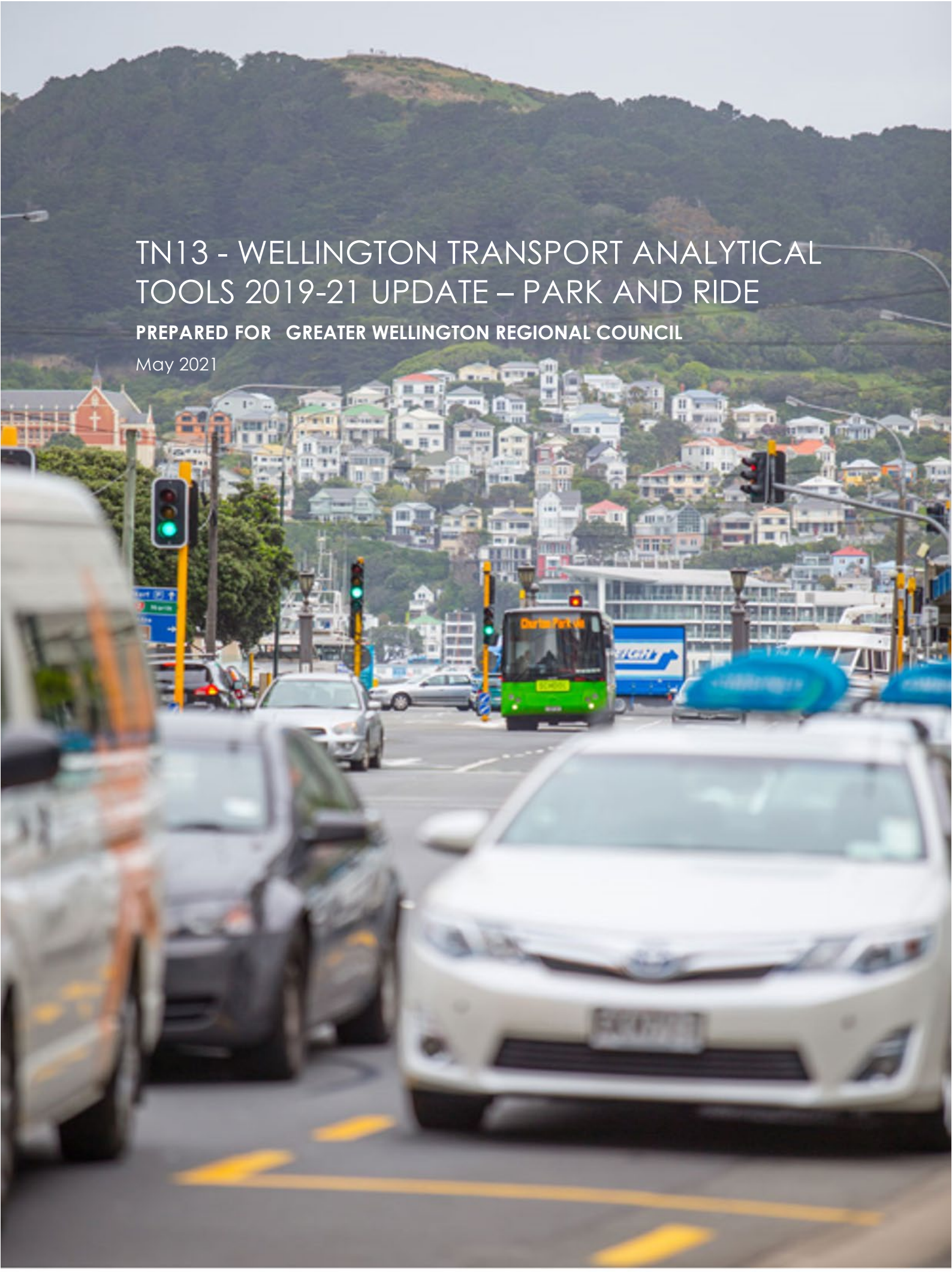

TN13 - WELLINGTON TRANSPORT ANALYTICAL TOOLS 2019-21 UPDATE – PARK AND RIDE

PREPARED FOR GREATER WELLINGTON REGIONAL COUNCIL

May 2021

Stantec | JACOBS

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QUALITY STATEMENT

PROJECT MANAGER	PROJECT TECHNICAL LEAD
Ali Siddiqui	Julie Ballantyne

PREPARED BY		
Tony Wicker Julie Ballantyne		26/05/2021
CHECKED BY		
Geoffrey Cornelis		26/05/2021
REVIEWED BY		
Alan Kerr		26/05/2021
APPROVED FOR ISSUE BY		
Alan Kerr		26/05/2021

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

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Greater Wellington Regional Council

TN13 - Wellington Transport Analytical Tools 2019-21 update – Park And Ride

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APPENDICES

Appendix A Park and Ride Parking Charge Inputs
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A.2 Vehicle Occupancy
Appendix B Comments and Responses

1. Introduction

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

At the top of the hierarchy of Analytical Tools is the "Demand Model" which is referred to as the Wellington Transportation Strategy Model (WTSM). Siting underneath is a more detailed public transport choice model, the Wellington Public Transport Model (WPTM).

The primary objective of the task reported in this technical note is to improve the representation of park and ride in WTSM. In particular, the following functionality was to be implemented in WTSM as part of the Stage 1 incremental improvements:

- Add car access leg to public transport to the road assignment (this was specified for Stage 2);
- Update the fixed access costs to/from public transport so that these are recalculated during the model run to reflect forecast congestion on the network; and
- Add parking costs to the generalised cost for park and ride, which will be a weighted average of formal and informal spaces.

This technical note is organised to document:

- Parking supply (capacity and charges) at rail stations with park-and-ride;
- Analysis of current rail station access modes;
- Current process in WTSM including specific weaknesses to be addressed;
- The changes incorporated and the rationale; and
- The implementation in the Python version of WTSM.

It is noted that this task is part of Stage 1 of the project, focused on delivering incremental improvements prior to the model rebuild in Stage 2.

2. Parking Supply at Park and Ride Sites

2.1 Parking Spaces - Formal

Formal park and ride spaces by rail stations were downloaded from the Greater Wellington Regional Council open data website (https://data-gwrc.opendata.arcgis.com/datasets/metlink-park-and-ride-areas/data).

This information was cross-checked with a summary of stations offering park and ride from the MetLink website (https://www.metlink.org.nz/getting-around/trains/park-and-ride-car-parks/). Where the GWRC source specified park and ride spaces but the Metlink source indicated there were none, the stations were visually checked with Google Street View. In all cases, the GWRC data was up-to-date.

The numbers of formal spaces are listed in the table below.

Table 2-1: Formal Park and Ride Spaces

Station	Line	Formal Park and Ride Spaces
Johnsonville	Johnsonville	55
Raroa	Johnsonville	45
Khandallah	Johnsonville	14
Simla Crescent	Johnsonville	34
Awarua Street	Johnsonville	20
Ngaio	Johnsonville	49
Crofton Downs	Johnsonville	54

Station	Line	Formal Park and Ride Spaces
Takapu Road	Kapiti	175
Redwood	Kapiti	147
Tawa	Kapiti	214
Porirua	Kapiti	811
Paremata	Kapiti	222
Mana	Kapiti	147
Plimmerton	Kapiti	157
Pukerua Bay	Kapiti	30
Paekakariki	Kapiti	79
Paraparaumu	Kapiti	527
Waikanae	Kapiti	470
Petone	Hutt	478
Melling	Melling	212
Ava	Hutt	54
Woburn	Hutt	159
Waterloo	Hutt	628
Naenae	Hutt	24
Taita	Hutt	120
Pomare	Hutt	87
Manor Park	Hutt	55
Silverstream	Hutt	132
Trentham	Hutt	127
Wallaceville	Hutt	126
Upper Hutt	Hutt	349
Featherston	Wairarapa	147
Woodside	Wairarapa	98
Carterton	Wairarapa	144
Solway	Wairarapa	87
Masterton	Wairarapa	87
TOTAL		**6,364**

2.2 Parking Spaces - Informal

Informal park and ride spaces refers to the use of adjacent resident streets or berms that are not explicitly provided for park and ride.

There is no observed data on informal park and ride capacity readily available. Assumptions will therefore need to be made, likely a percentage increase applied to the amount of formal capacity.

2.3 Parking Charges

There are currently no charges for using park and ride facilities at rail stations.

3. Rail Station Access Analysis

The 2017 rail passenger survey has been reviewed to investigate access/egress mode shares and patterns for passengers prior to boarding/alighting the train.

This survey distributed 15,000 postcards to passengers waiting on platforms between 13 and 25 June 2017 on weekday morning peaks, weekday off peaks, and weekends. This represented a sample of 15.7% according to the report "Wellington Rail Passenger Survey 2017", by Research New Zealand for GWRC.

The analysis in this technical note utilised an expanded and geocoded dataset provided by GWRC.

The dataset only has suburbs recorded as the origin with the street field blank for all records. This means there will be discrepancies in the calculation of access distance, which is based on the centroid of a suburb to the specified train station. For this reason, walk trips considered spurious (i.e. longer than 5km) were excluded while car trips parked at the station with an access distance of 250 metres or less were also removed from the analysis. Taxi trips were combined with "car – I was dropped off".

In the following table and figure, the overall proportion of access modes are shown for weekday expanded trips.

Table 3-1: Weekday Trips and Proportions by Access Mode

Rev No.	Bike	Bus	Car – Drop Off	Car - Parked at the Station	Car - Parked Elsewhere	Walk	Total
Trips	445	17,28	13,67	6,770	1,326	10,372	22,008
Percent	2%	8%	6%	31%	6%	47%	100%

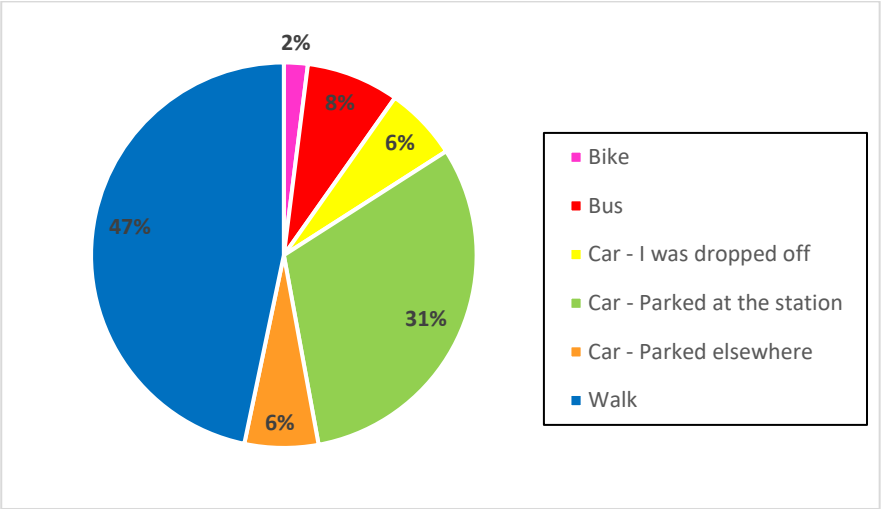

Figure 3-1: Overall Mode of Station Access

This shows that walking is the dominant access mode (47%). Car access is a similar magnitude, with drop off (kiss and ride and taxi), park and ride at the station, and park and ride elsewhere totalling 43%. Bus (8%) and bike (2%) access are minimal overall.

Mode of access by station was then examined, which is shown below.

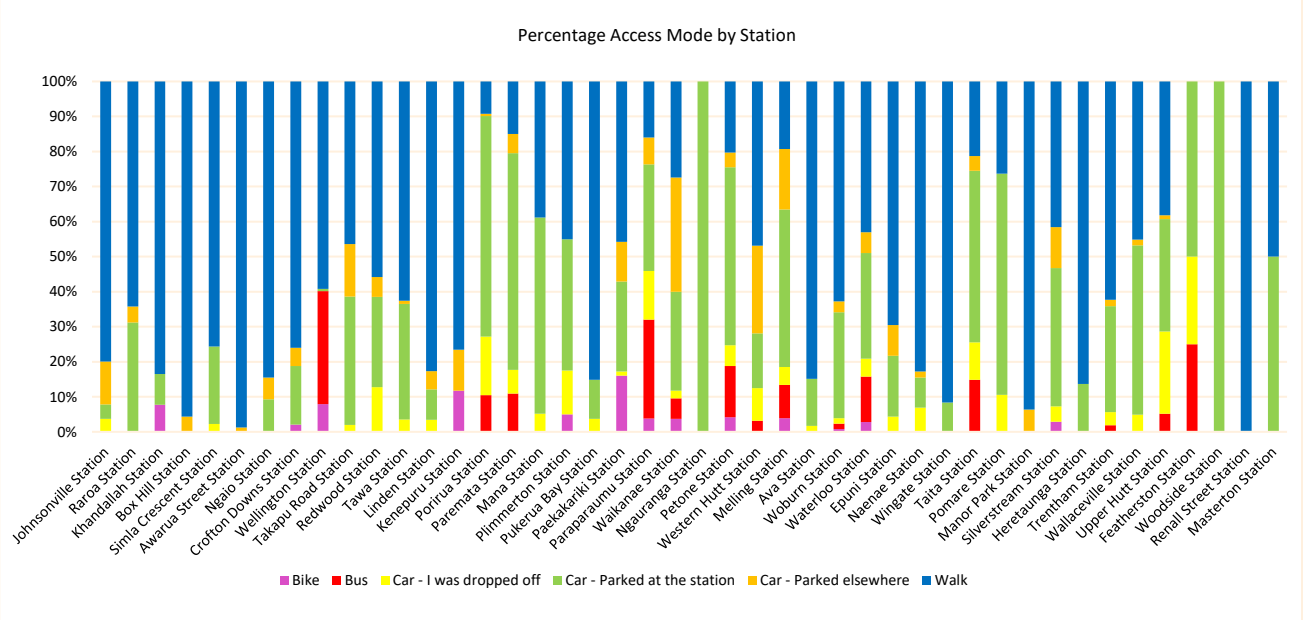

Figure 3-2: Mode of Access (Percentage) by Station

This shows that bus access to public transport (PT) is focused on a small number of stations, resulting in a low access mode share overall. Featherston, Melling, Paraparaumu, Paremata, Petone, Porirua, Taita, Upper Hutt, Waikanae, Waterloo stations and access to Wellington station in the morning/interpeak all have a relatively small proportion of bus access.

Based on this survey, bike access is relatively modest, with only 31 out of 2022 survey respondents using bike as an access mode. This may change in the future as electric bicycles make longer access/egress trips feasible.

Overall modal access by distance band is shown in the following figure. Again, this is expanded weekday trips in the morning/interpeak.

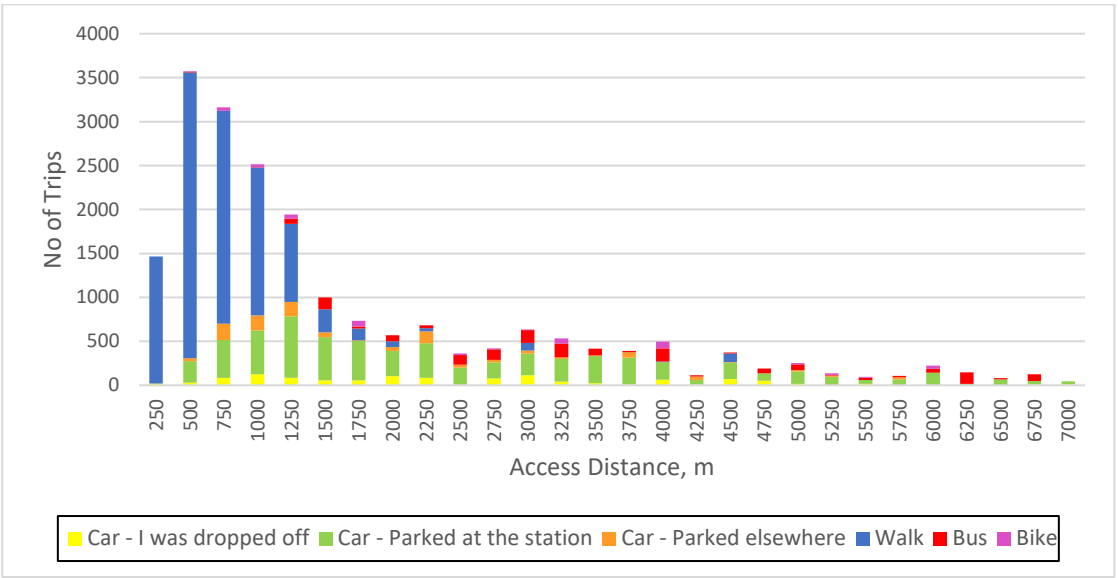

Figure 3-3: Mode of Access by Distance – All Stations

While walk represents just under half (47%) of the overall access mode, this is predominantly for trips less than 1.5 kilometres. The data also shows a significant decline in trips with an access distance of 1.5km or more.

There are trips with access distances greater than the 7km maximum shown in Figure 3-3. Some of these appear valid (83km, origin of Feilding, drove to Waikanae Station with a destination of Willis Street), while others are a result of the data needing cleaning (12km, Upper Hutt origin, boarding at Upper Hutt station). These outliers will not affect the current analysis as common sense will be used.

The overall car access to train stations is tabulated below.

Table 3-2: Car Access Breakdown

Rev No.	Car – Drop Off	Car - Parked at the Station	Car - Parked Elsewhere	Total
Trips	1367	6770	1326	22,008
Percent	14%	72%	14%	100%

4. Current WTSM Process

4.1 Access/Egress Times

In WTSM, passenger access/egress to rail is controlled through "p-connectors". These p-connectors represent car access (park and ride and kiss and ride), walk, and bus access to the rail network. Separate modes cannot be distinguished on the p-connectors.

A key issue to be addressed through this project is that the generalised cost ("cost") on the p-connectors is hardwired. Road access times therefore do not increase with road congestion.

It is understood that the costs were reviewed and updated during the 2011 model update, although the values remained fixed. In the 2011 update, the distances coded on the p-connectors were altered, with a speed of 15kph (for all modes) applied within the model scripts to calculate the access time component of generalised cost. The p-connectors have speeds coded in the network but these are not currently used in the model.

The figure from "Technical Note 1: Network Preparation" from the 2011 model update (Figure 2.8 in that report) illustrating p-connectors is replicated below.

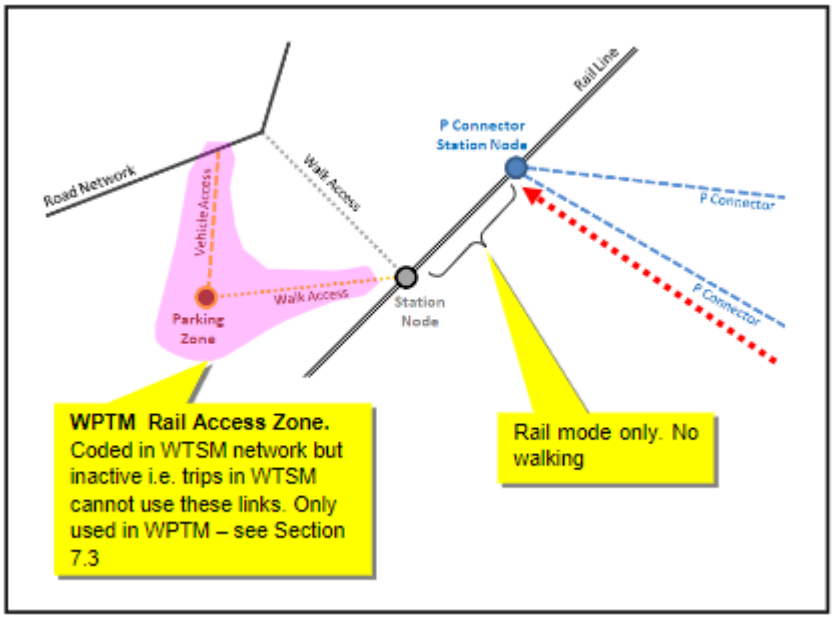

Figure 4-1: P-Connectors

Again, as reported in Technical Note 1 from the 2011 model update, car demand is extracted from p-connectors using the following equation. It has been confirmed that this equation is implemented in WTSM.

If the link length is less than 5 kilometres:

*Car Proportion of Total Demand = <p-connector demand> * (-0.0176*length^2 + 0.2027 * length)*

If the link length is greater than 5 kilometres:

*Car Proportion of Total Demand = <p-connector demand> * 0.6*

The "length" used in this equation is a crow-fly distance in kilometres calculated within the model.

This equation is shown graphically below, which is Figure 2.9 in Technical Note 1 of the 2011 model update. This is referred to as the "original" curve in this report.

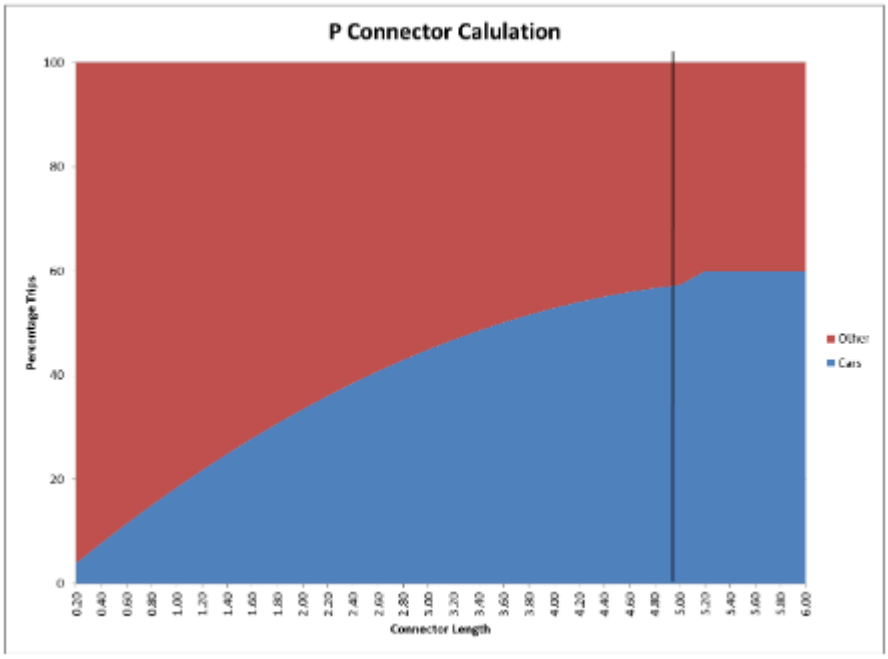

Figure 4-2: Original Equation to Split P-Connector Demand into Car vs Other

This equation is applied to the volume on the p-connectors to divide rail passenger access demand into car and "other", where car includes park and ride and kiss and ride. "Other" includes walk, bike, and bus access. The car access legs to rail stations are extracted using this equation and included in the road assignment. It is noted that including car access legs to PT in the road assignment was a Stage 2 project objective for this study, but this is already incorporated within WTSM.

For locations 5 kilometres or more from a train station, this equation allocates 60% to car and 40% to other (for access mode to rail). For 5 kilometres or more, it seems unlikely there will be walk trips (aside from perhaps a few) which is reenforced by the analysis in the previous section. This means that the "other" is completely bus/bike access trips. However, as demonstrated in the previous section, access by bus is also relatively small and focused on a few specific stations.

Based on professional judgement, it seems unlikely that this equation was representative of current conditions. The equation could not be checked further as its derivation has been lost over time.

4.2 Parking Facilities Considerations

There is no capacity constraint in WTSM at present relating to available supply of park and ride.

In terms of charging, parking at station facilities is currently free. WTSM does not include a mechanism to test charging to use park and ride at train stations.

5. Changes to WTSM Process

5.1 Summary

Considering the weaknesses in the current model and the observed data, the following will be revised in WTSM for park and ride:

- The equation to split demand on the p-connectors into car versus walk will be updated based on observed data ("revised equation");
- The calculation of a weighted average time for car and walk will be implemented in the model for p-connectors. This will use the revised equation referenced above for car versus walk so that realistic times are incorporated. Times will be adjusted within each distribution/mode split/assignment iteration. This will ensure rail access time reflects congestion on the road network;

- The revised equation will be applied to extract car trips from the p-connectors and add them to the road assignment. The validation will then be checked, and if this un-validates the model, the current equation will be retained in Stage 1 of the project (prior to the model rebuild in Stage 2); and
- A mechanism to incorporate charging for formal park and ride will be incorporated in the model.

The calculation of the equations/factors to deliver this functionality is documented below.

5.2 Car Mode Share Equation

5.2.1 One-Step Curve

As noted above, the curve in WTSM to divide demand into car and other did not seem representative. In the absence of local observed data, a modified curve was developed using high-level metrics sourced from the internet and professional judgement. This curve is shown in blue in the figure below.

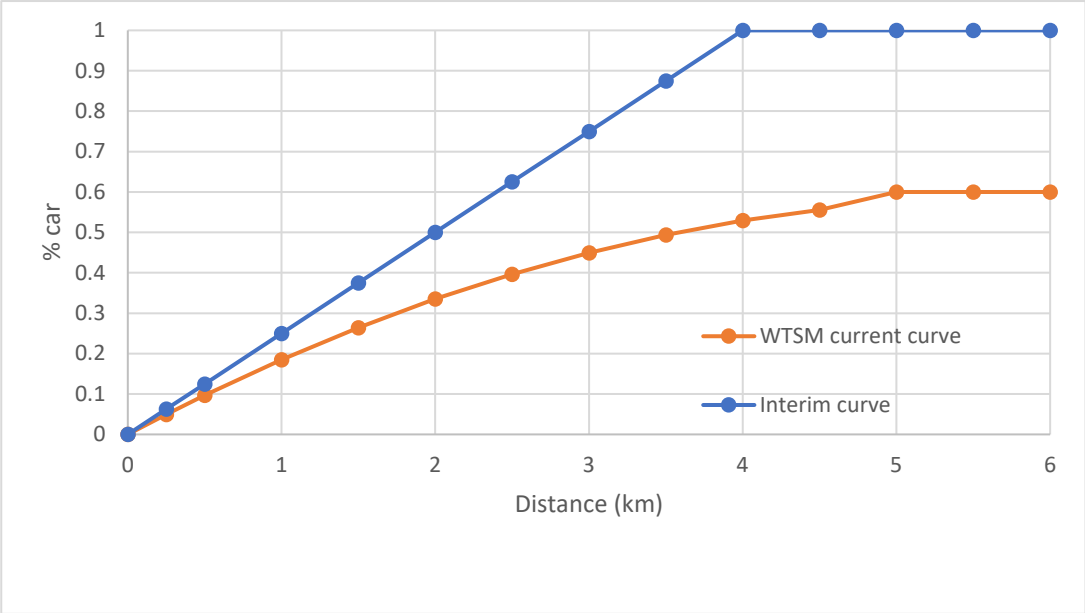

Figure 5-1: One-Step Curve for Rail Station Access Mode

This curve assumed that people would not walk more than 4km to access rail and allocated 100% of demand to car for access distances greater than 4km. A simple linear relationship was assumed for access distances less than 4km.

5.2.2 Two-Step Curve

After the one-step curve (Figure 5-1) was developed, implemented, and tested in WTSM, observed data for access to rail stations was located.

In the figure below, the observed data from the 2017 rail passenger survey is shown for car and walk access to rail. This excludes the small number of bike and bus trips, the latter only relevant at certain stations. The percentages have been calculated based on expanded morning/interpeak weekday trips with outliers removed (as documented in Section 3).

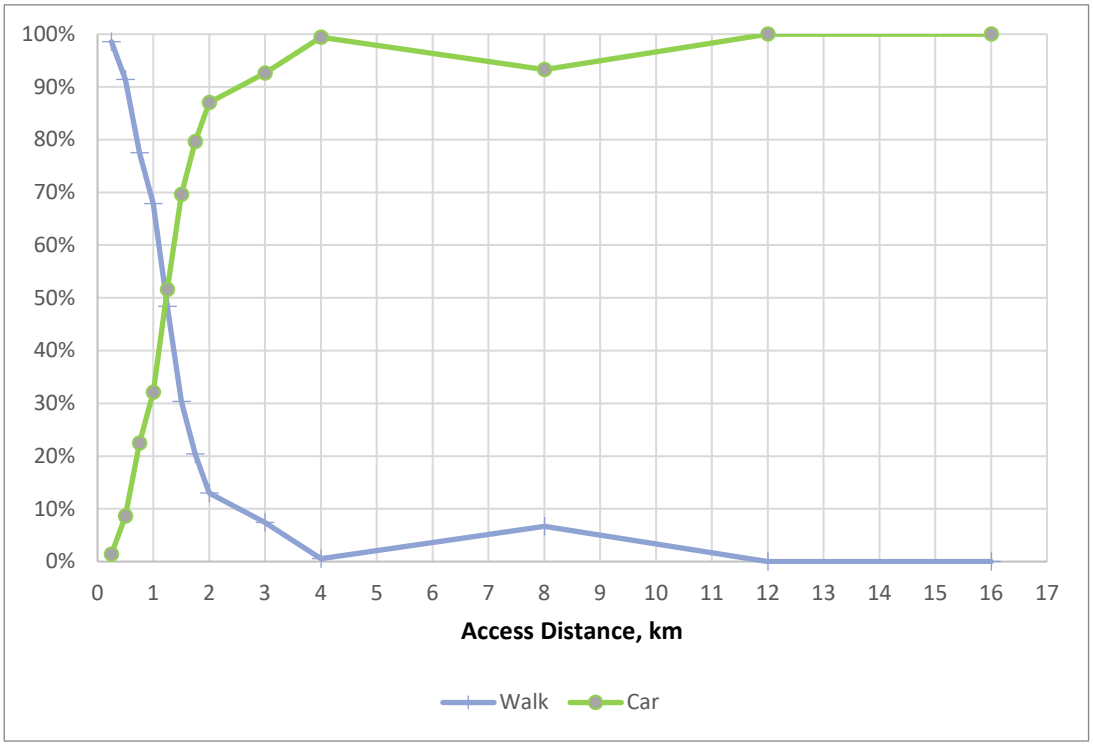

Figure 5-2: 2017 Observed Car vs Walk Access to Train Stations

To develop a curve to reproduce the proportion of car, a two-step linear equation would seem to fit the best. Polynomials were investigated, but these did not fit as well. The car proportion is shown below for access trips less than 2km and then separately for 2-4 km. Trendlines are fitted with the equation and R-squared reported. For access legs trips greater than 4km, 100% car access will be assumed which is supported by the observed data which only has one record with a walk access distance of 4.5km.

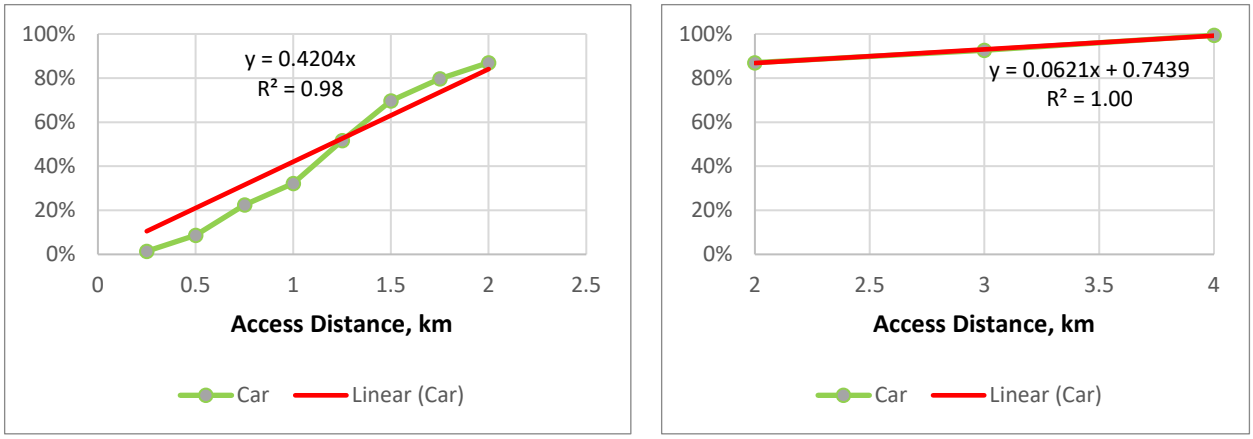

Figure 5-3: Fitting Equations to Car Proportion

The application of this equation to reproduce the proportion of car access to rail is shown below.

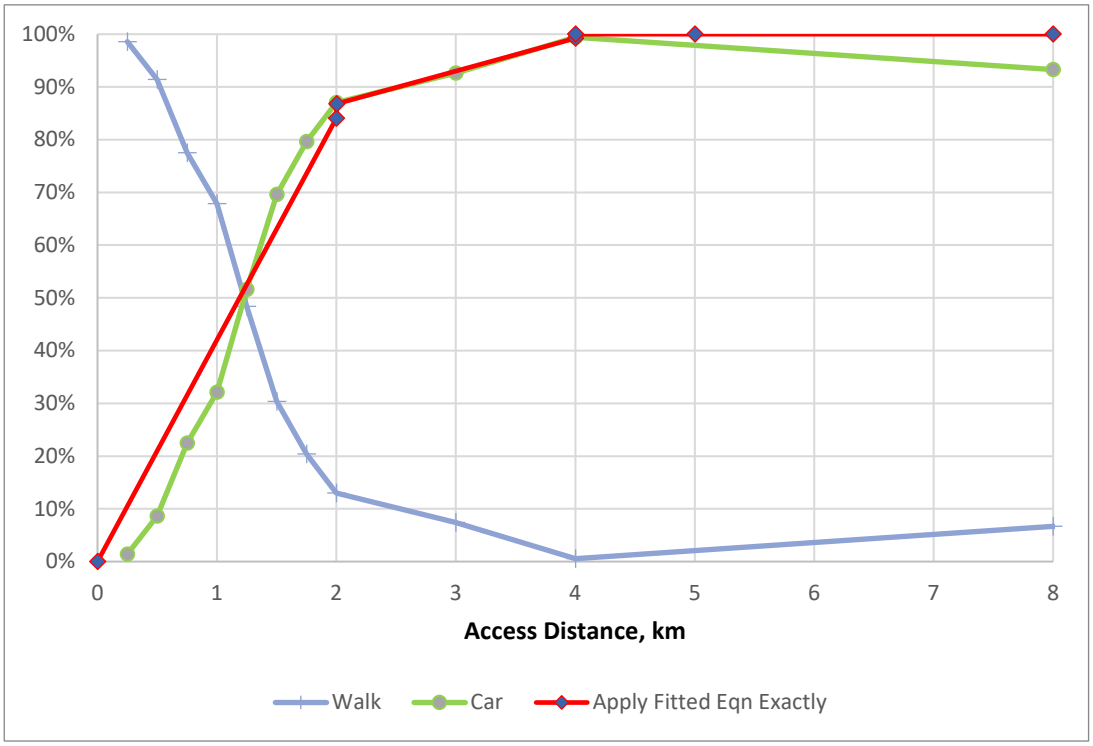

Figure 5-4: Apply Fitted Equations

The exact application of the fitted equation in Figure 5-4 has a small step change at 4km, but a slightly larger one at 2km as shown in Table 5-1. The equation for 0-2km was therefore adjusted to reduce the gap. The revised equation to be adopted is illustrated in Figure 5-5.

Table 5-1: Calculated Percentage of Car – Different Equations

Distance (km)	Percentage Car Trips	
	Apply Fitted Equation Exactly	Revised Equation
0	0.0%	0.0%
2	84.1%	86.0%
2.001	86.8%	86.8%
4	99.2%	99.2%
4.001	100.0%	100.0%
5	100.0%	100.0%
8	100.0%	100.0%

The revised two-step equation to produce the number of car trips is:

If the link length is 2 kilometres or less:

*Car Proportion of Total Demand = <p-connector demand> * (0.43 * length)*

If the link length is greater than 2 kilometres and less than or equal to 4 kilometres:

*Car Proportion of Total Demand = <p-connector demand> * (0.0621 * length + 0.74)*

If the link length is greater than 4 kilometres:

Car Proportion of Total Demand = <p-connector demand>

Again, the length will be a crow fly distance in kilometres. Consideration will be given in Stage 2 of the project to the appropriateness of using crow-fly rather than actual access distances as well as the whole concept of p-connectors and combined representation of all access modes.

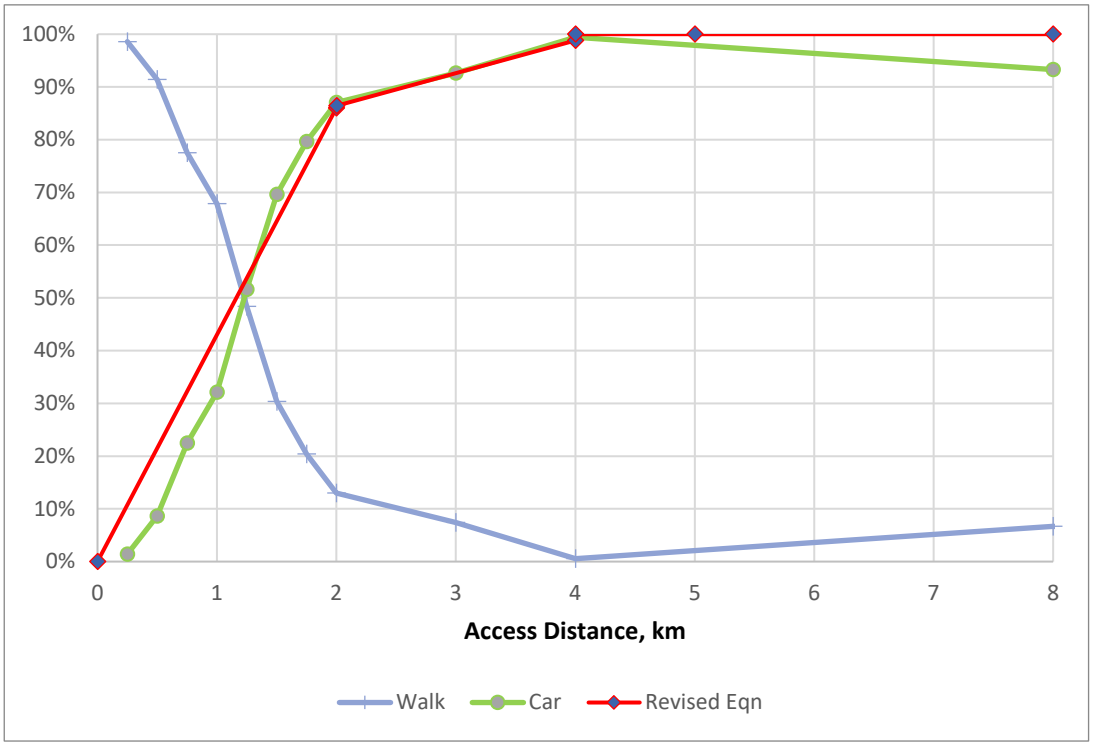

Figure 5-5: Two-Step Equation for Rail Station Access Mode

5.3 Modifying Inputs to Rail Access Mode Share in WTSM

The process was implemented in EMME and tested to determine the impact on the validation.

5.3.1 Update of P-Connector Access Times

The first step in testing a new process was to incorporate a calculated weighted time (walk and car) on the p-connectors instead of the current process in WTSM which is a modified distance with a 15kph speed applied. At this stage, only the one-step estimated curve (Figure 5-1) was available and this was used.

For this test, times on the p-connectors were not iteratively adjusted within the distribution/mode split/assignment loop but were incorporated at the start as a one-off fixed change to the inputs. The model was run for the base year of 2013 and the results examined. The table below gives the AM peak two-hour passenger boardings at each p-connector rail node for the original and revised models. Differences, percentage differences and GEH values are provided for each station. A GEH is a statistic to compare two datasets that is sensitive to the magnitude of the value, recognising that greater percentage errors in small values are less important than the same error in a large value. The higher the GEH statistic, the poorer the fit between modelled and observed.

Table 5-2: Station Boardings (AM 2-hours) – Original vs Revised P-Connectors (with no Adjustment Factor)

Model Node	Station Name	Station Boardings				
		Original	Revised - no P-Connector Adjustment	Original vs Revised		
				Diff	%Diff	GEH
30301	Upper Hutt Station	872	1117	245	28%	5.5
30302	Wallaceville Station	103	107	4	4%	0.3
30303	Trentham Station	231	349	118	51%	4.9
30304	Heretaunga Station	137	7	-130	-95%	10.8
30305	Silverstream Station	395	611	216	55%	6.8
30306	Manor Park Station	28	29	1	4%	0.1
30307	Pomare Station	0	0	0	-	-
30308	Taita Station	146	1103	957	655%	27.1

Model Node	Station Name	Station Boardings				
		Original	Revised - no P-Connector Adjustment	Original vs Revised		
				Diff	%Diff	GEH
30309	Wingate Station	0	0	0	-	-
30310	Naenae Station	396	516	120	30%	4.0
30311	Epuni Station	0	4	4	-	2.0
30312	Waterloo Station	1401	2779	1378	98%	21.3
30313	Woburn Station	587	458	-129	-22%	4.0
30314	Ava Station	252	195	-57	-23%	2.7
30315	Petone Station	595	862	267	45%	7.0
30316	Ngauranga Station	1	0	-1	-100%	1.0
30317	Kaiwharawhara Station	0	2	2	900%	1.2
30318	Wellington Station	0	0	0	-	-
30319	Johnsonville Station	607	1166	559	92%	13.3
30320	Raroa Station	142	136	-6	-4%	0.4
30321	Khandallah Station	188	190	2	1%	0.1
30322	Box Hill Station	38	25	-13	-34%	1.6
30323	Simla Crescent Station	47	0	-47	-100%	6.9
30324	Awarua Street Station	313	306	-7	-2%	0.3
30325	Ngaio Station	64	53	-11	-17%	1.0
30326	Crofton Downs Station	187	186	-1	-1%	0.1
30327	Waikanae Station	553	605	52	9%	1.5
30328	Paraparaumu Station	1078	1444	366	34%	7.3
30329	Paekakariki Station	173	170	-3	-2%	0.2
30330	Pukerua Bay Station	168	170	2	1%	0.1
30331	Plimmerton Station	329	315	-14	-4%	0.6
30332	Mana Station	61	59	-2	-3%	0.2
30333	Paremata Station	876	725	-151	-17%	3.8
30334	Porirua Station	1421	1802	381	27%	6.7
30335	Kenepuru Station	21	22	1	5%	0.2
30336	Linden Station	407	466	59	14%	2.0
30337	Tawa Station	100	97	-3	-3%	0.2
30338	Redwood Station	274	37	-237	-86%	13.4
30339	Takapu Road Station	52	318	266	512%	13.8
30340	Melling Station	367	418	51	14%	1.8
30341	Western Hutt Station	0	46	46	-	6.8
30342	Otaki Station	1	1	0	0%	0.0
30343	Masterton Station	300	277	-23	-8%	1.0
30344	Renall Street Station	0	0	0	-	-
30345	Solway Station	0	0	0	-	-
30346	Carterton Station	115	107	-8	-7%	0.5
30347	Matarawa Station	0	17	17	-	4.1
30348	Maymorn Station	0	0	0	-	-
30365	Woodside Station	17	15	-2	-12%	0.4

Model Node	Station Name	Station Boardings				
		Original	Revised - no P-Connector Adjustment	Original vs Revised		
				Diff	%Diff	GEH
30366	Featherston Station	232	243	11	5%	0.5
	TOTAL	**13275**	**17555**	**4280**	**32%**	

While there was some difference in total public transport trips, there was considerable change at some stations that was considered too significant. To compensate and ensure WTSM was not un-validated, an adjustment factor was calculated for every p-connector to reset the access times to match the validated 2013 values. These adjustment factors are included in the network variable @pconnadj reported in Section 6.1.1. This means that the 2013 validated model results are (essentially) reproduced and, as requested, access times will change in line with car access times for future year scenarios.

The main and significant weakness of this approach is that every p-connector has an individually calculated factor. Appropriate factors for any new connectors could not be calculated and would require judgement (similar to the p-connector 'distance' applied in the existing model). This is, however, a stop-gap adjustment to add incremental benefit to the model while ensuring the validated results are maintained. The p-connector adjustment factors will be removed during Stage 2 of the project for the model rebuild.

Nevertheless in the interim, it is clear the p-connector adjustment factors need to be retained.

5.3.2 Iterative Adjustment

Adopting the fixed p-connector adjustment factors, the next step was to iteratively update the access times within the mode split/distribution/assignment loop of WTSM.

In the current version of WTSM, there are separate processes where car and walk modes are aggregated and then disaggregated. This has been reported in previous sections but is reiterated here to contrast the changes that will be introduced to the model. First, a composite access time to rail on the p-connectors which represents all modes is input to the mode split/distribution. This is an input rather than a calculation and has a fixed speed of 15kph with a distance manually adjusted to reflect observed. After this, the forecast rail access demand is divided into car and walk using the diversion curve shown in Figure 4-2. Then the car demand is extracted and included in the road assignment.

To ensure the car access component to rail reflects road congestion, the first stage in the current version of WTSM had to be modified to be a calculation rather than an input. This was accomplished using a curve to calculate the proportion of car and walk trips based on distance in order to produce a weighted time for access to rail. The fixed p-connector time adjustment is also included to ensure the 2013 validated model results are reproduced (or close to).

The modified version of the model therefore has two stages:

- Calculate weighted access time to rail over all modes (stage 1); and
- Split total demand for access to rail back into car and walk (stage 2).

With the above functionality implemented, the two-step curve shown in Figure 5-5 was utilised to produce the weighted time (stage 1) and the car demand (stage 2). However, the model failed to converge even for the base year of 2013. This is because a much larger car demand is assigned to the road network – the result of changing the modal share from 60% car for trips greater than 5km to 100% for trips greater than 4km.

Adopting the original curve (Figure 4-2) for the diversion of demand into car and other, the one and two-step curves to produce a composite weighted rail access time were evaluated. Results from the following scenarios are tabulated below:

- Original model;
- P-connector access times updated to reflect current conditions including the adjustment factor to replicate observed. This is an assignment only, with no iterative recalculation of mode split/distribution;
- Updated and adjusted p-connector times as above, model run iteratively to calculate mode split/distribution/assignment with the one-step weighting curve applied; and
- As above but using the two-step curve to weight the car and walk times.

The 2013 AM peak period (2 hour) station boardings for each of these scenarios are provided below.

Table 5-3: Station Boardings (AM 2-hours) – Original vs Revised Models

Model Node		Station Boardings						
	Model	Original	Revised			Original vs Revised		
	Ref	A	B	C	D	% Difference to Original		
	P-Connectors	No Change	Updated & Adjusted			B vs A	C vs A	D vs A
	Iterated	Yes	No	Yes				
	Station Name			One-Step Weighted Time	Two-Step Weighted Time			
30301	Upper Hutt Station	872	894	890	979	3%	2%	12%
30302	Wallaceville Station	103	104	104	101	1%	1%	-2%
30303	Trentham Station	231	248	248	259	7%	7%	12%
30304	Heretaunga Station	137	143	143	46	4%	4%	-66%
30305	Silverstream Station	395	403	403	527	2%	2%	33%
30306	Manor Park Station	28	29	29	28	4%	4%	0%
30307	Pomare Station	0	0	0	-			
30308	Taita Station	146	186	187	709	27%	28%	386%
30309	Wingate Station	0	0	0	-			
30310	Naenae Station	396	425	425	404	7%	7%	2%
30311	Epuni Station	0	0	0	-			
30312	Waterloo Station	1401	1447	1442	1774	3%	3%	27%
30313	Woburn Station	587	605	605	672	3%	3%	14%
30314	Ava Station	252	247	247	204	-2%	-2%	-19%
30315	Petone Station	595	635	635	767	7%	7%	29%
30316	Ngauranga Station	1	1	1	1	0%	0%	0%
30317	Kaiwharawhara Station	0	0	0	0	0%	0%	0%
30318	Wellington Station	0	0	0	-			
30319	Johnsonville Station	607	603	603	834	-1%	-1%	37%
30320	Raroa Station	142	140	140	139	-1%	-1%	-2%
30321	Khandallah Station	188	186	186	25	-1%	-1%	-87%
30322	Box Hill Station	38	35	35	36	-8%	-8%	-5%
30323	Simla Crescent Station	47	47	47	218	0%	0%	364%
30324	Awarua Street Station	313	310	310	308	-1%	-1%	-2%
30325	Ngaio Station	64	64	64	63	0%	0%	-2%
30326	Crofton Downs Station	187	183	183	192	-2%	-2%	3%

Model Node		Station Boardings						
	Model	Original	Revised			Original vs Revised		
	Ref	A	B	C	D	% Difference to Original		
	P-Connectors	No Change	Updated & Adjusted			B vs A	C vs A	D vs A
	Iterated	Yes	No	Yes				
	Station Name			One-Step Weighted Time	Two-Step Weighted Time			
30327	Waikanae Station	553	549	551	553	-1%	0%	0%
30328	Paraparaumu Station	1078	1287	1291	1406	19%	20%	30%
30329	Paekakariki Station	173	177	177	176	2%	2%	2%
30330	Pukerua Bay Station	168	170	169	168	1%	1%	0%
30331	Plimmerton Station	329	332	332	330	1%	1%	0%
30332	Mana Station	61	61	61	61	0%	0%	0%
30333	Paremata Station	876	907	912	804	4%	4%	-8%
30334	Porirua Station	1421	1435	1435	1717	1%	1%	21%
30335	Kenepuru Station	21	21	21	21	0%	0%	0%
30336	Linden Station	407	429	429	429	5%	5%	5%
30337	Tawa Station	100	101	101	100	1%	1%	0%
30338	Redwood Station	274	286	285	302	4%	4%	10%
30339	Takapu Road Station	52	54	54	55	4%	4%	6%
30340	Melling Station	367	360	360	376	-2%	-2%	2%
30341	Western Hutt Station	0	0	0	42			
30342	Otaki Station	1	1	1	1	0%	0%	0%
30343	Masterton Station	300	297	297	303	-1%	-1%	1%
30344	Renall Street Station	0	0	0	-			
30345	Solway Station	0	0	0	-			
30346	Carterton Station	115	117	117	102	2%	2%	-11%
30347	Matarawa Station	0	0	0	17			
30348	Maymorn Station	0	0	0	-			
30365	Woodside Station	17	16	16	16	-6%	-6%	-6%
30366	Featherston Station	232	188	188	186	-19%	-19%	-20%
	TOTAL	**13275**	**13723**	**13724**	**15451**	**3%**	**3%**	**16%**

The calculated two-step curve for the weighted time produces considerable and concerning disparities with the original model results. It is acknowledged that the original model is not "observed", but it should be a good approximation as the 2013 original model validates.

Using the two-step curve produces 16% more total station boardings in the morning peak period. Taita and Simla Crescents stations have more than 300% additional boardings compared with the original model. While the two-step curve is based on observed data, it will likely un-validate the current version of WTSM. The one-step curve, however, does replicate the original model relatively well, with only a 3% increase in station boardings across the two hour period.

As a result, the one-step weighting curve (Figure 5-1) and the original diversion curve (Figure 4-2) have been adopted as defaults. This is referred to as the "revised model" below.

The model scripting has been written to be flexible, however, with input parameters to select either the original (Figure 4-2), one-step (Figure 5-1), or two-step (Figure 5-5)curves for each of the weighting and diversion stages. This is described further in section 6.

High-level validation results from the road assignment are shown below for the 2013 original model and the adopted revised model (one-step weighting and original diversion curve, iterative model, updated and adjusted p-connector times). Results are provided for total vehicles, for each of the three assignment peak periods, with GEH, percentage differences and R-squared values tabulated. These are actual validation results as each model is compared with 2013 observed data.

Table 5-4: Screenline Validation – 2013 Total Vehicles – Comparison of Original and Revised Model

	Targets				Original Model		Revised Model	
					No of Screenlines	(%)	No of Screenlines	(%)
AM Peak Period Average Hour (07:00-09:00)	GEH	<=	5	60%	16	(42%)	17	(45%)
		<=	10	95%	18	(89%)	17	(89%)
		<=	12	100%	2	(95%)	2	(95%)
		<=	Max	0%	2	(100%)	2	(100%)
	% Difference Less Than		10%	-	16	(42%)	14	(37%)
			20%	-	28	(74%)	28	(74%)
	R2			-	0.97		0.97	
Interpeak Period Average Hour (11:00-13:00)	GEH	<=	5	60%	18	(47%)	18	(47%)
		<=	10	95%	15	(87%)	15	(87%)
		<=	12	100%	3	(95%)	3	(95%)
		<=	Max	0%	2	(100%)	2	(100%)
	% Difference Less Than		10%	-	13	(34%)	13	(34%)
			20%	-	25	(66%)	26	(68%)
	R2			-	0.94		0.94	
PM Peak Period Average Hour (16:00-18:00)	GEH	<=	5	60%	18	(47%)	17	(45%)
		<=	10	95%	14	(84%)	15	(84%)
		<=	12	100%	1	(87%)	1	(87%)
		<=	Max	0%	5	(100%)	5	(100%)
	% Difference Less Than		10%	-	17	(45%)	16	(42%)
			20%	-	28	(74%)	28	(74%)
	R2			-	0.95		0.95	

There are some small differences in traffic assignment validation with one screenline moving category, however, these are considered insubstantial. This demonstrates that the changes incorporated do not impact on the road validation.

5.4 Adding Charges for Parking at Rail Park and Ride

5.4.1 Method

The current model does not include a mechanism for inclusion of a car parking charge at park and ride sites, as no such charge currently exists, or was considered likely to be added in the future.

Implementation of a parking charge within the current model will, necessarily, be a simplistic approach as the current model structure does not lend itself to its inclusion.

As no charge historically existed it will also be difficult to gauge/validate the model response to its inclusion; the perceived cost may be quite different to the actual cost.

It is also noted that parking charges cannot be explicitly allocated to car using rail park and ride, as the model has a composite "all mode" demand on the p-connectors. The parking charge is weighted based on the proportion of car verses other modes, but it means a lower parking charge will be applied to all modes. As a result in the current WTSM structure, incorporating a charge for parking at rail park and ride will not produce a direct and localised switch to other modes (walk, bike, and PT) as would be expected in reality. Model results will therefore need careful interpretation.

Implementation of the parking charges is summarised in Section 6.

Conversion of PnR parking charge to generalised minutes uses value of time (VoT) and VoT growth input files as defined for general parking (see Technical Note 7). A trip purpose weighted VoT is used to convert the dollar input parking charge to minutes, with the weighted VoT recalculated after each model iteration. There is a slight disconnect with the trip purposes using parking for rail park and ride and the weighted VoT[1], the latter based on trip purpose mix in the model overall rather than specifically using rail park and ride. But a more refined calculation would have required a full model restructure which is outside the scope of the Stage 1 of this project.

The input parking charge needs to take account of informal versus formal (charged) parking outside of the model environment. So the input parking charge should be adjusted to reflect informal parking. Furthermore, the model is set up to accept a fixed parking charge, and not a charge that varies by duration of stay. Given the simplifications and limitations that are required because of the current model structure, incorporating more detailed parking charges did not add value.

5.4.2 Parking Charge Sensitivity Test

A test including a $5 parking charge at all PnR stations was carried out, and the key model output statistics are given in Table 5-5 below.

Table 5-5: Implementation of $5 PnR Charge for 2013 – Key Output Statistics

	No PnR Charge	$5 PnR Charge	Change
AM Car Trips			
AM Car Trips	161,949	160,999	-0.6%
AM PT Trips	32,737	31,620	-3.4%
AM PT Mode Share	16.8%	16.4%	-2.4%
AM Trips to CBD			
AM Car Trips	25,431	25,839	1.6%
AM PT Trips	18,678	17,965	-3.8%
AM PT Mode Share	42.3%	41.0%	-3.1%
IP Car Trips			
IP Car Trips	148,742	148,949	0.1%
IP PT Trips	9,939	9,696	-2.4%
IP PT Mode Share	6.3%	6.1%	-2.4%
IP Trips to CBD			
IP Car Trips	17,579	17,637	0.3%
IP PT Trips	2,217	2,170	-2.1%
IP Mode Share	11.2%	11.0%	-2.2%

[1] [1] Based on a weighted VoT by trip purpose/vehicle occupancy for the whole model. Ideally this should be by station but the model structure does not readily allow for this distinction. The weighted VoT is recalculated for each main iteration.

	No PnR Charge	$5 PnR Charge	Change
PM Car Trips			
PM Car Trips	191,734	192,216	0.3%
PM PT Trips	26,328	25,383	-3.6%
PM PT Mode Share	12.1%	11.7%	-3.4%
PM Trips to CBD			
PM Car Trips	16,010	16,035	0.2%
PM PT Trips	2,886	2,842	-1.5%
PM Mode Share	15.3%	15.1%	-1.4%

These results show a drop in PT mode share of 2-3%, which is a move in the expected direction. The greatest impact is in the AM and PM peak periods for all trips, and car trips to the CBD in the morning. As mentioned previously, there is no historical data to calibrate/validate the effect of a PnR parking charge. The results presented below appear logical.

6. Implementation in WTSM

6.1 Access Time Update

As explained in the preceding sections, p-connectors are hard-wired with a speed of 15 kph, and the connector length is not a true crow-fly distance. Implementation of variable cost p-connectors, which take actual car access time into consideration, required changes to both the base network coding and the model scripts.

6.1.1 Base Network Changes

The base networks (10000, 10001, 10002) were modified to enable variable cost p-connectors by applying the following changes:

- P-connector link length changed to crow-fly distance;
- New link attribute @v1x added and set equal to the weighted access speed as calculated using the revised car proportion equation shown in Figure 5-1. Initial access time for car was skimmed from the original model;
- New link attribute @pconnadj was added and set equal to the factor required to adjust new access time (based on crow-fly distance and weighted access speed) to original access time (based on original p-connector distance and 15 kph);
- P-connector mode changed from 'p' to 'ap'. This enables calculation of 'timau' (congested travel time) via volume-delay function (VDF);
- P-connector attribute 'lanes' changed from 0 to 1 (although the VDF below does not use lanes EMME will return an error if lanes=0 and VDF<>0);
- P-connector VDF changed from 0 to 2;
- VDF transaction file ('function_13.411') amended to include:
    - fd2 = (length / el4 * el5) * 60

6.1.2 Script Changes

In order to implement variable p-connector costs the model scripts were amended, and new scripts created, as follows:

- `wtsm13_assigna.py` amended to set assignment extra function parameters:
    - el4 = @v1x
    - el5 = @pconnadj
- `wtsm13_assignam.py` amended to set assignment extra function parameters:

- el4 = @v1x
- el5 = @pconnadj

- `wtsm13_modelrun.py` amended to call new script `wtsm13_pconn_update.py`. This is called at the end of each main convergence loop (and therefore before call to final assignment);
- New script `wtsm13_pconn_update.py`. This script recalculates the p-connector speed (@v1x) based on equation shown in Figure 5-1.

For the 2018 validated interim version of WTSM, scripts named "wtsm13" are changed to "wstm18".

6.2 Parking Costs

The PnR parking charge has been implemented as follows:

- New link attribute @pnrlinkcharge created to hold the parking cost (fixed parking charge input in dollars and converted to minutes within the model[2]) for rail PnR links;
- New input files created to hold PnR parking charge per station, and PnR car occupancy by trip purpose. See Appendix A for details. Note that allowance has been made for a separate PnR related car occupancy by trip purpose to be specified, as this may need to be different from general car parking occupancy. Re-use of the general parking occupancy file is also allowed though;
- Extended Transit Assignment auxiliary transit cost set to new link attribute @pnrlinkcharge;
- Weighted auxiliary transit cost skimmed from extended transit paths for inclusion in mode split generalised costs. The cost weighting is based on the PnR weight curve (parameter PnRWeightVersion in the model control file), which increases the percentage of parking cost applied based on p-connector link length (100% by 4 km). This alleviates the issue associated with p-connectors being multi-modal.

Apart from the inclusion of PnR parking charges in the extended transit assignment and generalised cost, and the reading of additional input data, the model scripts have remained unaltered, except for those concerned with the aforementioned actions:

- `wtsm18_runasspt.py`: include @pnrlinkcharge in path costs and skim path weighted costs for inclusion in generalised costs (new matrices mf119, mf120, and mf121 for AM, IP, and PM; note PM not actually used);
- `wtsm18_parking.py`: read PnR related data and initialise variables for use in other modules.

Inclusion of PnR parking charges is controlled by new parameters in the model run control file:

- PnRChargeType: set equal to 'LINK';
- PnRDiversionVersion: 0 for original 2013 model (Figure 5-1, WTSM current curve), 1 for 2020 2 step linear model (Figure 5-5). Defaults to 0 if parameter name not specified;
- PnRWeightVersion: 0 for 2020 1 step linear model (Figure 5-1, interim curve), 1 for 2020 2 step linear model (Figure 5-5) . Defaults to 0 if parameter name not specified;
- PnRCharges: filename for parking charges by PnR (p-connector) station node, located in .\WTSM\Database\Parking;
- PnROccupancy: filename for vehicle occupancy per PnR trip purpose, located in .\WTSM\Database\Parking.

Details of the file contents for these two files is described in Appendix A.

[2] Based on a weighted VoT by trip purpose/vehicle occupancy for the whole model. Ideally this should be by station but the model structure does not readily allow for this distinction. The weighted VoT is recalculated for each main iteration.

Appendices

Appendix A Park and Ride Parking Charge Inputs

A.1 Parking Charge

Specifies the csv filename containing the parking charge ($) by Park and Ride station. Charges can be specified for a range of nodes (a-b) or individual nodes.

Suggested filename: `PnRpark$18_3a.csv`

(where 3a = user defined variant code)

File format:

```
node or range, $
30300-30399, 5
30301, 5
```

A.2 Vehicle Occupancy

Specifies the csv filename containing the vehicle occupancy by trip purpose.

Suggested filename: `PnROccupancy1.csv`

(where 1 = variant)

File format:

HBW,	EB,	HBED,	HBSH,	HBO,	NHBO
1.19,	1.09,	2.36,	1.35,	1.50,	1.39

Appendix B Comments and Responses

No.	Comment By	Comment	Response
1	Tony Brennand, Waka Kotahi	Sect. 4.1. The equation is problematic. No information is provided on the goodness of fit of this equation. I am concerned that the equation is discontinuous at the break point of length = 5Km. the car proportion of demand at length = 5Km using -0.0176*length^2 +0.2027*length gives a value of 0.574 whereas in the second part of the equation it jumps to a value of 0.6 at length = 5Km. These steps run the risk of being numerically unstable in iterative procedures. All efforts should be made to remove this discontinuity by ensuring both parts of the equation have the same value at the break point length = 5Km. Consequently, a move to a revised equation is supported provided the revised equation is continuous and there is clear information on its goodness of fit.	Section 4.1 & Fig 4.2 show the current diversion (car vs other) equation for PnR in WTSM. We have been unable to source the derivation, nor any information on the goodness of fit. As noted below, the equation in Section 4.1 is the current process included in WTSM to separate car from other at PnR. We acknowledge the discontinuity at 5km and concur this is undesirable. Our preference is to adopt an equation representative of observed data and without the problematic discontinuity. We have tested the application of such a curve, and since a significant amount of car access trips are added to the network, the model became unstable. We have therefore retained the current equation (with a discontinuity at 5km) for Stage 1 but plan to move to the equation in Fig 5.5 in Stage 2 of the project.
2		Fig 5.3 is again problematic. Using y = 0 .4204x delivers y = 0.8408 at x = 2 whereas y = 0.0621x + 0.7439 delivers y = 0.8681 at x = 2. This is a small step and may lead to instabilities in the iterative processes. The two lines should be forced to have the same value at x = 2 to avoid this risk. Further, the y = 0.4204x line forces the car proportion through the origin where the assumption and the observed data (in green) is that for distances less than 250m the trips are all walk trips and no car trips are made. This line should be forced to be zero at x = 0.25. Hence the first line should be y = 0.4961x – 0.1240 to ensure y = 0 at x =.25 and y = 0.8681 at x = 2. Sect. 5.3.2 Note than discontinuities or steps in our models are a common cause of instability leading to lack of convergence of models.	We concur. The equation shown in Fig 5.3 is smoothed in Fig 5.5 (adopted) to remove the step change.
3	Andy Ford, GWRC	Fig 3.2 – prefer data present at a line level in chronological order.	Figure updated with stations in order along the lines. Note there are a few stations missing because there was no interview data.
4		Bike access is 'miniscule' – suppose it is (31 from 2022), however there might be sample bias and the survey was 2017; another source could be to ask at Metlink to see what the latest estimates are (they have cameras on stations and can count bike occupancy if needed).	Sentence reworded as "relatively modest" and acknowledged this is based on the survey data available. Noted that Metlink cameras might provide updated bike counts, but access distance required which the cameras will not provide.

No.	Comment By	Comment	Response
			A greater proportion of bike access will not have any impact on the diversion curve unless there is a substantial shift from car access to PNR to bike. Increased bike use can be reflected in the model when observed data is available by modifying the diversion curve.
5		4.1 – Good analysis of current access / egress time and the issues with p-connectors.	Noted.
6		5.3.1 – Can see logic in p-connector adjustments, although validation seems to be 'worst' at the stations that are either busiest or (Taita) have high frequencies, something to consider during Phase 2.	Noted. Revised curve (based on observed data) to be tested in Stage 2.
7		Section 5.3: o In terms of not converging, it is unsurprising that additional vehicle trips cause congestion, probably exacerbated by WTSM not representing all roads in the road network; i.e. stations like Waterloo, there are many ways to access whereas WTSM may only represent a couple of these. o 2013 did validate, however looking back at WPTM observed data - you can see that taking Taita as an example, 330 pax in AM peak plus 70 off at Pomara and Wingate that have zero in WTSM; my point is that WTSM validated in 2013 well at a line level but there are some unders / overs at a station level which a more refined representation of access costs and the two-step curve might solve. o Johnsonville line has always been tricky because of coarse zone system (225) plus sensitivity between rail and bus. o I'd be interested to see what the two-step (and one-step) processes look like for 2018 given there has been an 8% increase in pop between 2013 and 2018 but around 20% increase in rail; therefore whilst two-step may unvalidate the 2013 model, it might work fine for the 2018 model given recent growth (accepting that the congestion issue would need to be solved) so perhaps shouldn't be taken off the table at this stage.	We concur that the relatively coarse zone system (225 zones), the strategic-level network, and previous line-based validation are all contributing factors to the instability that occurred when the diversion curve was changed (the revised diversion curve producing more car access trips for distances greater than 5km). We will re-test the modified diversion curve as part of the 2018 validation of current WTSM in Stage 1 to determine if the instability issues remain.

No.	Comment By	Comment	Response
8		5.4 – parking charge weighted based on car proportion is as you note a limitation, particularly as split will vary from one station to another; accept probably out of scope for Phase 1, however would be good for Phase 2 if the two step approach in section 4 might be able to be used to develop a more nuanced way of representing the parking charge to reflect observed car / walk split.	In Stage 2 of the project, our preference is to add PnR as a nest to the logic model which will separate the car/walk components.
9		"Implementation of the parking charge is summarised in……" complete the sentence.	Addressed.
10		Parking charge results seem intuitive, though as you quite rightly mention, difficult to gauge / validate model response and there are limitations to approach so whilst this is another tool in the tool kit we should use with caution.	Completely agree that the parking charges at PnR stations should be used with caution.
11		Next steps – interested to see how it all works in 2018 model, particularly whether the two-step approach is more appropriate and improves the validation when you look at station level; gut feel is that until we move to finer zone system, there could still be challenges with the two-step approach and the impact of congestion on convergence.	We concur that the finer zone system (225->820) will likely be required to stabilise the model with the additional (more representative) car access trips to PnR. As requested and noted above, we will retest the two-step (Fig 5.5) diversion curve in the 2018 validation of the 225 zone model but anticipate the same instability issues will arise.
12	Ian Clark, Flow	Comment already made on walk distances, and some walk trips seem surprisingly long, according to the previous survey results. I've encountered this issue recently in Auckland, and there is research by Auckland Council which also suggests long walk trips (eg it states that the median walk distance to the Albany Busway Station is 2.7km – a figure I don't believe can be true). Perhaps people responding to surveys of this nature may have been asked how they got to a station – and people may have walked the final leg, but not the whole trip. So while Section 5 of TN13 suggests that the proportion of walk trips of over 2km to stations may be fairly low (about 13%), I wonder if the real figure is lower still. Indeed, the recent MoE report which accompanies the National Policy Statement on Urban Development ("Understanding and Implementing Intensification Provisions for the NPS on Urban Development") notes (at page 23) that 1km may be the upper end of a walkable catchment for a rapid	There could potentially be an issue in the way the survey was conducted (in terms of reporting the whole trip distance when only the final leg was walk). This will obviously depend on good survey design and implementation. We cannot comment further on the observed data, but concur that some of the reported walk access distances seem exceptionally long and unlikely. In Hong Kong, the maximum walk distance to heavy rail was 800-1000m, and about 500m to stations in the urban centres. So your quoted figures align with our overseas experience. It is noted that the "other" non-car access includes walk, bike, and bus access and with ebikes, access distances may extend over time. The diversion curve could be changed now – but it would be preferrable to have data or a robust evidence base

No.	Comment By	Comment	Response
		transit stop. In this case, I wonder if the figures in Table 5.1, leading on to the formulae below that table, may require adjustment.	to confirm the shape of the curve. The PnR diversion curve has been implemented so that it can be changed if new observed data is available.
13		Interested how formal vs informal park and ride is treated in the hinterland around stations. Section 2.2 refers to the matter of informal parking and to the possibility of percentage increases, and to see how this has been applied.	Current WTSM has no parking capacity restraint (PnR or car access parking) and so formal verses informal PnR is a pricing consideration rather than a capacity issue. In Stage 1 of the project, the input parking charge per station should be adjusted outside of the model to allow for informal PnR use. This is stated in Section 5.4. Maintaining this outside the model environment ensures the model remains flexible. This approach is partly due to no data on informal PnR capacity.
14		The validation information in Table 5.4 only demonstrates that the changes to the treatment of PnR have not significantly affected the overall traffic validation - it does not necessarily demonstrate that the PnR module is working well. The previous tables show the effects on PT boardings, but again it's not possible to ascertain whether the PnR module is helping the accuracy of the model.	It's a valid point that we have not demonstrated that the PnR module is working well in terms of validation to observed. The objective of this task was to add functionality rather than specifically improve the validation. Hence we have added the functionality requested, and demonstrated that the PnR module performs similarly to before.

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

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