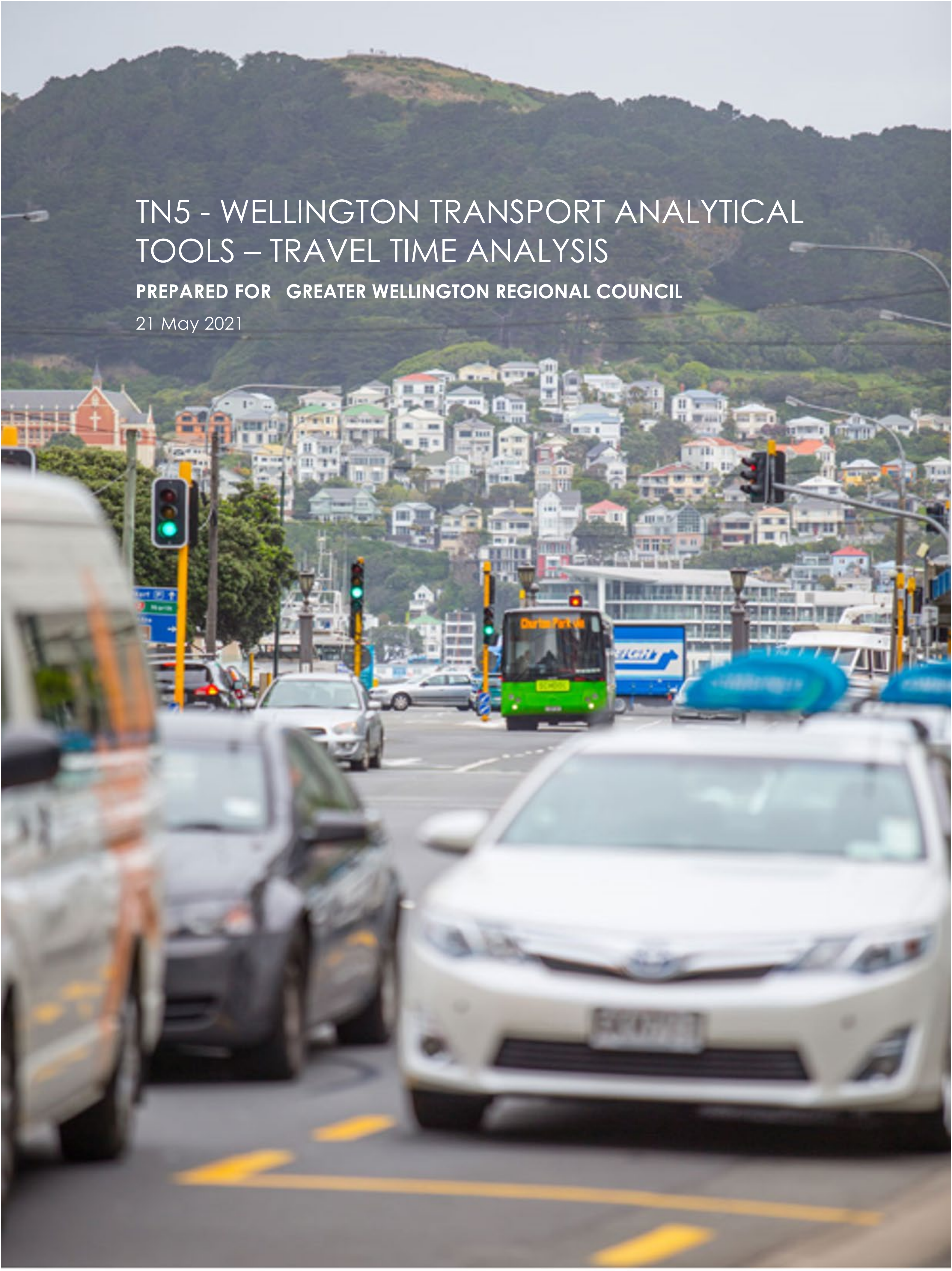
TN5 - WELLINGTON TRANSPORT ANALYTICAL TOOLS – TRAVEL TIME ANALYSIS

PREPARED FOR GREATER WELLINGTON REGIONAL COUNCIL

21 May 2021



Stantec | JACOBS

This document has been prepared for the benefit of Greater Wellington Regional Council. No liability is accepted by this company or any employee or sub-consultant of this company with respect to its use by any other person.

This disclaimer shall apply notwithstanding that the report may be made available to other persons for an application for permission or approval to fulfil a legal requirement.

QUALITY STATEMENT

PROJECT MANAGER	PROJECT TECHNICAL LEAD
Ali Siddiqui	Julie Ballantyne

PREPARED BY		
Dave Hunter	....	21/5/2021
CHECKED BY		
Julie Ballantyne	....	21/5/2021
REVIEWED BY		
Julie Ballantyne	....	21/5/2021
APPROVED FOR ISSUE BY		
Julie Ballantyne	....	21/5/2021

CHRISTCHURCH
Hazeldean Business Park, 6 Hazeldean Road, Addington, Christchurch 8024
PO Box 13-052, Armagh, Christchurch 8141
TEL +64 3 366 7449, FAX +64 3 366 7780

REVISION SCHEDULE

Rev No.	Date	Description	Signature or Typed Name (documentation on file)			
			Prepared by	Checked by	Reviewed by	Approved by
1	18/2/21	First draft	Dave Hunter	Julie Ballantyne	Julie Ballantyne	Julie Ballantyne
2	21/5/21	Final version	Dave Hunter	Julie Ballantyne	Julie Ballantyne	Julie Ballantyne

Greater Wellington Regional Council

TN5 - Wellington Transport Analytical Tools – Travel Time Analysis

CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1. Introduction

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

1.1 Purpose of this Report

This report sets out the assessment of vehicle travel times within the current GWRC model. This includes:

- Comparison of the current 2013 model travel time results with manual floating car surveys and the more comprehensive Bluetooth TomTom travel time surveys;
- Review of the parameter in the volume-delay (speed-flow) curves used in the model to calculated congested travel times and testing modifications to these relationships.

2. 2013 Model Travel Time Issues Evaluation

A necessary part of ensuring a model is operating correctly is to ensure that modelled movements throughout the model are occurring at the appropriate speeds and include intersection delays that represent those occurring in reality. One of the methods for evaluating this is to undertake travel time surveys that include critical routes and intersections that are important to network operation and compare them to modelled outputs.

This section of the technical note evaluates what issues exist with the current model with respect to travel time validation. It looks at both the surveyed data used in the validation and the modelled results.

2.1 Floating Car Travel Survey Data

Floating car travel time data was used to evaluate travel times along six important routes. Bi-directional data for each route was obtained with daily data collated to reflect typical travel behaviour on each individual weekday. The evaluation of the data is included in this assessment so that locations of high delay can be identified, measured and determined if the delay occurs on a daily basis or appears to be sporadic in nature. If delays appear to be sporadic, then further investigation can be undertaken to determine if the delays consistently relate to a particular day or are as a result of an irregular extreme event.

Table 2-1 details initial observations of possible surveyed travel time events that may impact on model validation. Irregular extreme events will skew the average weekly conditions that the model is being validated to and potentially result in inappropriate model behaviour. The routes used for the travel time assessment are shown in Appendix A.

Table 2-1: Period Floating Car Travel Time Survey Comments

Route	Direction	AM Peak	Inter Peak	PM Peak
1	NthBnd	Very High delays from Cobham/Calibar to Ruahine/Taurima on Wednesday only	Surveyed travel times consistent throughout the week	Very High delays from Cobham/Calibar to Ruahine/Taurima on Friday only
	SthBnd	Very High delays from Mackays Railway Crossing to Wairaki Rd (Pukerua Bay) Very High delays Newlands I/C onramp to Taranaki/Vivan on Tuesday only	Surveyed travel times consistent throughout the week	Very High delays from Vivan St to Mt Victoria Tunnel/Dufferin on Wednesday only
2	NthBnd	High delay from Bunny/Waterloo Quay to Featherston/Thornton Quay on Wednesday only	Surveyed travel times consistent throughout the week	Very high delay at Ngauranga offramp Tuesday/Wednesday only

Route	Direction	AM Peak	Inter Peak	PM Peak
		Very high delay at Ngauranga offramp Friday only		
	SthBnd	High delay Moonshire to SH2/Fergusson Monday/Tuesday only	Surveyed travel times consistent throughout the week	Surveyed travel times consistent throughout the week
3	WstBnd	Surveyed travel times consistent throughout the week	Surveyed travel times consistent throughout the week	Surveyed travel times consistent throughout the week
	EstBnd	Surveyed travel times consistent throughout the week	Surveyed travel times consistent throughout the week	Surveyed travel times consistent throughout the week
4	NthBnd	Wednesday overall travel much slower	Wednesday overall travel much slower	Wednesday overall travel much slower
	SthBnd	Extreme delay from Karori/Sth Karori to Northland on Wednesday only	Surveyed travel times consistent throughout the week	Surveyed travel times consistent throughout the week
5	NthBnd	Extreme delay from Adelaide/Luxford to Adelaide/Riddiford on Wednesday only	High delay Cambridge/Basin Reserve to Cambridge/Wakefield Wednesday and Thursday only	Extreme delay from Taranaki/Jervois Quay to Jervois/Customhouse Quay on Wednesday only
	SthBnd	Extreme delay approach to Kent Tce/Basin Reserve on Tuesday only	Surveyed travel times consistent throughout the week	Large delay approach to Kent Tce/Basin Reserve on Friday only
6	NthBnd	Low travel time Wainone/Seaview to Hutt/The Esplanade Monday only	Surveyed travel times consistent throughout the week	Surveyed travel times consistent throughout the week
	SthBnd	Low travel time Dowse/Hutt to The Esplanade Rbt Monday only	Surveyed travel times consistent throughout the week	Low travel time Hutt/The Esplanade to Wainone/Seaview Monday only

2.2 2013 Modelled Travel Times Compared to Floating Car Survey

2013 Modelled travel times include a combination of travel along links and intersection delays where these are modelled. Observations of the current 2013 modelled travel times are shown in Table 2-2. These observations are general comments on how certain modelled links or intersections appear to be operating differently to surveyed behaviour.

Clearly, as a result of an in-depth investigation into the possible surveyed travel times issues detailed earlier is undertaken, some of the following model related comments may change.

Table 2-2: Modelled Period Travel Time Comments

Route	Direction	AM Peak	Inter Peak	PM Peak
1	NthBnd	Modelled route slow between Ruahine/Wellington and Wellington Inner City Bypass	Modelled travel times are consistent with manual survey data	Modelled travel times are consistent with manual survey data
	SthBnd	Modelled route too fast from Tawa offramp to Clifton offramp	Modelled travel times are consistent with manual survey data	Modelled travel times are consistent with manual survey data
2	NthBnb	Modelled route too slow from Dowse Dr/Melling Link to Melling Link/Fairway Dr	Modelled route too fast overall	Modelled route too fast up to Ngauranga Gorge ramp Extreme delay up to Petone onramp
	SthBnd	Modelled route too fast Korokoro to Petone onramp Model too slow Petone to Ngauranga Gorge ramp	Modelled route too slow overall but particularly Upper Hutt Railway to Gibbons St	Modelled route too slow - Melling Link to Dowse Dr
3	WstBnd	Modelled route slow from SH2 to Paekakiriki Hill Rbt	Modelled route slow from SH2 to Paekakiriki Hill Rbt	Modelled route slow from SH2 to Paekakiriki Hill Rbt

Route	Direction	AM Peak	Inter Peak	PM Peak
	EstBnd	Modelled travel times are consistent with manual survey data	Modelled travel times are consistent with manual survey data	Modelled travel times are consistent with manual survey data
4	NthBnd	Modelled route slow Northland Rd to Karori / Sth Karori	Modelled travel times are consistent with manual survey data	Modelled route 2min fast Taranaki/Jervois to Terrace/Salamanca
	SthBnd	Modelled route generally slow Delay at Terrace/Salamanca and Taranaki/Courtney	Modelled route generally slow Delay at Terrace/Salamanca and Taranaki/Courtney	Modelled route generally slow Delay at Terrace/Salamanca and Taranaki/Courtney
5	NthBnd	Modelled travel times are consistent with manual survey data	Modelled travel times are consistent with manual survey data	Modelled travel times are consistent with manual survey data
	SthBnd	Modelled travel times are consistent with manual survey data	Modelled travel times are consistent with manual survey data	Modelled travel times are consistent with manual survey data
6	NthBnd	Modelled route too little delay at The Esplanade Rbt	Modelled travel times are consistent with manual survey data	Modelled route too fast Parkside/Bell to Wainone/Seaview
	SthBnd	Modelled route too little delay at The Esplanade Rbt (6min fast)	Modelled travel times are consistent with manual survey data	Modelled route too fast Hutt/The Esplanade to Wainone/Seaview (4min fast)

2.3 TomTom Travel Time Evaluation

As part of the 2018 model update, observed travel times from TomTom data are being collated. At the same time, 2013 observations were collated for this evaluation of model performance. The 2013 TomTom observed travel time dataset will be different to the 2013 floating car survey data used in the model validation (due to methodology, amount of data, etc). However, it is a more detailed dataset (sample size, disaggregation of time, etc) and enables insight into the model performance. This section of the technical note evaluates what issues exist between the 2013 modelled travel times and available 2013 TomTom data.

TomTom travel time data was used to evaluate travel times along seven important routes. Bi-directional data for each route was downloaded for every weekday during March 2013. The evaluation of the data is included in this assessment so that locations of high delay can be identified and determined if the delay is sporadic in nature.

The TomTom data was compiled into bins that reflect the various percentile levels of traffic travelling at different speeds along each link travelled. These speeds were converted into link travel times using the link distance travelled for each bin. Bins ranging from 5%ile to 95%ile in 5% increments were used to indicate the percentage of trips taking shorter time than that bin.

In this assessment the average 50%ile travel times were used to compare the model outputs to. Travel time profiles for each 15min interval during the peak periods were used to provide an understanding of the changes in travel times within the peaks. For this assessment the AM Peak was assumed to extend from 6am-9pm and the PM Peak from 3pm-6pm.

The 15-minute travel times along the seven routes are shown in Appendix B. Individual travel time profiles have been colour-coded as follows:

Blue: 6-7am, 3-4pm

Red: 7-8am, 4-5pm

Green: 8-9am, 5-6pm

Black: Modelled route travel time

Modelled travel times include a combination of travel along links and modelled intersection delays. Observations of how the current modelled travel times compare with the TomTom data are shown in Table 2-3. This comparison focuses on the three hours covering the peak periods and include 7-9am for the AM peak and 4-6pm for the PM Peak to ensure consistency between 2013 modelled and observed time periods (shown in red and green).

These observations are general comments on how certain modelled links or intersections appear to be operating differently to surveyed behaviour. Clearly, as a result of an in-depth investigation into the possible surveyed travel times issues detailed earlier is undertaken, some of the following model related comments may change.

Table 2-3: Modelled Period Travel Time Comments

Route	Direction	AM Peak	PM Peak
1	NthBnd	Model consistent with TomTom data	Model consistent with TomTom data Model delay at Hutt Rd – Western Hutt Rd interchange appears high
	SthBnd	Model consistent with TomTom data Model delay at Wellington Urban Motorway merge appears high	Model consistent with TomTom data Model delay at Hutt Rd – Western Hutt Rd interchange appears high
2	NthBnb	Model generally slow in CBD area leading to Aotea Quay	Model consistent with TomTom data
	SthBnd	Model slow around SH1 / Main Rd	Model consistent with TomTom data
3	NthBnd	Model consistent with TomTom data	Model consistent with TomTom data Model delay along Hutt Rd approach to Petone Interchange appears high
	SthBnd	Model consistent with TomTom data	Model consistent with TomTom data
4	NthBnd	Model consistent with TomTom data	Model consistent with TomTom data
	SthBnd	Model consistent with TomTom data	Model consistent with TomTom data
5	NthBnd	Model consistent with TomTom data	Model consistent with TomTom data
	SthBnd	Model consistent with TomTom data	Model consistent with TomTom data Model appears slightly fast in CBD area
6	SthBnd	Model appears slightly slow in CBD area around Vivian St	Model consistent with TomTom data
	NthBnd	Model consistent with TomTom data	Model consistent with TomTom data
7	SthBnd	Model appears slightly slow in CBD area	Model consistent with TomTom data
	NthBnd	Model consistent with TomTom data Model appears slightly slow in CBD area	Model consistent with TomTom data

2.4 Recommendations

This assessment has shown that the 2013 model appears to reflect observed travel time data reasonably well with the exception of several locations involving high volume merge movements and some locations within the CBD.

It is recommended that the method for modelling merge conditions be investigated to determine if an alternative method can produce better results.

Aside from one location on some of the travel time routes, the model generally reflects average period observed travel times within typically acceptable bounds. For locations where the model does not reflect observed (other than motorway merges), improving the model's reflection of observed will be considered as part of the Phase 2 model update when more substantial changes to the model form will be incorporated.

3. Link Travel Time Function J_A Reassessment

Link travel time functions are used by the model to calculate the travel time to traverse a homogenous link ignoring any delays experienced at significant intersections at the end of the link. The current model uses travel time functions that are based on a formulation proposed by Rahmi Akcelik, which in turn was based on Modified Davidson functions. The volume-delay functions ensure that:

- Delays are monotonically increasing to ensure convergence to a unique solution;
- Delays increase sharply for Volume/Capacity (V/C) ratios exceeding one, but not so sharply as to cause stability and numerical problems; and
- They have some positive slope for V/C ratios less than one so that the assignment process does not degenerate into an all-or-nothing assignment on low volume links.

To do this, the functions use a combination link lane capacity, free flow speed, arrival rate and a delay parameter (J_A) which corresponds to the quality of service provided by the road section and is independent of both capacity and free flow speed. The higher the J_A, the more it indicates flow interruption along the link as a result of intersections.

The Akcelik functions, used in the current model, were created to better recreate the change in link speed within built-up areas where intersections have greater levels of impact and are an important element of the SIDRA INTERSECTION analysis program. The capacity, free flow speed and J_A values used in curves describing links below Expressway and Motorway status appear to be reasonable and reflect the environment the lower level links are in. Table 3-1 shows the default set of speed flow curves used in the current model.

Table 3-1: Default Current Model Link Parameters

Link Type	Description	Free Flow Speed	Capacity veh/hr/lane	J_A
1	Centroid	40	5000	NA
2	Centroid - Walk	40	5000	NA
3	CBD/Shopping-High Friction	40	600	1.80
4	CBD/Shopping-Low Friction	45	800	1.60
5	Local	48	1000	1.20
6	Collector-High Friction/Poor Alignment	50	1100	1.20
7	Collector-Low Friction/Good Alignment	52	1250	1.00
8	Urban Arterial-Low Speed	52	1350	1.00
9	Urban Arterial-High Speed	55	1450	0.80
10	Expressway	95	1800	0.80
11	Motorway	100	2000	0.40
12	Onramp	70	1800	0.60
13	Offramp	70	1800	0.60
14	Rural-Restricted Speed	70	1400	1.40
15	Rural-Unrestricted Speed	100	1400	1.40

However, there has been concern that the modelled Expressway and Motorway links are not reflecting the changes in actual travel time occurring in the network during congested periods.

3.1 Expressway / Motorway Function

As indicated in the previous section, the Akcelik function partially developed from the Modified Davidson function to, in part, better take into account the impact of intersection interference along links. Whilst this works reasonably well in built-up areas where intersections occur with some regularity, research undertaken for the State of Florida Department of Transportation has shown that along motorways and expressways where intersection interference is less prevalent, the Akcelik formulation has some deficiencies.

Analysed field data from Interstate 95 was compared to various travel time functions, see Figure 3-1.

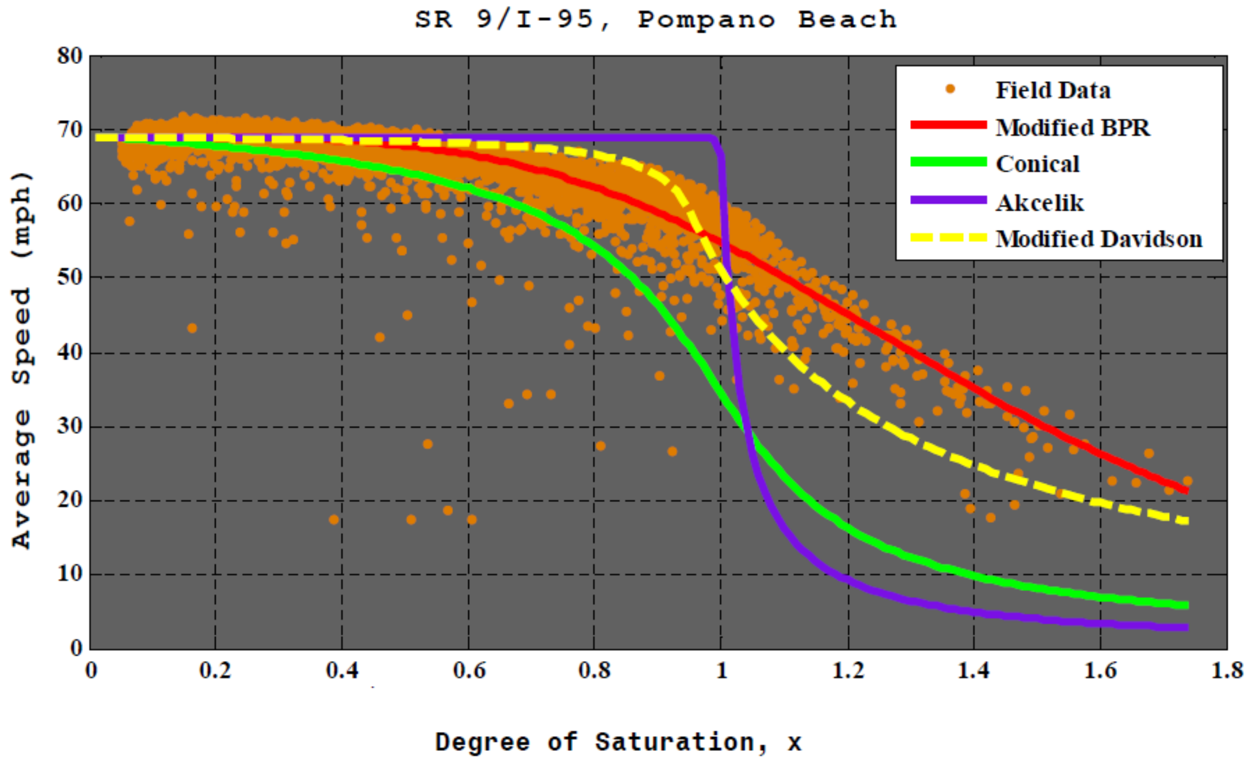


Figure 3-1: Speed-volume Relationship for Fitted Curves to I95 Data

The research found that a modified or fitted BPR fitted the data well, followed by a modified Davidson, conical delay function, and lastly the Akcelik function. However, goodness of fit statistics for the various curves showed that the best overall function was the Davidson function. Table 3-2 shows the various fit statistics for the methods used.

Table 3-2: Goodness of Fit Statistics for Calibrated Volume Delay Curves

Model	Root Mean Squared Error	Mean Squared Error	R2
Fitted BPR	2.888	8.339	0.710
Conical	5.074	25.745	0.551
Modified Davidson	2.214	4.902	0.878
Akcelik	4.374	19.134	0.610

The Modified Davidson and Akcelik functions are shown below:

Modified Davidson function: ....$t = t_o \{1 + 0.25\, r_f\, [z + (z^2 + 8\, J_D\, x / r_f)^{0.5}]\}$................................Eq 1

Akcelik function: ....$t = t_o \{1 + 0.25\, r_f\, [z + (z^2 + 8\, J_A\, x / (Q\, t_o\, r_f))^{0.5}]\}$........................Eq 2

Where:

t = average travel time per unit distance (e.g. in seconds per km)

t_o = minimum (zero-flow) travel time per unit distance (e.g. in seconds per km)

J_D = Davidson delay parameter

J_A = Akcelik delay parameter

$z = x - 1$

$x = q / Q$ =degree of saturation

q = demand (arrival) flow rate (in veh/hour)

Q = capacity (in veh/hour per lane)

$r_f = T_f / t_o$, i.e. ratio of flow (analysis) period to minimum travel time

The time-dependent form of the Akcelik function is identical to the Modified Davidson function except for the additional use of Q and t_o in the divisor part of the equation. The implication of using these additional factors appears to be that the resulting travel time curve results in a more abrupt change in travel time with increasing traffic flow. Figure 3-2 shows the difference in speed-flow curve for each function using the same input data.

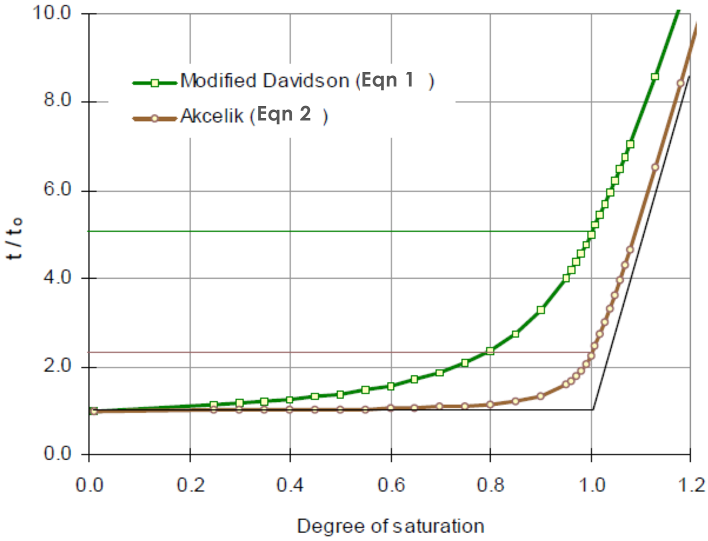


Figure 3-2: Travel Time Curves for Modified Davidson and Akcelik Functions using Same Inputs for Q, J and q.

Whilst the existing Akcelik curves appear to represent the more built-up areas of the model, the more abrupt nature of the Akcelik curve appears to underrepresent the gradual slowing of traffic on motorways as volumes increase and the slower speeds around capacity.

In order to better represent the changes in speeds along the Wellington Motorway network, the use of fitted Modified Davidson curves is proposed.

3.2 Proposed Motorway Curves

The TomTom data used in assessing issues with the 2013 model travel time validation was used to determine the most suitable function values for various parts of the Wellington Motorway network. Rather than tailor curves for each section of the motorway network individually, a rationalised set of curves are proposed to represent all motorway sections that have similar speed, number of lanes and lane capacity characteristics.

A number of motorway locations were selected that were both far enough from interchanges so as to minimise the impact of merging traffic and were at locations that traffic count data at 15-minute intervals were also available in March 2013. The following methodology was used:

1. The harmonic average speeds for each location was obtained from the TomTom travel time data for weekdays in March 2013
2. NZTA counts in the immediate vicinity of each location were obtained at 15-minute intervals for weekdays in March 2013
3. Speed profiles by direction at each location were plotted for the AM Peak period from 6am-10am and the PM Peak period from 3pm-7pm. This will allow for the assessment of the proposed curve over a greater range of traffic volumes
4. The average total one-hour flow for each 15-minute interval was obtained from traffic counts
5. The flow per lane for each 15-minute interval was used to calculate the estimated Modified Davidson lane speed
6. Lane capacity and J_D coefficient were adjusted until a combination were obtained that produced a time dependent speed curve that best reflected the surveyed speed profiles for each type of link

The following plots, Figure 3-3 to Figure 3-8 are the indicative results at the locations assessed. The surveyed 2013 speed profiles at the assessed locations and the final Davidson Function profiles fitted to the average count data are shown. Purple solid lines represent northbound Lanes, orange lines represent southbound lanes and the representative Davidson Curves are indicated with dotted lines and solid squares.

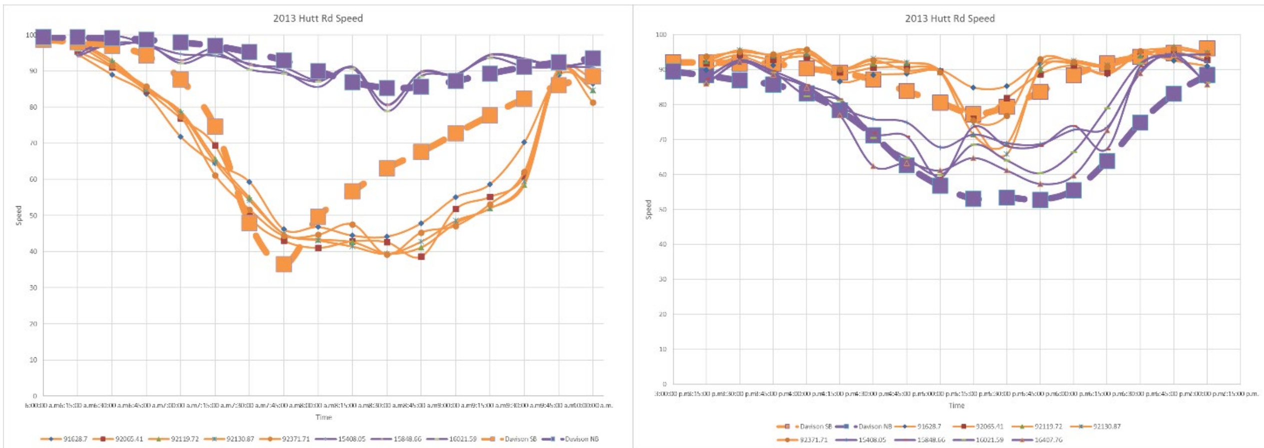


Figure 3-3: AM/PM Peak Speed Profiles at Hutt Road between The Esplanade and SH1 N (100kph / 2000vphpl / J_D=0.07)

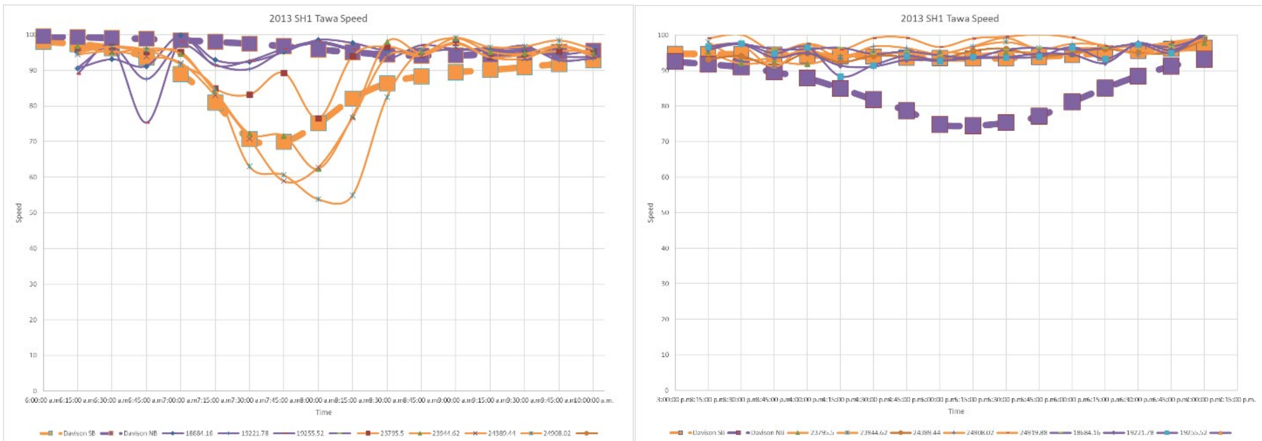


Figure 3-4: AM/PM Peak Speed Profiles on SH1 at Tawa (100kph / 2000vphpl / J_D=0.12)

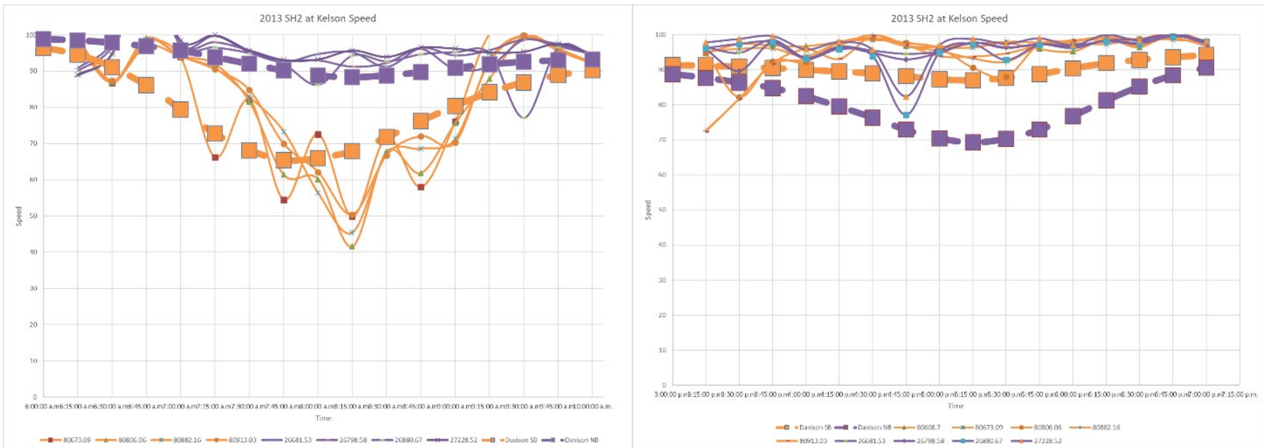


Figure 3-5: AM/PM Peak Speed Profiles on SH2 North of Fairway Drive (100kph / 1800vphpl / J_D=0.25)

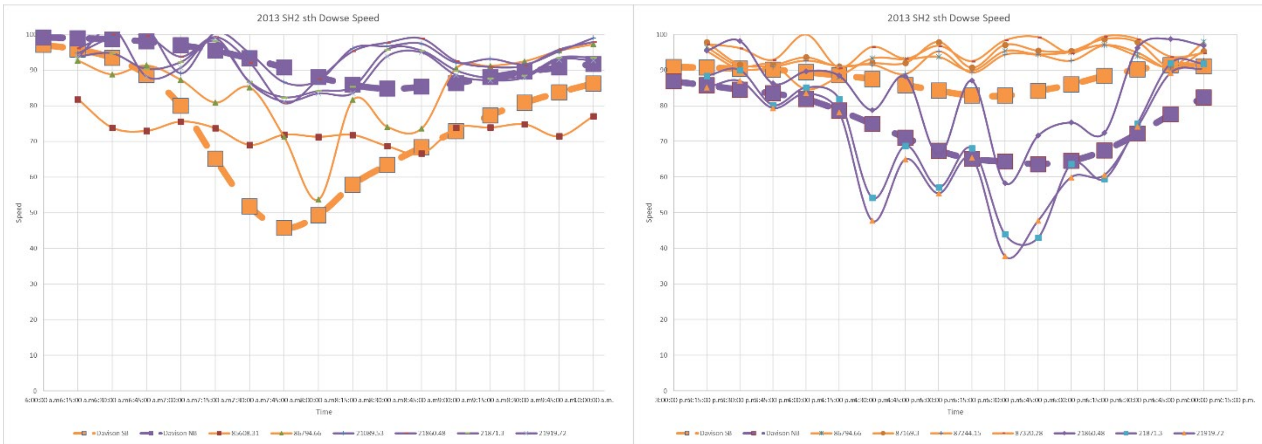


Figure 3-6: AM/PM Peak Speed Profiles on SH2 North of The Esplanade (100kph / 1800vphpl / J_D=0.25)

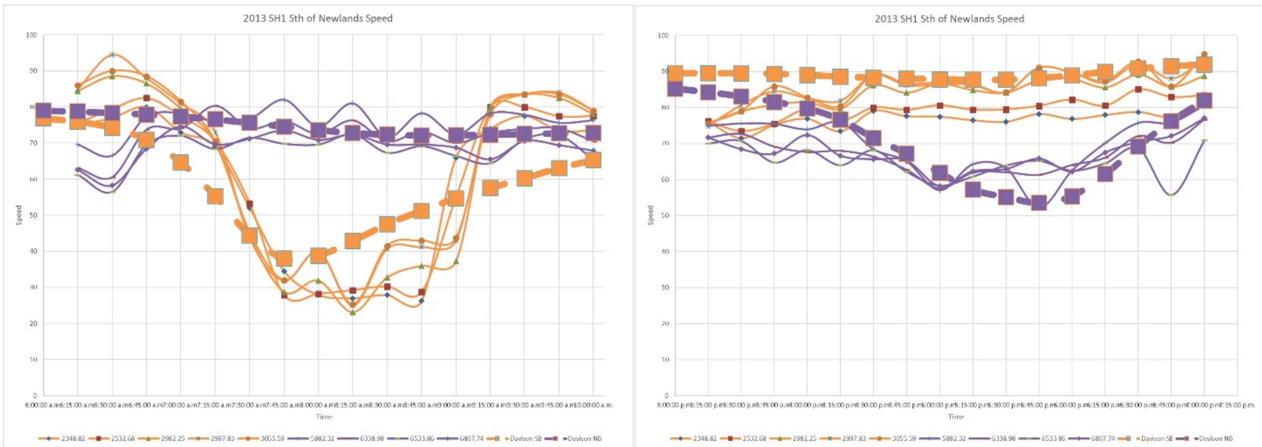


Figure 3-7: AM/PM Peak Speed Profiles on SH1 South of Newlands Interchange (100kph / 1800vphpl / J_D=0.25)

Figure 3-8: AM/PM Peak Speed Profiles on SH1 at Terrace Tunnel (80kph / 1700vphpl / J_D=0.25)

3.3 Recommendation

The assessment of changes in speed at locations along the Wellington Motorway system indicated that the use of Akcelik generated curves resulted in a significant underrepresentation of travel time along motorway or expressway links. The Modified Davidson equation however produced a less sudden onset of reduced vehicle speed with increased volume and represented reduced link speed reasonably well in most instances. Whilst the calculated speed profiles are not perfect for all instances, many of the discrepancies are as a result of downstream merge delays and a desire to limit the number of new motorway link type equations.

As a result, it is proposed that motorway links be recoded with the Davidson function and have the proposed Davidson Function Motorway link types below along with the proposed function coefficients shown in the following Table 3-3.

Table 3-3: General Motorway Link Types

Type	Speed	Lane Capacity	J_D	Comment
1	100 kph	2000	0.07	Multi-lane, wide shoulders, >3km intersection separation
2	100 kph	2000	0.12	Multi-lane, reduced shoulders, >3km intersection separation
3	100 kph	1800	0.25	Multi-lane, <3km intersection separation
4	80 kph	1700	0.25	Multi-lane, <2km intersection separation, Built-up area

4. Motorway Merges

An additional element of the validation of the motorway network travel time is the representation of speed at merge areas where two traffic streams come together. Traditionally motorway merging has been regarded as a major source of congestion on motorways but has also been recognised as an area in which modelling has been relatively weak. Traditionally, traffic models represented the merge using gap-acceptance approach, with the merging traffic giving-way to traffic on the dominant carriageway and imposing little or no delay to the motorway traffic. This tends to result in an underestimation of capacity at the merge, an overestimation of delays to the merging traffic and an underestimation of delays to the motorway traffic.

In the UK, the typical method of motorway merge assessment is provided by the UK Department of Transport Design Manual for Roads and Bridges (DMRB). In the USA, the typical method is provided by the Transport Research Board Highway Capacity Manual (HCM).

Both methods differ in analysis method, definition of the merge area of influence, volume impacted and delay of impacted vehicles. The DMRB uses a two-part process where it calculates capacity at the merge and then applies a delay at the merge to all vehicles in the area of influence of up to 2000m. The HCM estimates the volume of traffic in the kerbside two lanes of the merge area of influence of up to 500m and then calculates speeds of traffic in the area. No additional merge delay is used.

Rather than add a completely different motorway merge form, which tends to be applicable to interchanges separated by significant distances, and to add an element of consistency with the proposed methodology for analysing motorway links, the use of Modified Davidson functions within the merge area of influence was investigated.

4.1 Proposed Motorway Merge Curves

The TomTom data was again used to determine the most suitable function values for various merge areas within the Wellington Motorway network. Again, rather than tailor curves for each section of the motorway merge individually, a rationalised set of curves are proposed to represent all motorway merges that have similar speed, number of lanes and lane capacity characteristics.

Several motorway major merge locations were selected that were at locations that both traffic count data at 15-minute intervals and TomTom travel data were available in March 2013. The following methodology was used:

1. The harmonic average speeds for an approximate 500m length at each merge location was obtained from the TomTom travel time data for weekdays in March 2013
2. NZTA counts in the immediate vicinity of each location were obtained at 15-minute intervals for weekdays in March 2013 and total merging vehicle volumes per lane were calculated
3. Merge area of influence speed profiles at each location were plotted for the AM Peak period from 6am-10am as the majority of merge issues occur at southbound merges in the morning
4. The average total one-hour flow for each 15-minute interval was obtained from traffic counts
5. The flow per lane for each 15-minute interval was used to calculate the estimated Modified Davidson lane speed
6. Lane capacity and J_D coefficient were adjusted until a combination were obtained that produced a time dependent speed curve that best reflected the surveyed speed profiles for each type of link

The following plots, Figure 4-1 to Figure 4-5 are the indicative results at the merge locations assessed. The surveyed 2013 merge speed profiles at each of the locations and the final Davidson Function profiles fitted to the average count data are shown. In addition, the equivalent Akcelik curves are provided to show how Akcelik calculated curves would operate with the same input coefficients. Davidson merge curves are indicated with thick orange lines and solid squares whilst the equivalent Akcelik curves are shown in thick dotted blue lines and triangles.

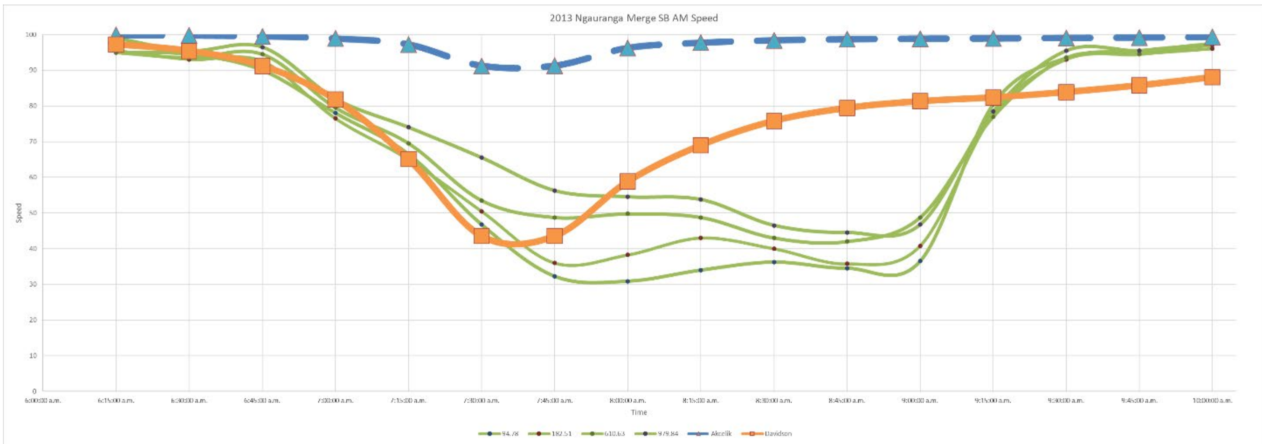


Figure 4-1: AM Peak Profiles on SH1 at Southbound Ngauranga Merge (100kph / 2000vphpl / J_D=0.10)

Figure 4-2: AM Peak Profiles on SH1 at Southbound Westchester Merge (100kph / 1800vphpl / J_D=0.30)

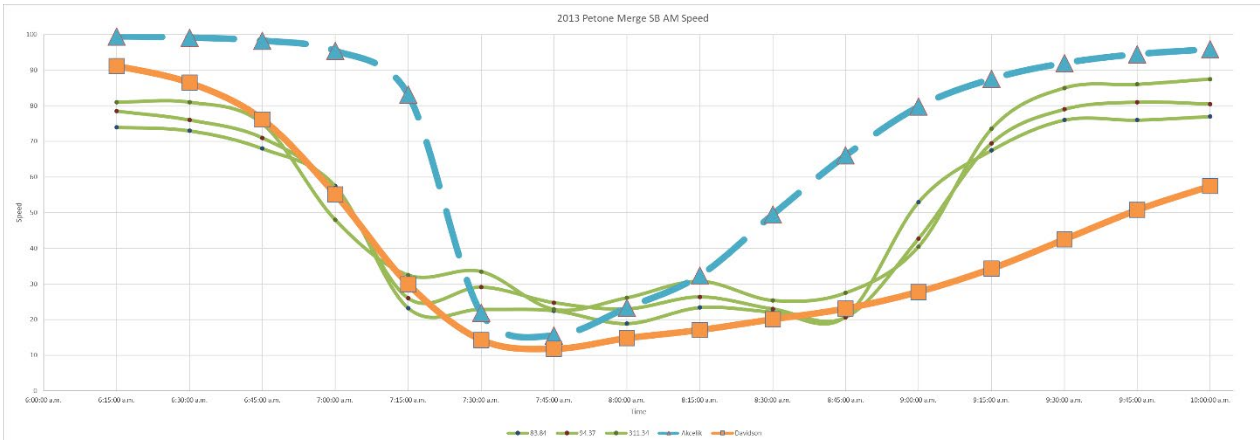


Figure 4-3: AM Peak Profiles on SH2 at Southbound The Esplanade Merge (100kph / 1800vphpl / J_D=0.30)

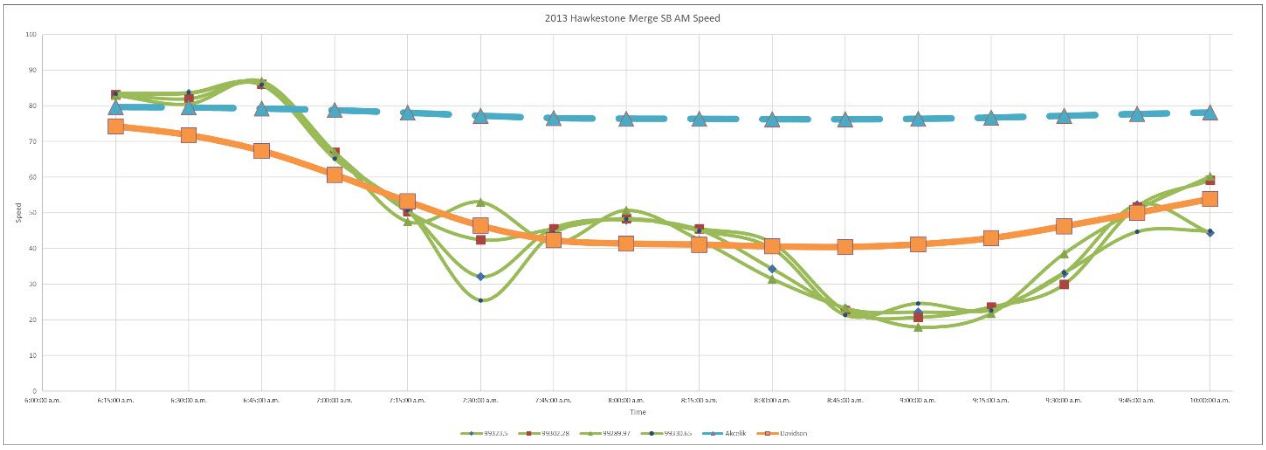


Figure 4-4: AM Peak Profiles on SH1 at Southbound Hawkestone Merge (80kph / 1700vphpl / J_D=0.50)

Figure 4-5: AM Peak Profiles on SH1 at Southbound Newlands Merge (80kph / 1700vphpl / J_D=0.50)

4.2 Recommendation

The assessment of changes in speed at merge locations along the Wellington Motorway system indicated that the use of Akcelik generated curves resulted in a significant underrepresentation of travel time along motorway or expressway links. The use of Modified Davidson equations however again produced a less sudden onset of reduced vehicle speed with increased volume and represented reduced link speed reasonably well in most instances. Whilst the calculated speed profiles are not perfect for all instances, many of the discrepancies are as a result of downstream merge delays and a desire to limit that number of new motorway link type equations.

As a result, it is proposed that motorway merge locations be recoded with the Davidson function and have the proposed Davidson Function Motorway merge types below along with the proposed function coefficients shown in the following Table 4-1.

Table 4-1: General Motorway Link Types

Type	Speed	Lane Capacity	J_D	Comment
1	100 kph	2000	0.10	Multi-lane, wide shoulders, >3km intersection separation
3	100 kph	1800	0.30	Multi-lane, <3km intersection separation
4	80 kph	1700	0.50	Multi-lane, <2km intersection separation, Built-up area

Merge links should be coded for a distance of 500m from the initial point of merge.

5. Implementation of Modified Motorway Merges

5.1 Spreadsheet Test

A spreadsheet-based test on the impact of introducing the proposed Davidson Functions to certain motorway links and merge areas was undertaken. This test was a simplified assessment that replaced relevant motorway link descriptions along survey travel time Route 1. This also meant that there was no re-routeing or volume changes when the travel time calculation function was changed, enabling a like-with-like comparison.

These tests found that sections of Route 1, affected by the proposed Davidson functions, showed an increase in localised travel time which trended toward the surveyed results. As expected, this trend only occurred in the direction and time of peak model flow along the surveyed corridors. Whilst the changes to the motorway functions test did not result in an exact match with the survey results, it is believed that a large element of the remaining local travel time discrepancy may be improved when the motorway link coding throughout the model is rationalised. Figure 5-1and Figure 5-2 show the relevant changes in travel time profiles for Route 1 AM Peak southbound and PM Peak northbound locations.

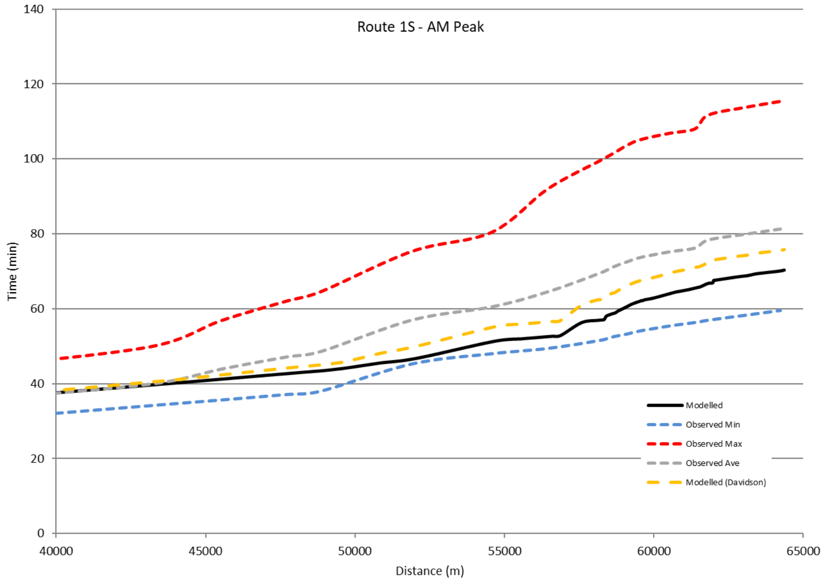


Figure 5-1: Route 1 AM Peak Southbound Travel Profile

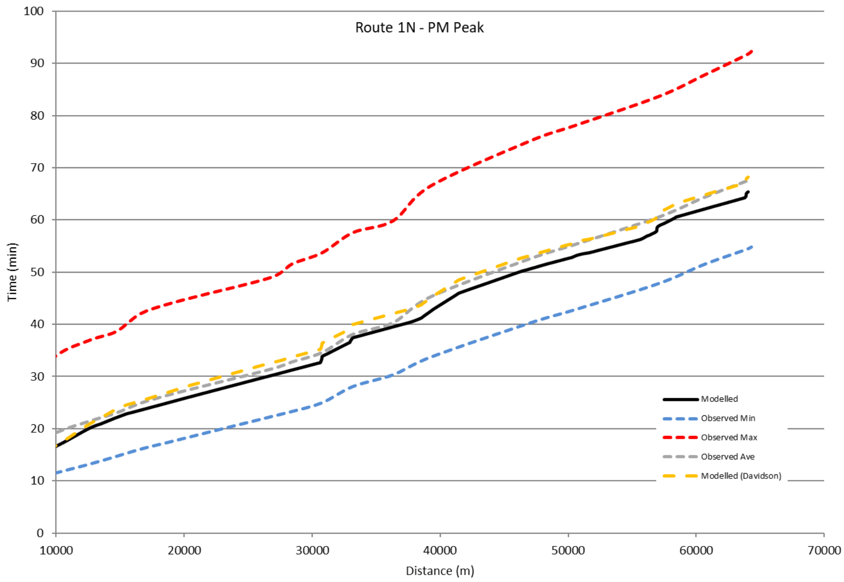


Figure 5-2: Route 1 PM Peak Northbound Travel Profile

5.2 EMME Test

Following the apparent success of the spreadsheet test, a real-world test of the Davidson curves was undertaken using the 2013 EMME model. General motorway links as well as merge links were recoded to accept the new Davidson formulation and the 2013 model was rerun. Table 5-1 shows the pre and post Davidson curve test results for the AM peak for the major merge locations along the Wellington motorway system. The test showed a general increase in travel time and reduction of speed along merge links as a result of the change. The level of travel time changes generally related to traffic density but it should be noted that the volume on the merge links are not the same in both the pre and post Davison test due to model redistribution/reassignment.

Table 5-1: Merge Link Travel Time Change Due To Davidson Function

Location	Volume/Lane	Base Travel Time (mins)	Davidson Travel Time (mins)	Change %
Southbound Ngauranga Merge	3712	273.3	288.4	106%
Southbound Newlands Merge	3029	26.1	55.2	211%
Southbound Westchester Merge	3025	19.1	28.9	151%
Southbound Dowse Merge	2906	29.1	47.5	163%
Southbound Esplanade Merge	2772	18.5	27.5	148%
Southbound Titahi Bay Merge	2397	13.1	17.5	133%
Southbound Hawkestone Merge	2163	9.3	11.9	128%
Northbound Clifton Tce Merge	1382	13.0	14.8	114%
Northbound Johnsonville Merge	1323	15.7	17.6	112%
Northbound Dowse Merge	1195	16.4	18.3	111%
Northbound Westchester Merge	1176	16.7	18.4	111%
Northbound Ngauranga Merge	1144	7.8	9.4	120%
Northbound Hawkestone Merge	1128	20.4	22.3	109%
Northbound Porirua Nth Merge	1087	25.0	27.6	110%
Northbound Takapu Merge	1043	19.0	20.8	109%
Northbound Titahi Bay Merge	722	15.8	16.7	106%

Clearly, travel time within each of the merges has increased as anticipated and should assist with representing the increased delay within merge areas.

6. Recommendation

This assessment has shown that the 2013 model appears to reflect observed travel time data reasonably well. Aside from one location on some of the travel time routes, the model generally reflects average period observed travel times within typically acceptable bounds. For locations where the model does not reflect observed (other than motorway merges), improving the model's reflection of observed will be considered as part of the Phase 2 model update when the model will be rebuilt.

The assessment of changes into travel time along the Wellington Motorway system has indicated that motorway links within the model be recoded to the Davidson function and have the characteristics indicated in Section 4.2.

Appendices

Appendix A Travel Time Routes

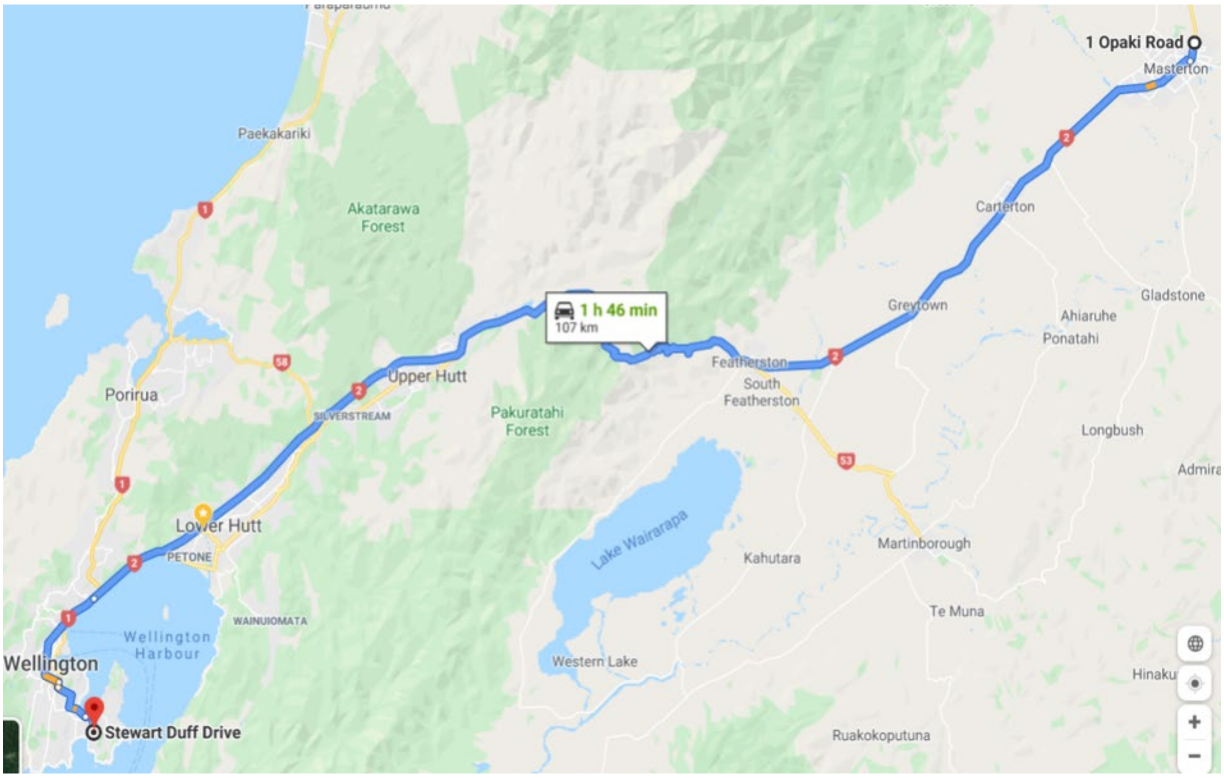


Figure A-1: Route 1

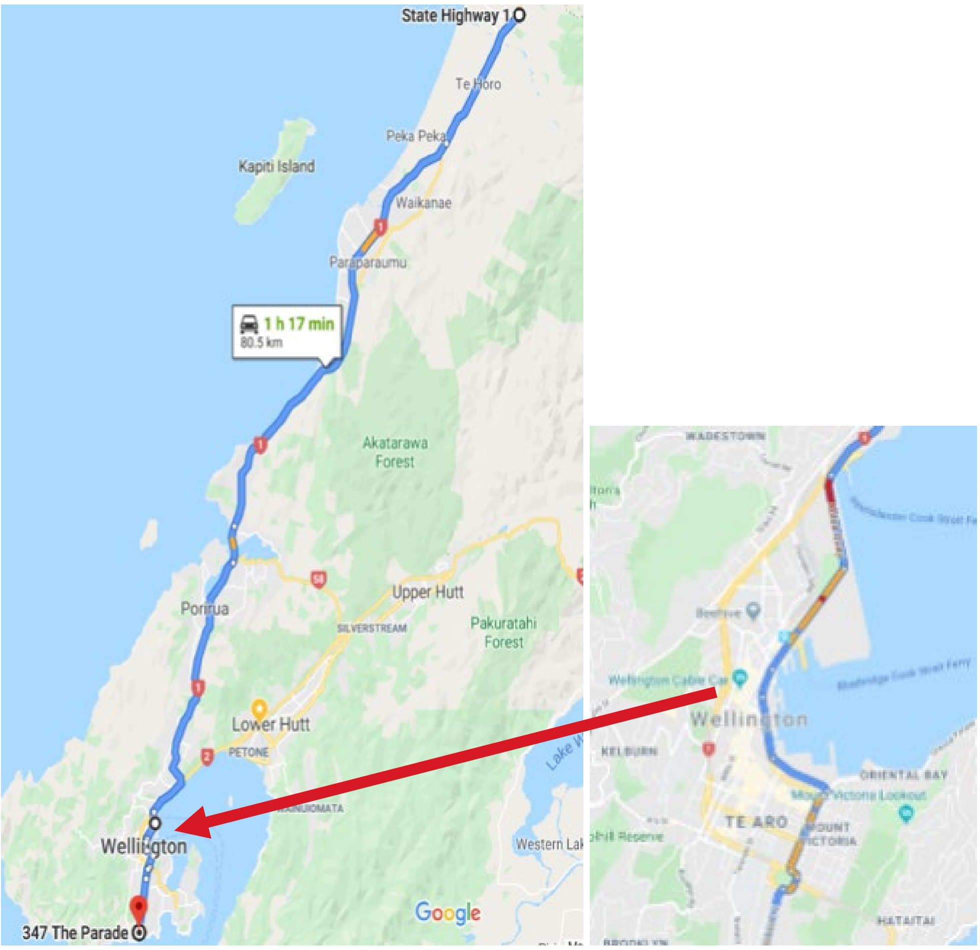


Figure A-2: Route 2

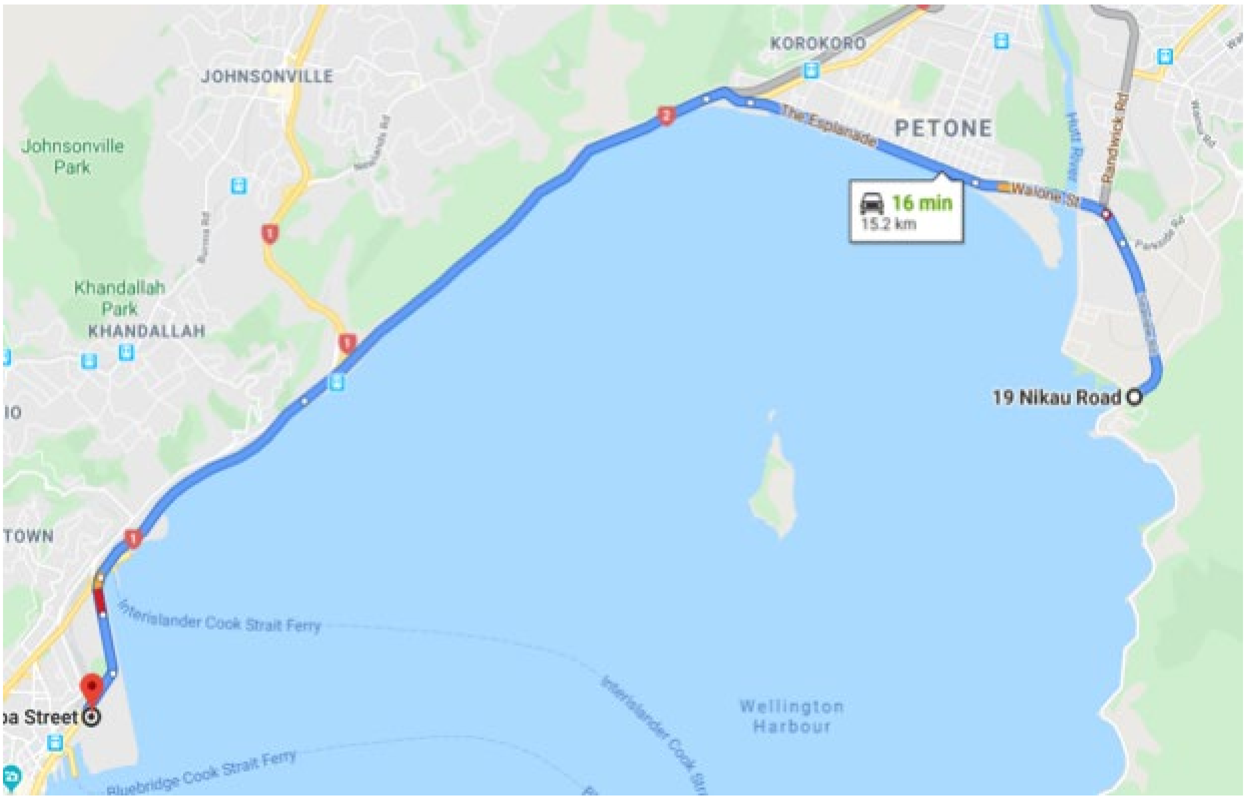


Figure A-3: Route 3

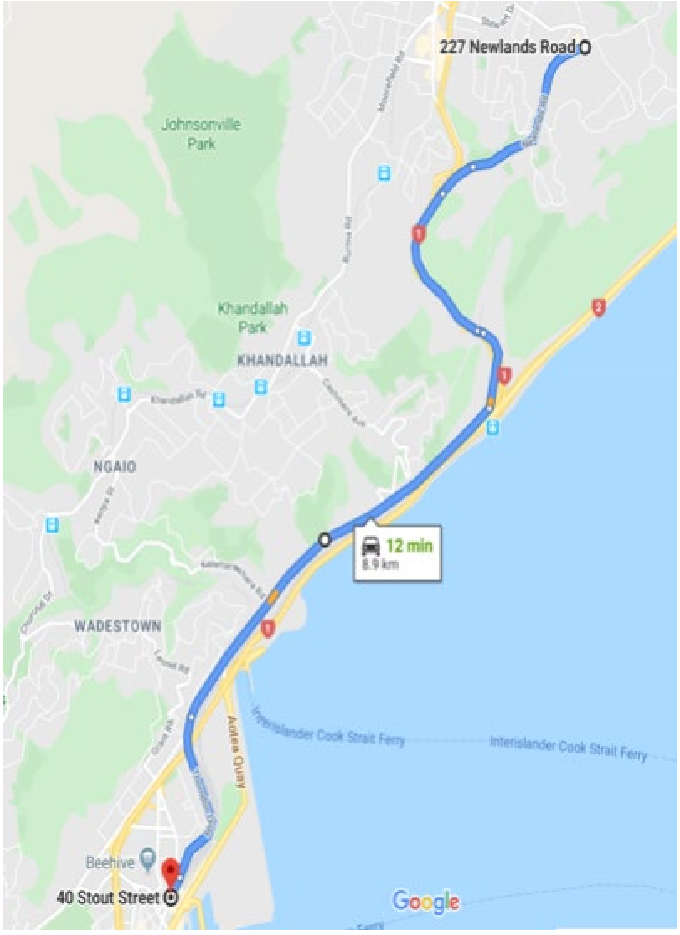


Figure A-4: Route 4

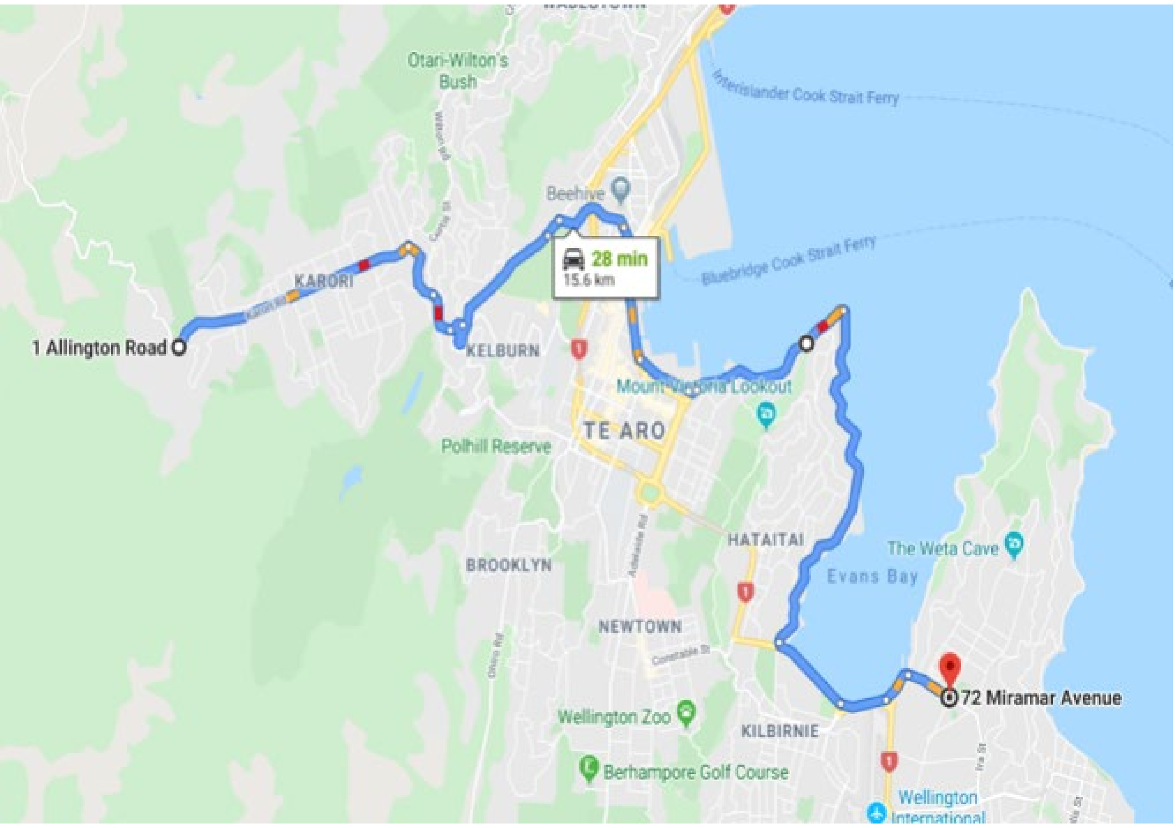


Figure A-5: Route 5

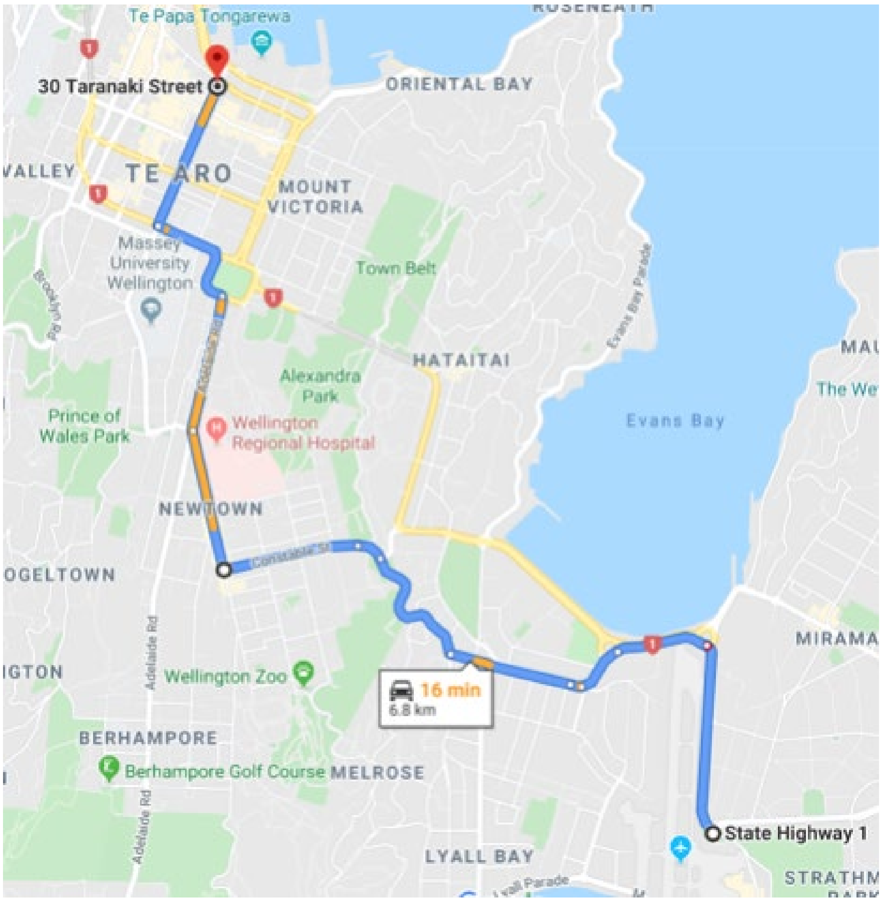


Figure A-6: Route 6

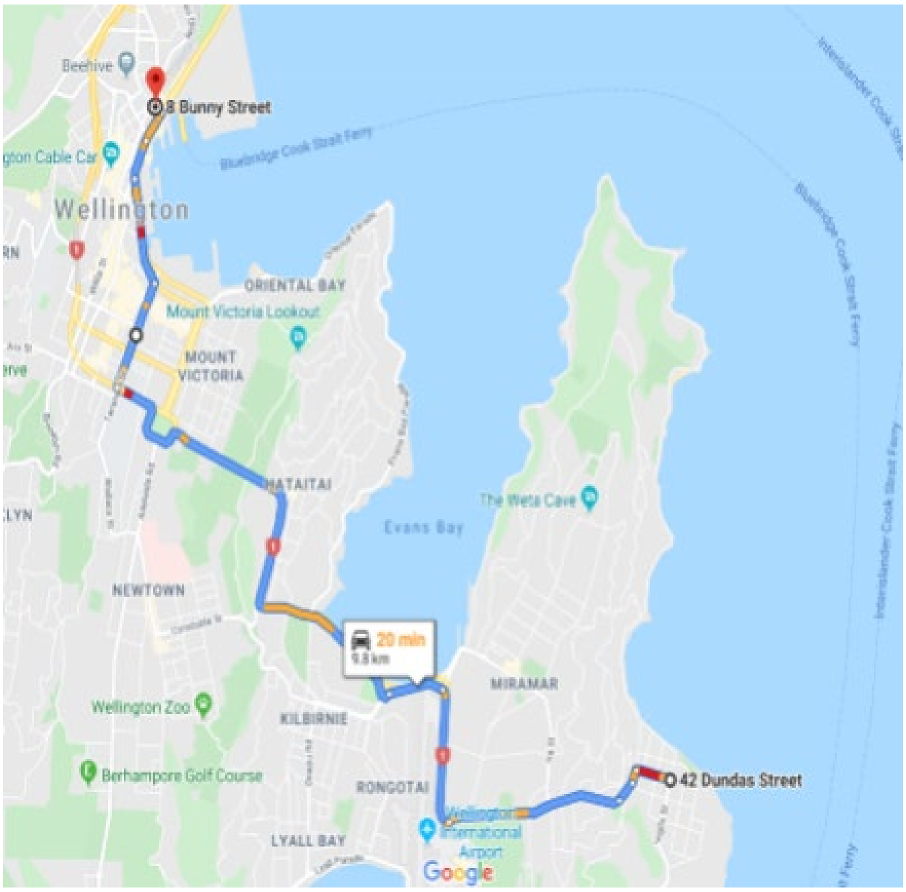


Figure A-7: Route 7

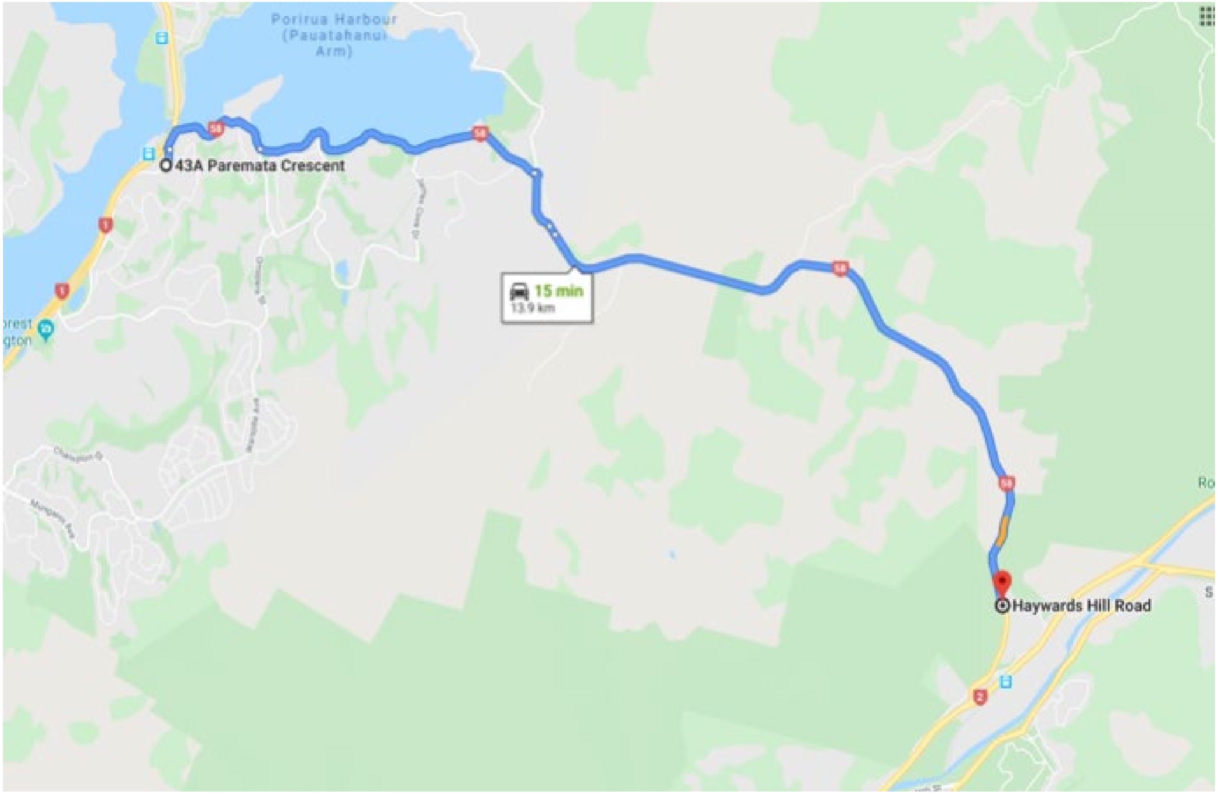


Figure A-8: Route 8

Appendix B 2013 TomTom Route Travel Time Profiles

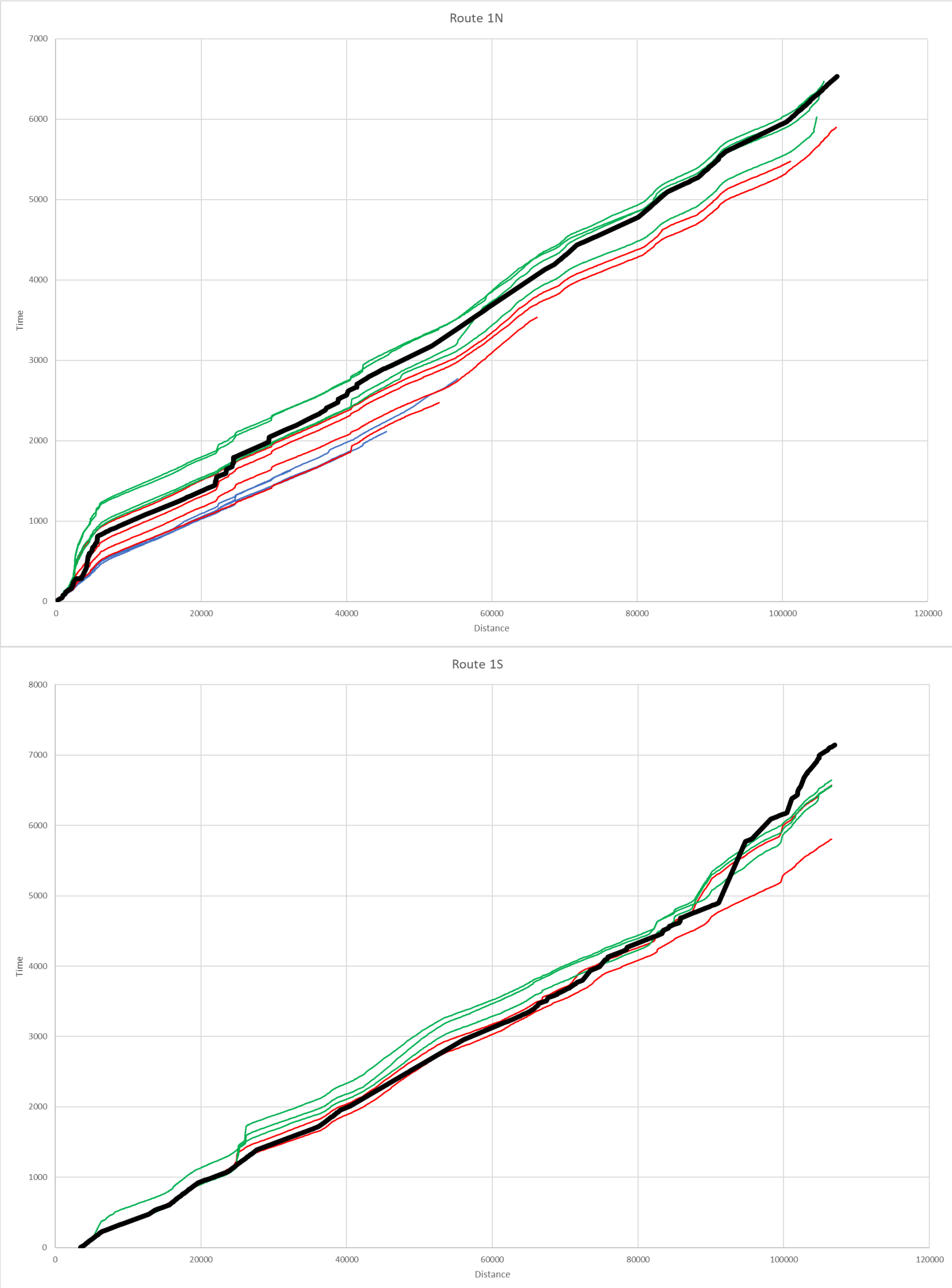


Figure B 1: Route 1 Travel Times – AM Peak

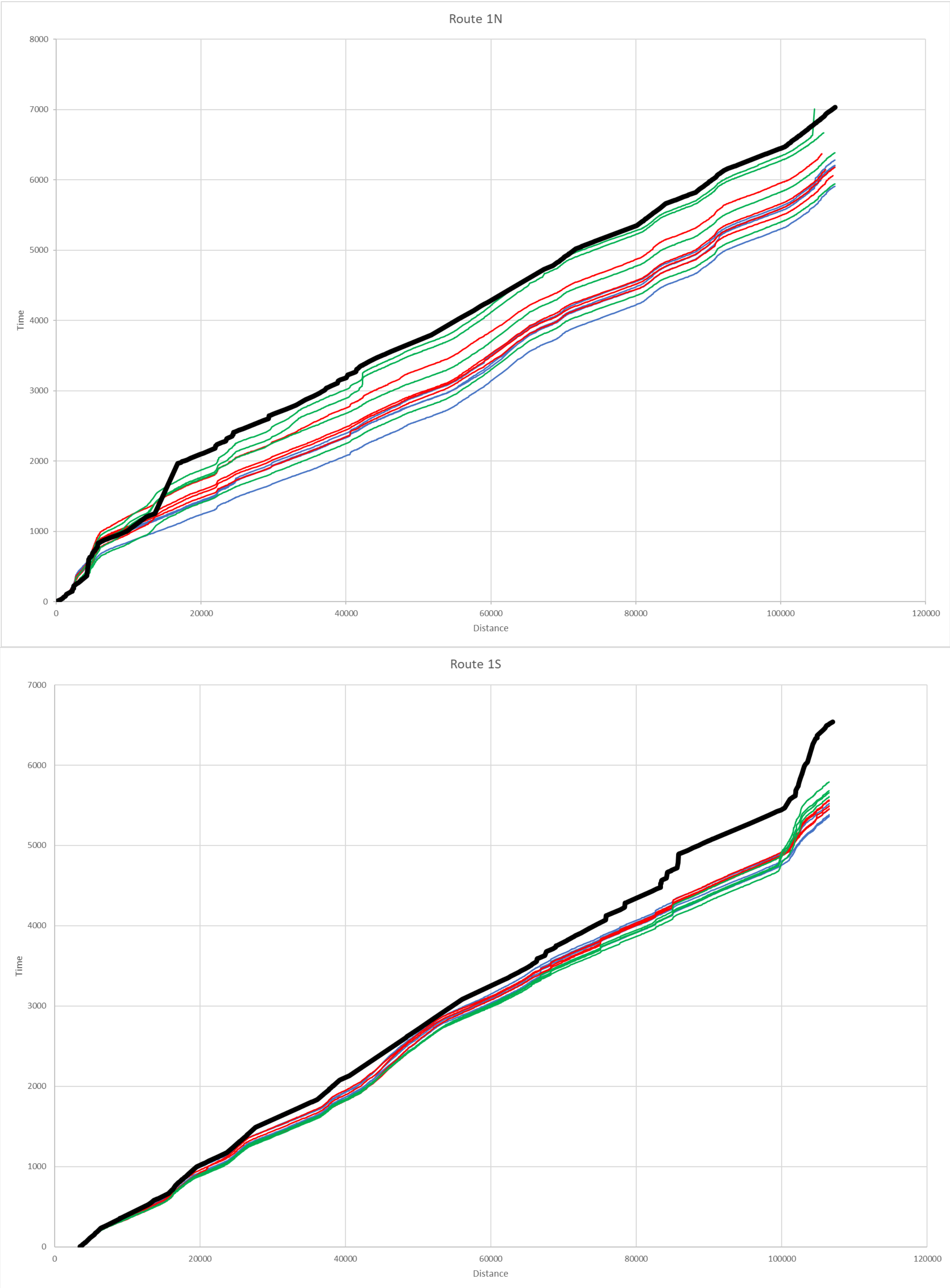


Figure B 2: Route 1 Travel Times – PM Peak

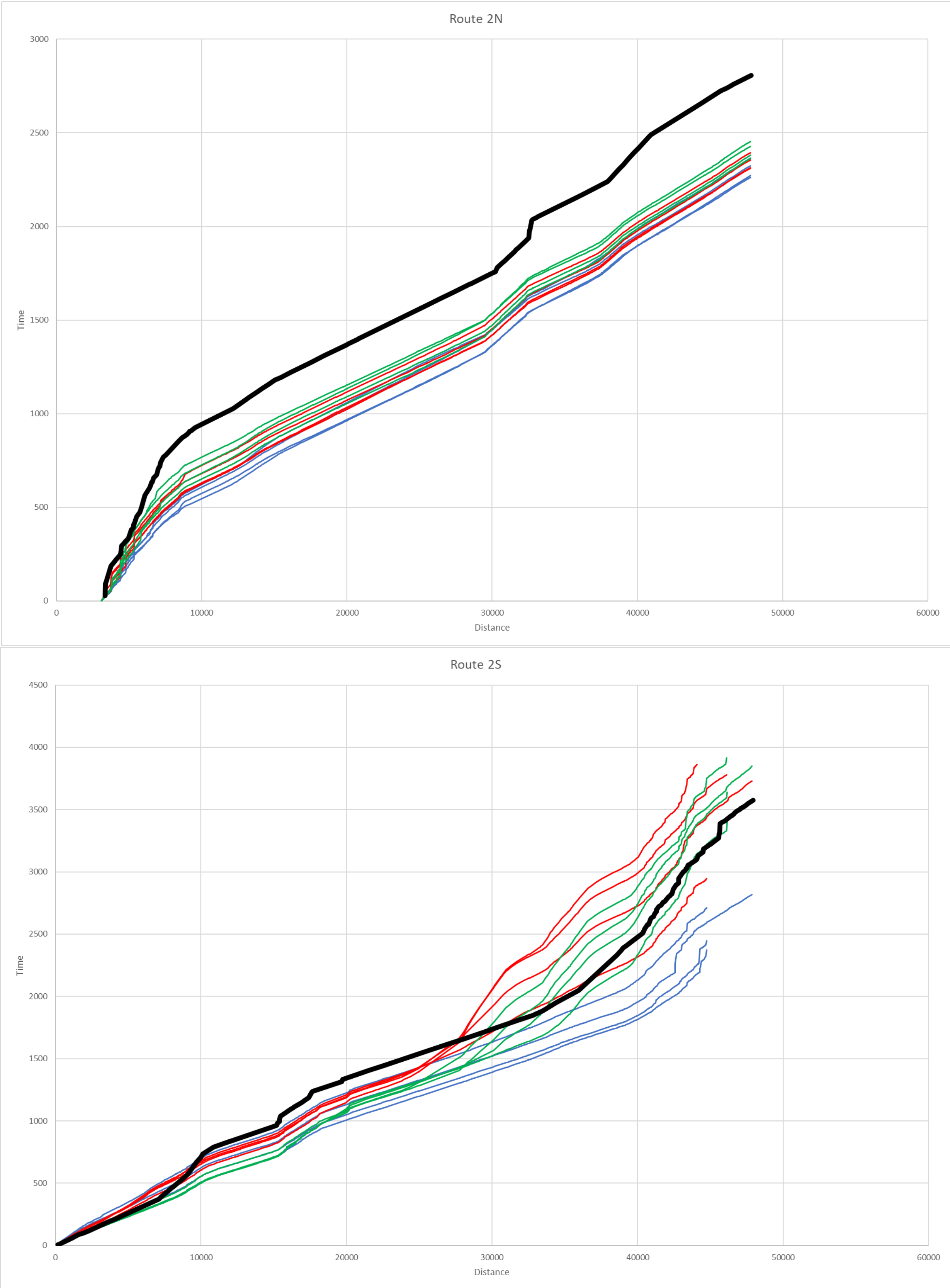
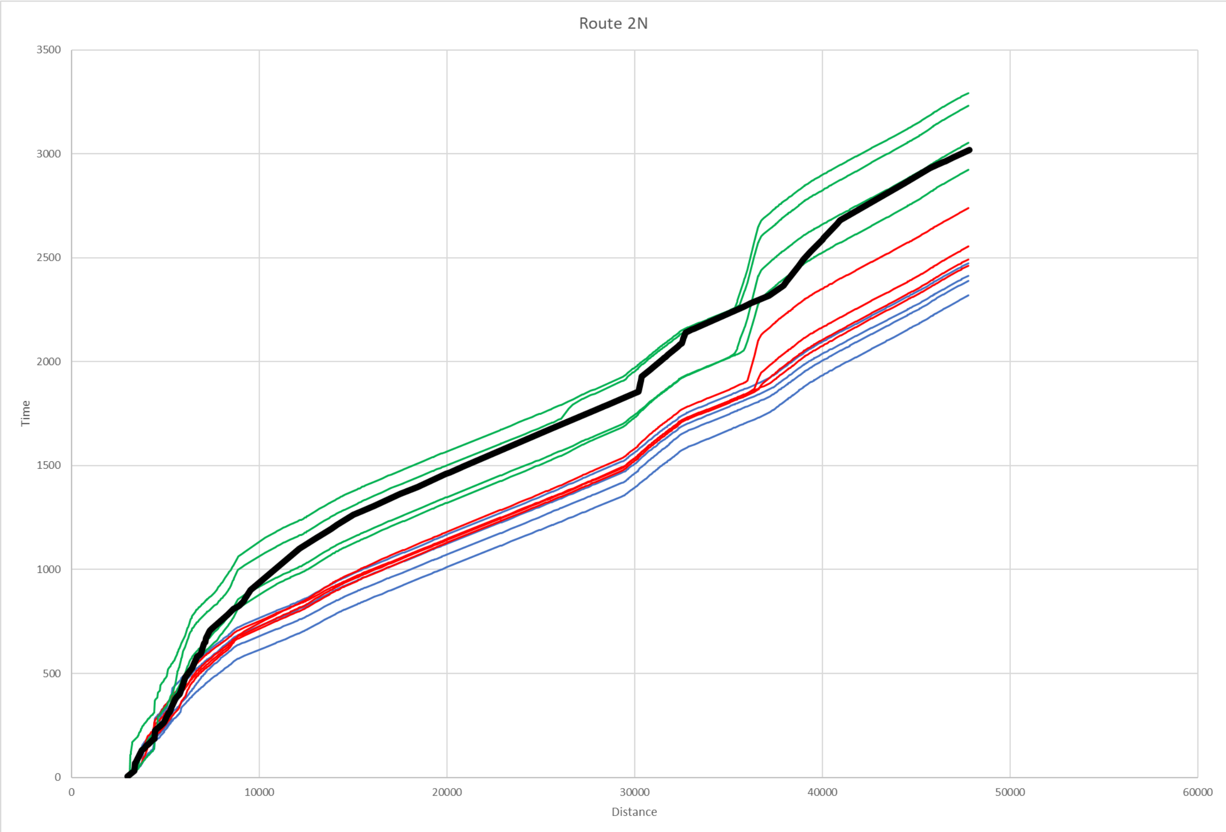


Figure B 3: Route 2 Travel Times – AM Peak



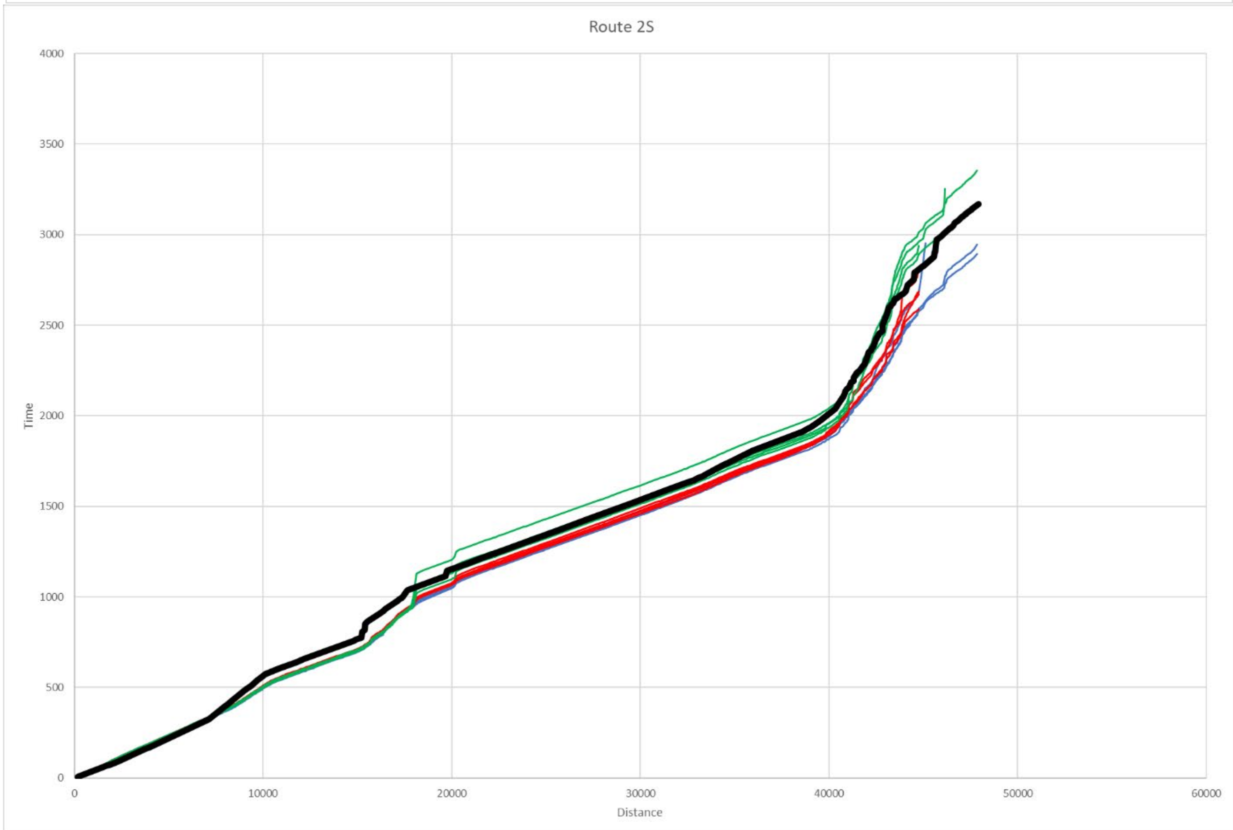


Figure B 4: Route 2 Travel Times – PM Peak

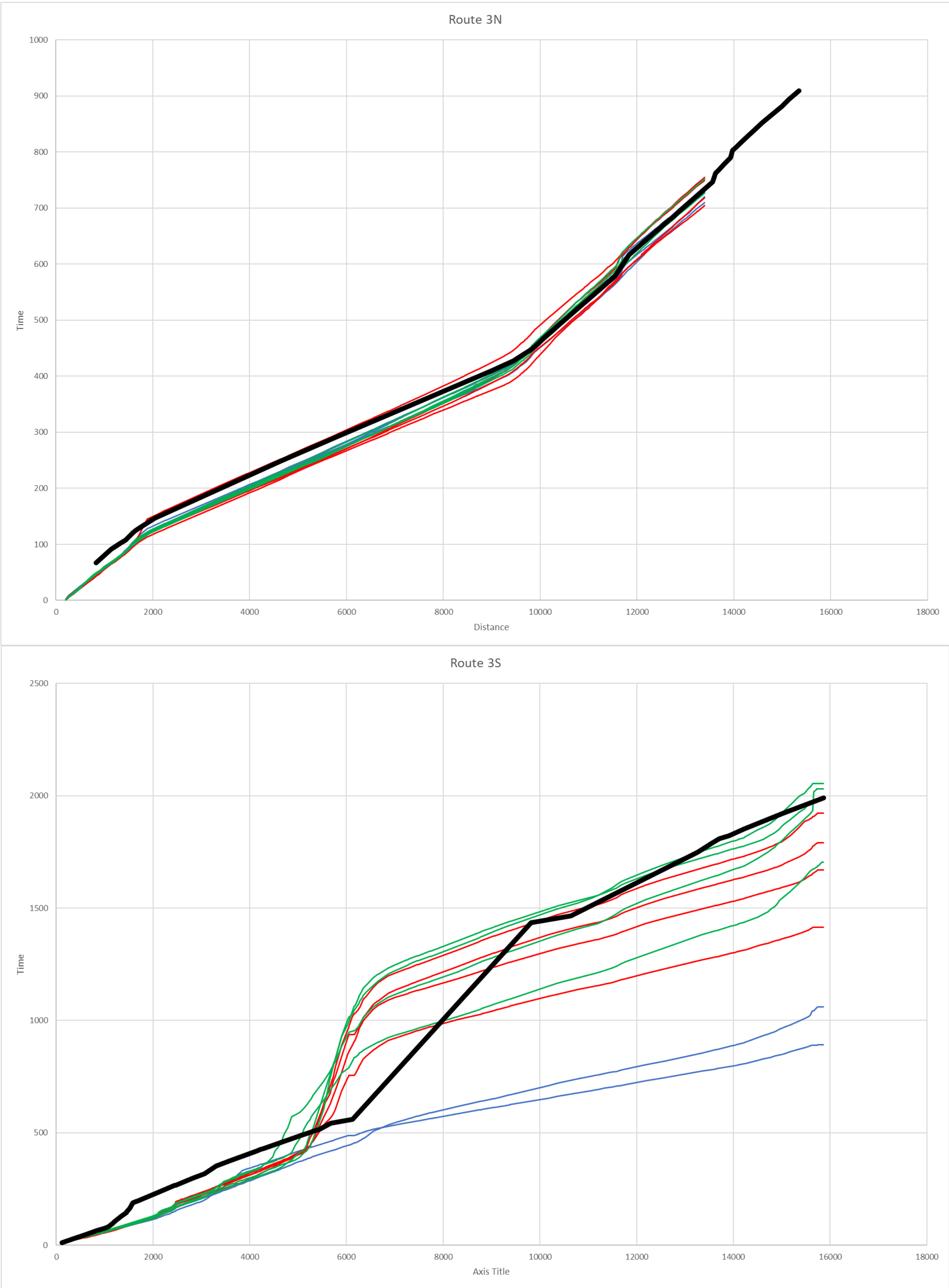
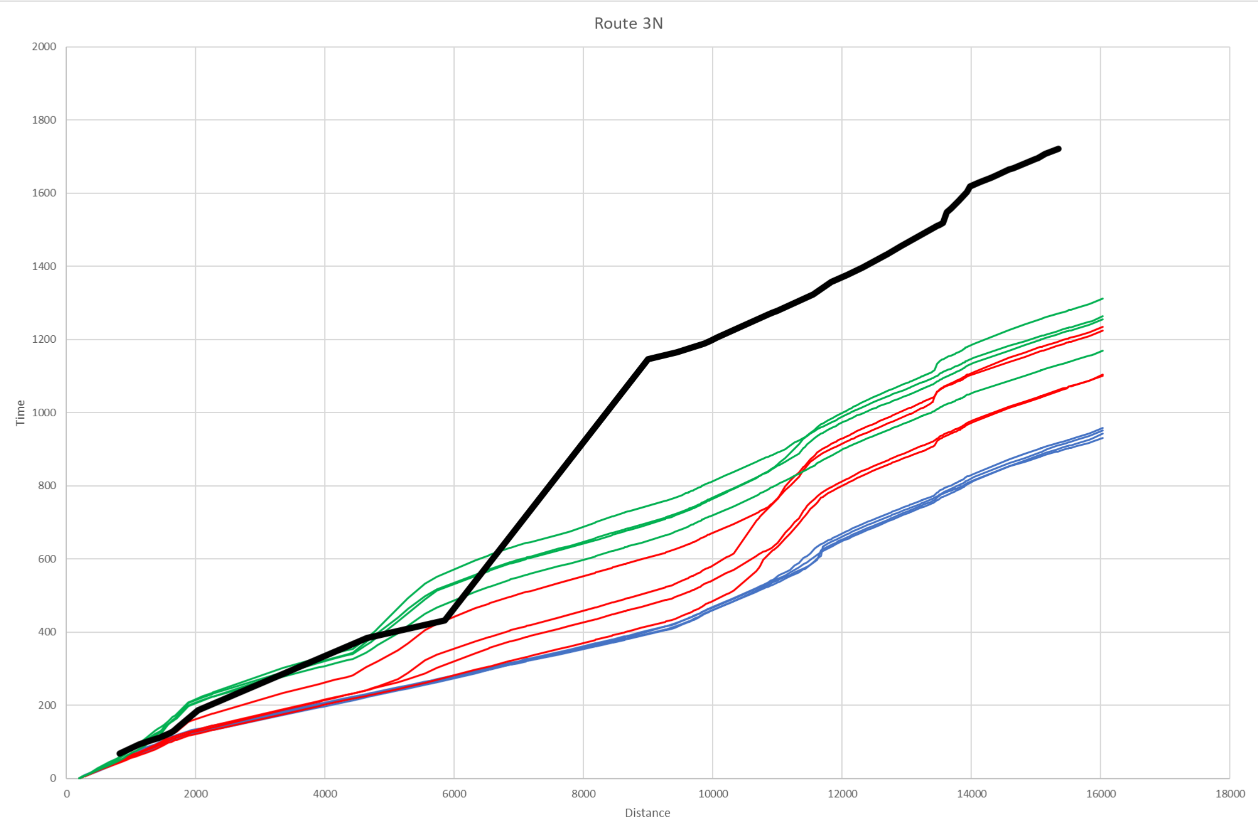


Figure B 5: Route 3 Travel Times – AM Peak



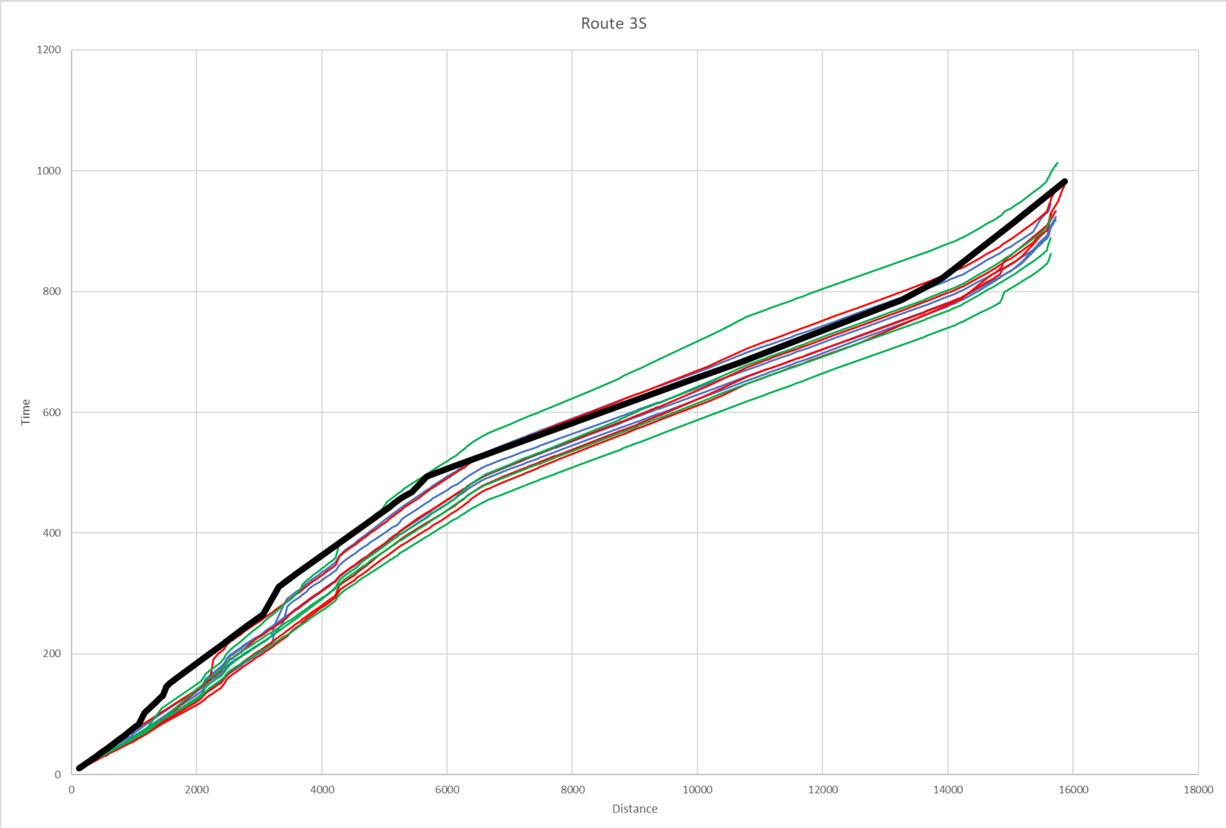


Figure B 6: Route 3 Travel Times – PM Peak

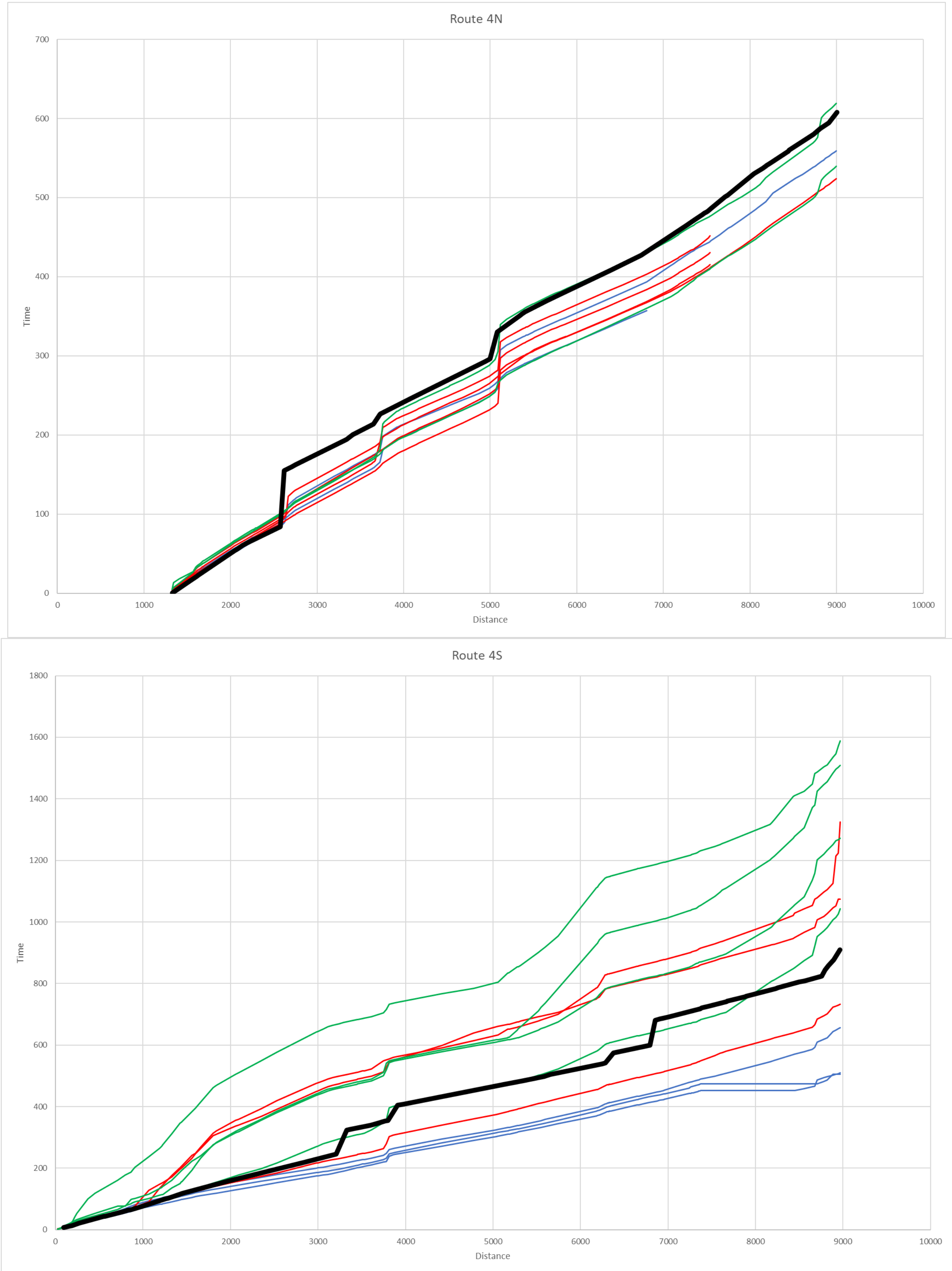
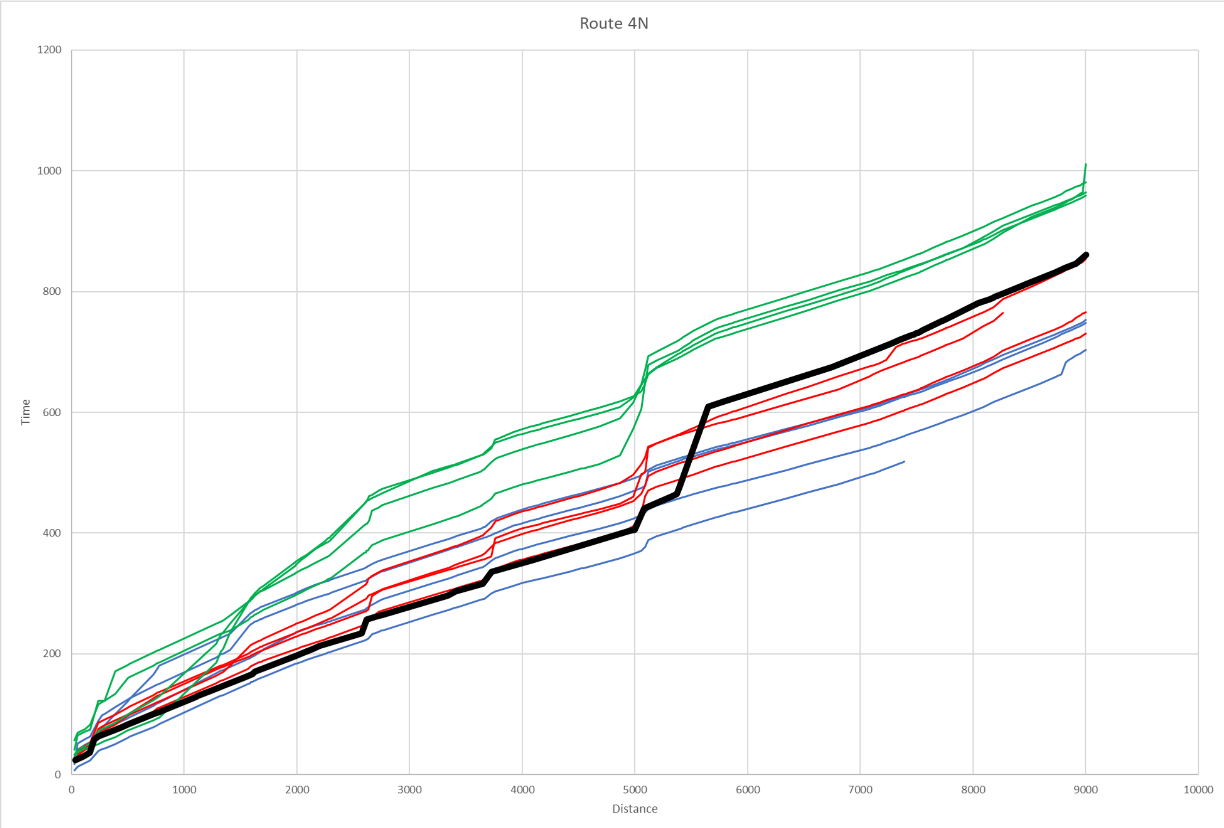


Figure B 7: Route 4 Travel Times – AM Peak



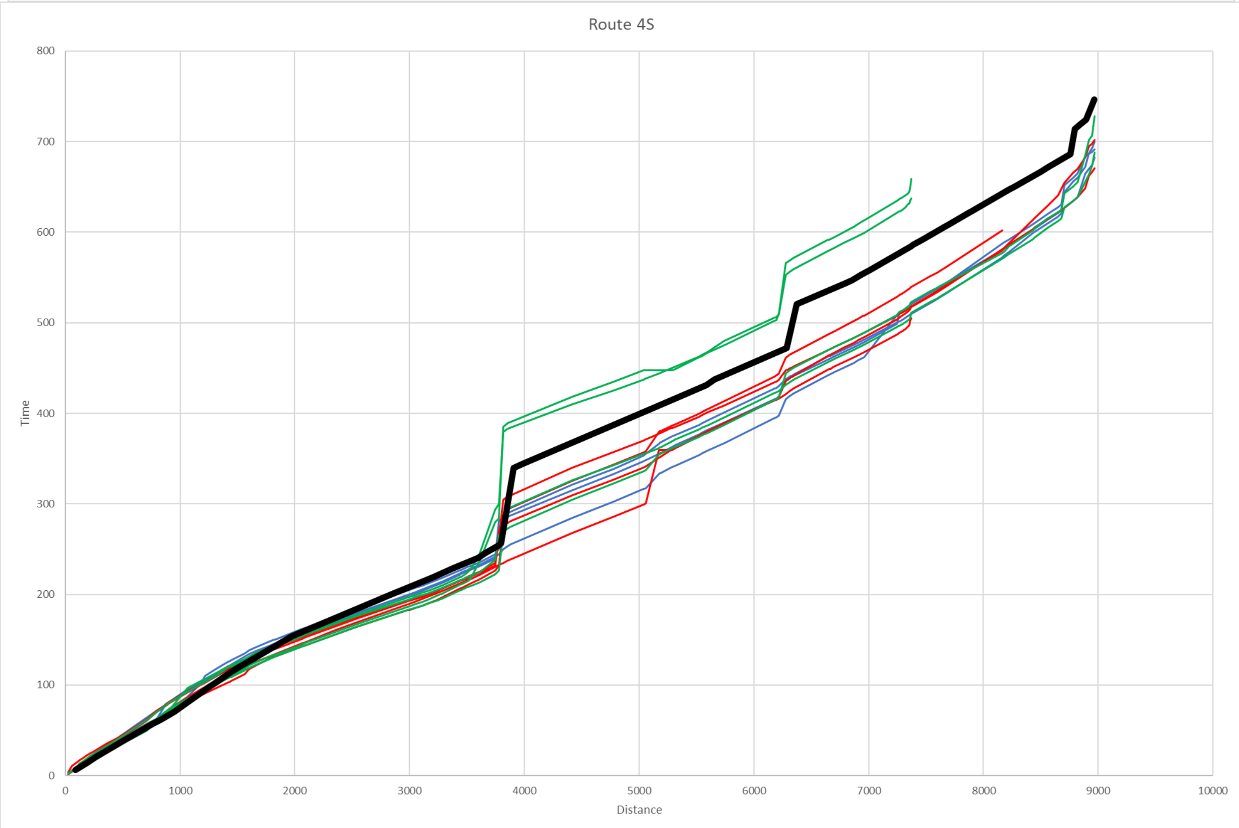
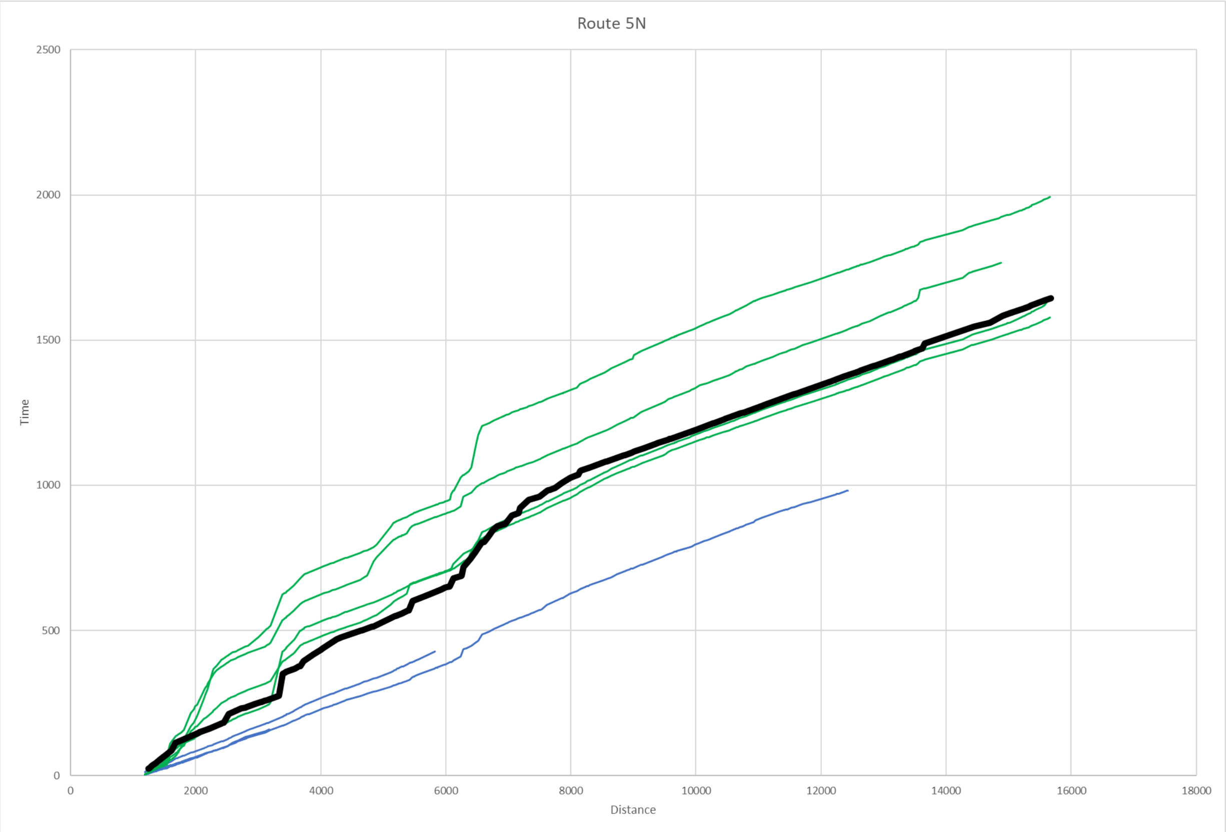


Figure B 8: Route 4 Travel Times – PM Peak



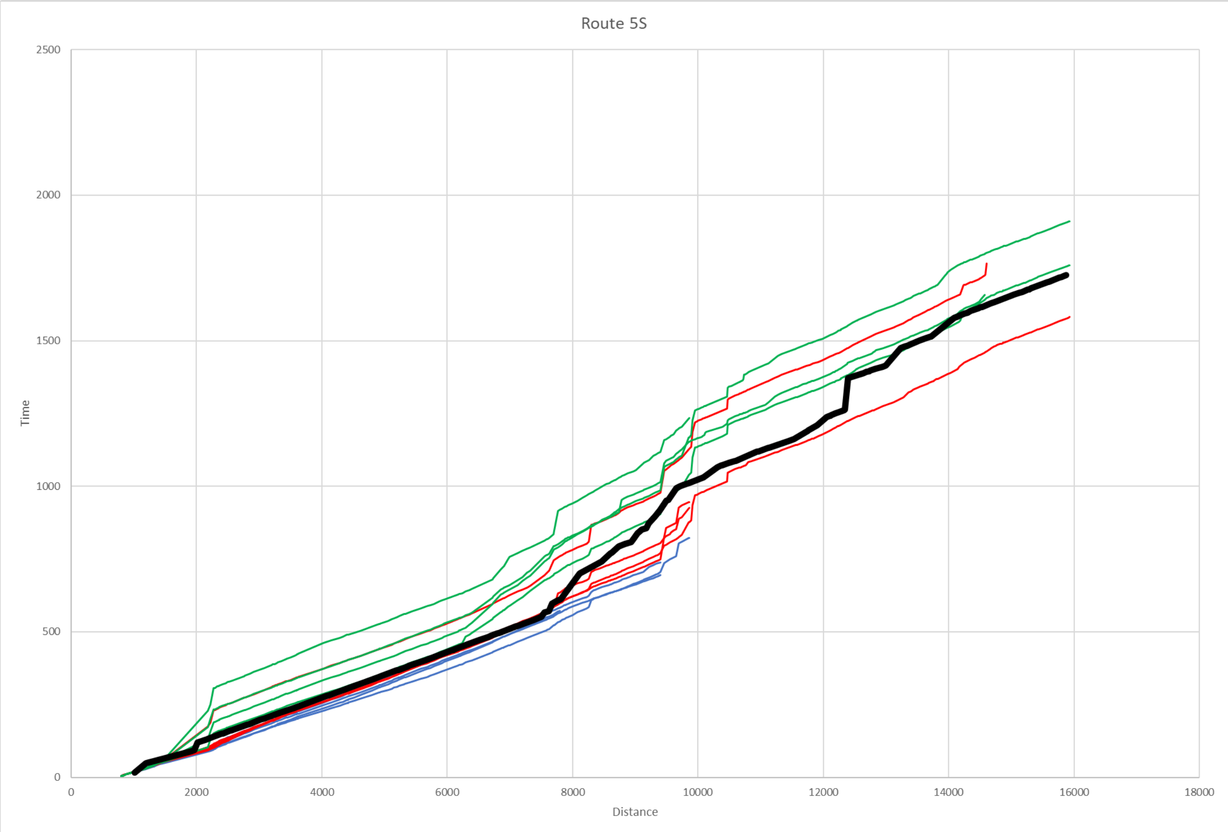
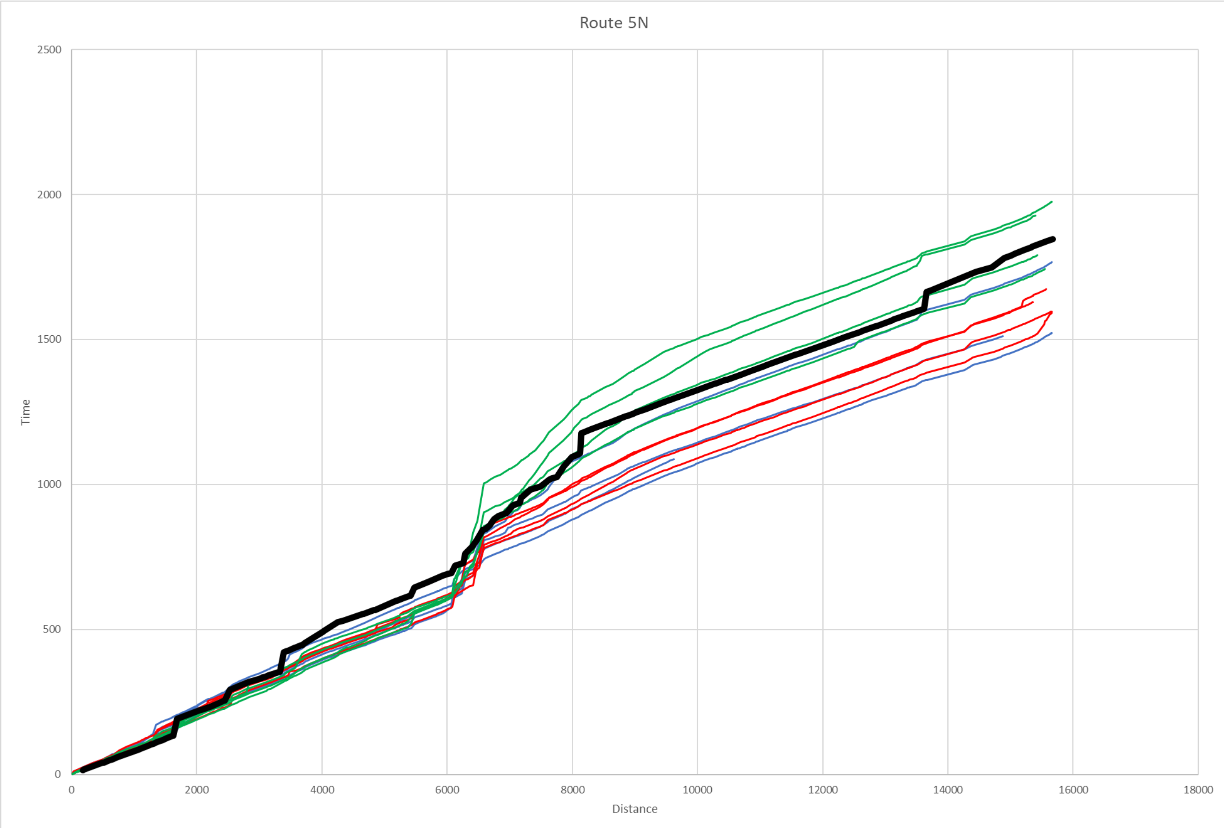


Figure B 9: Route 5 Travel Times – AM Peak



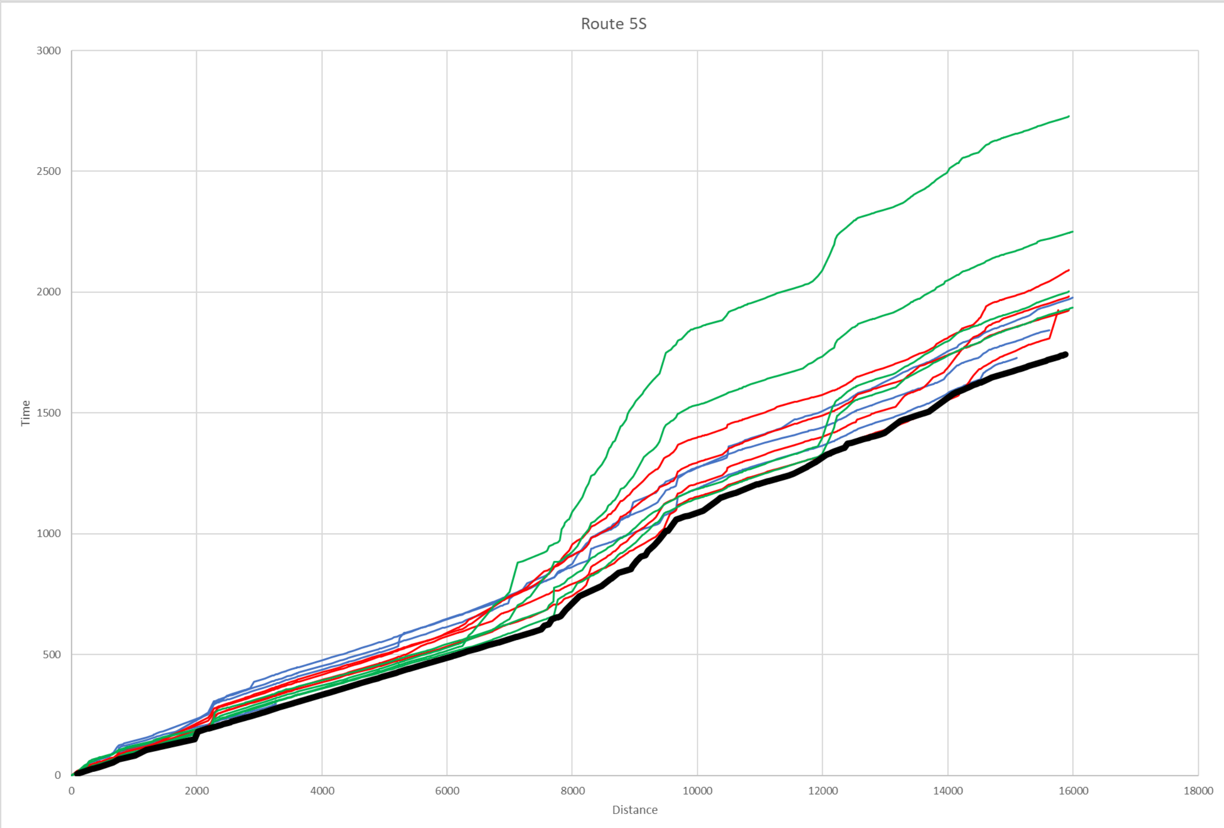
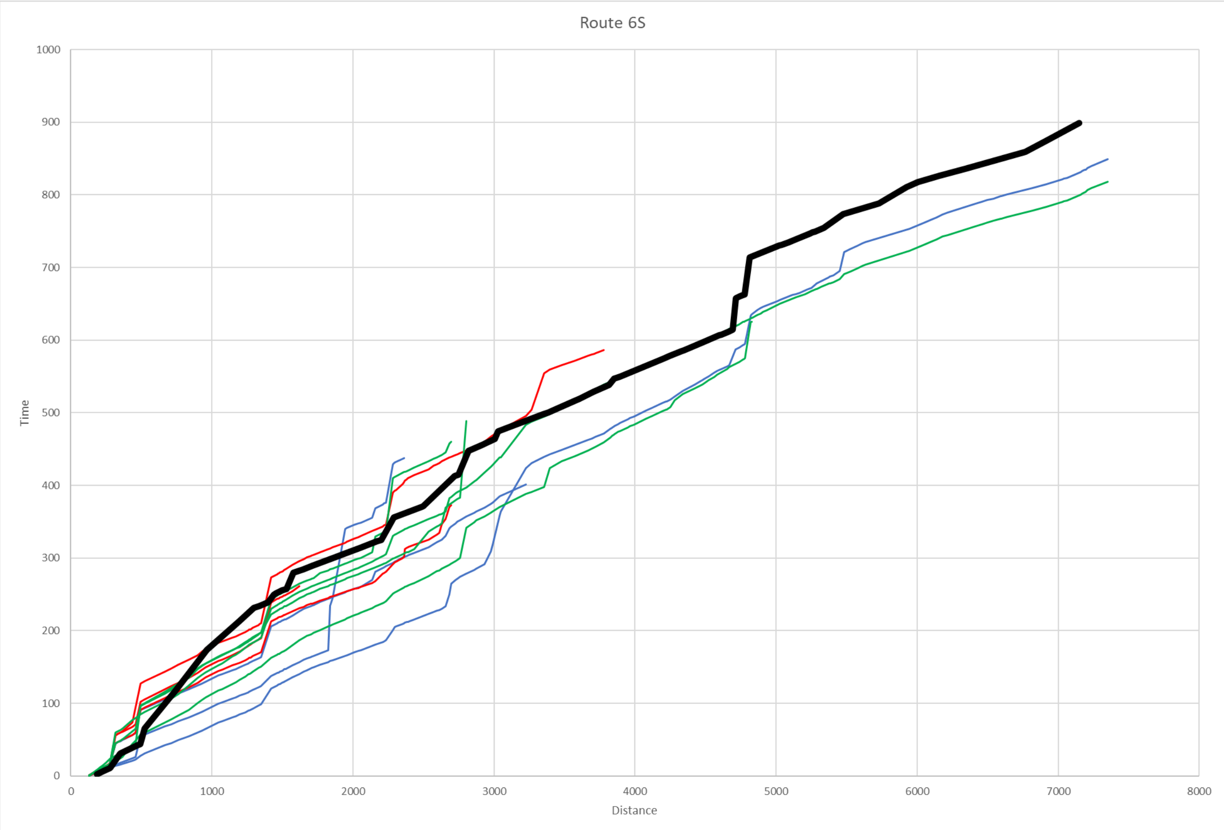


Figure B 10: Route 5 Travel Times – PM Peak



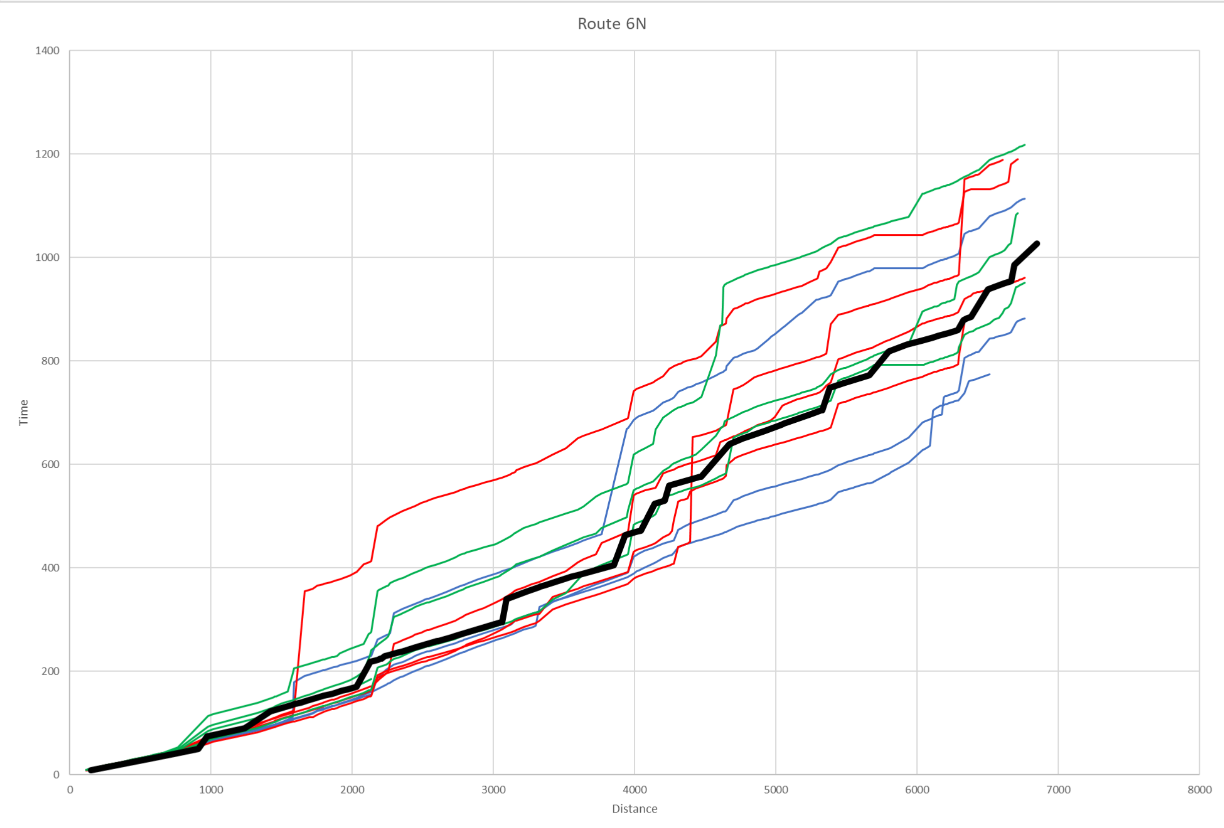


Figure B 11: Route 6 Travel Times – AM Peak

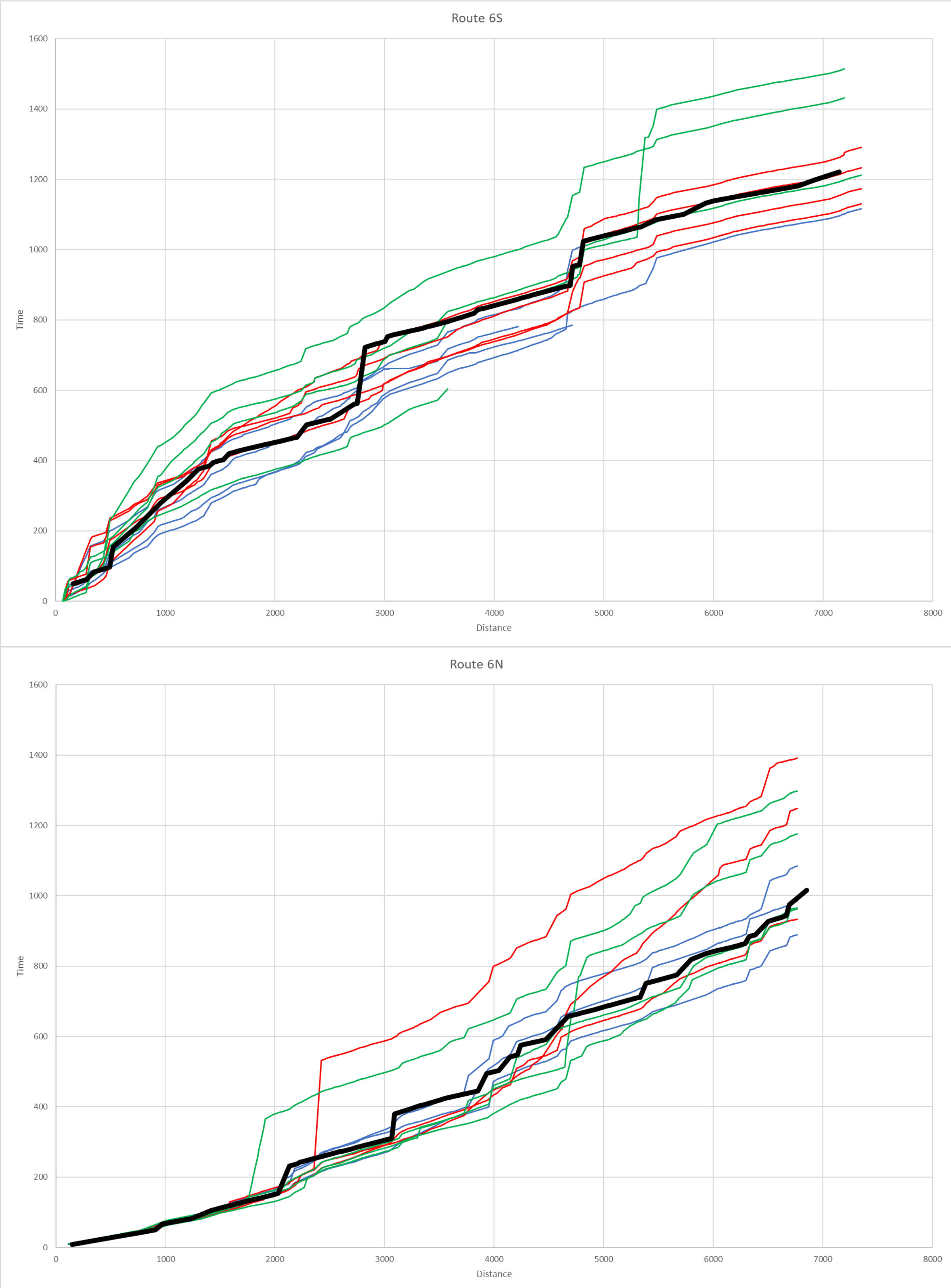


Figure B 12: Route 6 Travel Times – PM Peak

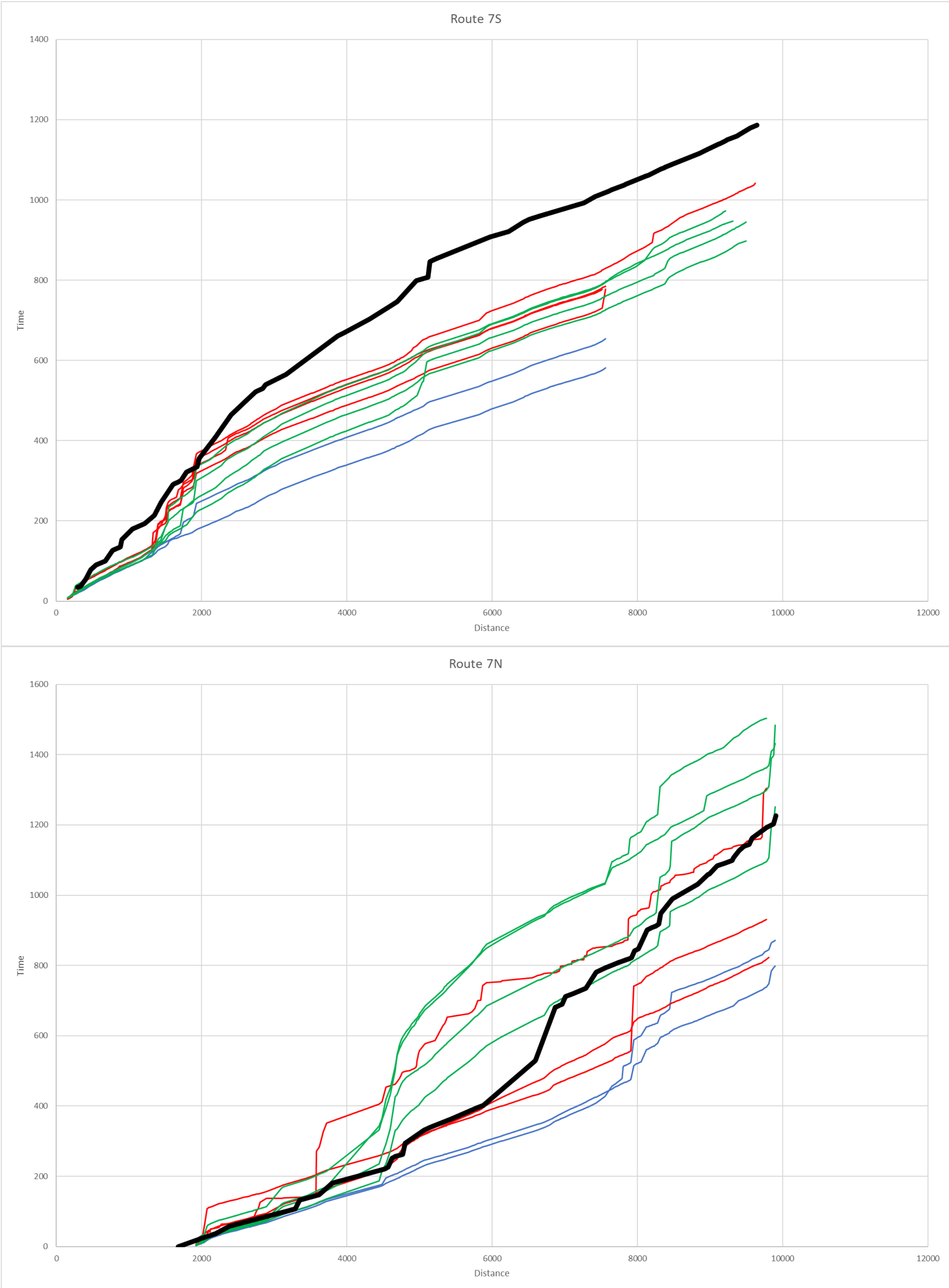
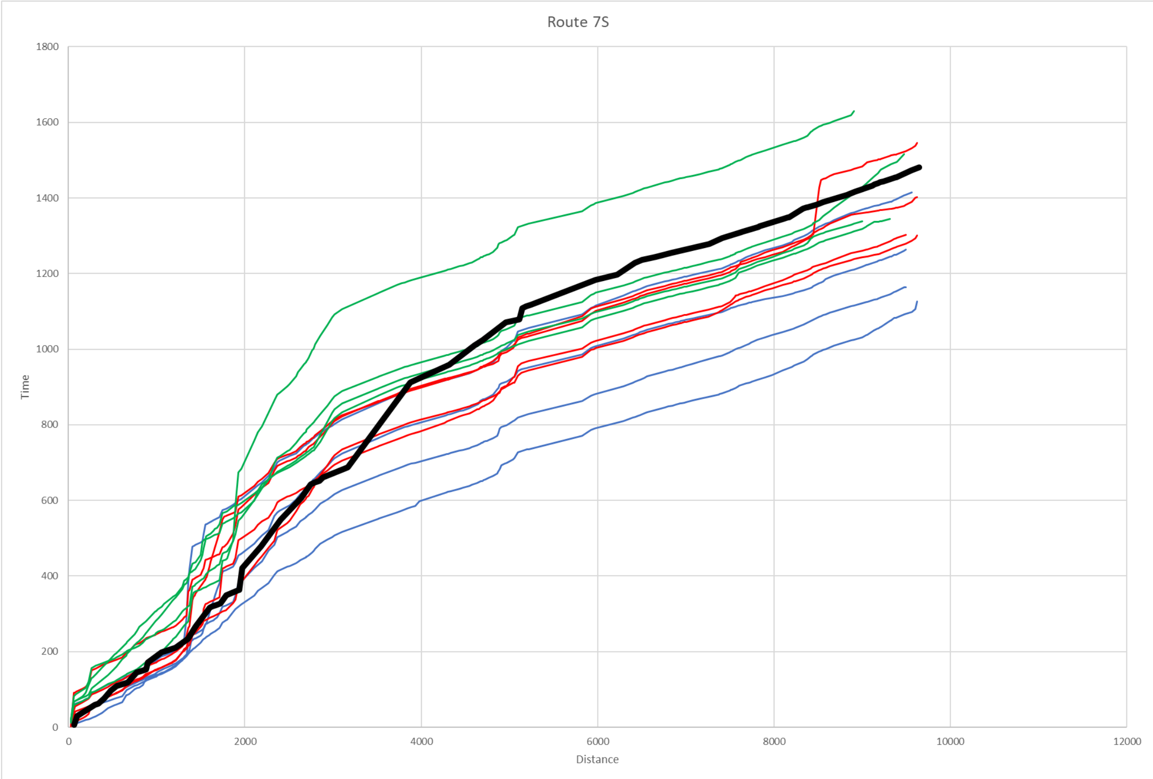


Figure B 13: Route 7 Travel Times – AM Peak



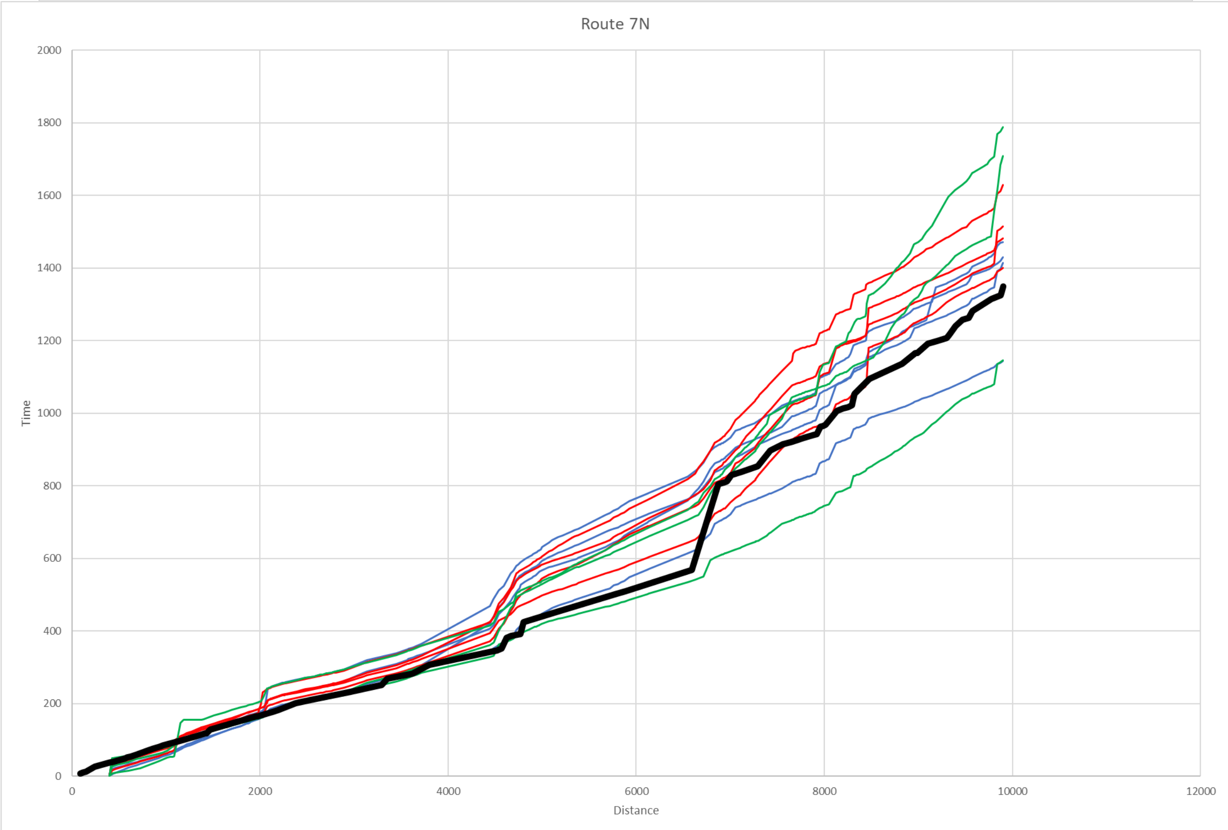


Figure B 14: Route 7 Travel Times – PM Peak

Appendix C Comments and Responses

No.	Comment By	Comment	Response
1	Tony Brennand, Waka Kotahi	Generally I am not unhappy with a move from the Akcelik curves to modified Davidson curves. Mathematically they are similar. My concern is that we have some key links in the network which have some extreme characteristics which appear to control major flows between key parts of the network. In particular we have Ngauranga Gorge with its extreme gradient and SH2 Ngauranga to Petone with tight curves and limited sight lines because of embankments creating a series of discrete bottlenecks in both directions. Both pieces of highway are also prone to large amounts of weaving. These various features have big impacts on capacity (where I suspect at high volumes is strongly stochastic), free flow speed and speed at capacity. I would be interested in understanding how observed speed flow curves deviate in shape and form from the more standard motorway /Expressway links and whether each deserves its own curve as they are critical controlling links for network traffic flows.	We accept that there are key locations that have a significant effect on network-wide flows, particularly Ngauranga. This technical note does review operation at Ngauranga and other motorway locations, so the analysis you recommend has been undertaken and reported. With a strategic model that does not include queue propagation or explicitly model weaving, there are limitations in what we can replicate using volume-delay curves. We concluded that the Davidson curve had a slightly better representation of motorway travel times based on analysis of a significant volume of observed data from TomTom. As I'm sure you know, Davidson curves were developed for motorways. We are not proposing to move away from the Akcelik curves which are still used for the non-motorway parts of the network.
2	Nadine Dodge, WCC	I agree with Tony's comments on the move from the Akcelik curves to modified Davidson curves. It all looks fine as far as I can tell.	Noted.
3	Nadine Dodge, WCC	If possible, would like to see more refinement of the model link parameters outlined in Tale 3-1 on page 5. In particular, traffic lane width, presence of side friction from parking, and curvature/gradient all play a strong role in determining capacity and free flow speed. My suspicion is that the current assumed values don't really correspond to Wellington conditions. For example, the two collector values - High Friction/Poor Alignment with a free flow speed of 50 and Low Friction/Good alignment with a free flow speed of 52, don't really seem to align with my experience of Wellington roads. I know there are many arterials with low capacity and free flow speeds due to a	We agree that side friction, lane width, presence of parking, etc effects capacity (and thus travel time), but consider this is best represented explicitly in a more detailed form of model rather than a strategic model. Even for the next tier of model, the wide-area microsimulation models, these elements (on-street parking, lane width, etc) are usually not specifically coded. Every road is not modelled in WTSM, which is appropriate for a strategic model, so a link can represent more than one road. Specifying a very explicit capacity would be problematic. Other constraints include how to reliably source this information, which

		combination of narrow lanes, friction from parking, and gradient/curvature. It would be good to have road links assigned a free flow speed and capacity that accurately corresponds to current layout: width, presence of parking, and curvature/gradient. In my view, this would offer two benefits: • Improved model accuracy and replication of real-world conditions • Ability to understand impacts of potential changes, e.g. removal of parking, lane widening, etc. Happy to work with you further on this and help with the thinking on how these things can be incorporated.	would vary by time period, for the entire region as well as how to forecast on-street parking by road 40 years into the future. Aside from the motorways (where parking obviously does not impact capacity), in the urban areas the main driver of travel time delays will be at intersections. We are focusing on how to improve representing delay at intersections which are coded simplistically at the moment. If you are aware of specific roads in the model where the coded capacity is inappropriate because of parking (etc), we would be happy to adjust the capacity on those links. Unfortunately, a comprehensive review/update of link capacity by road is outside the scope of our current commission but could perhaps be considered as a separate investigation.
4	Nadine Dodge, WCC	FOLLOW UP COMMENT TO ABOVE While I agree that the model doesn't need to have detail on the cause of the current free flow speed and capacity, I do think that getting the correct free flow speed and capacity for road links is critical. Otherwise, the model will be calibrated incorrectly, and reduced speeds would be incorrectly ascribed as delay/congestion when in actual fact it is just reduced speed/capacity due to poor road geometry.	For urban areas, network capacity will be driven by intersections and we are investigating methods to significantly improve intersection capacity and delay estimation. It would be feasible to do this for motorways, although on straight sections the free flow speed is likely to be 10kph greater than the posted speed limit. Again, there would need to be some tasks removed from the scope to enable link capacity review/update to be added unless this was investigated as a separate task in parallel to the model update.
5	Nadine Dodge, WCC	I am attaching the analysis I completed as part of the Bus Priority Action Plan on the impact of narrow lanes on traffic speeds. For many streets with core bus routes, there are reductions in speeds as high as 10 km/h. This does not incorporate delays due to curvature and slope so will be a significant underestimate of total reduction in speed due to road geometry. The analysis is based on parameters in the HCM.	Thank you for sharing this analysis.
6	Nadine Dodge, WCC	In order to give feedback on specific roads in the model where I think the model capacity is too high, I would need a summary of roads and what link type they have been assigned, as per Table 3-1.	Appreciated. Network shape file supplied which has all the coded information.

7	Nadine Dodge, WCC	Could another potential option be to derive free flow speed from TomTom data, by using overnight operating speeds as a proxy for free flow speed?	This could provide very accurate free-flow speeds for existing roads. New roads would still an estimated free-flow speed coded, although these could be based on the analysis of data for existing roads. However, this task is extensive (many months). There is the cost/time to extract the data from TomTom and then process it. It is unfortunately beyond what can be delivered within this project.
8	Andy Ford, GWRC	From my perspective it is well researched, well written and has the justification to support the approach to moving to use Davidson curves for motorways in WTSM / WTAM.	No response required.
9	Andy Ford, GWRC	The fact that 2013 travel times validate reasonably well should probably be placed in the context of WTSM representing an 'average across a 2hr period' with the reality being that variation would be expected throughout the 2hr time period and from day to day. As always, we have to keep this context front of mind when presenting / interpreting results and note that other tools (such as AIMSUN) are better suited for assessing reliability and variation across a longer time period.	We concur that it is important to remember that the model is replicating 'average 2 hour' conditions and that actual peaks-and-troughs within the period are not explicitly represented in a strategic model such as WTSM with a static assignment.
10	Ian Clark, Flow	The technical note is well written, and the recommendations clearly based on analysis.	No response required.
11	Ian Clark, Flow	The proposed speed flow curves have some attraction, with reductions in speeds expected, even on a motorway, before a link reaches capacity.	Agreed.
12	Ian Clark, Flow	There may well be a need for refinement as we go, particularly for non-standard conditions (e.g. gradient/curvature).	We can consider targeted adjustments to speed-flow curves for Ngauranga in Stage 2 of the project (model rebuild). Although its noted that the more specific changes that are introduced, the greater risk of reduced confidence in model outputs due to less clarity on appropriate coding for new infrastructure.

Christchurch

Hazeldean Business Park, 6 Hazeldean Road
Addington, Christchurch 8024
PO Box 13-052, Armagh
Christchurch 8141
Tel +64 3 366 7449
Fax +64 3 366 7780

Please visit **www.stantec.com** to learn more about how Stantec design with community in mind.