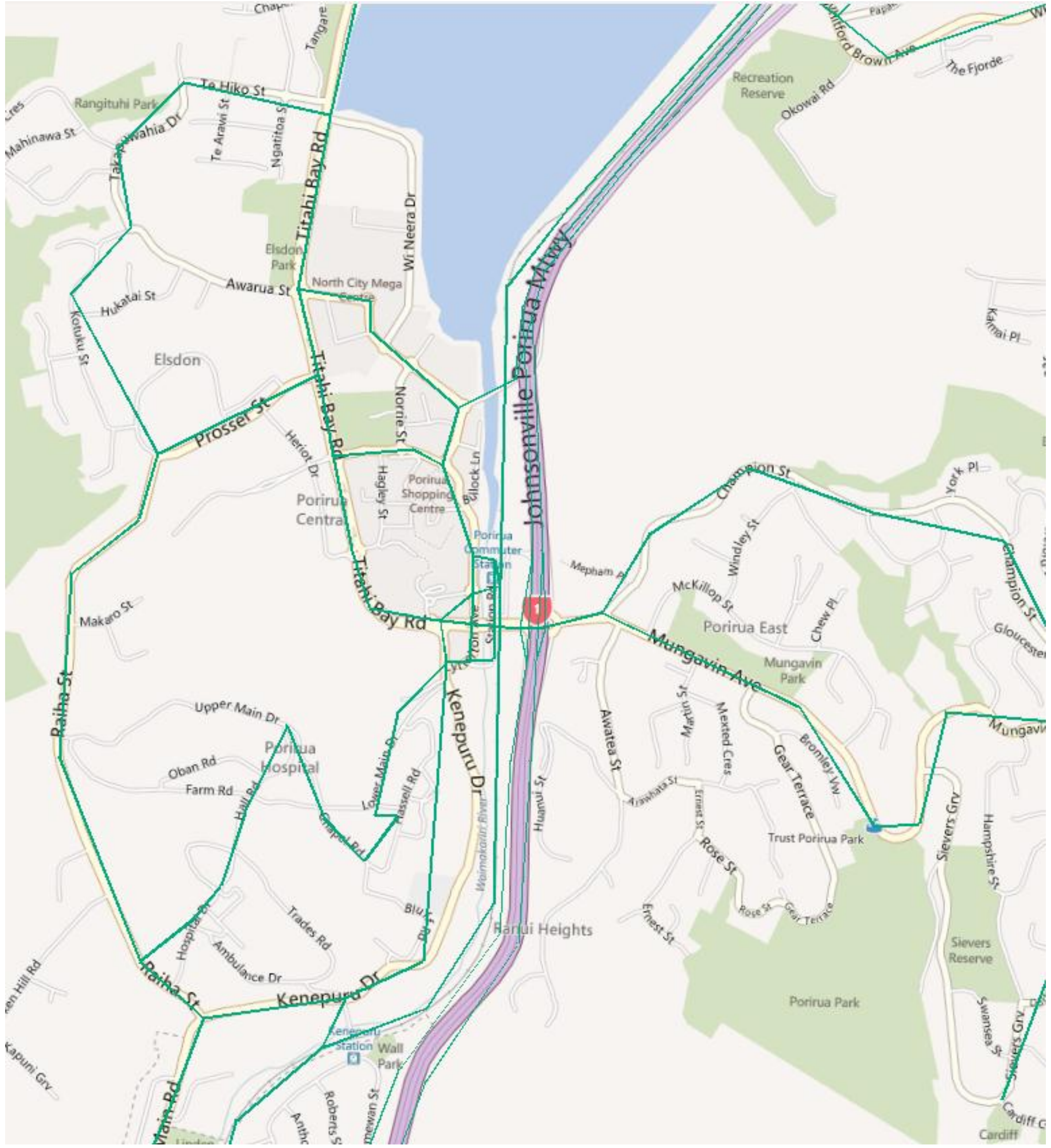


2011 Model Wellington CBD



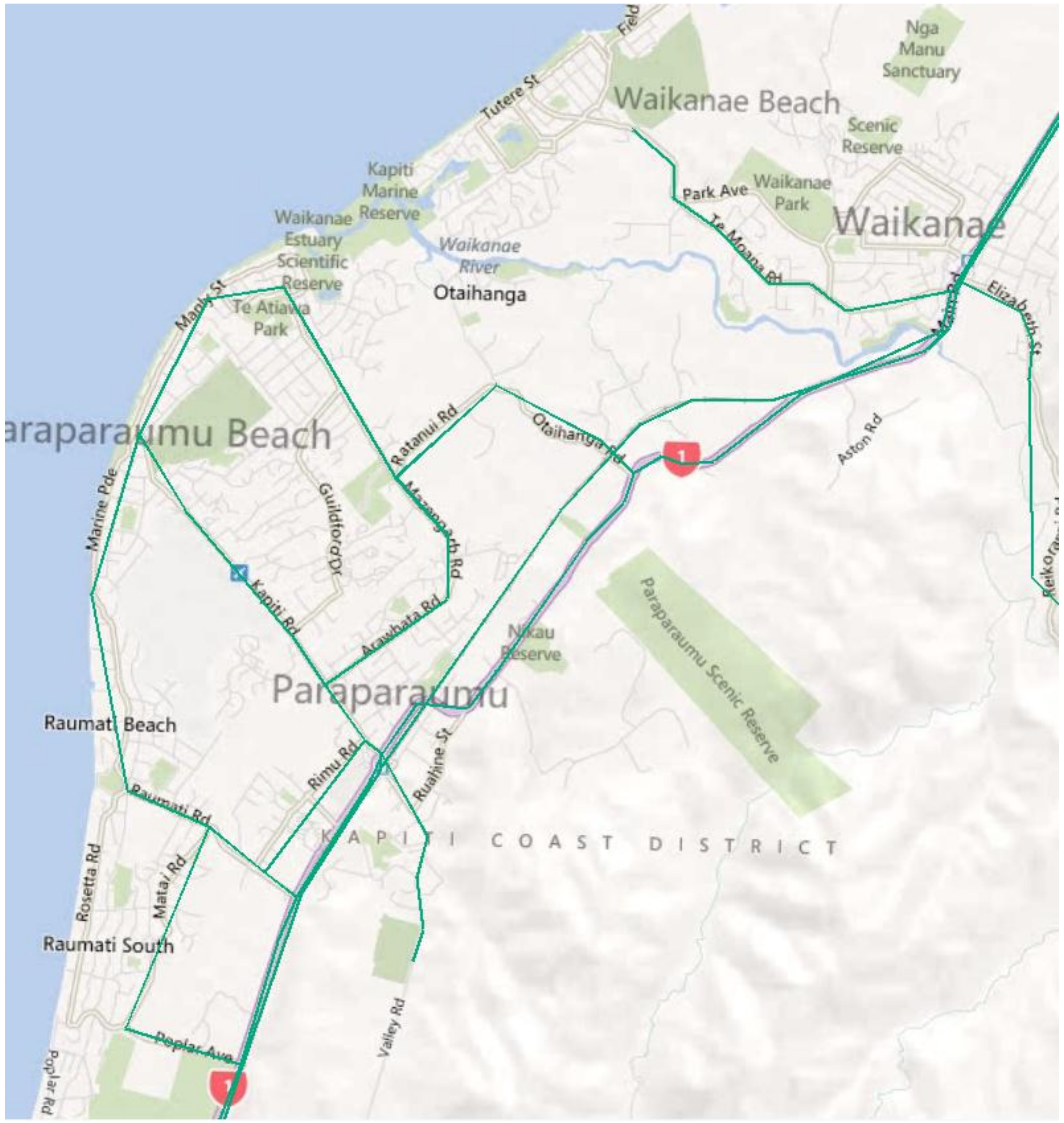
2006 Model Lower Hutt District

2011 Model Lower Hutt District

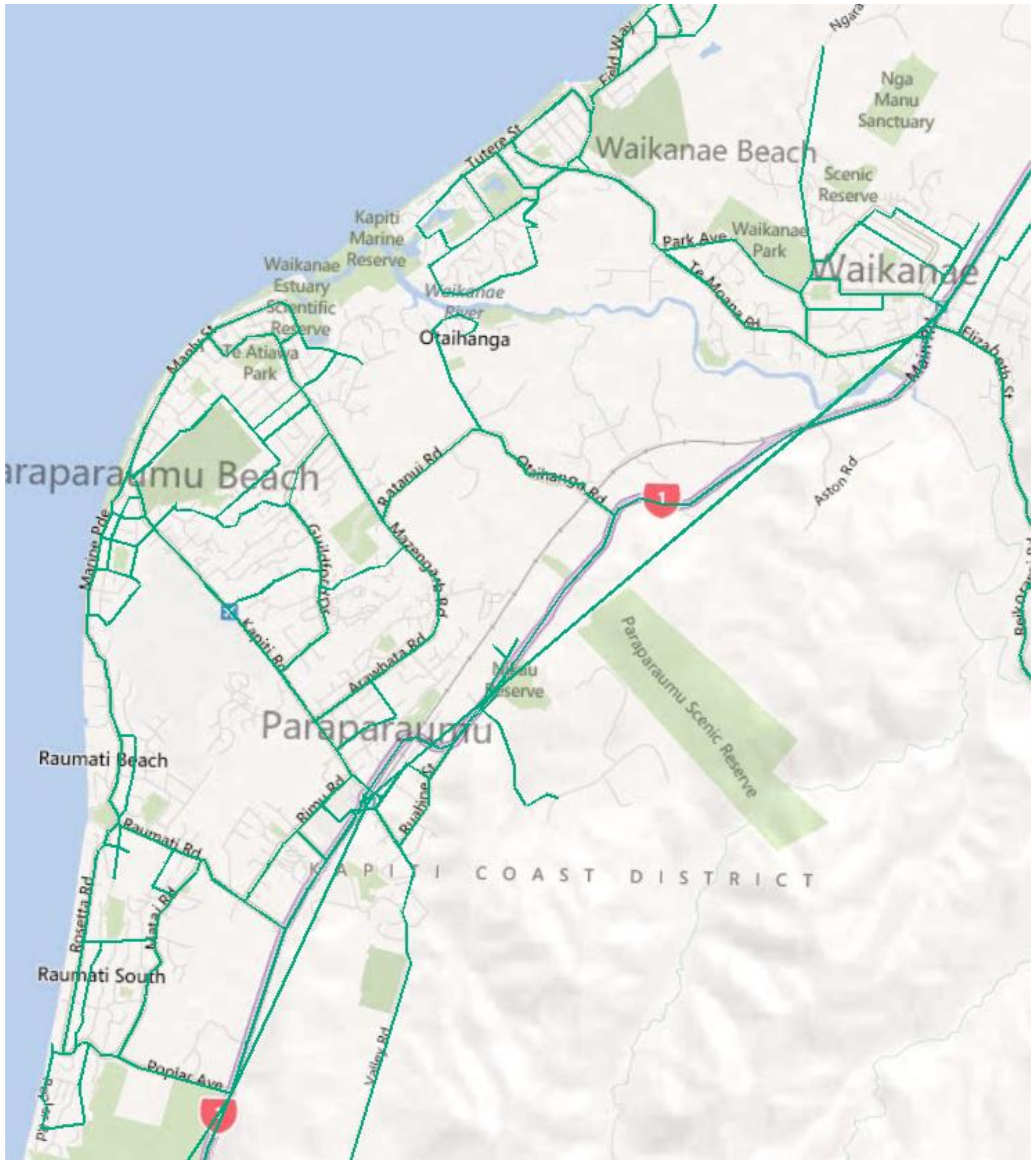


2006 Model Porirua City

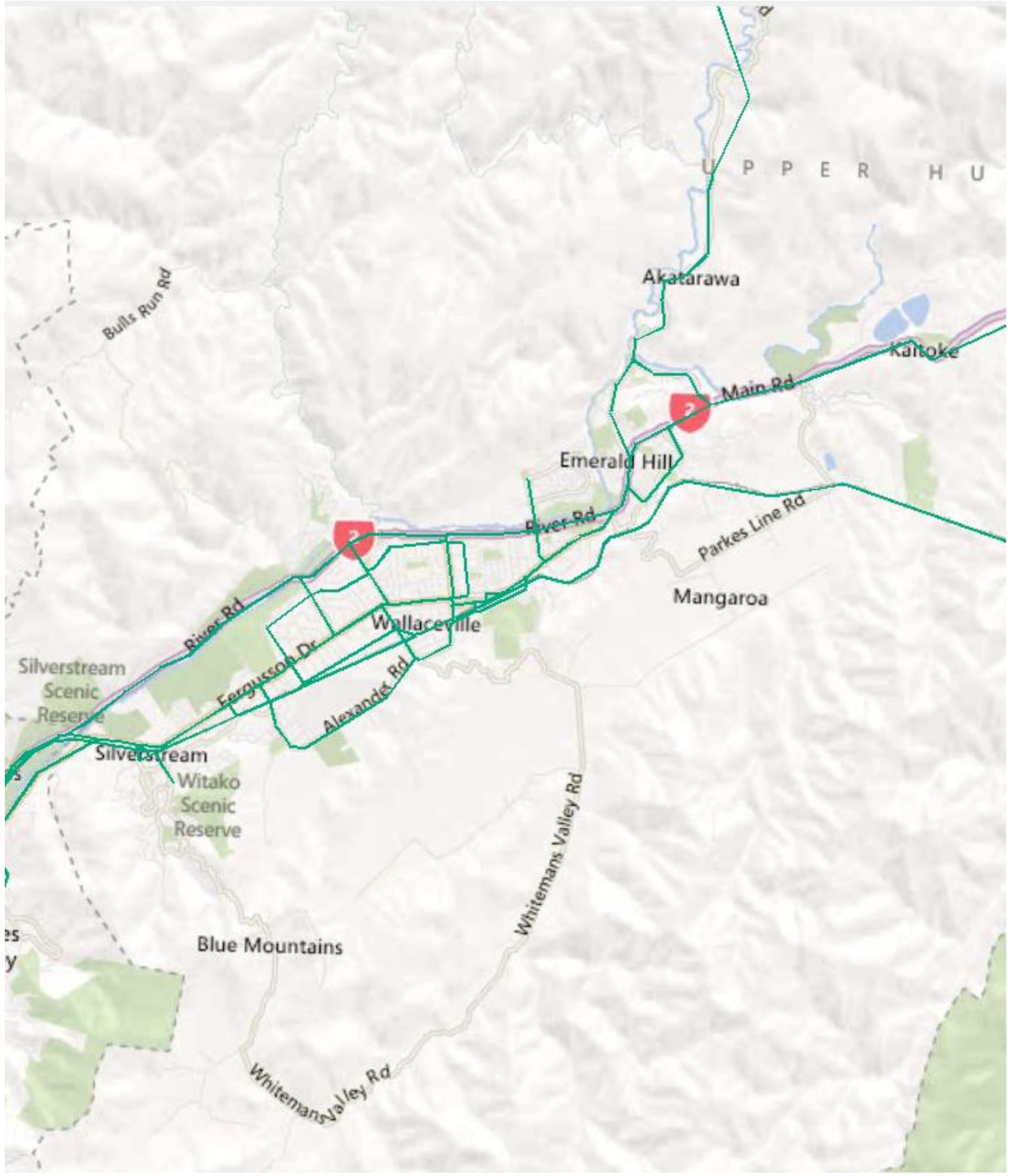
2011 Model Porirua City



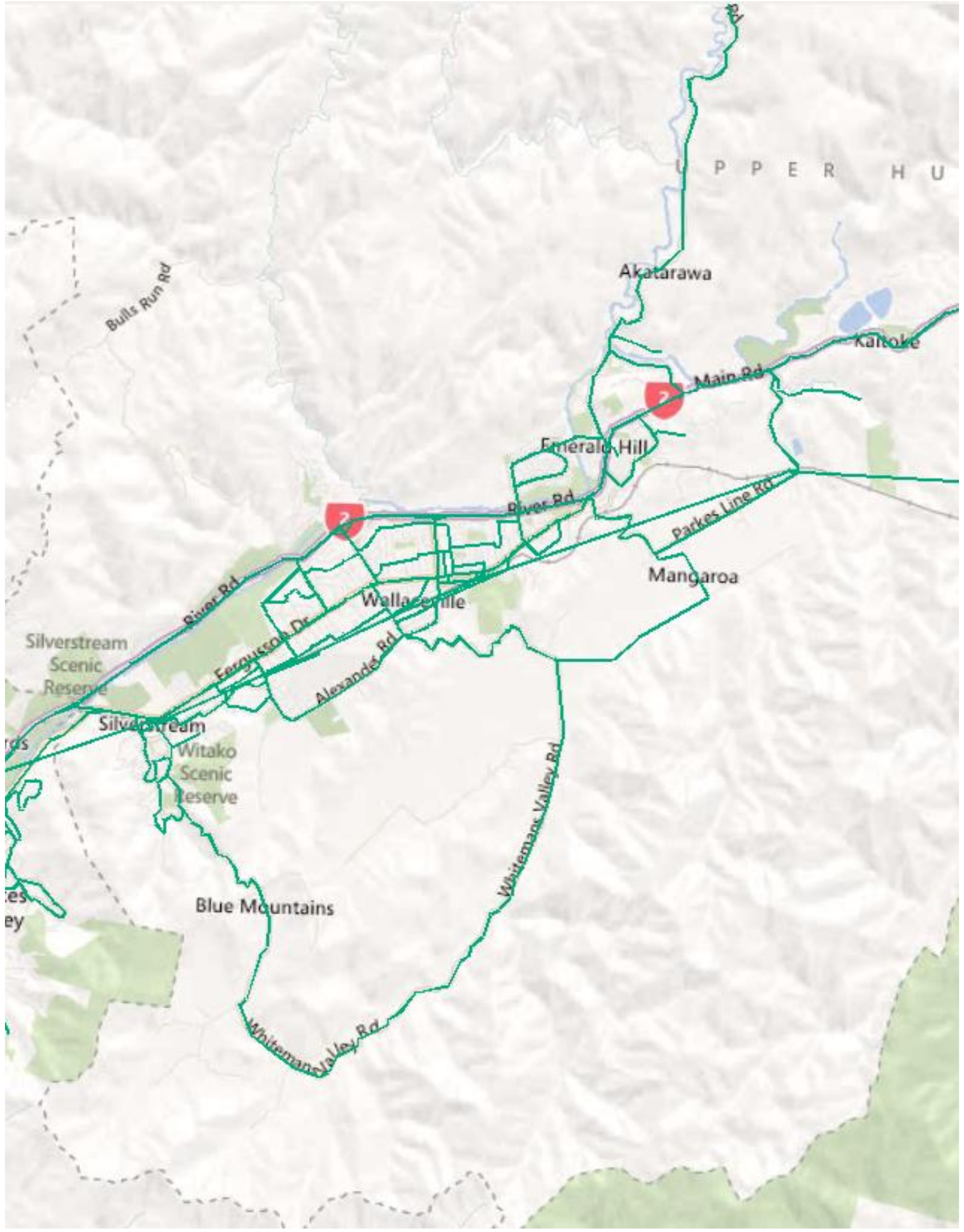
2006 Model Kapiti Coast District



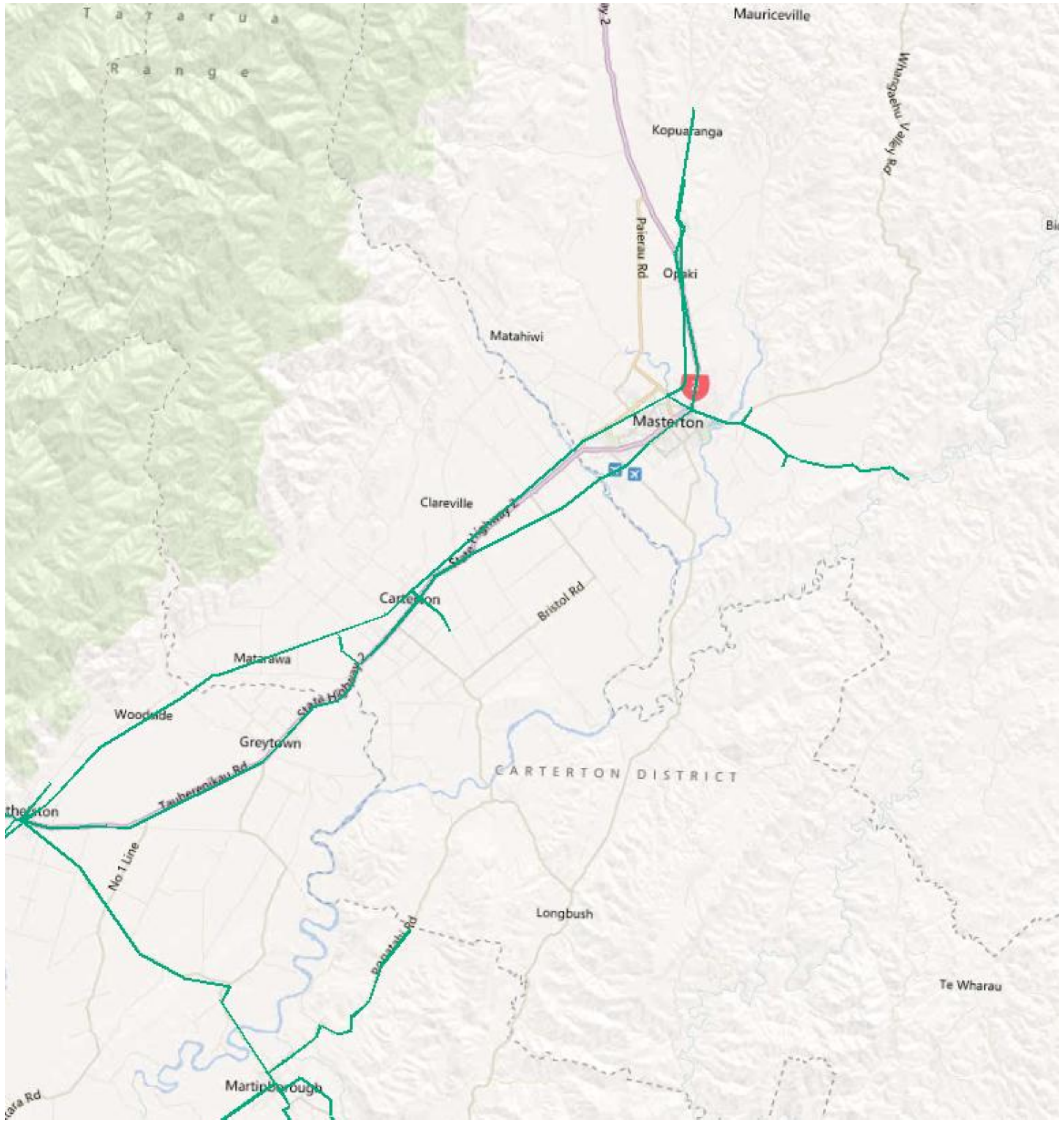
2011 Model Kapiti Coast District



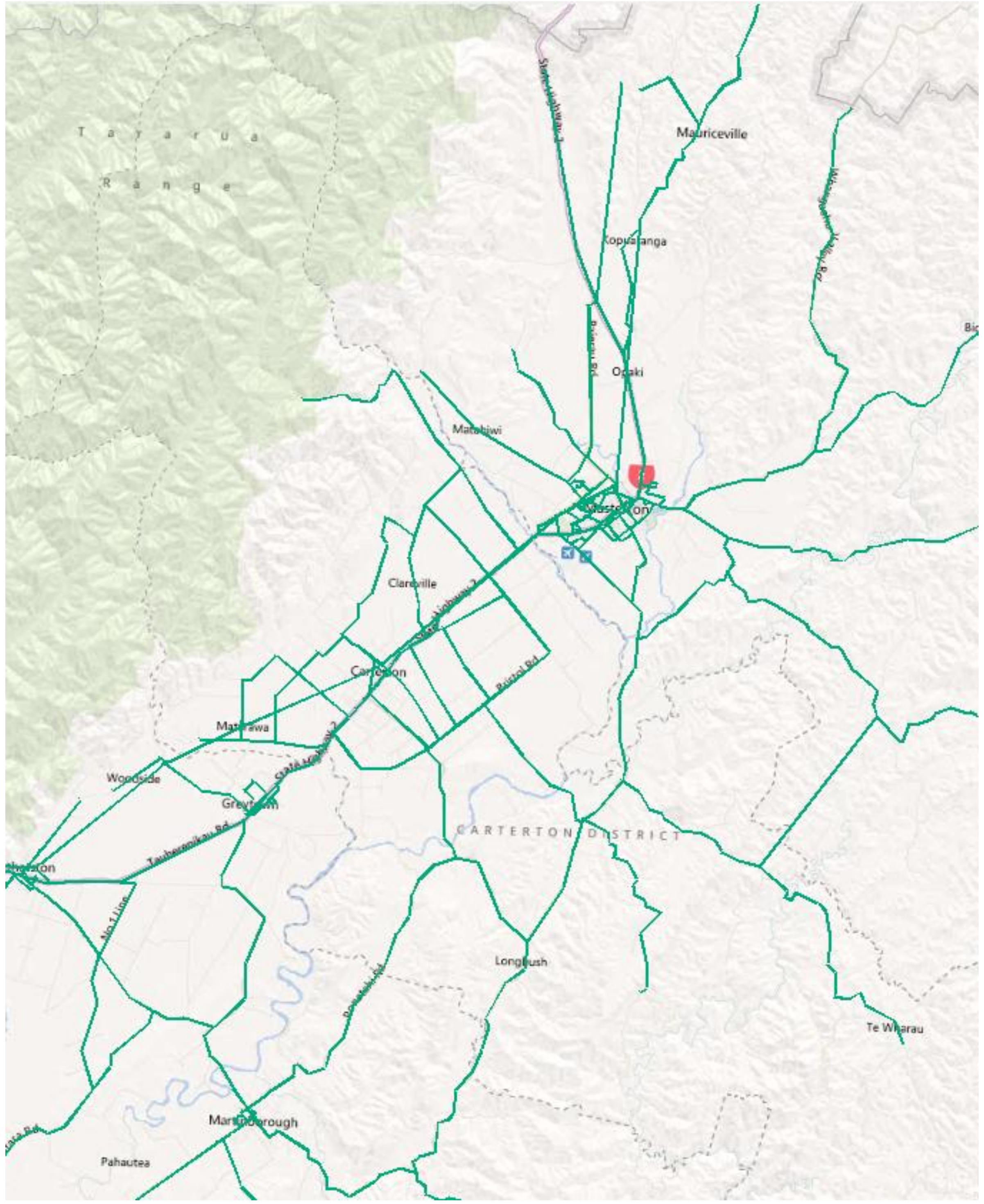
2006 Model Upper Hutt City



2011 Model Upper Hutt City



2006 Model Carterton and Masterton Districts



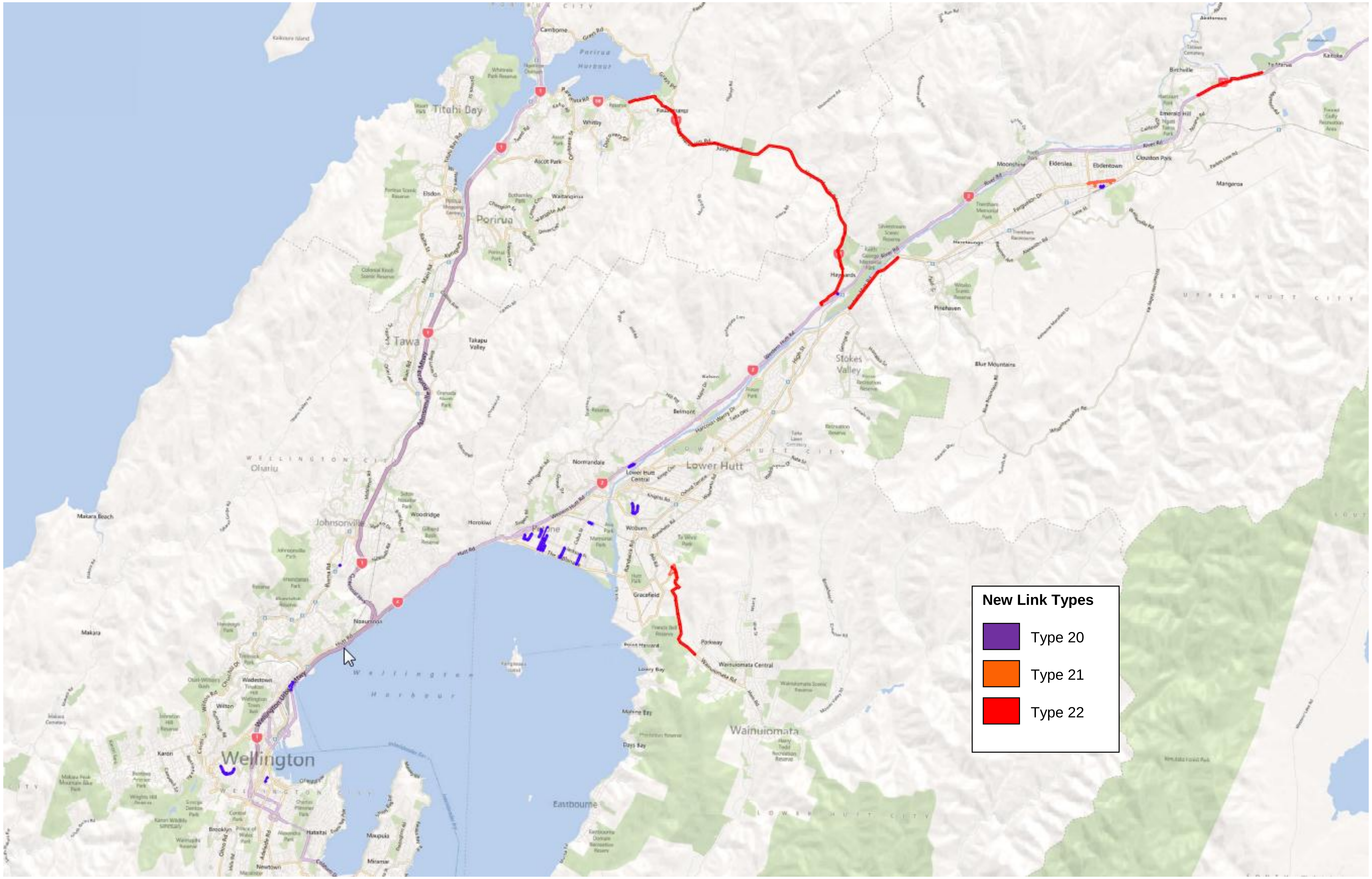
2011 Model Carterton and Masterton Districts

APPENDIX B – Rail Node Number Correspondence Table

2006 WTSM	2011 WTSM	Station Description
8033	30001	Upper Hutt Station
8032	30002	Wallaceville Station
8031	30003	Trentham Station
8030	30004	Heretaunga Station
8029	30005	Silverstream Station
8028	30006	Manor Park Station
8027	30007	Pomare Station
8026	30008	Taita Station
8025	30009	Wingate Station
8024	30010	Naenae Station
8023	30011	Epuni Station
8022	30012	Waterloo Station
8021	30013	Woburn Station
8020	30014	Ava Station
8012	30015	Petone Station
8011	30016	Ngauranga Station
8010	30017	Kaiwharawhara Station
8001	30018	Wellington Station
8009	30019	Johnsonville Station
8008	30020	Raroa Station
8007	30021	Khandallah Station
8006	30022	Box Hill Station
8005	30023	Simla Crescent Station
8004	30024	Awarua Street Station
8003	30025	Ngaio Station
8002	30026	Crofton Downs Station
8114	30027	Waikanae Station
8113	30028	Paraparaumu Station
8112	30029	Paekakariki Station
8110	30030	Pukerua Bay Station
8109	30031	Plimmerton Station

2006 WTSM	2011 WTSM	Station Description
8108	30032	Mana Station
8107	30033	Paremata Station
8106	30034	Porirua Station
8105	30035	Kenepuru Station
8104	30036	Linden Station
8103	30037	Tawa Station
8102	30038	Redwood Station
8101	30039	Takapu Road Station
8014	30040	Melling Station
8013	30041	Western Hutt Station
8115	30042	Otaki Station
8039	30043	Masterton Station
-	30044	Renall Street Station
-	30045	Solway Station
8038	30046	Carterton Station
8037	30047	Matarawa Station
8034	30048	Maymorn Station
8036	30065	Woodside Station
8035	30066	Featherston Station

APPENDIX C – Location of New Link Types



APPENDIX D – Modelled and "Observed" Timetable Bus Counts

Wellington CBD Cordon
Inbound (no. buses per 2 hour period)

Stop No	Location	Time Table	Modelled
5492	Thorndon Quay at Motorway (Handy Rentals)	75	77
4113	Murphy Street - Wellington Girls	46	46
4312	Tinakori Road at St Mary Street (near 360)	35	34
4915	Victoria University - Kelburn Parade (near 42)	22	21
7711	Willis Street - Abel Smith Street	24	24
7913	Taranaki Street (near 274)	30	30
7013	Cambridge Terrace at Basin Reserve	57	57
7212	Elizabeth Street at Kent Terrace	62	63
7514	Oriental Parade at Freyberg Pool (opposite)	13	13
		364	**365**

Lower Hutt Cordon
Inbound (no. buses per 2 hour period)

Stop No	Location	Time Table	Modelled
8123	Hutt Hospital - High Street	24	25
9100	Oxford Terrace at Epuni Street (near 77)	4	5
9166	Waterloo Road (near 259)	9	13
8142	Guthrie Street at Trafalgar Street (near 6)	17	17
9157	Ludlam Crescent at Wai-iti Crescent (near 41)	10	9
9112	Victoria Street at Weltec, Block F	20	19
9106	Railway Avenue (near 21)	4	4
9150	Melling Station (bus Stop)	9	8
		97	**101**

Porirua Cordon
Inbound (no. buses per 2 hour period)

Stop No	Location	Time Table	Modelled
2866	Titahi Bay Road at Whanga Cres Walkway (opposite)	10	10
2356	Champion Street at Mepham Place (Shell)	5	4
2178	Mungavin Park - Mungavin Avenue (opposite)	8	7
3934	Kenepuru Drive at Bowland (opposite)	5	3
3926	SDA School - Raiha Street	10	9
2026	Porirua Library - Norrie Street (opposite)	22	22
		60	**56**

Paraparaumu Cordon
Inbound (no. buses per 2 hour period)

Stop No	Location	Time Table	Total
1007	Raumati Road, Chocolate Factory (near 156)	0	1
1380	Raumati Road at Matai Road (opposite 68)	7	7
1194	Kapiti Road at Moana Road (near 36)	18	17
1072	Ruapehu Street (near 48B)	4	4
		29	**28**

Wellington CBD Cordon
Outbound

Stop No	Location	Time Table	Modelled
5024	Thorndon Quay at Motorway (Hirequip)	29	31
5113	Molesworth Street - New World	19	25
5312	Tinakori Road at St Mary Street	14	15
5915	Victoria University - Kelburn Parade	18	19
6710	Victoria Street - Vivian Street	16	16
6913	Taranaki Street (near 217)	21	22
6013	Kent Terrace at Basin Reserve	37	34
6212	Elizabeth Street at Kent Terrace (near 7)	18	21
6514	Oriental Parade at Freyberg Pool	8	7
		180	**190**

Lower Hutt Cordon
Outbound

Stop No	Location	Time Table	Modelled
9223	Hutt Hospital - High Street (opposite)	21	19
8100	Oxford Terrace at Epuni Street (opposite 77)	5	4
8166	Waterloo Road (near 260)	13	9
9142	Guthrie Street at Brook Street (near 11)	9	12
8157	Ludlam Crescent at Wai-iti Crescent (near 28)	11	11
8112	Victoria Street at Weltec, Block F (near 64)	18	20
8107	Railway Avenue (Brendan Foot Motors)	0	1
8106	Marsden Street at Bridge Street	6	5
		83	**81**

Porirua Cordon
Outbound

Stop No	Location	Time Table	Modelled
2816	Titahi Bay Road at Whanga Cres Walkway	8	9
2300	Champion Street at Mepham Place (opposite Shell	4	4
2100	Mungavin Park - Mungavin Avenue	6	7
3942	Kenepuru Drive at Bowland	11	11
3929	SDA School - Raiha Street (opposite)	8	8
2024	Porirua - Pak n Save	5	5
2012	Porirua Library - Norrie Street	17	18
		59	**61**

Paraparaumu Cordon
Outbound

Stop No	Location	Time Table	Modelled
1008	Raumati Road, Chocolate Factory (near 139)	0	1
1306	Raumati Road at Matai Road (near 68)	3	3
1102	Kapiti Road at Ngahina Street (near 39)	15	17
1062	Ruapehu Street at Redwood Close (opposite)	4	4
		22	**25**

GWRC Wellington City CBD Cordon PT Survey

Note: Directions refer to screenlines compiled from the observed and modelled data.

Overall	
	Lines
Obsv.	329
Model	365
Diff	**36**
% Diff	9.81%

North		**West**	
	Buses		**Buses**
Obsv.	108	**Obsv.**	72
Model	124	**Model**	79
Diff	**16**	**Diff**	**7**
% Diff	12.76%	**% Diff**	8.40%
South		**East**	
	Buses		**Buses**
Obsv.	77	**Obsv.**	72
Model	87	**Model**	75
Diff	**10**	**Diff**	**3**
% Diff	11.70%	**% Diff**	4.26%