Cross Harbour Walking and Cycling Connection

DRAFT Transport Modelling and Economic Evaluation

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flow TRANSPORTATION SPECIALISTS LTD
Level 1, 11 Blake Street, Ponsonby | PO Box 47497, Ponsonby, Auckland 1144 | p 09 970 3820 | f 09 970 3890 | www.flownz.com

EXECUTIVE SUMMARY

This report considers a proposed shared use, walking and cycling facility across the Waitemata Harbour. While the exact configuration of any cross-harbour facility is yet to be determined, it is anticipated that the project would connect Northcote Point on the North Shore to Westhaven in Central Auckland, via the existing Auckland Harbour Bridge. Connections to the facility are anticipated to be in the locations of the existing bridge abutments.

Flow Transportation Specialists (Flow) has been commissioned by the New Zealand Transport Agency to:

- Develop pedestrian and cyclist estimates for the project
- Carry out operational assessments of the project
- Assess the traffic effects of removing general traffic capacity from the existing Auckland Harbour Bridge to accommodate the walking and cycling facility, for design options that may have this effect
- Assess the road user economic benefits of the project.

The following table summarises the estimated daily trips on the proposed walking and cycling connection in 2026.

Table ES1: Estimated Daily Pedestrian and Cyclist Trips across Harbour Bridge, 2026

	Utility[1]	Recreational	Tourist[2]	Total
Pedestrian trips	1,400		320	1,720
Cyclist trips	1,020	1,530	230	2,780
Total trips	3,950		550	4,500

The above estimates represent one-way trips across the harbour, and as such someone making a return journey contributes two one-way trips. Should each person complete a return trip, the 4,500 trips equates to 2,250 individual daily pedestrians/cyclists.

The above figures represent annual average daily trips, and significant seasonal and daily variation is expected.

The operational assessment has focussed on estimated peak volumes for shared path Level of Service (LOS) considerations and structural capacity considerations. The operational assessment has concluded that:

- A 4 m wide shared path is likely to result in recommended cyclist LOS criteria being exceeded during busy periods, and potentially on most days of the year

[1] Utility cycle trips are those where cycling is a mode choice, used to get from an origin to a destination, rather than as a recreational activity. Typical utility cycle trips include trips to work, school and university, among others.
[2] Both domestic and international tourist trips

- A 4 m wide shared path is unlikely to exceed recommended LOS criteria for cyclists
- The peak loadings on the proposed facility are predicted to initially remain well below the 500 to 600 person structural capacity supplied by the Transport Agency. However, forecast demands on the facility are predicted to increase over time. We also understand that the structural capacity has historically been trending downward over time as the traffic loading increases. The operational assessment has identified a risk that, should this trend continue, peak loadings on the facility would exceed the available capacity, and a mechanism will be needed to manage future demand. Any such mechanism will limit the utility that the proposed walking and cycling connection provides to the public, and will ultimately cap the project's benefits.

The economic evaluation of the project is summarised below, for the 'default' assessment that does not apply tolling to the facility, and that does not remove general traffic capacity from the Auckland Harbour Bridge.

Table ES2: Summary of Predicted Benefits for Cross Harbour Walking and Cycling Connection

Benefit Stream	Discounted Benefit
Cyclist travel time cost savings	$12.4 million
Health benefits for cyclists	$143.4 million
Health benefits for pedestrians	$19.1 million
Safety benefits	nil for default option
Road traffic reduction benefits (decongestion)	$53.8 million
Agglomeration benefits	$23.0 million
Tourism benefits	$2.0 million
Tolling benefits	nil for default option
Road traffic dis-benefits	nil for default option
Total Benefits	**$253.7 million**

A series of sensitivity tests has been run on the above assessment, testing input assumptions to both the demand assessment and to the economic evaluation. The tests resulted in estimated discounted project benefits ranging from $134 million to $331 million.

Construction costs have been supplied by the Transport Agency and sum to $201 million, including design, property, construction and maintenance. The resulting Project BCR has been estimated at 1.3, with a sensitivity test range of 0.7 to 1.7.

CONTENTS

APPENDICES

1 INTRODUCTION

This report considers a proposed shared use, walking and cycling facility on the Auckland Harbour Bridge, connecting Northcote Point on the North Shore to St Marys Bay in Central Auckland. Flow Transportation Specialists (Flow) has been commissioned by the Transport Agency to:

- Develop pedestrian and cyclist estimates for the project
- Carry out operational assessments of the project
- Assess the traffic effects of removing general traffic capacity from the existing Auckland Harbour Bridge to accommodate the walking and cycling facility
- Assess the economic benefits of the project.

The evaluation draws on information from multiple sources, but has principally involved:

- Using the Auckland Cycle Model[3] (ACM) to estimate recreational and utility[4] cycle trips
- Using Tamaki Drive as a benchmark to estimate recreational and utility walking trips
- Using San Francisco's Golden Gate Bridge as a benchmark to estimate tourist trips
- Using hourly demand profile data from Tamaki Drive to estimate peak hour use of the proposed cross harbour walking and cycling connection, in order to carry out operational assessments of:
  - Demand limitations, given the proposed width of the facility
  - Demand limitations, given the structural capacity of the facility
- Using the Upper Harbour SATURN model to assesses the traffic implications and economic effects of project options that affect general traffic capacity
- Adapting procedures from the Transport Agency's Economic Evaluation Manual (EEM) to assess transport-related benefits of the project. Wider Economic Benefits (WEBs) associated with agglomeration and increased tourism spend have been separately supplied by MRCagney.

This report documents the above processes.

2 SUPPORTING INFORMATION

2.1 Land Use Forecasts

The following table documents land use predictions from Auckland Council's "Scenario I11" forecast, aggregated across the areas of Northcote, Takapuna and the CBD/inner west. Scenario I11 is Auckland

[3] The Auckland Cycle Model was developed and is operated by Flow Transportation Specialists Ltd. It has been reviewed and considered appropriate for forecasting future cycle demands.
[4] Utility cycle trips are those where cycling is a mode choice, used to get from an origin to a destination, rather than as a recreational activity. Typical utility cycle trips include trips to work, school and university, among others.

Council's current land use forecast scenario, and is consistent with that used to inform the Auckland Transport Alignment Project (ATAP), as well as other current transport projects.

Table 1: Scenario I11 Land Use Forecasts (predicted growth from 2016 in brackets)

Area	Population			Employment (FTE jobs)		
	2016	2026	2046	2016	2026	2046
Northcote	16,800	19,800 (+18%)	22,800 (+36%)	7,600	7,600 (-)	7,700 (+1%)
Takapuna	5,100	10,500 (+106%)	16,700 (+227%)	11,400	13,400 (+18%)	17,500 (+54%)
Auckland CBD and Inner West	73,200	89,100 (+22%)	109,300 (+49%)	111,900	134,400 (+20%)	180,100 (+61%)

Population growth is predicted to occur within all three areas in the above table, and employment growth is predicted within Takapuna and the CBD/inner west. Long term growth (ie to 2046) is in particular predicted for Takapuna and the CBD/inner west.

2.2 Comparisons with Tamaki Drive

The evaluation draws significantly on the comparisons between the proposed cross harbour facility, and the existing causeway section of Tamaki Drive. These comparisons are presented below.

Table 2: Auckland Harbour Bridge and Tamaki Drive Comparisons

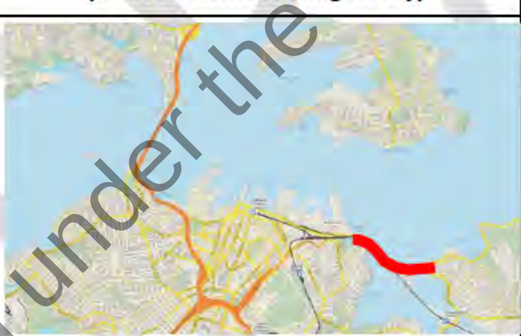
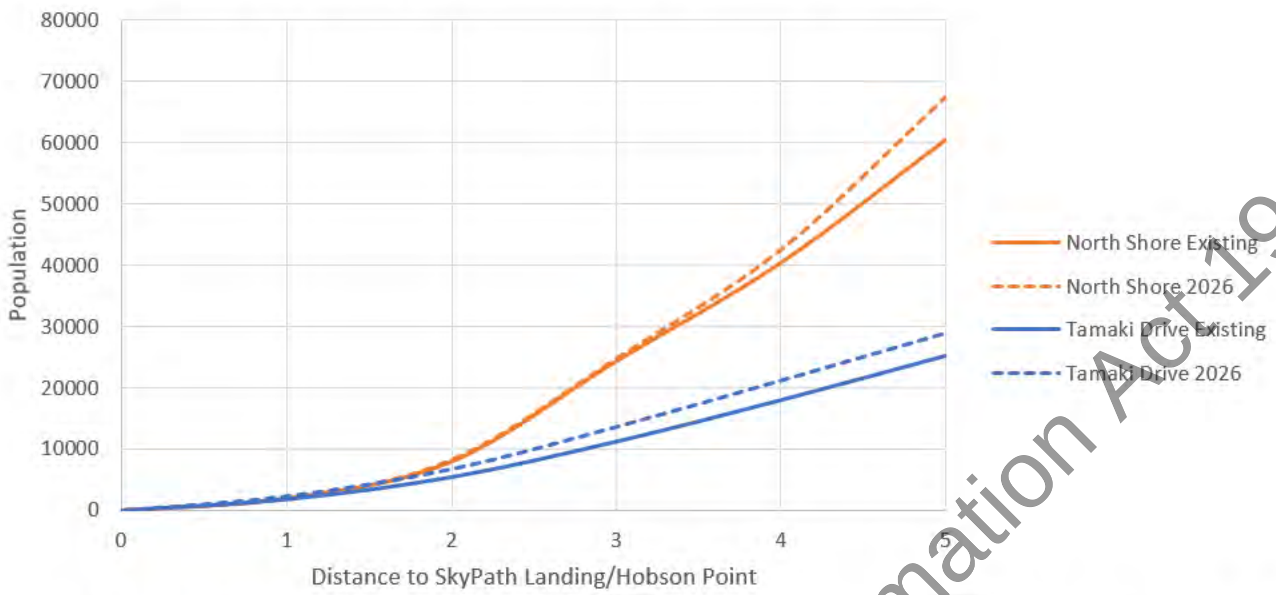
	Tamaki Drive Causeway (Hobson Point to Judges Bay)	Auckland Harbour Bridge
Location		
General description	1.6 km coastal route across Hobson Bay	1.3 km coastal route across Waitemata Harbour
Use	Popular with utility and recreational cyclists and pedestrians.	Expected to be popular with utility and recreational cyclists and pedestrians, as well as tourists.
Connections	City connections:	City connections:

Table 2: Auckland Harbour Bridge and Tamaki Drive Comparisons

	Tamaki Drive Causeway (Hobson Point to Judges Bay)	Auckland Harbour Bridge
	◆ Harbour side route to city centre, via Quay Street cycleway ◆ Steep uphill routes to Parnell, via St Stephens Avenue (pedestrians only) or via St Georges Bay Road	◆ Harbour side route to city centre, via Westhaven Boardwalk shared use path ◆ Steep uphill route to Ponsonby, via Curran Street
	Eastern connections: ◆ Inland local road route to Orakei, via Ngapipi Road (and in future via Glen Innes to Tamaki Drive shared use path) ◆ Coastal route to Eastern Bays, via Tamaki Drive	Northern connection: ◆ Inland local road route to Northcote, via Northcote Safe Routes ◆ Coastal route to Takapuna, via proposed SeaPath shared use path
Key Distances	From Hobson Point: ◆ 1.4 km to Parnell Baths ◆ 2.9 km walk to Parnell via St Stephens Avenue ◆ 3.5 km cycle to Parnell via St Georges Bay Road ◆ 3.7 km to City Centre (Queen Street/ Customs Street)	From Northern Landing: ◆ 1.3 km to southern landing ◆ 2.9 km to Wynyard Quarter ◆ 3.1 km to Ponsonby (Three Lamps) ◆ 4.4 km to City Centre (Queen Street/ Customs Street)
Adjacent Land Uses	Very few – Auckland Outboard Boat Club, minigolf course and pedestrian footbridge to St Stephens Avenue on southern side	None (harbour both sides)
Residential catchment	Refer Figure 1	
Active Mode Infrastructure	Two existing shared use paths, both approximately 2.5 m wide. Generally poor standard with uneven surface due to tree roots, low branches, street furniture and pinch points. Future two-way separated cycleway proposed by Auckland Transport.	Proposed shared use path, minimum 4 m width.

Figure 1 illustrates the existing and forecast 2026 residential populations within 5 km radii of the Hobson Point landing of Tamaki Drive, and of the proposed northern landing of the Auckland Harbour Bridge. It can be seen that both the Tamaki Drive causeway and the Auckland Harbour Bridge have very comparable residential catchments for pedestrian trips (ie within one to two km). In terms of cycling catchments however (ie within five km), the proposed cross harbour walking and cycling connection would have a residential catchment approximately double that of the Tamaki Drive causeway.

Figure 1: Tamaki Drive and Northern Auckland Harbour Bridge Residential Catchments



Overall, it is considered that the existing Tamaki Drive causeway provides a very useful comparison to the proposed cross harbour walking and cycling connection, with the only significant differentiator being the residential catchments.

3 DEMAND ESTIMATES

3.1 Pedestrians

Given the similarities between the proposed cross harbour walking and cycling connection and the existing Tamaki Drive causeway, the two facilities are anticipated to operate with comparable pedestrian demands. Manual surveys of pedestrians on Tamaki Drive were carried out on Wednesday 14th November 2018 and on Saturday 17th November 2018. The surveys were carried out immediately east of the pedestrian footbridge connecting Tamaki Drive to Parnell Baths. The weather was fine on both occasions, and the following pedestrian volumes were recorded:

- 245 pedestrians in the weekday morning period (6 to 9 am)
- 253 pedestrians in the weekday interpeak period (12 to 2 pm)
- 294 pedestrians in the weekday evening period (4 to 7 pm)
- 1,210 pedestrians throughout a Saturday (6 am to 7 pm).

Notably, approximately 20% of the surveyed pedestrians were wheeled pedestrians, including electric scooters.

Automated pedestrian count data from four shared path sites across Auckland[5] has been used to factor the above counts into annual average daily pedestrians, correcting for weather and season. The

[5] Orewa shared path, Twin Streams shared path Henderson, Mangere Harbour bridge and Waterview Unitec shared path

resulting estimated 2018 annual average daily pedestrian volume on Tamaki Drive is 1,190 daily pedestrian trips. The same 'existing' pedestrian demand of 1,190 daily pedestrians has been assumed to apply to a walking and cycling facility across the Auckland Harbour Bridge, if it were available today, given both facilities have comparable population catchments within 2 km of their northern/eastern landings, and have comparable connections to the city centre.

The above figure relates to 2018 pedestrians, and this would be expected to grow over time. There are multiple drivers behind future growth in pedestrian trips across the harbour, including land use changes and the future cost of travel by other modes. Land use growth has been used as a proxy for pedestrian demand growth as documented below.

From the land use data presented in Figure 1 previously, very little land use growth is anticipated within a 2 km radius of the proposed northern landing of the Auckland Harbour Bridge. Significant growth is forecast however near the southern landing, and Table 3 presents the existing and forecast 2026 land uses within a 2 km radius of the bridge's southern landing.

Table 3: Auckland Harbour Bridge Southern Landing Land Use Catchments

Area	Population			Employment		
	2016	2026	Growth	2016	2026	Growth
1 km radius of landing	1,035	1,203	+16%	1,584	1,582	-
2 km radius of landing	7,073	8,851	+25%	26,106	34,598	+33%

The southern landing is predicted to experience land use growth of up to 33% to 2026. A 20% increase has been estimated to apply to the 2018 pedestrian demands above, to give estimated 2026 demands of 1,400 pedestrian trips per day (ie 2.5% per annum).

Beyond 2026, land use growth is predicted to slow to between 0% to 2% within the above catchments. However, the future costs of travel by other modes is reasonably expected to grow at a higher rate than this, so future pedestrian growth beyond 2026 has been set at 2.2% per annum (linear increase), based on the forecast growth in cycle trips on the facility (refer Section 3.2). This assumption has been sensitivity tested in the economic evaluation in (Section 6.12).

3.2 Utility and Recreational Cyclists

3.2.1 Methodology

The ACM has been used to develop estimates of average weekday peak period cyclist trips on cross harbour walking and cycling connection (both utility and recreational trips). The ACM estimates future cycling demand and:

- Reflects predicted land use (according to Auckland Council's scenario I11 land use forecasts)
- Reflects cyclists' route choice – with cyclists generally opting to travel via a slightly longer route if it provides a higher standard of infrastructure, or less adverse gradients

- Reflects realistic cycling trip lengths – with longer trips less likely to be undertaken by bicycle than shorter trips, with a probability distribution applied that is based on the existing Auckland cycle trip length distribution
- Reflects realistic cycle trip types – with trip types such as home-to-work and home-to-education more likely to be undertaken by bicycle than trip types such as trips for employer's business
- Is responsive to changes in cycle infrastructure (in terms of both demands and trip assignment), in that high quality cycle infrastructure between any two nodes will result in more trips between those nodes being undertaken by bicycle, than a scenario with poorer quality cycle infrastructure
- Reflects both utility and recreational cyclist components, but not tourist trips.

The model was built to represent a 2013 base year, and a 2016 forecast model has also been developed that includes all cycling infrastructure constructed between March 2013 and July 2016, notably including new infrastructure in Grafton Gully, Nelson Street, LightPath, Beach Road, Carlton Gore Road and Quay Street.

The 2016 model was calibrated against automated cycle count data collected from 21 locations, to refine the model's cycle demand process. In this way, the model's response to cycle infrastructure investment has been calibrated to match the growth observed between 2013 and 2016, given the investment in Auckland cycle infrastructure over this period.

The ACM is informed by the Auckland Macro Strategic Model (MSM, previously the Auckland Regional Transport Model, ART), and its development is documented more fully in a Model Development Report, appended to this document.

For the economic evaluation of the Project, 2026 and 2046 forecast models have been used. These models are based on Auckland land use scenario I11 (the most recent available, and that reflecting Auckland Unitary Plan zoning).

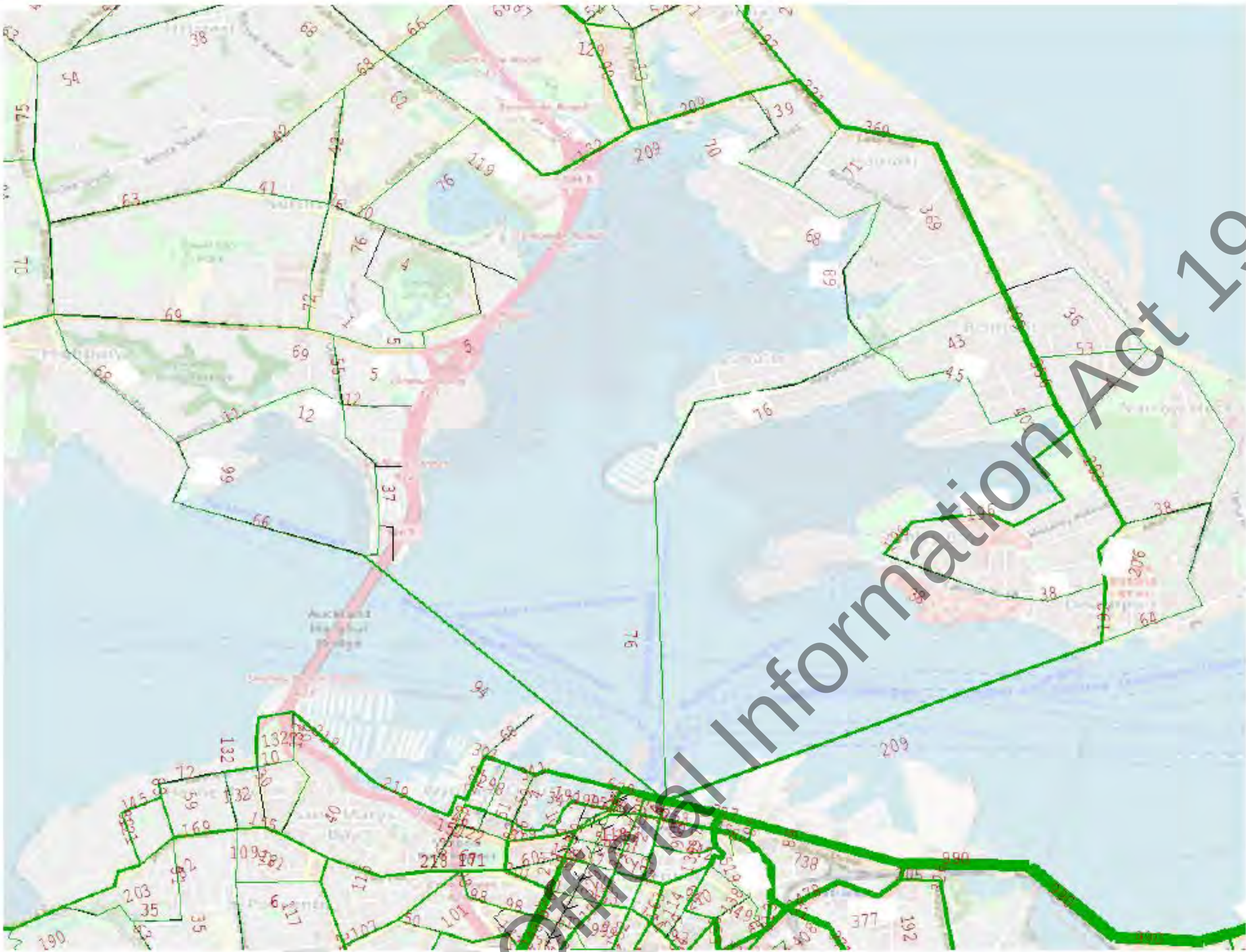
The model represents morning and evening peak period (two hour) cyclist demands for each forecast year. Estimates of daily cyclist demands have been derived by factoring the morning and evening peak period forecasts. A factor of 2.3 has been used in this process in order to replicate the off-peak and weekend profiles currently observed on Tamaki Drive and anticipated to similarly apply to a future cross harbour walking and cycling connection. It is noted that lower factors tend to apply to cycle routes that that have a lower proportion of recreational trips, such as the Northwestern Cycleway.

3.2.2 2016 Forecast Model

As discussed previously, a 2016 ACM forecast has been developed, based on 2016 I9 land use forecasts[6]. Figure 1 presents a plot of forecast daily cyclists from the 2016 model.

[6] Scenario I9 was the last land use forecast scenario that was modelled by a 2016 regional transport model (ART or the MSM).

Figure 2: 2016 Modelled Daily Cyclist Plot



The ACM is relatively coarse grained, in that it does not include local street links nor the detailed land uses and accesses that result in cyclist volumes varying along a given section of road. A factor of 2.3 has been used to calibrate the estimated daily cyclist demands against the 2016 observations (refer Section 3.2.1). It should be recognised that applying a network-wide factor as such will result in some demands being under-estimated on routes that attract a high proportion of off peak and recreational users, such as Tamaki Drive and Te Wero Bridge. Conversely, demands will be over-estimated on routes with a commuter focus, such as the Northwestern Cycleway. It is also important to recognise that this approach has produced differing estimated daily demands relative to those in the Model Development Report (Appendix B), where route-specific factors were applied to each cycleway.

A comparison of the 2016 forecast model's outputs was undertaken using historic cycle count data. Counts in Northcote were manual surveys carried out by Auckland Transport in November 2016 and March 2017, and average counts are presented where there were multiple count sites and dates. The remaining counts are annual average counts for 2016 obtained from Auckland Transport's automatic counters.

Table 4: Comparison of 2016 Model and Count Data

Road	Section	Existing Daily Count	2016 Model	
			Daily Cyclists	Difference
North Shore Count Data				
Northcote Road	SH1 to Akoranga Road	75	66	-9
	Akoranga Road to Lake Road	51	68	+17
Lake Road (Northcote)	Northcote Road to Exmouth Road	36	42	+6
	Exmouth Road to Onewa Road	24	72	+48
Queen Street	North of Belle Vue Avenue	25	55	+30
	South of King Street	107	37	-70
Lake Road (Takapuna)	South of Eversleigh Road	281	369	+87
City Centre Count Data				
Curran Street	North of Sarsfield Street	252	132	-120
Te Wero Bridge	Te Wero Bridge	550	342	-208
Quay Street	Spark Arena	738	755	+17
Tamaki Drive	East of Solent Street	1,176	1,032	-144
Lightpath	South of Union Street	529	524	-5
Northwestern Cycleway	Kingsland	657	774	+117

The 2016 forecast model generally predicts an appropriate quantum of cyclists on each route, given the following considerations:

- The morning and evening commuter peak cycle model outputs were factored to develop the daily estimates above, as documented previously. The blanket factoring of all routes by the same factor will have over-estimated daily demands on commuter-oriented routes such as the Northwestern Cycleway, and under-estimated demands on routes with significant sports/recreational use such as Tamaki Drive and Te Wero Bridge.
- The model underestimates the number of cyclists using Queen Street to access the Northcote Ferry, and predicts that more cyclists will instead join this ferry service at Birkenhead. The total number of cyclists estimated to use the Birkenhead/Northcote ferry is 94 per day, and this agrees with Auckland Transport data from 2013 which provided a figure of 83 daily cyclists. As a result, the quantum of cyclists predicted to cross the Waitemata Harbour via the Birkenhead/Northcote ferry is considered appropriate.

3.2.3 Future Scenarios Assessed

The Project has been benchmarked against a future Reference Case that includes all existing cycle infrastructure, in addition to future infrastructure either currently proposed, or expected to be implemented in the future. The projects assumed within the future Reference Case for 2026 and 2046 are identified below.

2026 Future Reference Case:

The 2026 future Reference Case includes all existing cycle infrastructure, as well as all future projects either currently under construction or with committed funding. These include:

- The SeaPath shared use path between Akoranga Road and the Auckland Harbour Bridge northern landing
- The proposed Northcote Safe Routes (a combination of shared use paths and on street cycle facilities on Northcote Road, Lake Road and Queen Street),
- Completion of the Auckland Urban Cycleways programme[7], including cycling improvements from Pt Chevalier to Herne Bay, the Waitemata Safe Streets, Jervois Road and College Hill (currently programmed for completion in 2020)
- The NZ Transport Agency's proposed cycle infrastructure included in the Northern Corridor Improvements project, which include shared paths parallel to SH1 (Oteha Valley Road to Constellation Drive) and SH18 (SH1 to Albany Highway).

2046 Future Reference Case:

The 2046 future Reference Case includes all infrastructure included in the 2026 Reference Case. It also includes limited future cycle infrastructure that, while not committed, is considered the 'bare minimum' level of ongoing cycle investment over the next 30-year period. This is consistent with the Auckland Cycling Programme Business Case which proposes significant future investment in cycle infrastructure across Auckland. If no further background investment was assumed, this would unrealistically limit the long-term connectivity of the proposed Project. Infrastructure included is:

- A future shared use path parallel to SH1, from Constellation Drive to Esmonde Road
- Future cycle infrastructure on lower North Shore arterials to extend the reach of SeaPath and the proposed cross harbour connection, including on Glenfield Road, Mokoia Road, Waipa Street, Birkdale Road, Kitchener Road, Hurstmere Road and Killarney Street
- Future cycle infrastructure on Ponsonby Road, Jervois Road, College Hill, West End Road and Richmond Road, the latter where not already provided by the Waitemata Safe Routes project.

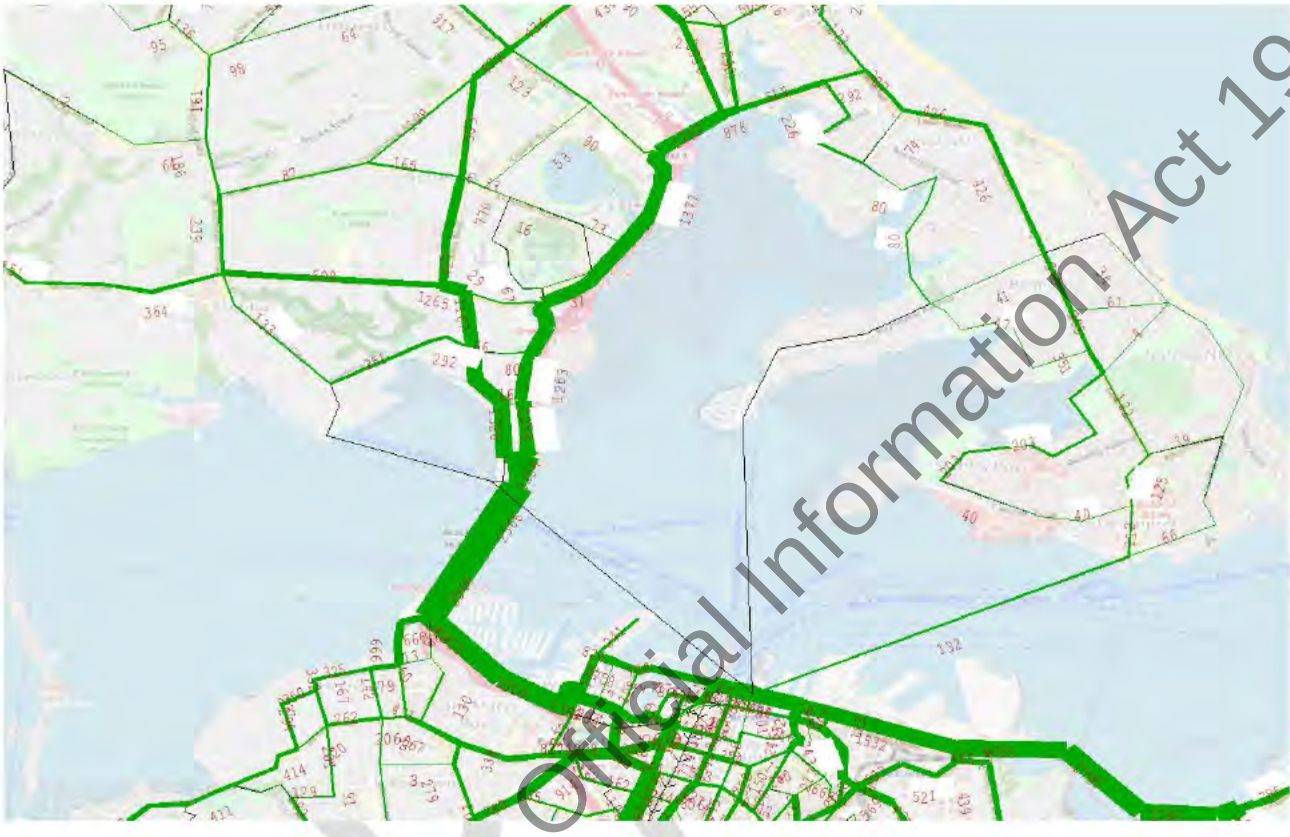
It is noted that the Auckland Cycle Network (ACN) is Auckland Transport's proposed long-term network of cycle infrastructure and it contains significantly more investment than the above, with dedicated cycle infrastructure on all arterial routes and parallel to all motorway and rail corridors. A sensitivity test on the economic assessment of the Project, should the ACN be completed, is included in Section 3.2.8.

[7] https://www.nzta.govt.nz/walking-cycling-and-public-transport/cycling/investing-in-cycling/urban-cycleways-programme/auckland-urban-cycleways-programme/

3.2.4 Demand Estimates

The following figure illustrates the average annual daily cyclist trips (utility and recreational trips) predicted by the ACM.

Figure 3: 2026 Forecast Daily Cycle Trips (Utility and Recreational Trips)



Approximately 2,550 daily cyclist trips are forecast on the proposed cross harbour walking and cycling connection in 2026. Of these, 40% or 1,020 trips are estimated to be utility trips (ie mostly commuter trips likely to be making return trips, therefore 510 people) and 1,530 are estimated to be recreational trips. This split has been based on:

- Manual observations made on Tamaki Drive , where the observed split was 39% utility cyclists and 61% recreational cyclists[8]
- Data from interview surveys carried out by Auckland Transport on Quay Street , where the split was 53% utility cyclists and 47% recreational cyclists[9]
- Data from the Household Travel Survey, which suggests that approximately 30% of existing cycle trips in Auckland are for work purposes.

The ACM predicts that the proposed facility will result in cyclists travelling an additional 19,540 daily kilometres across the modelled network in 2026. Of the 2,550 daily cyclists on the facility predicted

[8] Wednesday 14th and Saturday 17th November 2018. 39% utility cyclist estimate is a weighted average of 3 hour morning peak period (53%), 2 hour interpeak period (13%), 3 hour evening peak period (79%) and 13 hour surveyed Saturday period (1%)
[9] Unspecified Thursday and Saturday in 2016; 53% utility cyclist estimate is weighted average of weekday cyclists (78%) and weekend cyclists (6%).

above, 2,200 of these are predicted to be new users, with the remaining 350 transferring from ferry services or the Upper Harbour Bridge. As a result, the average new cycle trip length on the facility is predicted by the ACM to be 19,500 / 2,200 = 8.9 km. This approximately corresponds to the distance between Takapuna and the city centre.

In reality however the average new trip will be slightly shorter. Existing cyclists are expected to cycle a little further out of their way to use the facility, meaning a portion of the additional 19,500 cyclist-km will be carried out by these existing users.

The following table summarises the forecast 2026 daily demand on the proposed facility, as well as on related infrastructure, both with and without the facility:

Table 5: Summary of Forecast 2026 Average Annual Daily Cyclists (Utility and Recreational)

	2026 Without Project	2026 With Project
Auckland Harbour Bridge	n/a	2,550
SeaPath (north of Harbour Bridge)	0	1,250
Queen Street, Northcote	170	1,350
Curran Street, Ponsonby	160	1,000
Westhaven Drive/Boardwalk	250	1,900
Northcote Ferry	190	0
Bayswater Ferry	80	0
Devonport Ferry	230	130
Upper Harbour Bridge	200	200

3.2.5 Mode Share

The existing mode share for commute to work trips by bicycle in the Auckland region is in the order of 1%[10], and this reflects the lack of appropriate cycle infrastructure at the time of the 2013 census. In terms of Auckland Council Local Board areas, the Kaipatiki Local Board has one of Auckland's lowest existing cycle to work mode shares, at 0.7%. Conversely, the Devonport-Takapuna Local Board has an existing cycle to work mode share of 2.1% – one of Auckland's highest. Higher mode shares, in the order of 4%, were recorded locally at the Census Area Unit level, notably in Devonport, Takapuna, Grey Lynn, Pt Chevalier and Mt Eden.

On completion of a cross harbour walking and cycling connection (in addition to the other investment included in the 2026 Reference Case scenario), the following forecast cycle to work mode shares are estimated in 2026:

- 2.2% for the Auckland region
- 2.6% for the Devonport-Takapuna Local Board area
- 2.3% for the Kaipatiki Local Board area.

[10] New Zealand Census, 2013

These forecast mode shares are considered realistic, given the level of cycle infrastructure investment to 2026, that includes not only the proposed cross harbour walking and cycling connection, but SeaPath, the Northcote Safe Routes, and completion of the Auckland Urban Cycleways Programme.

3.2.6 Auckland Comparisons

The above 2,550 daily cyclist trips forecast across the proposed cross harbour walking and cycling connection in 2026 can be benchmarked against existing, historic and forecast daily cyclist volumes on other significant Auckland cycleways. This comparison is presented below. The historic and existing data is from Auckland Transport's automated cycle counters unless otherwise stated, and the forecasts are from the same ACM scenario that produced the estimated 2,550 trips across the harbour connection.

Table 6: Comparison of Demand Estimates for Proposed Cross Harbour Connection to Other Auckland Cycle Routes

Cycleway	2013 Average Daily Cyclists	2018		2026 ACM Forecasts	
		Average Daily Cyclists	Annual Growth 2013-2018	Forecast Average Daily Cyclists	Forecast Annual Growth 2018-2026
Cross Harbour Connection	n/a	n/a	n/a	2,550	n/a
Tamaki Drive	1,100	1,250	3%	1,900	7%
Quay Street totem	660[11]	960	9%	1,500	7%
Northwestern Cycleway	400	880	24%	1,050	2%

The above comparisons show that while the forecast 2,550 daily cyclist trips on the proposed cross harbour walking and cycling connection is high relative to existing counts on Auckland's major cycle routes, it is a sensible estimate relative to the future forecasts for these other routes. Understandably the forecast for the cross harbour connection is higher than the forecasts for Tamaki Drive and the Northwestern Cycleway, as the proposed facility will be the only cycling connection to the North Shore other than the Upper Harbour Bridge. By contrast, the Northwestern Cycleway has multiple alternative parallel corridors, while Tamaki Drive serves a smaller catchment.

The existing Upper Harbour Bridge has not been used as a comparator facility however, as this bridge serves a significantly smaller catchment than any of the four routes compared above. The Upper Harbour Bridge is also not considered a realistic alternative to the proposed cross harbour facility, due to the significant distances involved in routing via the former.

Finally, it is noted that Tamaki Drive currently accommodates some 1,250 average daily cyclist trips. As discussed in Section 2.2, the proposed facility will provide access to approximately double the residential catchment within a 5 km radius, relative to the Tamaki Drive causeway, and will share many other contributing features. It follows that approximately 2,500 daily cyclist trips could be expected on the proposed cross harbour walking and cycling facility, before accounting for any land use growth (ie double the existing 1,250 cyclist trips using Tamaki Drive). While there are many other factors that determine

[11] Estimate of daily cyclists, based on weekday peak period and weekend morning manual surveys

cycle demands on a facility, this simple population analysis suggests that at a high level, the estimated 2,550 daily cyclist trips using the proposed facility in 2026 is a conservative assessment.

3.2.7 International Comparisons

The 2,550 daily cyclist trips and the 1,400 daily pedestrian trips forecast on the proposed cross harbour walking and cycling facility in 2026 (from Sections 3.1 and 3.2) can also be benchmarked against existing cyclist volumes on significant international bridges. This comparison is presented below.

Table 7: International Comparisons to Proposed Cross Harbour Walking and Cycling Facility

International Example	Similarities	Differences
Golden Gate Bridge, San Francisco 5,500 daily pedestrians 4,000 daily cyclists[12]	Broadly similar urban population to Auckland. Very popular tourist and recreational activity. Similar climate. No alternative active mode routes available, except ferry.	2.7 km long, approximately twice the length of the Auckland Harbour Bridge. Greater distance to CBD than Auckland Harbour Bridge. Better connecting cycling facilities than Auckland. No significant population on northern landing, and little within 2 km of southern landing. Little use by utility cyclists. Greater international tourist status.
Story Bridge, Brisbane 2,280 people daily[13]	Similar urban population to Auckland. Comparable densities to Auckland. Popular tourist activity. Comparable in length. Comparable waterfront cycleway network.	Closer to CBD than Auckland Harbour Bridge. Smaller catchment area Multiple parallel bridges to the west (Go Between Bridge, William Jolly Bridge, Victoria Bridge, Kurilpa Bridge).
Sydney Harbour Bridge 3,500 daily pedestrians[14] 1,750 daily cyclists[15]	Popular tourist activity. Comparable length. Similarly connects CBD to North Shore. No alternative routes available, except ferry. Comparable cycle network to Auckland.	Higher density than Auckland. Greater international tourist status. Business districts situated on both landings.

[12] August to October 2015 data, supplied by Golden Gate Bridge Highway & Transportation District
[13] 1st January 2016 to 31st December 2016 data, supplied by Brisbane City Council, Infrastructure Division
[14] 1.3 million annual pedestrians quoted by email by New South Wales Roads and Maritime Services
[15] Cycling statistics; Roads and Maritime Services, Government of New South Wales; March 2016.

Table 7: International Comparisons to Proposed Cross Harbour Walking and Cycling Facility

International Example	Similarities	Differences
ANZAC Bridge, Sydney 1,200 daily cyclists[16]	Popular tourist activity. Comparable spiral approach ramps to those proposed for Auckland Harbour Bridge. Similar proximity to CBD.	Higher density than Auckland, although relatively little land use close to western landing. Shorter span – approximately 800 m. Much smaller catchment – bridge spans small inlet, with multiple inland routes available approximately 1 km to the south.
Brooklyn Bridge, New York 2,300 daily cyclists[17]	Popular tourist activity. Comparable length.	Higher density than Auckland, but much smaller catchment area. More developed connecting cycling infrastructure. Colder winter climate. Multiple parallel bridges (Manhattan Bridge is approximately 400 m to the east; see below).
Manhattan Bridge, New York 4,600 daily cyclists[17]	Comparable length.	Higher density than Auckland. More developed connecting cycling infrastructure. Colder winter climate. Multiple parallel bridges (see Brooklyn Bridge above).
Forth Road Bridge, Scotland 600 people daily (July – November 2018)[18]	No alternative active mode routes available, except ferry.	2.5km long, approximately twice the length of the Auckland Harbour Bridge. Lower population density on both landings. No Business District within proximity of bridge. Not identified as a popular tourist activity. Colder climate.

It is important to recognise the many differences between the above international examples and any proposed cross harbour walking and cycling facility in Auckland, and that the daily volumes on the above examples are historic numbers from 2015 to 2018, while the forecasts for the proposed facility are 2026 predictions. As such, it is difficult to draw conclusions from direct comparisons of the above international examples and the proposed facility. Nonetheless, the proposed cross harbour walking and cycling facility's forecasts of 2,550 daily cycle trips and 1,400 daily pedestrian trips in 2026 sit relatively

[16] Cycling statistics; Roads and Maritime Services, Government of New South Wales; March 2016.
[17] Daily average across April and May 2018, New York City Department of Transport
[18] 16th July 2018 to 6th November 2018 data, supplied by Forth Estuary Transport Authority

well within the above range, being significantly fewer travellers than the Golden Gate Bridge, Sydney Harbour Bridge and Manhattan Bridge, and more travellers than Sydney's ANZAC Bridge and the Forth Road Bridge.

3.2.8 Sensitivity Tests

A series of sensitivity tests have been run on the assessment, focussing on the utility and recreational cyclist component of the proposed facility's demand estimates. The sensitivity tests investigate the impacts of:

- The effect on the project, should SeaPath not be constructed
- The effect on the project, should various tolls be applied to all pedestrians and cyclists
- Faster/slower land use growth, relative to the I11 default forecasts
- The effect of a large future uptake in e-bikes resulting in a higher proportion of long trips being undertaken by bicycle[19]
- Varying the factor used to develop estimates of daily cyclists; the default factor used is 2.3, with a low value of 2.0 (the factor observed on the Northwestern Cycleway), and a higher value of 3.1 (being the observed factor on Great North Road).

The results of the sensitivity tests are presented below.

Table 8: Cyclist Demand Estimates – Sensitivity Tests

Sensitivity Test Scenario	ACM Forecast 2026 Daily Cycle Trips
Tolling: $2 per trip	1,550
Tolling: $1 per trip	2,000
SeaPath not constructed	2,150
Lower daily cyclist factor (2.0)	2,200
20% slower land use growth	2,500
Default 2026 Daily Cyclists	**2,550**
20% faster land use growth	2,600
Higher daily cyclist factor (3.1)	3,400
High uptake in e-bikes	4,500

The forecast number of daily cyclists on the proposed facility is very insensitive to changes in land use growth, but is conversely very sensitive to assumptions around tolling, and to the potential effect of e-bikes. The latter in particular has the potential to significantly increase the use of the facility, as e-bikes would make relatively long distance, cross harbour cycle trips more accessible for more people. Depending on the path width provided by the proposed facility however, this level of demand may not be achievable (refer Section 4).

[19] This test doubles the likelihood of trips over 5.0 km in length being carried out by bicycle, with smaller increases to short trips. The resulting forecast 2026 average Auckland cycle trip length increases from 5.0 km to 5.5 km.

3.3 Tourists

3.3.1 Demand Estimate

San Francisco's Golden Gate Bridge provides a useful comparison for a walking and cycling tourist facility across the Waitemata Harbour. The Golden Gate Bridge connects San Francisco to the small village of Sausalito. On the southern (San Francisco) side the bridge lands at the base of an extensive public park (Presidio of San Francisco) and as a result there is very little urban land use within 2 km of the bridge's southern landing. Beyond this, the CBD is an approximately 10 km cycle from the southern bridge landing. To the north, Sausalito has a population of approximately 7,000, and is 3 to 6 km cycle from the bridge's northern abutment.

As a result of this geography, the Golden Gate Bridge connects very few urban land uses within a walkable or cycle-able distance. Relatively few walking and cycling trips across the bridge are considered to be utility trips (ie commute to work or education trips), and the bridge is instead used primarily as a recreational and tourist connection. In August to October 2015, the bridge carried on average 4,000 daily cyclist and 5,500 daily pedestrian trips.

Key factors when comparing the tourism potential of a future walking and cycling connection on Auckland Harbour Bridge and the Golden Gate Bridge include:

- Golden Gate Bridge has a significantly higher international profile than the Auckland Harbour Bridge
- San Francisco received 25.1 million tourists[20] in 2016, while Auckland received 2.72 million visitor arrivals[21] in the year to March 2018, a ratio of approximately ten-to-one[22]
- San Francisco has a broadly comparable climate and topography to Auckland, similarly amenable to walking and cycling
- San Francisco has a more developed cycle network and bicycle culture than Auckland generally, but Auckland will have a comparable network within the city centre on completion of the Urban Cycleways Programme
- The Auckland Harbour Bridge is significantly closer to Auckland's city centre than the Golden Gate Bridge is to San Francisco's city centre, and will be connected by an appealing harbourside route (the Westhaven Boardwalk)
- A proposed cross harbour walking and cycling connection would form part of a cohesive and continuous waterfront walking and cycling route consisting of SeaPath, the Auckland Harbour Bridge, the Westhaven Boardwalk, the Wynyard Quarter, Te Wero Bridge, Quay Street and Tamaki

[20] https://www.sftravel.com/article/san-francisco-travel-reports-record-breaking-tourism-2016; retrieved 20 October 2018
[21] https://www.stats.govt.nz/news/annual-visitor-arrivals-up-more-than-1-2-million-in-five-years; retrieved 20 October 2018
[22] The San Francisco figure includes both domestic and international arrivals, while the Auckland figure includes only international. The latter however also includes international arrivals transiting through Auckland en route to other destinations in New Zealand. As a result, the use of the two figures to form a broad comparison is considered appropriate

Drive. This presents greater leveraging opportunities for walking and cycling tourism along the waterfront, relative to the Golden Gate Bridge, which is a more isolated tourist attraction.

An estimate of annual average daily tourist trips on the proposed facility has been developed by the following process:

- Assuming that half of those using the Golden Gate Bridge are tourists, either domestic or international, with the remainder being local recreational trips
- Acknowledging the Auckland Harbour Bridge's lesser international reputation than the Golden Gate Bridge, but assuming that this will be offset by:
  - The Auckland Harbour Bridge's better proximity to hotels, international cruise terminal and tourist facilities in the city centre
  - Opportunities presented by Auckland's more cohesive and continuous waterfront walking and cycling route
- Assuming that tourists visiting the facility are proportional to overall city visitor numbers, with Auckland broadly receiving 10% of San Francisco's visitors.

On the basis of the above, the proposed facility is estimated to receive approximately 200 tourist cycle trips and 275 tourist pedestrian trips per day, averaged across a year. Assuming 50% of those would make a return trips across the facility, and the remaining 50% would complete only a one-way trip and return by ferry, this is broadly equivalent to 130 daily tourists on bicycles plus 180 pedestrians, or approximately 115,000 visitors annually. This estimate can be compared to other Auckland tourist attractions that include 931,000 visitors to Auckland Museum[23], 698,000 visitors to Auckland Zoo[24], and 155,000 visitors to the New Zealand Maritime Museum[25].

The above estimates are based on existing tourist data however, and must be inflated to account for growth in tourism to 2026.

This growth has been estimated based on the following:

- An estimated 18%/82% split between international and domestic tourists, based on research carried out by MRCagney[26]
- Forecast annual growth in international tourists from Auckland Tourism, Events and Economic Development (ATEED), who estimate that international tourist visitors to Auckland will increase 39% between 2017 and 2023 – a 6.5% annual increase[27]
- Annual growth in domestic tourists based on the forecast New Zealand population of growth of 1.2%[28] per annum.

[23] Auckland Museum Annual Review 2017/2018
[24] Auckland Council Summary Annual Report 2017/2018
[25] NZ Maritime Museum Annual Report; 2015/2016
[26] Wider Economic Benefits of a New Walking and Cycling Link Across the Waitemata Harbour; MRCagney; December 2018
[27] Destination Auckland 2025: Supplementary Report; Auckland Tourism, Events and Economic Development
[28] Stats NZ median projection to 2028

The above growth rates have been applied to the estimated daily trips to arrive at an estimated 230 daily tourist cyclist trips and 320 daily tourist pedestrian trips on the proposed facility in 2026 (550 daily tourist trips in total). This is broadly equivalent to 150 individual daily tourists by bicycle, plus 210 pedestrian tourists, or 130,000 annual visitors.

3.3.2 Demand Estimate – Local Comparison

The peer reviewer of this study has recommended that other local walking and cycling trails that may be able to benchmark the estimated tourist trip forecasts for the proposed cross harbour walking and cycling facility be investigated. A useful New Zealand comparison to the proposed cross-harbour walking and cycling facility is the Queenstown trail. This trail network received an estimated 332,400 annual users in 2017, with 58% being visitors to Queenstown[29]. This corresponds to approximately 530 daily tourist users, averaged across the calendar year. On the surface, this presents a useful comparison to the 550 daily tourist users estimated to use the proposed cross-harbour walking and cycling facility in 2026.

These tourist daily numbers must be considered against the similarities and differences between the two facilities and their context:

- Visitor numbers: Auckland receives a significantly higher number of tourists than Queenstown, with 2.72 million recorded at Auckland airport in the year to March 2018 and 272,000 at Queenstown airport over the same period[30]. Auckland received a further 211,000 cruise ship visitors[31], although there will be some overlap between Auckland's airport and cruise ship visitors
- Visitor type: Queenstown is generally known as an adventure tourism destination, which differs from Auckland's more general tourist visitors. This suggests that visitors to Queenstown may be more amenable to cycle tourism. The Queenstown Trail however attracts a relatively older profile of tourists, with 70% of users being over 40 years old[32], and 50-60 being the most popular ten-year age bracket
- Facility type: The Queenstown Trail is a network with approximately 120 km of off-road mountain bike trails. As a result, 75% of the Queenstown Trail's users are cyclists, with 23% on foot[33]. Auckland's cross harbour facility would be 2 km long, and part of an approximately 17 km long waterfront route of paved and sealed cycleways and shared use paths
- Climate: Queenstown's climate features more extreme winter weather events, with snow and frost likely to reduce tourist use of the Queenstown Trail over winter. Cycle tourist numbers in Auckland's winter climate, while warmer and snow free, will be affected by higher rainfall.

It is not practicable to develop estimates of daily tourist users on the proposed cross-harbour walking and cycling facility based on the 530 average daily tourist users of the Queenstown Trail, given the differences between these two facilities and their context. However, the latter provides some

[29] Review of Queenstown Trails – Economic Impacts and User Satisfaction; Queenstown Trails Trust; July 2017
[30] https://www.stats.govt.nz/news/annual-visitor-arrivals-up-more-than-1-2-million-in-five-years; retrieved 20 October 2018
[31] Cruise ship traveller and expenditure statistics: Year ended June 2018; Statistics New Zealand
[32] Review of Queenstown Trails – Economic Impacts and User Satisfaction; Queenstown Trails Trust; July 2017
[33] ibid

confidence that the separately estimated 550 daily tourist users of the proposed cross-harbour walking and cycling facility is sensible.

Other New Zealand cycle trails, such as the Hauraki Rail Trail and the Central Otago Rail Trail, tend to be in less accessible locations and provide a less useful comparison to the proposed cross harbour walking and cycling facility.

3.4 Micro Mobility

The demand forecasts presented above are estimates only, and like all future forecasts they come with uncertainty associated with input assumptions, methodology limitations and future unknowns. Particular mention should be made however of the future of 'micro mobility', and the risks and opportunities this may present to the above forecasts. Micro mobility is a term used to group recent new technologies in small scale, motorised travel including e-bikes, e-scooters and other modes.

As discussed in Section 3.1, approximately 20% of existing pedestrians along Tamaki Drive, when surveyed in November 2018 were wheeled pedestrians. Many of these were on e-scooters, either privately owned or rented through an e-scooter app. This is a significant finding, given Lime e-scooters had only launched in Auckland one month prior, and e-scooters have only been commercially available for a short number of years.

There is significant uncertainty around the future of e-scooters and their ongoing use on Auckland's footpaths and cycleways. Indeed Lime e-scooters and other dockless operators have been banned in a small number of cities internationally, including Madrid, and have had restrictions imposed in others such as San Francisco. Maximum speeds have been suggested in New Zealand and elsewhere. Their current popularity within central Auckland may be somewhat due to the novelty factor, but equally may be the start of an increasing trend.

The extremely rapid rise of this technology should be considered a signal that the future of micro mobility – be that e-scooters or some other future technology – is rapidly changing. This may particularly be the case for relatively long distance active mode trips, such as those across any future cross harbour walking and cycling connection. It may be that future micro mobility options make walking or cycling trips across the harbour less attractive, and indeed make short car, bus or ferry trips across the harbour less attractive. This may have the effect of reducing the overall demand on the proposed facility, but would more likely increase demand. A possible implication of this scenario however, is that if more trips on the proposed facility are motorised rather than self-propelled, fewer people will benefit from the health benefits of physical exercise. The effects of this on the project's economic evaluation have been assessed in a sensitivity test (Section 6.12).

Clearly there is significant uncertainly surrounding the future of micro mobility, and this presents both risk and opportunity to the project.

3.5 Demand Summary

The following table summarises the forecast daily pedestrian and cyclist trips on the proposed cross harbour walking and cycling connection for the variety of trip purposes considered.

Table 9: Summary of Forecast Trips on Proposed Cross Harbour Facility

Trip Type		2026 Forecast	2046 Forecast	Annual Growth
Pedestrians	Utility and recreational	1,400	2,050	2.3%
	Tourists	320	440	1.2% for domestic 6.5% for international
Cyclists	Utility	1,020	1,500	2.3%
	Recreational	1,530	2,250	2.3%
	Tourists	230	320	1.2% for domestic 6.5% for international
Total trips		4,500	6,560	2.3%

4 OPERATIONAL ASSESSMENTS

4.1 Variations in Demand

The use of the proposed facility is expected to vary seasonally and from day to day, and in this regard, Tamaki Drive can be considered a useful comparison. Figure 4 presents data for the busiest hour for cyclists on Tamaki Drive, for each day of the 2017 calendar year, obtained from Auckland Transport's automated cycle counter.

Figure 4: Tamaki Drive Peak Hour Cycling Profiles

The above illustrates the degree of variability of cyclist volumes on Tamaki Drive throughout the year, with for example:

- The busiest hour of the 90th percentile Saturday and Sunday recording 211 hourly cyclist trips, or 17% of the average annual daily cyclist volume
- The busiest hour of the 90th percentile weekday recording 239 hourly cyclist trips, or 19% of the average annual daily cyclist volume.

It is assumed that similar profiles would apply to both pedestrians and cyclists on the proposed facility, and the following peak periods have been considered for the subsequent operational assessment in Section 4:

Operational capacity: 95th percentile days

This design hour has been used in Section 4 to size the desired width of the proposed shared path, acknowledging that on some busy occasions it will be acceptable for the capacity to be exceeded.

- The busiest hour of the 95th percentile Saturday and Sunday in the year 2026 is predicted to have approximately 775 trips on the proposed facility. This hourly peak would be exceeded on 5% of Saturdays and Sundays, or on approximately five occasions in 2026
- The busiest hour of the 95th percentile weekday of 2026 is predicted to have approximately 935 trips on the proposed facility. This hourly peak would be exceeded on 5% of weekdays, or on approximately 12 weekday occasions in 2026.

Structural capacity: Busiest day of the year:

This design hour has been used in Section 4 to assess the peak loading effects on the structure of the bridge. This higher design hour has been used as exceeding the structural capacity of the bridge will not be acceptable at any time.

- The single busiest peak hour on a Saturday or Sunday in 2026, corresponding to the 99th percentile weekend. This scenario would see approximately 850 trips in those hours on the proposed facility
- The busiest peak hour on a weekday in 2026, corresponding to the 99.6th percentile weekday. This scenario would see approximately 1,290 trips in those hours on the proposed facility.

The implications of these peak hours volumes are discussed in the following sections.

4.2 Shared Path Levels of Service

4.2.1 Weekend Summer Peak Hour

As discussed previously, during the peak hour of the 95th percentile Saturday or Sunday of 2026, an estimated 775 trips are predicted to use the proposed cross harbour walking and cycling connection. Assuming the same split of pedestrians to cyclists applies during this peak hour as for the proposed facility overall, these 775 trips would consist of approximately 295 pedestrian trips and 480 cyclist trips per hour.

Based on the weekend data collected on Tamaki Drive and Quay Street presented previously, these trips would be expected to be largely for recreation, with no significant utility component. As a result, directional splits are anticipated to be broadly 50/50.

4.2.2 Weekday Summer Peak Hour

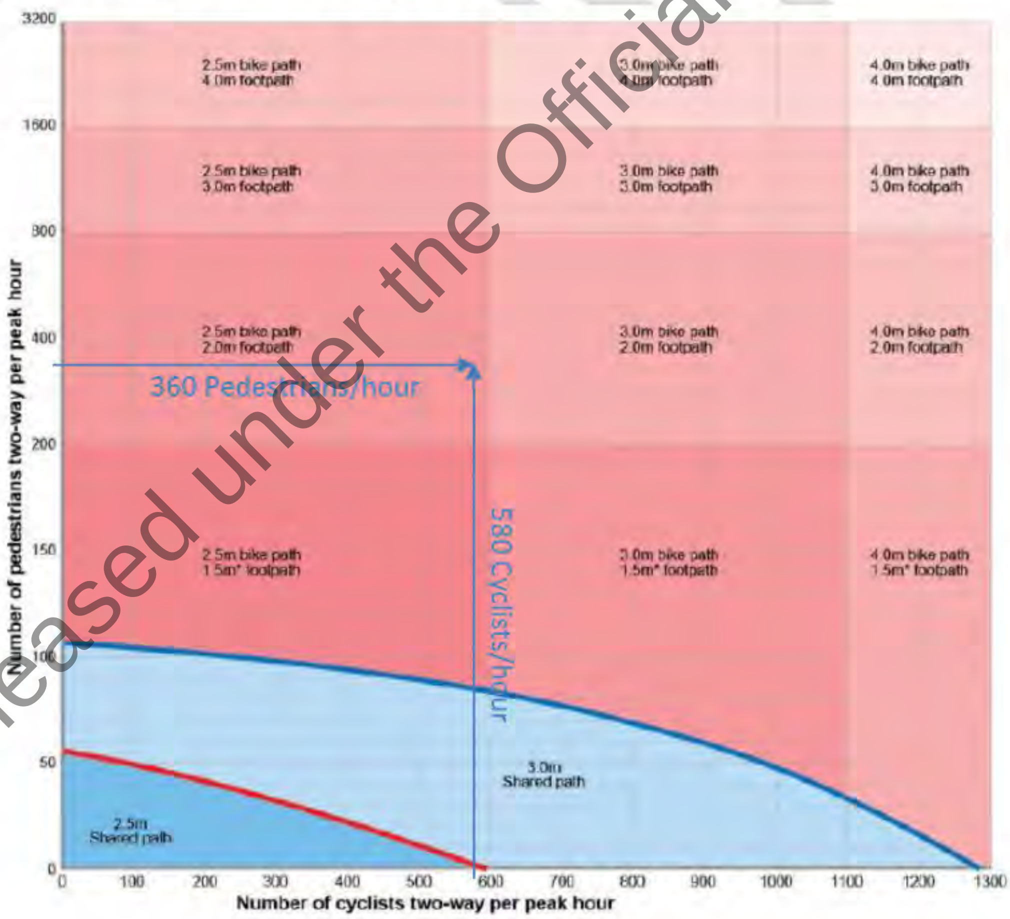
During the peak hour of the 95th percentile weekday of 2026, an estimated 935 hourly trips are predicted to use the proposed cross harbour walking and cycling facility. Assuming the same split of pedestrians to cyclists applies during this peak hour as for the proposed facility overall, these 935 trips would consist of approximately 360 pedestrian trips and 580 cyclist trips per hour. The morning peak is expected to be the critical time period, based on observations from other Auckland shared paths, where the morning peak tends to be higher and the evening peak tends to be more disbursed.

Weekday peak hour travellers would be expected to be largely commuters, with smaller recreational and tourist components. Directional splits are anticipated to be broadly 70% southbound and 30% northbound, from ACM outputs.

4.2.3 Shared Path Width Requirements

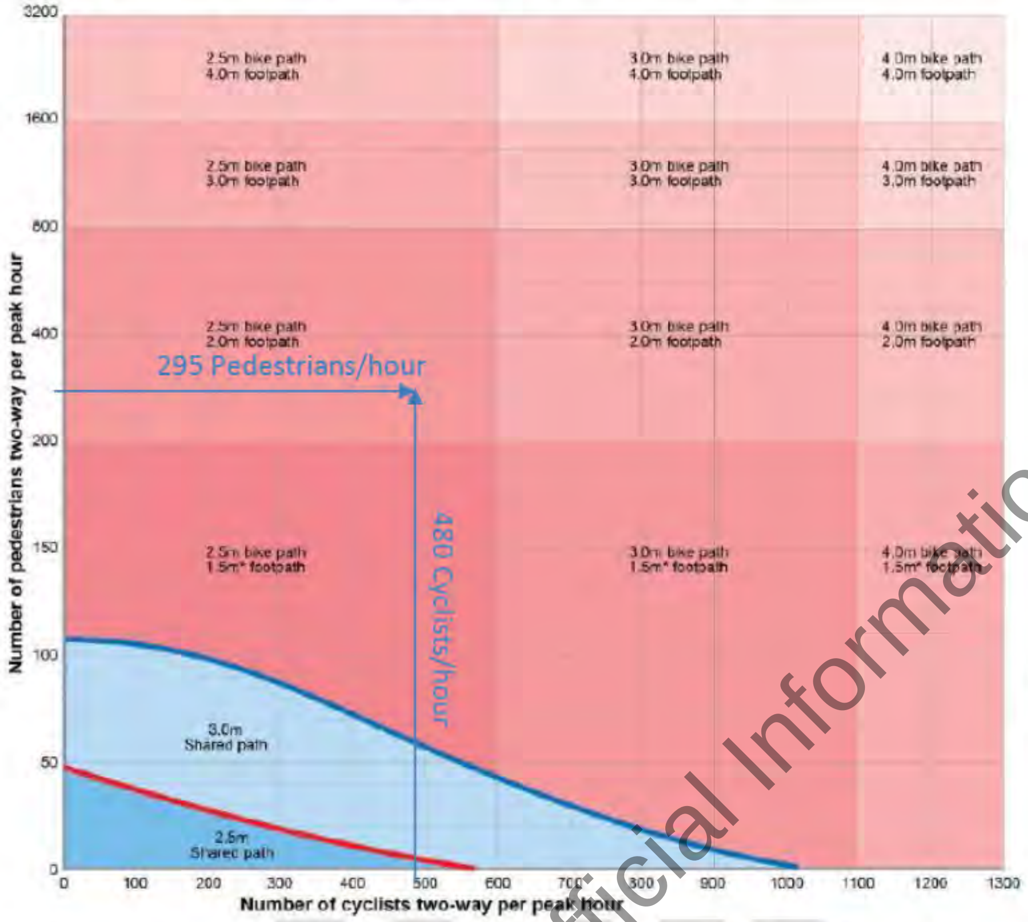
Austroads produces a design guide[34] offering recommended widths for shared use paths as a function of pedestrian and cyclist volumes, shown in Figure 5 and Figure 6. The recommended widths shown in these tables have been developed based on a desirable Level of Service (LOS) for cyclists, defined as twelve or fewer delayed passing instances per hour. The estimated 95th percentile weekday and weekend peak hour demands are overlaid on these figures.

Figure 5: Austroads Shared Path Design Width, 75/25 Directional Split



34 Cycling Aspects of Austroads Guides; Austroads; August 2013

Figure 6: Austroads Shared Path Design Width, 50/50 Directional Split



Applying this method to the 2026 weekend peak hour demands of 480 cyclist trips and 295 pedestrian trips from Section 4.2.1, as well as the 50/50 weekend directional split, Austroads recommends a facility width of 4.5 m. The 2026 weekday peak hour demands of 580 cyclist trips and 360 pedestrian trips, and the estimated 70/30 directional split, similarly results in a recommended facility width of 4.5 m.

It is noted that the Austroads method does not account for the gradient of the Auckland Harbour Bridge, and cyclists may require more space when traversing gradients, whether this is downhill and faster or uphill and more unstable.

Other documents referred to in the Transport Agency's National Cycle Network Design Guidance do not provide design widths for shared path facilities with anticipated demands as high as the proposed cross harbour facility's.

4.3 Structural Capacity

It is understood that the structural capacity of the existing Auckland Harbour Bridge clip-ons may limit the number of pedestrians and cyclists able to use the proposed facility at any one time, with a maximum of 500 to 600 people provided by the Transport Agency. It is understood however that this capacity is trending downward, as traffic loadings on the bridge have increased since this assessment was carried out in 2014.

The following section estimates the number of people expected to be on the proposed facility at any one time, considering the single busiest weekend and weekday of year from Section 4.1.

4.3.1 Busiest Weekend Peak Hour

As discussed previously, during the busiest weekend peak hour of 2026 an estimated 850 trips are predicted on the proposed facility. Assuming the same split of pedestrians to cyclists applies during this peak hour as for the proposed facility overall, these 850 trips would consist of approximately 325 pedestrian trips and 525 cyclist trips per hour.

- 325 pedestrians, traversing the 1.3 km bridge at an average speed of 5 km/h = 84 pedestrians on the proposed facility at any one time
- 525 cyclists, at an average speed of 20 km/h = 34 cyclists on the proposed facility at any one time
- Total design loading on the proposed facility at any one time = 119 people
- This number increases to 190 people if each person stops at viewing platforms on the bridge for on average five minutes, 260 people if this average stop is ten minutes, and 330 people if this average stop is 15 minutes.

It is noted that not all people will stop midway on the bridge, with tourists and recreational users (including families with children) much more likely to do so than commuters. This behaviour is relatively likely to occur on weekends, when almost all travellers are expected to be recreational and tourists. As such, the 10 minute average stop duration may be an appropriate estimate, and the peak weekend occupancy is estimated to be 260 people. At this level of use, 119 people would be expected to be walking or cycling on the bridge, while the remaining 141 people would be stopped within the viewing platforms.

4.3.2 Busiest Weekday Peak Hour

During the busiest weekday peak hour of 2026 an estimated 1,290 trips are predicted on the proposed facility. Again assuming the same split of pedestrians to cyclists applies during this peak hour as for the proposed facility overall, these 1,290 trips would consist of approximately 490 pedestrian trips and 800 cyclist trips per hour.

- 490 pedestrians, traversing the 1.3 km bridge at an average speed of 5 km/h = 128 pedestrians on the proposed facility at any one time
- 800 cyclists, at an average speed of 20 km/h = 52 cyclists on the proposed facility at any one time
- Total design loading on the proposed facility at any one time = 180 people
- This number increases to 290 people if each person stops at viewing platforms on the bridge for on average five minutes, and to 400 people if this average stop is ten minutes.

It is again noted that not all people will stop on the bridge. The majority of people during the weekday peak are expected to be commuters who are unlikely to stop at all. As such, an average stop time of zero to five minutes may be appropriate, and the weekday peak hour users are estimated at between 180 and 290 people.

4.3.3 Structural Capacity Conclusions

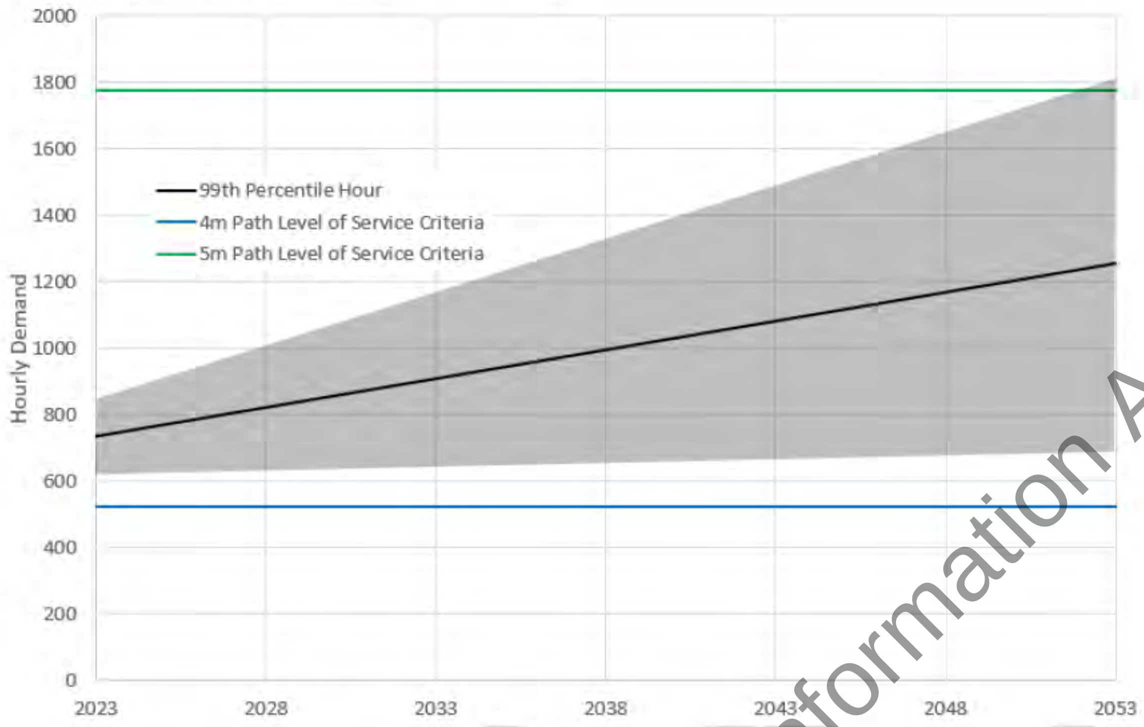
The above assessment has indicated that up to 290 people are predicted to use the proposed facility at any one time in 2026, and this is significantly below the 500 to 600 capacity supplied by the Transport Agency. We understand however that this capacity was determined in 2014 and that since that time, traffic loadings on the bridge have increased, resulting in reduced structural capacity being available for the proposed facility. There is a risk that, should this trend continue, peak loadings on the proposed facility would exceed the available capacity, and a mechanism would be needed to manage demand. Any such mechanism will limit the utility that any future cross harbour walking and cycling connection provides to the public, and will ultimately cap the project's benefits.

It is estimated that growth in pedestrian and cyclist trips across the proposed cross harbour facility will grow at approximately 2% per annum beyond 2026, based on cyclist demand forecasts from the ACM, in turn based on adjacent land use forecasts. At this rate of growth, it may take some 30 years (ie 2056) before the structural capacity of 500 to 600 persons is exceeded. More likely is that the reverse occurs, with traffic demands on the Auckland Harbour Bridge's clip-ons increasing, and that the available structural capacity falling to meet the pedestrian and cyclist demands. When this may occur is unclear, and will be a function of how quickly the structural capacity of the existing clip-ons reduces.

4.4 Implications of Structural Capacity and Levels of Service Criteria

Further analysis has been undertaken to estimate if and when the Austroads LOS criteria may be exceeded, for different shared path widths. Figure 7 below illustrates this, showing the predicted demand on the 99th percentile hour (ie demand is predicted to be exceeded on approximately 90 occasions per year). This demand has been shown as a shaded band, showing a range of ±20% demand estimates in 2026, rising to ±40% in 2046; this reflects the uncertainty in forecasting pedestrian and cycle demands, particularly longer term. Also plotted on this figure are the approximate demand thresholds for 4 m and 5 m wide paths, above which the LOS would fall below the Austroads LOS criteria.

Figure 7: Shared Path Peak Demand vs LOS Criteria

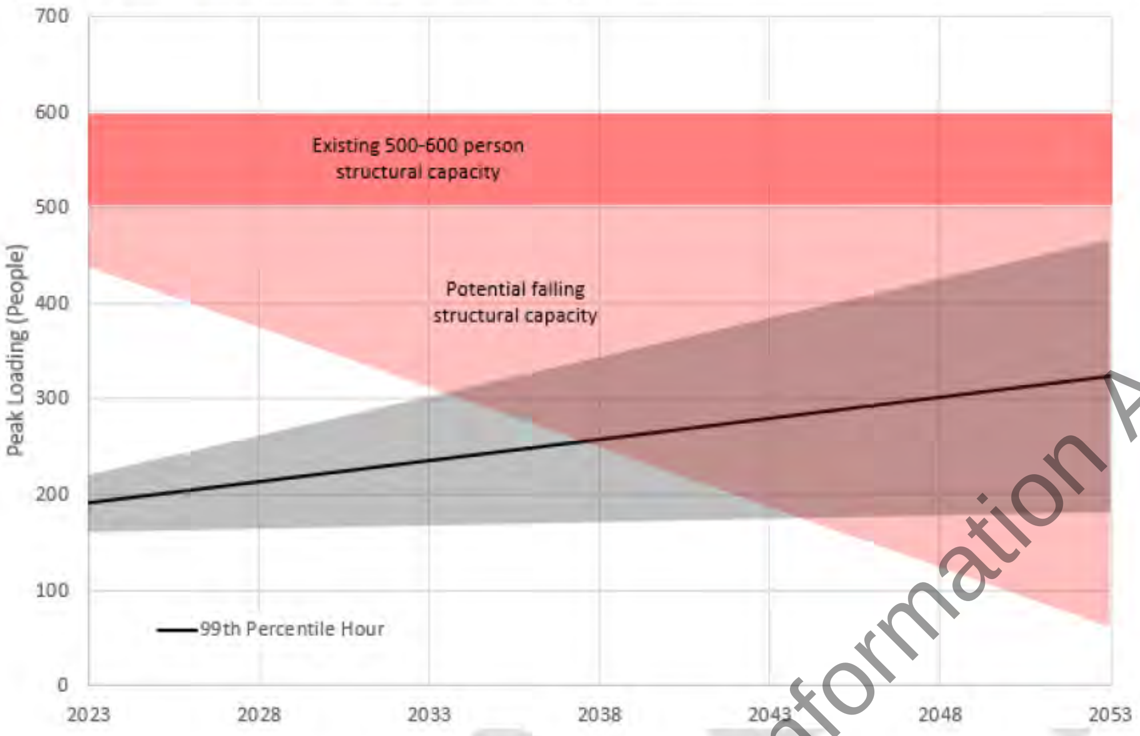


It can be seen that the peak demands on the facility are predicted to exceed the Austroads LOS criteria for a 4 m wide path (ie the LOS criteria would be exceeded on more than 90 occasions per year). When considering a wide range in demand estimates (the shaded grey area in Figure 7), this is expected to remain the case longer term, with these occasions potentially increasing significantly. Demands are however predicted however to remain below the LOS threshold for a 5 m path, even when considering the upper range demand estimates.

Figure 8 overleaf presents the forecast 99th percentile peak loading, with a range of loadings presented using the same demand range definitions as above. Against this is plotted the approximate structural capacity of the existing harbour bridge. A range of structural capacities have been shown, including:

- The existing (approximately 2018) estimated structural capacity of 500 to 600 persons (darker red band)
- A range of potentially falling structural capacities, with the lower bound existing capacity of 500 persons assumed to reduce by 50% in 20 years (lighter red band), reflecting the risk that traffic loadings have historically increased on the bridge and that if this continues, the available structural capacity for a walking and cycling facility may decline over time.

Figure 8: Shared Path Peak Loading vs Structural Capacity



The above figure illustrates that the peak loadings are not predicted to exceed the existing bridge structural capacity of 500 to 600 persons. Should this capacity reduce over time however, there is a risk that the capacity will be exceeded during peak periods.

The following figures illustrate the frequency per year that the proposed cross-harbour walking and cycling facility is predicted to exceed either the level of service or structural capacity criteria. The first of these in Figure 9 illustrates the frequency in terms of the number of hours per year (from a total of 8,760 hours each year). The second in Figure 10 illustrates the frequency in terms of the number of days per year (ie the number of days where the LOS or capacity criteria are predicted to be exceeded at least once that day).

These figures have been developed based on the 500 to 600 person structural capacity on the Auckland Harbour Bridge, assessed in approximately 2018 and provided by the Transport Agency. This analysis tests the scenario that this structural capacity will continue to reduce, halving within 20 years (from 2018). It is important to recognise that this may not be the case, and that the below illustrations are scenario testing only.

In these figures, shaded bands have been used to illustrate:

- For LOS criteria: the forecast demand range of ±20% in 2026 and ±40% in 2046 from above, reflecting the uncertainty in the predicted demands
- For structural capacity criteria: the above forecast demand range in addition to a range of structural capacities (ie 500 to 600 users in 2018), reflecting uncertainty in both demand and structural loadings.

Figure 9: Hours per Year Criteria Exceeded

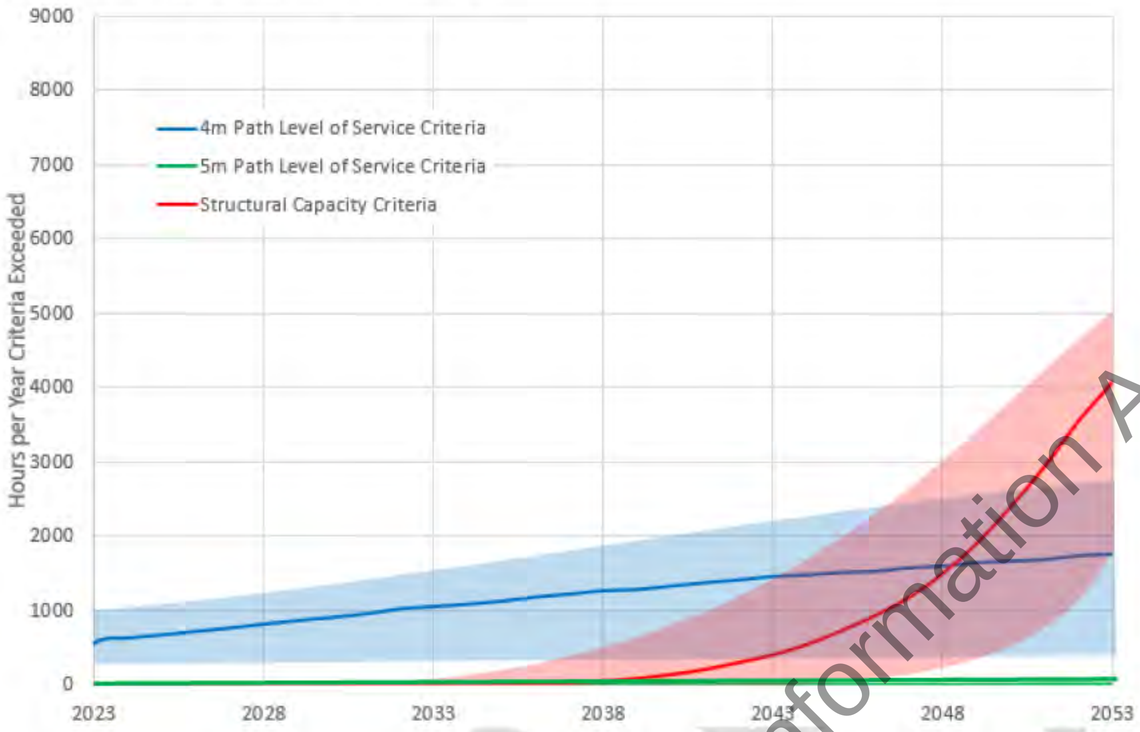
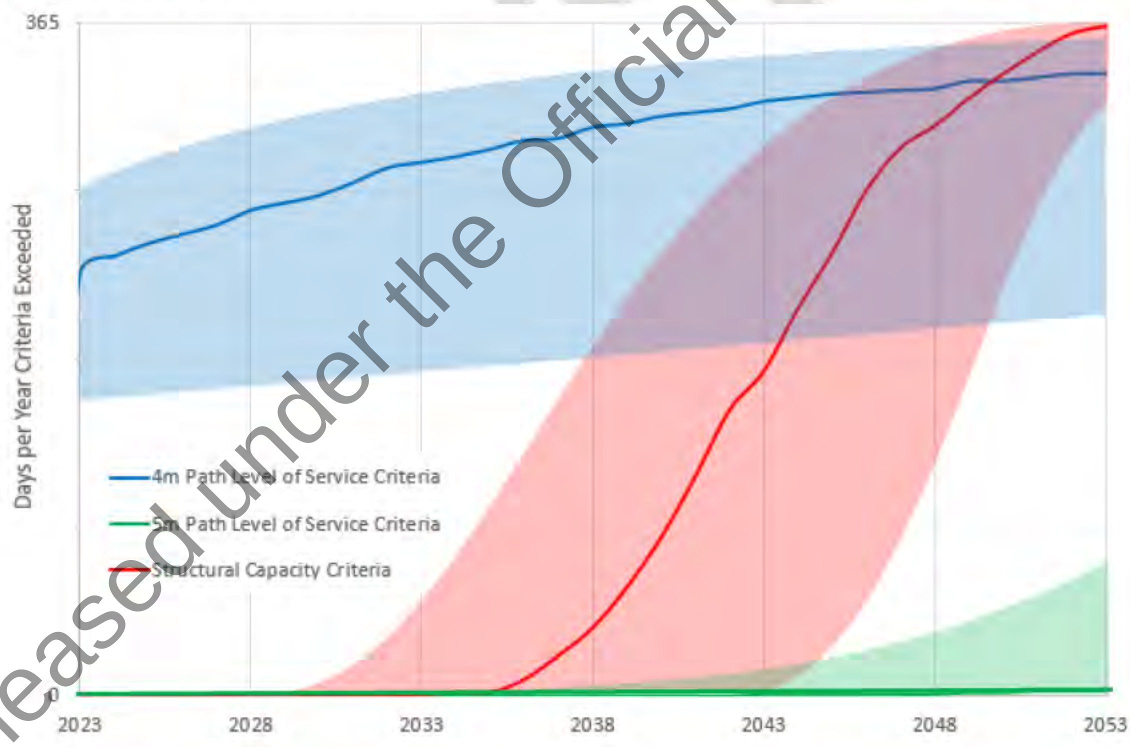


Figure 10: Days per Year Criteria Exceeded



Firstly, it is clear from the above figures that the assumed ranges in demand estimates and structural capacity result in considerable future uncertainty in how the LOS and structural capacity criteria will affect the proposed facility. This is evident in the width of the coloured bands in the figures above.

Nonetheless, the above figures illustrate that:

- A 4 m wide shared path is predicted to fall below Austroads' LOS criteria during busy periods, potentially affecting a large number of hours per year, and many days per year
- A 5 m wide shared path is generally predicted to fall below Austroads' LOS criteria only infrequently, and only in the upper demand estimate range
- Should the structural capacity of the Auckland Harbour Bridge reduce as assumed in this scenario, this may become a limiting factor during busy periods as little as five to ten years after opening. Over time, structural capacity has the potential to become a limiting factor a significant proportion of the time.

It should be recognised however, that should the available structural capacity of the bridge reduce at a greater pace than that assumed in the above test, or not reduce at all, then the conclusions of the above operational assessment would be significantly different.

5 AUCKLAND HARBOUR BRIDGE ALTERNATIVE CONFIGURATIONS

Alternative configurations for a walking and cycling link across the Auckland Harbour Bridge have been proposed that would each reduce the general traffic capacity of the existing bridge. Three potential scenarios have been considered, being:

- Scenario 1: Removing one traffic lane, and operating the remaining lanes in a four/three configuration during the peaks, with three southbound lanes in the inter peak
- Scenario 2: Removing one traffic lane, and operating the remaining lanes in a five/two configuration during the peaks, with three southbound lanes in the inter peak
- Scenario 3: Retaining eight traffic lanes, but reducing the width of the two southbound clip-on lanes.

The traffic effects of these three scenarios have been assessed in a separate technical note by Flow. This assessment concluded that Scenarios 1 and 2 would have significant impacts on the wider transport environment, in 2026. Scenario 3 however was predicted to have only a relatively moderate effect.

The technical note is appended to this report.

6 ECONOMIC EVALUATION

6.1 Methodology

This section quantifies the transportation economic benefits of the proposed cross harbour walking and cycling connection; a separate assessment by MR Cagney considers non-transportation benefits of the project. The economic benefit evaluation has been based on Simplified Procedures 11 (SP11) from the New Zealand Transport Agency's EEM. Recognising however that SP11 is intended for evaluating projects with capital costs under $5 million, and that SP11 contains a number of simplistic approximations, the SP11 procedures have been extended, primarily by using the 2026 and 2046 ACM to inform a full economic procedure, rather than using SP11's default demand estimation tool.

Cycling benefits for intermediate years have been interpolated from the two forecast years. This differs from SP11, which typically considers only a single opening year, and applies a growth rate for cyclist predictions to future years. In this way, the methodology used is more robust.

The project has been assessed with a 40-year evaluation period. A two-year construction period beginning in January 2021 has been assumed, during which time no benefits accrue, followed by a 38-year benefit period.

The economic benefit evaluation has been undertaken by comparing future Reference Case and future Option scenarios, as documented in Section 3.2.3.

The economic evaluation has been carried out using the EEM's most recent update factors (1 December 2018), including:

- 1.21 for walking, cycling and public transport benefits
- 1.50 for travel time cost savings
- 1.07 for vehicle operating cost savings
- 1.06 for crash costs.

6.2 Benefit Streams

The following benefit streams have been assessed for the project:

- Cyclist Travel Time Benefits – calculated using the EEM's SP11 and informed by ACM outputs
- Health Benefits for Cyclists – calculated using a modified procedure developed from the EEM's SP11, informed by ACM outputs
- Health Benefits for Pedestrians – calculated using the EEM's SP11 and informed by ACM outputs
- Safety Benefits – assumed to be negligible
- Road Traffic Reduction Benefits – calculated using standard economic evaluation procedures to quantify vehicle travel time, congestion and operating cost benefits, informed by the Northern Corridor Improvements SATURN models
- Agglomeration Benefits – provided by MR Cagney
- Tourism Benefits – provided by MR Cagney
- Traffic Dis-benefits – calculated using standard economic evaluation procedures to quantify vehicle travel time, congestion and operating cost benefits, informed by the Northern Corridor Improvements SATURN models
- Tolling Benefits – calculated using standard economic evaluation procedures to aggregate tolling revenue over time.

Further detail on each of the above benefit streams is provided in the following sections.

6.3 Cyclist Travel Time Cost Savings

Cyclist travel time cost savings associated with the project have been evaluated, based on outputs from the ACM. The evaluation has applied the EEM's Relative Attractiveness rating to weight travel time by the perceived cost on each route according to that route's infrastructure standard. This is consistent with the travel time cost calculations included in the EEM's SP11 procedure. The travel time costs on each modelled link included in the ACM have been aggregated across the Reference Case and Project networks, using fixed trip matrices, and compared to determine user cost savings for existing users. These have then been applied to predicted new users of the facility, using the rule of half.

In 2026 for example:

- The ACM predicts cyclists will travel 206,715 daily cyclist-km across the 2026 Reference Case network. When adjusting this for Relative Attractiveness on each link, the daily perceived distance is 154,170 cyclist-km
- With the project, the perceived travel distance reduces to 153,075 cyclist-km, a saving of 1,095 daily cyclist-km, shared by the 400 existing daily users that are predicted to use the project (ie cyclists that divert from ferries or the Upper Harbour Bridge)
- A further 2,170 new daily users are predicted to use the facility. To these users, half of the above perceived travel time cost savings, per user, have been applied. Ie: 1,095 / 400 x 2,170 x 0.5 = 2,980 cyclist-km per day
- The total perceived distance saving is 1,095 + 2,980 = 4,075 cyclist-km per day
- The above 4,075 daily cyclist-km has been monetised, by applying an estimated 20 km/h average speed[35], a weighted travel time cost of $7.26/hour[36], the relevant EEM update factor of 1.50, and multiplying by 365 days per year: 4,075 x $7.26 x 1.5 x 365 / 20 = $809,565 per year in 2026.

When also applied to the 2046 model outputs and discounted, the net discounted travel time cost savings are $12.65 million, or approximately 5% of the overall project benefits.

6.4 Health Benefits for Cyclists

This benefit stream calculates the health benefits gained from additional cycling activity. SP11 calculates health benefits only for that portion of a cyclist's trip that takes place on the facility itself, as per Equation 1 below. This is a significantly conservative assumption, as the average new cycle trip using the proposed facility is predicted to be in the order of 8.9 km, and only a portion of that trip will be on the proposed facility itself.

Equation 1: Cycling Health Benefits Calculation

$$\text{Length of new cycling facility} \times \text{Number of new daily cyclists} \times \text{Benefit rate from SP11}$$

[35] From cycle tube counters placed on various Northcote streets
[36] $7.80/hr for cycle commuting purposes and $6.90 for other cycling purposes, applying a 40%/60% utility/recreational split as per section 3.2.4 of Flow's report

To better account for this benefit stream, cyclist health benefits have been calculated for the full length of each new cyclist's trip. This quantity has been obtained directly from the model, with the total length of cyclist-km travelled under the Reference Case and Project scenarios compared, and the difference being the total distance of new cyclist-km trips. This value replaces both the 'Length of new cyclist facility' and the 'Number of new daily cyclists' from Equation 1 above.

SP11 applies a composite rate of $1.40 to cyclist health and environment benefits, with $0.10 of this attributable to environmental benefits (road traffic reduction, or decongestion). To avoid double counting of benefits, this latter component has been removed from this benefit stream, and dealt with separately as documented below.

This benefit stream has been calculated for utility and recreational cyclists using the proposed facility forecast by the ACM, and also for the estimated domestic cycle tourists. The utility and recreational component has resulted in the largest portion of overall benefits for the proposed facility, of some $9.36 million annual benefits in 2026 (undiscounted). Equation 2 below presents this benefit calculation.

Equation 2: Annual Health Benefits Calculation for Utility and Recreational Cyclists, 2026

$$\left(\text{226,260 daily cyclist-km with project} - \text{206,715 daily cyclist-km without project}\right) \times \text{\$1.30 EEM benefit rate} \times \text{1.21 EEM update factor} \times \text{365 days/year} = \text{\$9.36 million}$$

Discounted over the 40-year evaluation period of the Project, this benefit stream equates to $143 million.

For domestic cycle tourists, the calculation of health benefits has assumed that these users will cycle on average 3 km – the distance from the Wynyard Quarter to Northcote Point. This is considered conservative in that while some tourists will only cross the bridge itself and no further (ie 1.3 km), others will cycle across the proposed facility as part of a much longer waterfront trip (Northcote Point to Mission Bay for example being 13 km). This assumption has been sensitivity tested in Section 6.12.

The resulting health benefits from domestic cycle tourists are estimated to be $4.0 million, discounted over the 40-year evaluation period.

In total, discounted cyclist health benefits (utility, recreational and tourist) are estimated to be $146.7 million.

6.5 Health Benefits for Pedestrians

SP11 also allows health benefits to be calculated for new pedestrian trips, at a rate of $2.60 per new pedestrian-km travelled, using the below equation:

Equation 3: Pedestrian Health Benefits Calculation

$$\text{Length of new pedestrian facility} \times \text{Number of new daily pedestrians} \times \text{Benefit rate from SP11}$$

As with the cycling health benefits above, this benefit stream reflects the health benefit gained by increased walking activity, and again the EEM's environmental benefit of $0.10 per new pedestrian-km travelled has been removed from the analysis.

From Section 3.1, 1,400 utility and recreational pedestrian trips are forecast on the proposed facility in 2026, but without a pedestrian model it is not clear how many of these trips will be new trips, or how far these people will be walking. To estimate this benefit stream, 50% of the 1,400 utility and recreational pedestrian trips forecast using the proposed facility in 2026 have been assumed to be new pedestrian trips. The remaining 50% of pedestrians are assumed replace existing trips elsewhere, with no net increase in the distance walked. This assumption has been sensitivity tested in Section 6.12.

The 1.3 km length of the proposed facility has been applied in equation 3 above, consistent with SP11. The resulting annual health benefits from pedestrian trips are estimated to be $14.9 million, discounted over the 40-year evaluation period.

This benefit stream also applies to domestic tourists, whose increased physical activity will result in health benefits. It has been assumed that each domestic tourist pedestrian trip on the proposed facility is 1.3 km long. The resulting annual health benefits from domestic pedestrian tourists are estimated to be $4.8 million, discounted over the 40-year evaluation period.

In total, discounted pedestrian health benefits (utility, recreational and tourist) are estimated to be $19.6 million.

6.6 Safety Benefits

Walking and cycling safety benefits typically accrue where new or improved infrastructure reduces the crash risk for pedestrians or cyclists on a given route, or at a specific location. In the case of the proposed facility, the existing crash risk for active modes crossing the Waitemata is close to zero, as those people either travel on ferries, travel via other modes, or don't travel at all. As a result, safety benefits for the proposed facility have been assumed to be zero.

In reality, there will likely be some safety gains, and some losses, as:

- People transferring from private car travel will reduce the risk of and therefore incidence of vehicle crashes
- People transferring to active modes will result in increased walking and cycling on the routes leading to each the proposed facility landing, resulting in an increased risk of active mode crashes on these routes; this would be mitigated in part by safe active mode infrastructure either side of the proposed facility, such as the proposed SeaPath shared use path
- There could be crashes between active mode users on the proposed facility itself that wouldn't otherwise have occurred
- Assuming the proposed SeaPath shared use path is constructed, existing cycle trips across the Waitemata Harbour via the Bayswater and Devonport ferry services will transfer to SeaPath, which may be a safer route for cyclists than those connecting to the Bayswater or Devonport ferry terminals.

The EEM's SP11 economic procedures places are relatively modest value on the safety benefits of cycle infrastructure – at $0.05 per new and existing cyclist-kilometre travelled. As a result, safety benefits typically account for only 1% to 2% of the overall project benefits, for new cycle infrastructure.

When considering the above, the net effect of the above safety gains and losses are considered negligible, within the context of the other, much larger benefit streams.

On the suggestion of the peer reviewers however, a sensitivity test has been carried out to assess potential safety benefits, based on the following process:

- Vehicle crash costs: Using the crash cost rate of A$0.03 per car-km from the Transport from New South Wales (TfNSW) economic evaluation procedures[37], converting this to New Zealand dollars and applying this to the predicted car-km removed from the network by the project
- Bicycle crash costs: Using the crash cost rate of A$0.27 per cycle-km from the TfNSW document and applying this to the predicted increase in cycle trips due to the project. The cycle-km travelled on the 1.3 km cross harbour facility itself has been omitted from this analysis, as the A$0.27 rate is not considered appropriate on this facility, where there will be no conflict between cyclists and motorised traffic
- Summing the two benefit streams above.

This sensitivity test result in total discounted safety benefits of -$21.7 million (ie dis-benefits). This analysis is considered pessimistic, as the A$0.27 cycle crash rate is a NSW regional value for application in typical NSW road environments, whereas most approaches to the proposed cross harbour facility would be on separated cycle infrastructure, where significantly lower cycle crash costs would be expected.

6.7 Road Traffic Reduction Benefits

Decongestion benefits are expected to be a significant proportion of the overall project benefits, as the proposed facility would provide an alternative to private car travel on currently congested road corridors, including the Northern Motorway, Onewa Road and Esmonde Road. As a result, any mode shift in favour of active modes will reduce existing (or forecast future) congestion on the road network.

The default EEM decongestion value for Auckland is $1.89 per vehicle-km removed from the network (Table SP9.1, updated to 2017 values). This flat value does not however recognise the high levels of congestion currently experienced on the Northern Motorway and its approaches during the commuter peak periods, and does not reflect how this congestion is expected to change over time.

The evaluation has instead used the Northern Corridor Improvements (NCI) SATURN models to quantify the benefits of each cross-harbour car trip removed from the road network. These models have recently been updated to reflect Council's latest I11 land use forecasts, so are consistent with the land use assumptions used to generate the cycle demand forecasts.

To quantify these benefits per vehicle-km, a small number of cross-harbour vehicle trips[38] have been removed from the morning peak, evening peak and interpeak period NCI SATURN models. The NCI model runs with and without these trips have then been compared, and standard economic evaluation

[37] Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives; Transport for New South Wales; June 2018
[38] Cross harbour trips between Northcote/Takapuna and the CBD/Inner west have been removed only.

methodologies have been used to quantify the vehicle travel time, congestion and operating cost benefits per peak period, with cross-harbour vehicle trips removed from the network.

This process has resulted in the following decongestion values, which have been applied to the economics:

2026 Decongestion Rates

- $4.85 per vehicle-km removed from the road network during the commuter peaks
- $1.38 per vehicle-km during the weekday interpeak period

2036 and 2046 Decongestion Rates

- $7.10 per vehicle-km removed from the road network during the commuter peaks
- $1.48 per vehicle-km during the weekday interpeak period

The values derived above are higher than the EEM's default rate of $1.89 per vehicle-km removed from the road network, and reflect that the proposed facility would remove vehicle trips from an area of the network that is significantly more congested than the Auckland average.

Weekend and off-peak decongestion values have conservatively been assumed to be zero, and no growth has been applied to these values beyond 2036. This reflects the conflicting factors of increasing land use and traffic volumes, but the decongestion expected following construction of the Additional Waitemata Harbour Crossing (potentially in approximately 2041).

It is noted that no I11 2046 NCI SATURN model is available at this time.

Forecasts of new commuter peak cycle trips have been obtained directly from the ACM, with daily cyclist count profiles obtained from Tamaki Drive used to develop estimates of new interpeak cycle trips. Estimates of new pedestrian trips have been developed based on the earlier assumption that 50% of the proposed facility's forecast daily pedestrian trips will be new trips, with commuter peak and interpeak proportions based on pedestrian profiles obtained from Tamaki Drive.

It is important to recognise that not every new cross-harbour active mode trip on the proposed facility would otherwise take place by private car. Recognising this, the number of new active mode trips has been factored down to reflect:

- Car mode share across the Auckland Harbour Bridge (57% in the commuter peaks in 2026 and 51% in 2046, 77% in the 2026 interpeak and 70% in 2046, from the Auckland Regional Transport model),
- Average car occupancy (1.30 during the commuter peaks and 1.25 during the interpeak, from the Auckland Regional Transport model),
- Non-utility cycling trips – some new cross-harbour trips will be recreational trips and therefore not replacing a trip by any other mode. 70% of new cycle trips are estimated to be utility trips during the commuter peaks, and 15% during the interpeak period, based on survey data collected on Quay Street and Tamaki Drive.

It is noted that car mode share may not directly correspond to car diversion, as public transport users may be more willing to change mode to cycling than car users. This would particularly be the case for users who do not have access to a vehicle. The 2013 Census data however indicates that only 5% of households within the Devonport-Takapuna and Kaipatiki Local Board areas did not have access to a car. Nonetheless, this suggests that an additional factor may be necessary, to account for this bias.

Conversely however, we consider that car/public transport diversion is also corridor specific, and will vary depending on the respective levels of service offered for each mode. In the case of the Auckland Harbour Bridge and its approaches, existing level of service by car is very poor, with significant queues and delays for car users during the commuter peak periods. Levels of service for bus users however are relatively good, with bus or transit lanes on the key arterial corridors that supply the Northern Motorway (Onewa Road, Esmonde Road and Akoranga Drive on the North Shore, and Fanshawe Street in the city centre), and bus priority through interchanges.

The two factors above offset each other to some degree, but it is not possible to quantify to what extent. As a result, the car diversion rates applied to the economic evaluation have been developed based on car mode shares, as documented below.

The car diversion rates applied to new cycle trips in the economic evaluation range from 0.09 to 0.31 as set out below, in the 2026 interpeak and commuter peaks, respectively:

- 2026 interpeak: 15% utility trips x 77% car mode share / 1.25 car occupancy = 0.09
- 2026 commuter peak: 70% utility trips x 57% car mode share / 1.3 car occupancy = 0.31

Lower car diversion rates were applied in subsequent forecast years, to reflect the reduced car mode share across the Auckland Harbour Bridge predicted by the regional macro simulation model (MSM).

As a result, decongestion benefits have been calculated using the following process:

Equation 4: Annual Commuter Peak Period Decongestion Benefits (Cyclists), 2026

8.9 km average new cycle trip length	x	797 new peak period utility/ recreational cycle trips, from ACM	x	0.31 diversion rate	x	$4.85 benefit rate	x	245 weekdays/ year	=	$2.61 million

The above process has been repeated for the interpeak period, for pedestrians (assuming a shorter, 1.3 km average trip length), and for the other forecast years. The resulting general traffic decongestion benefits have been estimated to be $54.8 million, discounted over the 40-year evaluation period.

Sensitivity testing has been carried out on the economic evaluation to assess the effects of higher and lower car diversion rates.

6.8 Other Benefit Streams

In a separate study[39], MRCagney have estimated the agglomeration and tourism benefits of the proposed cross harbour walking and cycling connection. These discounted benefits have been determined to be $23.0 million and $2.0 million, respectively, over the 40-year evaluation period.

6.9 Traffic Dis-benefits

As documented in Section 5, alternative configurations for the proposed facility have been considered that variously reduce the general traffic capacity of the Auckland Harbour Bridge. Of three scenarios considered, Scenario 3 was considered the only practicable option, unless policy decisions to reduce capacity are made or until such time as an additional Waitemata Harbour crossing is built. This scenario retains eight general traffic lanes on the bridge, but narrows the two southbound clip-on lanes, reducing their capacity accordingly.

The economic effects of this alternative configuration have been assessed, using the 2026 and 2036 Upper Harbour SATURN models to quantify general traffic travel time, vehicle operating cost, and congestion (drive frustration) dis-benefits. These benefit streams have been capped beyond 2036.

The resulting discounted traffic dis-benefits have estimated to be $114 million, discounted over the 40-year evaluation period. Note that this differs slightly from the $113 million quoted in the Auckland Harbour Bridge Traffic Assessment technical note included in Appendix A, as the higher figure applies current EEM update factors that were released subsequent to the technical note.

The default economic evaluation assumes however that the project can be constructed without affecting road traffic capacity on the Auckland Harbour Bridge or elsewhere.

6.10 Tolling Benefits

The economic effects of several tolling options have been considered, being:

- Tolling tourists only (ie those people without an Auckland permanent address), at a rate of $1 per trip
- Tolling tourists only (ie those users without an Auckland permanent address), at a rate of $2 per trip
- Tolling all those using the proposed facility, at a rate of $1 per trip
- Tolling all those using the proposed facility, at a rate of $2 per trip.

No annual inflation to the above tolling rates has been applied. No administration costs have been included and costs of a scheme where only tourists are tolled have not been considered.

It has been assumed for the economic analysis that the above tolls will not have any effect on the number of tourist trips on the proposed facility, partly because (for cycling tourists) the above toll fees

[39] Wider Economic Benefits of a New Walking and Cycling Link Across the Waitemata Harbour; MRCagney; December 2018

are likely to be small relative to the cost of bicycle hire. For the scenarios that toll all users however, tolls were previously predicted to have significant impacts on forecast demands (refer Section 3.2.8), and as a result the increased revenue from tolling has been offset by reduced transport benefits.

The results are summarised below.

Table 10: Summary of Predicted Tolling Economic Effects

Scenario	Net Discounted Benefit
Tolling tourist users only, $1 per trip	$2.7 million
Tolling tourist users only, $2 per trip	$5.4 million
Tolling all users, $1 per trip	-$24.7 million
Tolling all users, $2 per trip	-$49.1 million

Tolling tourists is estimated to have a relatively modest economic benefit, while tolling all people using the proposed facility is estimated to have a significant negative effect, by reducing the overall number of people on the facility.

The above assessment excludes the costs of implementing and managing any tolling mechanism, which may well result in negative benefits for all of the above tolling options.

The default economic evaluation assumes that no tolling is applied.

6.11 Benefit Summary

The following table presents the total discounted benefits predicted for the proposed cross harbour walking and cycling connection, for the 'default' assessment that does not apply tolling, and that does not remove general traffic capacity from the Auckland Harbour Bridge.

Table 11: Summary of Predicted Project Benefits

Benefit Stream	Discounted Benefit
Cyclist travel time cost savings	$12.4 million
Health benefits for cyclists	$143.4 million
Health benefits for pedestrians	$19.1 million
Safety benefits	nil for default option
Road traffic reduction benefits (decongestion)	$53.8 million
Agglomeration benefits	$23.0 million
Tourism benefits	$2.0 million
Tolling benefits	nil for default option
Road traffic dis-benefits	nil for default option
Total Benefits	**$253.7 million**

6.12 Sensitivity Tests

A series of sensitivity tests have been run on the economic assessment, focussing on the larger benefit streams of the Project. The sensitivity tests investigate the impacts of:

- The sensitivity tests carried out on the proposed facility's forecast demands, as documented in Section 3.2.8 and including:
    - Faster/slower land use growth
    - The effects should the full Auckland Cycle Network (ACN) be completed by 2046
    - Varying the factor used to develop estimates of daily cyclists
    - The effect of a large future uptake in e-bikes (this test has also reduced health and environment benefits for cyclists by 50%, reflecting the motorised nature of these cycle trips[40])
    - The effect should SeaPath not be constructed
    - The effects should tourist numbers be 50% lower or higher than forecast
    - Faster/slower growth in pedestrian trips beyond 2026 (2.2% assumed in the default analysis, 0% and 3% sensitivity tested)
- Changes to the assumptions used to assess general traffic decongestion – the default assumption is that new active mode trips across the harbour transfer from car, bus and ferry trips in proportion to each mode's overall cross-harbour mode share. This sensitivity test considers the effects if bus and ferry users are 50% more likely to transfer than car travellers
- Related to the above, higher and lower car diversion rates have been tested, with the default 2026 peak period car diversion rate of 0.31 varied to test a low rate of 0.10 and a high rate of 0.60.
- Assuming a shorter average new cycle trip length across the Waitemata – the default calculation of health and environment benefits for cyclists applies the average new trip length forecast by the ACM (8.9 km, the approximate distance from Takapuna to the city centre). This test assumes a 50% reduction in this length (4.5 km, the approximate distance from Onewa Road to Ponsonby)
- The effects of an alternative configuration that reduces the traffic capacity on the existing Auckland Harbour Bridge, as documented in Section 6.9 (Scenario 3)
- The effects of various tolling scenarios being applied, as documented in Section 6.10
- The effects should future changes in micro mobility, such as e-scooters, reduce the health benefits of new pedestrian trips
- The effect should the EEM's default SP11 calculation be used to assess cyclist health benefits (applying health benefits only on the facility itself)
- The effect should the EEM's default decongestion rate be used ($1.89 per vehicle-km removed)
- The effect should the structural capacity become a limiting factor during peak periods, as per the scenario documented in Section 4.4, where the structural capacity reduces over time. This test

[40] There is no data to support the estimate that a future high uptake in e-bikes would reduce the per-km health benefits by 50%; this test is carried out as a 'what if' analysis.

caps the project benefits during time periods when the predicted demand exceeds structural capacity, but does not quantity the dis-benefits associated with delaying or turning away users

- The effect should a higher or lower proportion of predicted pedestrian trips on the facility be 'new' trips that generate health benefits; the default assessment assumed 50%, and the sensitivity tests consider 25% and 75%
- The effect should the average cycle trip length for domestic tourists reduce from the assumed 3 km to 1.5 km (eg Westhaven Marina to Northcote Point), or increase to 4.5 km (eg Queen Street to Northcote Point)
- Including crash costs according to the conservative TfNSW method documented in Section 6.6.

The results of the sensitivity tests are presented below.

Table 12: Benefit Cost Ratios – Sensitivity Tests

Sensitivity Test Scenario	Discounted Project Benefits
EEM SP11 default cyclist health benefits #	$134 million
Alternative configuration that reduces traffic capacity on bridge	$140 million
Reduced new cycle trip length (-50%)	$184 million
Tolling all users, $2 per trip #	$205 million
EEM default decongestion rate #	$214 million
SeaPath not being constructed #	$219 million
Demand limited by falling structural capacity on bridge	$220 million
Low car diversion rate (0.10 in 2026 peak periods)	$220 million
Higher proportion of new users transferring from buses/ferries #	$227 million
Tolling all users, $1 per trip	$229 million
Conservative crash cost assessment (refer Section 6.6)	$232 million
Low daily cyclist factor (2.0) #	$234 million
Low land use growth (-20%) #	$241 million
Reduced pedestrian health benefits due to e-scooter use (-50%) #	$244 million
Reduced proportion of pedestrian trips being new trips (25%)	$246 million
Reduced tourist numbers (-50%) #	$248 million
Low growth in pedestrian trips (0% per annum beyond 2026)	$250 million
Shorter average domestic tourist cycle trip (1.5 km)	$252 million
Default Benefits	**$254 million**
High growth in pedestrian trips (3% per annum beyond 2026)	$256 million
Longer average domestic tourist cycle trip (4.5 km)	$256 million
Tolling tourists only, $1 per trip	$256 million
Tolling tourists only, $2 per trip *	$259 million

Table 12: Benefit Cost Ratios – Sensitivity Tests

Sensitivity Test Scenario	Discounted Project Benefits
Increased tourist numbers (+50%) *	$259 million
Increased proportion of pedestrian trips being new trips (75%)	$261 million
High land use growth (+20%) *	$268 million
Full Auckland Cycle Network by 2046 *	$270 million
High daily cyclist factor (3.1) *	$307 million
High car diversion rate (0.60 in 2026 peak periods)	$327 million
High future uptake in e-bikes *	$331 million

* and # see extreme case tests below

The economic evaluation of the proposed cross harbour walking and cycling facility has been found to be most sensitive to changes involving tolling, e-bikes, and the calculation of cyclist health and traffic decongestion benefits.

Two further sensitivity tests have been considered that examine extreme cases, where the high and low effects of the above sensitivity tests are combined. The results of these tests are presented below. It is noted that these combinations are considered relatively unlikely.

Table 13: Benefit Cost Ratios – Extreme Case Sensitivity Tests

Sensitivity Test Scenario	Discounted Project Benefits
A worst-case scenario that combines those tests marked with a # above	$76 million
A best-case scenario that combines those tests marked with an * above	$448 million

A number of sensitivity tests within Table 12 were not included in the above worst-case/best-case scenarios. These sensitivity tests either:

- Conflict with another sensitivity test already included within the worst-case/best-case scenarios
- Were assessed after the completion of the worst-case/best-case scenario tests, in response to queries raised by the peer reviewer.

6.13 Project Costs

Project costs have been supplied by the Transport Agency. Costs include:

- $230 million in design, property and construction costs, including a 30% contingency. Discounted, this sums to $192 million
- Annual and regular maintenance which, when discounted, sums to $8.8 million

A 2½ year construction programme has been estimated, beginning January 2021.

6.14 Benefit Cost Ratios

The following table summarises the Benefit Cost Ratio (BCR) for the Project, taking into consideration the estimated default project costs and benefits, as well as the highest and lowest single sensitivity tests shown in Table 12.

Table 14: Benefit Cost Ratio Ranges

	Discounted Costs	Discounted Benefits	BCR
Lowest sensitivity test	$200.8 million	$133.6 million	**0.7**
Default benefits		$253.7 million	**1.3**
Highest sensitivity test		$330.9 million	**1.7**

The Project has an expected BCR of 1.3, and a range of 0.7 to 1.7.

APPENDIX A Auckland Harbour Bridge Traffic Assessment

technical note

PROJECT	**AUCKLAND HARBOUR BRIDGE WALKING AND CYCLING FACILITY**
SUBJECT	**DRAFT TRAFFIC MODELLING RESULTS**
TO	**ROBERT STRONG (NZTA), NEIL CREE (NB CONSULTING)**
FROM	ROB FRANKLIN, MICHAEL JONGENEEL
REVIEWED BY	IAN CLARK
DATE	16 NOVEMBER 2018

1 SUMMARY

The Upper Harbour SATURN traffic model has been used to assess the potential impacts of removing a traffic lane from the Auckland Harbour Bridge, to accommodate a walking and cycling facility. Three test scenarios have been compared against the Future Reference Case using a 2026 forecast year: namely:

- Scenario 1: Removing one traffic lane, and operating the remaining lanes in a four/three configuration during the peaks, with three southbound lanes in the inter peak
- Scenario 2: Removing one traffic lane, and operating the remaining lanes in a five/two configuration during the peaks, with three southbound lanes in the inter peak
- Scenario 3: Retaining eight traffic lanes, but reducing the width of the southbound clip-on lanes.

Scenario 1 is predicted to result in greater queues in the peak directions (southbound during the morning peak and northbound in the evening peak), and also southbound in the interpeak period. In the evening peak, northbound traffic arrival flows are predicted to exceed capacity by approximately 1,800 vehicles per hour, or approximately one lane of traffic.

Scenario 2 is predicted to result in significant effects in the contra-peak direction (northbound in the morning peak and southbound in the evening peak), due to the reductions in capacity in these directions from three to two lanes. As a result, widespread redistribution of traffic is predicted, via SH18/SH16, with greater overall increases in travel times than those with Scenario 1.

Scenario 3 is predicted to have little significant impact on the operation of the Auckland Harbour Bridge, although there would be slightly greater queues and delays southbound in the evening peak.

It should be noted that while diversion of traffic to the SH18/SH16 route is possible within the Upper Harbour model, the scenarios have been assessed using fixed overall traffic demands. It is to be hoped and expected that some car drivers will change mode, and either cycle due to the provision of the new facility with Scenarios 1 to 3, or that they will use public transport due to the greater traffic congestion expected with Scenarios 1 and 2. However the extent of the latter will be reduced by the fact that public transport will become caught up with additional congestion on the Bridge itself, in the contrapeak directions with Scenario 1, and in the peak directions, with Scenario 2.

2 INTRODUCTION

This Technical Note outlines the findings of traffic modelling undertaken to assess the potential impacts of lane reductions or restrictions on the Auckland Harbour Bridge, in order to accommodate a possible walking and cycling facility.

To assess the potential impacts of the facility, the Upper Harbour SATURN model has been used, supported by data obtained from the Transport Agency's Traffic Monitoring System (TMS). The following sections set out the methodology of the modelling process and the subsequent results.

3 MODEL CALIBRATION

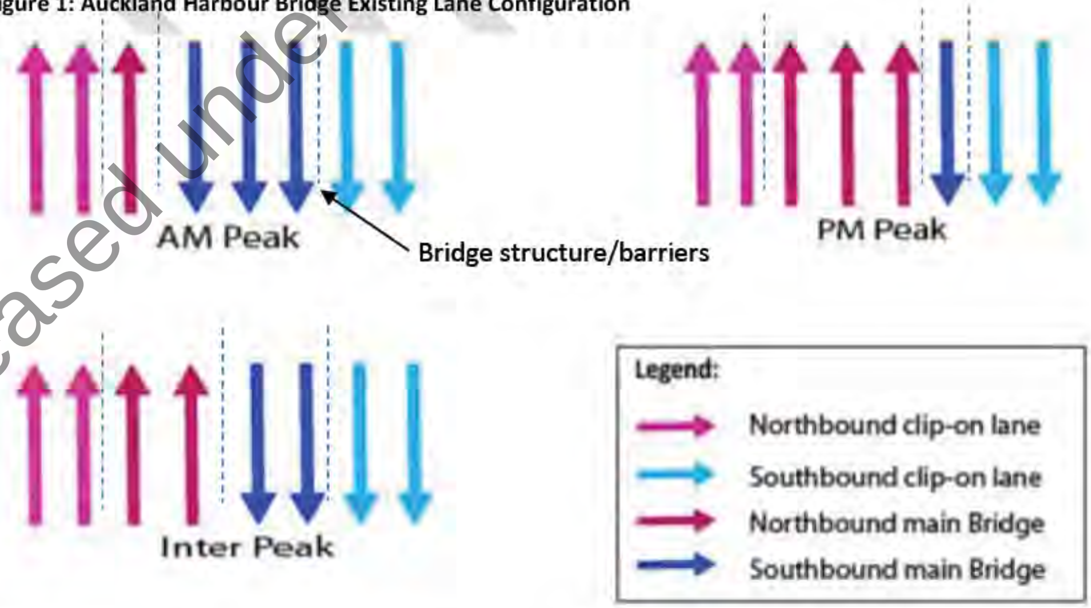
There is a currently a total of eight traffic lanes on the Harbour Bridge, which operate with differing configurations throughout the day:

- 4 am to 10 am on weekdays: five southbound traffic lanes and three northbound lanes
- 3 pm to 8 pm on weekdays: three southbound traffic lanes and five northbound lanes
- 10 am to 3 pm and 8 pm to 4 am on weekdays, plus all day at weekends: four lanes in each direction.

The structure of the original Auckland Harbour Bridge sits between lanes 2 and 3, and between lanes 6 and 7. Also, a moveable lane barrier is provided between the opposing directions of flow in adjacent lanes, on the original bridge. As a result, some traffic lanes are narrower than others at different times of the day, resulting in reduced traffic capacities on these lanes. In particular, the single northbound lane in lane 3 in the morning peak, and the single southbound lane in lane 6 in the evening peak, can accommodate lower flows than other groups of two or more adjacent lanes.

The lane configuration during the peak periods is further demonstrated in Figure 1.

Figure 1: Auckland Harbour Bridge Existing Lane Configuration



The Upper Harbour SATURN traffic model has been reconfigured using the capacities indicated by the TMS data. Traffic volumes were obtained for each traffic lane across the Auckland Harbour Bridge, for the month of August 2018, noting the maximum traffic flows in each traffic lane, per hour. This data was used to determine the peak capacities in each direction, during the morning, inter and evening peak periods, for each lane type.

As a result of this calibration process, the following saturation flows have been applied to the Auckland Harbour Bridge groups of lanes:

- 1 lane – 1,650 vehicles/hour
- 2 lanes – 3,600 vehicles/hour
- 3 lanes 5,400 vehicles/hour

Based on the above, Table 1 documents the anticipated capacities for each approach, under the existing configuration.

Table 1: Auckland Harbour Bridge Peak Period Capacities (vehicles/hour)

Peak Period	Lanes	Northbound		Southbound	
Morning Peak	Lane configuration	2	1	3	2
	Lane capacity	3,600	1,650	5,400	3,600
	Total capacity	**5,250**		**9,000**	
Interpeak	Lane configuration	2	2	2	2
	Lane capacity	3,600	3,600	3,600	3,600
	Total capacity	**7,200**		**7,200**	
Evening Peak	Lane configuration	2	3	1	2
	Lane capacity	3,600	5,400	1,650	3,600
	Total capacity	**9,000**		**5,250**	

As demonstrated in Table 1, the capacity available in each direction changes during the day, depending on how many northbound and southbound lanes are available. The following section discusses the results of the forecast modelling scenarios, which examines future 2026 scenarios without and with the walking and cycling facility.

4 2026 MODEL SCENARIOS

As noted, the calculated capacity of each traffic lane passing over the Auckland Harbour Bridge was coded to the traffic links within the SATURN Model. The following scenarios have been tested:

- Reference Scenario – 2026 with existing layout
- Scenario 1: Removing one traffic lane, and operating the remaining lanes in a four/three configuration during the peaks, with three southbound lanes in the inter peak
- Scenario 2: Removing one traffic lane, and operating the remaining lanes in a five/two configuration during the peaks, with three southbound lanes in the inter peak

- Scenario 3: Retaining eight traffic lanes, but reducing the width of the southbound clip-on lanes.

Forecast traffic flows presented in the following sections represent the sum of 'actual' traffic flows predicted to arrive at the base of the Auckland Harbour Bridge, plus any queued traffic flow on the immediate approaches. That is to say, it is known that there is a significantly higher demand flow southbound in the morning peak, with queued or slow moving traffic extending north from Esmonde Road and back up Onewa Road, but the following results relate to flows that actually can reach the Bridge during the peak hours. This Technical Note refers to such flows as "arrival flows".

4.1 Reference Scenario – 2026 with Existing Layout

The SATURN modelling results for the 2026 Reference Scenario are documented in Table 2 below. Instances where the forecast traffic arrival flows exceed the estimated capacities are highlighted red.

Table 2: Reference Scenario Model Outputs – 2026 with Existing Layout - SATURN Modelling Results (vehicles/hour)

Peak Period	Lanes	Northbound		Southbound	
Morning Peak	Lane configuration	2	1	3	2
	Arrival flow	5,340		7,940	
	Capacity	5,250		9,000	
Interpeak	Lane configuration	2	2	2	2
	Arrival flow	6,280		6,010	
	Capacity	7,200		7,200	
Evening Peak	Lane configuration	2	3	1	2
	Arrival flow	9,380		5,650	
	Capacity	9,000		5,250	

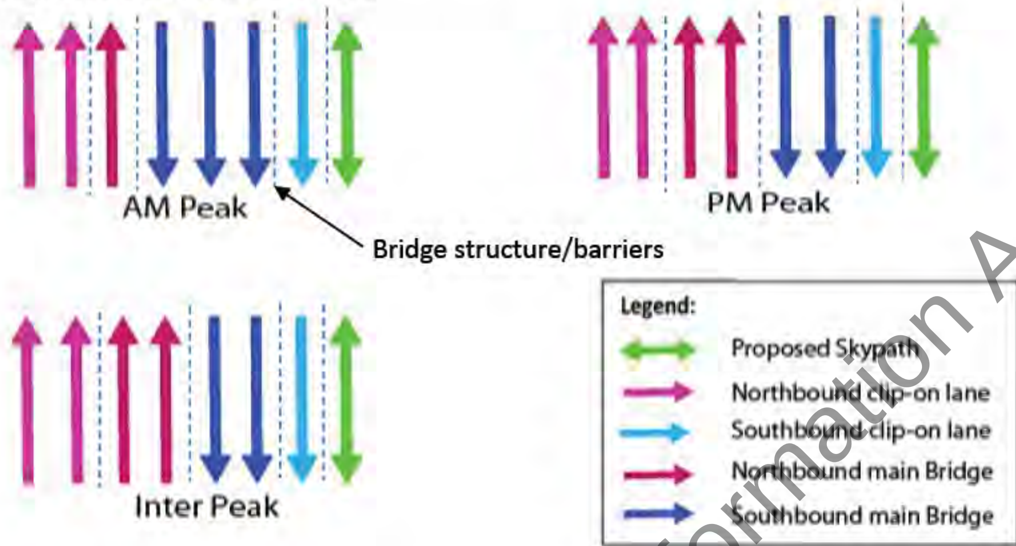
Table 2 indicates that the Auckland Harbour Bridge is anticipated to operate at capacity in 2026, northbound, in both the morning peak (with 3 lanes) and the evening peak (with five lanes). The arrival flows are predicted to exceed capacity in these periods by around 100 to 400 vehicles per hour (2% to 4%, respectively). Similarly, the southbound arrival flow in the evening peak (with 3 lanes) is predicted to exceed capacity by about 400 vehicles. However, the southbound arrival flow in the morning peak (with 5 lanes) is predicted to be within capacity, as the five southbound lanes on the Bridge are fed by three traffic lanes from Esmonde Road to Onewa Road, plus a single lane from Onewa Road, plus the bus lanes (both from Esmonde Road to Onewa Road and from Onewa Road).

4.2 Scenario 1 – 2026 with Walking and Cycling Facility Layout 1

With Scenario 1, the eastern-most traffic lane would be re-purposed to provide a walking and cycling facility. As a result, the bridge would operate with only seven traffic lanes, and the remaining southbound clip-on lane would always operate as a single, narrow lane (i.e. with a barrier separating traffic from the walking/cycling facility).

In this scenario, it is expected that during peak hours, the bridge would operate with a four/three traffic lane configuration. The proposed configuration is demonstrated in Figure 2.

Figure 2: Auckland Harbour Bridge Scenario 1



As shown, there would be a reduction in southbound lanes during the morning peak and inter peak periods and a reduction of one northbound lane during the evening peak. The modelling results for Scenario 1 are shown in Table 3. Again, instances where the forecast arrival flows are predicted to exceed the estimated capacities are highlighted red.

Table 3: Scenario 1 Model Outputs – 2026 with Walking and Cycling Facility Layout 1 (vehicles/hour)

Peak Period	Lanes	Northbound		Southbound	
Morning Peak	Lane configuration	2	1	3	1
	Arrival flow	5,320		7,940	
	Capacity	5,250		7,050	
Interpeak	Lane configuration	2	2	2	1
	Arrival flow	6,250		5,620	
	Capacity	7,200		5,250	
Evening Peak	Lane configuration	2	2	2	1
	Arrival flow	9,010		5,550	
	Capacity	7,200		5,250	

Given the change in lane configuration, with the walking and cycling facility implemented, the modelling indicates that a number of approaches would operate over capacity, namely:

- Both directions during the morning peak
- Southbound during the interpeak
- Both directions during the evening peak.

Table 3 indicates that northbound vehicles during the evening peak period would be the most affected, with predicted arrival flows expected to exceed the available capacity by approximately 1,800 vehicles per hour (25%). In addition, with this scenario, the Bridge itself would become the bottleneck southbound in the morning peak (whereas under the existing situation (and the Reference Scenario), as noted above, the southbound morning peak bottlenecks are on the approaches to the Bridge, not on the Bridge itself). Therefore Scenario 1 would adversely affect bus travel times and reliability, southbound in the morning peak and northbound in the evening peak, as buses have to share road space with general traffic on the Bridge itself.

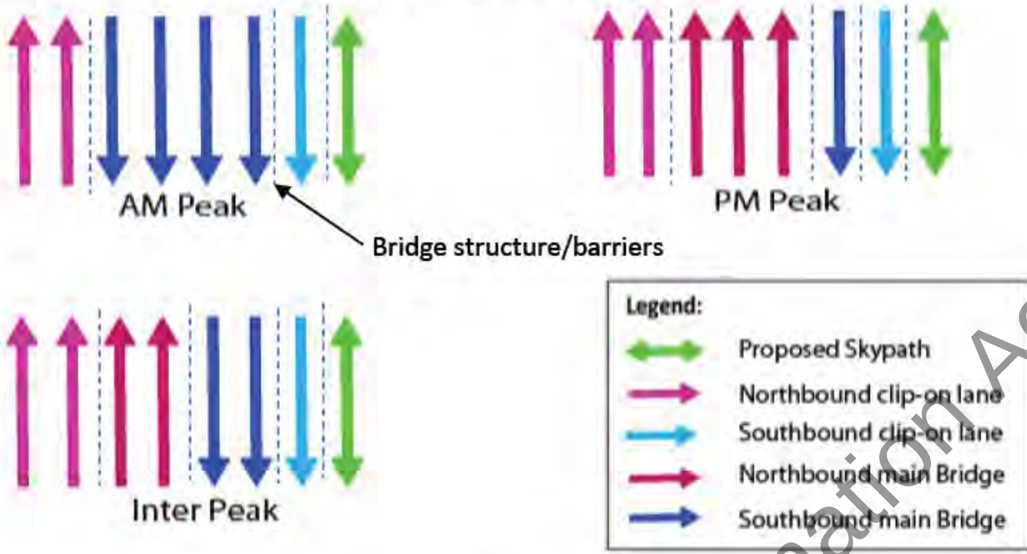
In addition, the following points are noted:

- Southbound arrival flows are predicted to exceed the capacity during all modelled periods, suggesting that queued conditions may extend throughout the day.
- The traffic model allows some vehicles to divert via State Highways 18 and 16 to avoid queues on the approaches to the Auckland Harbour Bridge, hence the reduction in the number of vehicles when comparing Table 2 and Table 3, in some instances. Conversely however, the model indicated some increases in traffic volumes in some instances, due to traffic spilling over from the "pre peak" hour into the peak hour. Such increases have not been included within Table 3, on the basis that the concept of a **reduction** in traffic lanes leading to an **increase** in traffic seems counter-intuitive – but the logic from a traffic modelling point of view is worth noting
- The scenarios have been assessed using fixed overall demands. It is to be hoped and expected that some car drivers will change mode, and either cycle due to the provision of the new facility with Scenario 1, or that they will use public transport due to the greater traffic congestion with this scenario (although as noted above, public transport will become caught up with additional congestion on the Bridge itself).

4.3 Scenario 2 – 2026 with Walking and Cycling Facility Layout 2

Scenario 2 also assesses the Auckland Harbour Bridge with the proposed walking and cycling facility implemented, but applies an alternative lane configuration which is demonstrated in Figure 3. Under this configuration, the peak directional capacity would be as existing (ie five lanes southbound in the morning peak and northbound in the evening peak), leaving only two lanes in the contrapeak direction. It is noted that this scenario would leave only two southbound lanes in the evening peak, and both will be narrow, single lanes, while the two northbound lanes in the morning peak would be "standard" width.

Figure 3: Auckland Harbour Bridge SkyPath Lane Configuration 2



The modelling results for Scenario 2 are demonstrated in Table 4. Again, instances where the forecast traffic flows exceeds the estimated capacity are highlighted red.

Table 4: Scenario 2 Model Outputs – 2026 with Walking and Cycling Facility Layout 2 (vehicles/hour)

Peak Period	Lanes	Northbound		Southbound	
Morning Peak	Lane configuration	2	0	4	1
	Arrival flow	4,450		7,950	
	Capacity	3,600		8,850	
Inter Peak	Lane configuration	2	2	2	1
	Arrival flow	6,250		5,620	
	Capacity	7,200		5,250	
Evening Peak	Lane configuration	2	3	1	1
	Arrival flow	9,340		3,870	
	Capacity	9,000		3,300	

The results for Scenario 2 also demonstrate that a number of approaches would operate over capacity during the peak periods, namely:

- Northbound during the morning peak
- Southbound during the inter peak
- Both directions during the evening peak.

Ostensibly the extent to which traffic volumes exceed the estimated capacities are less than those predicted in Scenario 1. This is however due to the widespread redistribution of contra-peak traffic via SH18 in Scenario 2 (ie northbound traffic in the morning peak and southbound in the evening). This is reflected in the overall network summary statistics, presented in Section 4.5.

4.4 Scenario 3 – 2026 with Walking and Cycling Facility Layout 3

Scenario 3 assesses the Auckland Harbour Bridge with an alternative walking and cycling facility, built as an extension to the existing southbound clip-on. This configuration would retain the existing number of lanes and their configuration, but would narrow the two southbound clip-on lane widths to approximately 3.2m and as a result, reduce their capacity. An estimated capacity of 3,400 vehicles/hour has been assumed for this clip-on.

The modelling results for Scenario 3 are demonstrated in Table 5. Again, instances where the forecast traffic flows exceed the estimated capacity are highlighted red.

Table 5: Scenario 3 Model Outputs – 2026 with Walking and Cycling Facility Layout 3 (vehicles/hour)

Peak Period	Lanes	Northbound		Southbound	
Morning Peak	Lane configuration	2	1	3	1
	Arrival flow	5,300		8,000	
	Capacity	5,250		8,800	
Inter Peak	Lane configuration	2	2	2	2
	Arrival flow	6,270		6,010	
	Capacity	7,200		7,000	
Evening Peak	Lane configuration	2	3	1	2
	Arrival flow	9,380		5,650	
	Capacity	9,000		5,050	

Scenario 3 is generally predicted to operate very similarly to the Reference Scenario. However, while the reduction in capacity is not predicted to be critical southbound in the morning peak, it is predicted to be critical southbound in the evening peak, leading to additional delays for general traffic and buses.

4.5 Summary Statistics

Table 6 presents the network-wide summary statistics from the modelled scenarios, in terms of overall vehicle-hours and vehicle-kilometres travelled. Little weight should be given to the absolute figures provided, as the values are a function of the size of the network modelled. However, the statistics are useful to compare scenarios on a like for like basis, to illustrate which scenarios have a greater, or lesser, impact on the wider transport network.

Table 6: Modelled Summary Statistics

	Refence Scenario	Scenario 1	Scenario 2	Scenario 3
Overall travel time (pcu-hr per hr)				
Morning Peak	19,560	20,280	21,680	19,600
Interpeak	10,300	10,950		10,310
Evening peak	24,890	27,500	29,120	24,890[1]
Overall travel distance (veh-km per hr)				
Morning Peak	689,000	694,000	713,000	689,000
Interpeak	548,000	555,000		548,000
Evening peak	803,000	825,000	831,000	804,000

The table above indicates that Scenario 2 is predicted to have significantly greater overall network impacts than Scenario 1, due to the widespread redistribution of traffic in the former. Scenario 3 however is predicted to result in negligible changes in network operations, overall, relative to the Reference Scenario.

Reference:\\Flow-dc01\Projects\NZTA\158 SkyPath\4.0 Reporting\TN1A181116.docx - Rob Franklin
Models: P:\NZTA\158 SkyPath\7.0 Assessment\2026_I11
Reference Scenario: uiscam26_Alliance_Design_Rdale_Base
Scenario 1: uiscam26_Alliance_Design_Rdale_Opt
Scenario 2: uiscam26_Alliance_Design_Rdale_OptA
Scenario 3: uiscam26_Alliance_Design_Rdale_OptB

[1] Scenario 3 is predicted to reduce travel times relative to the Reference Scenario in the evening peak, due to model noise/instability on SH16. The value for the Reference Case has been used to represent Scenario 3 instead.

APPENDIX B Auckland Cycle Model – development report

Auckland Cycle Model

Model Development Report

September 2018

flow
TRANSPORTATION SPECIALISTS

flow
TRANSPORTATION SPECIALISTS

Project: Auckland Cycle Model
Title: Model Development Report
Document Reference: P:\Aeco\004 SeaPath\4.0 Reporting\R2D180907 Auckland Cycle Model Development Report.docx
Prepared by: Michael Jongeneel
Reviewed by: Ian Clark

Revisions:

Date	Version	Reference	Approved by	Initials
16 August 2018	A	R1A180816	Ian Clark	IC
3 September 2018	B	R1B180903	Ian Clark	IC
6 September 2018	C	R1C180906	Ian Clark	IC
7 September 2018	D	R1D180907	Ian Clark	IC

CONTENTS

APPENDICES

1 INTRODUCTION

This report has been prepared by Flow Transportation Specialists (Flow) to document the development of the Auckland Cycle Model. The Auckland Cycle Model was initially developed in 2014 to support the Indicative Business Case for the NZ Transport Agency's SeaPath shared use path project, and has been substantially extended and revised since. It has subsequently been used to evaluate cyclist demands for cycle infrastructure projects across Auckland, on behalf of both Auckland Transport and the NZ Transport Agency, including:

- SeaPath shared use path
- Wynyard Quarter cycle infrastructure
- New Lynn to Avondale shared path
- Quay Street cycleway
- Auckland Urban Cycleways Programme
- Glen Innes and New Lynn Cycle Links to Public Transport
- Mangere Inlet shared path
- Auckland Cycling Programme Business Case
- Te Whau Pathway
- Burnley Terrace cycle link
- The Pt Chevalier, Westmere and Grey Lynn package of cycle routes
- Ti Rakau Drive cycleway component of AMETI project
- The Hingaia South cycle network
- The cycling infrastructure component of the Northern Corridor Improvements project
- Glen Innes to Tamaki Drive shared path
- Inner East and West cycle routes

This report documents the model as it stands in August 2018, including:

- The model's extent, periods represented and level of detail
- The 2013 base model, including its calibration and validation processes
- The forecast demand methodology and the calibration of this process
- The model's limitations.

2 INPUT DATA USED

The development of cyclist demands has relied on inputs from multiple sources, including:

The 2013 New Zealand Census:

- Journey to work cycling trips within the model area (some 5,680 daily cycling trips, representing 96% of the Auckland regional journey to work cycle trip total);
- The trip length profile for cycling journeys to work in the Auckland region.

The Auckland Regional Transport (ART) model:

- Morning and evening peak period person trips for non-active modes, by trip type, for the 2026 and 2046 forecast years.

Auckland Council Land Use Forecasts:

- Projected population and employment forecasts for the Auckland region, by ART model zone.

The UK Department for Transport's (DoT) National Travel Survey Statistics:

- The proportion of daily journey to work trips that took place between 7 and 9 am (60%), and the proportion of work trips to home between 4 and 6 pm (49%).

Strava cycle data:

- Heat maps of routes used by Auckland cyclists using smartphone apps and fitness equipment linked to Strava.

Auckland Transport cycle count data:

- Manual count data collected on a single weekday, generally on a fine day in March 2013 but from a variety of sources and dates, and
- Automatic count data from the 54 cycle counters that Auckland Transport monitors across the region; this automatic data has provided average cyclist numbers over a period of months, or longer.

Where appropriate, count data has been seasonally adjusted, and has been corrected for weather using the procedures in the NZ Transport Agency's Research Report 340 "Estimating Demand for New Cycling Facilities in New Zealand" (McDonald, et at., 2007).

The automatic cycle counters provide continuous data throughout the day, and the analysis of this data has found that weekday cyclist numbers across these count sites have typically fluctuated ±65% from the annual average in 2016. Similarly, weekly counts have fluctuated typically ±25% from the average. This illustrates the considerable fluctuation in cycle volumes, not only seasonally but also weekly and daily.

This fluctuation has also been evident in the manual count data obtained; multiple manual counts were often available for single locations, or for adjacent locations, with these counts fluctuating significantly.

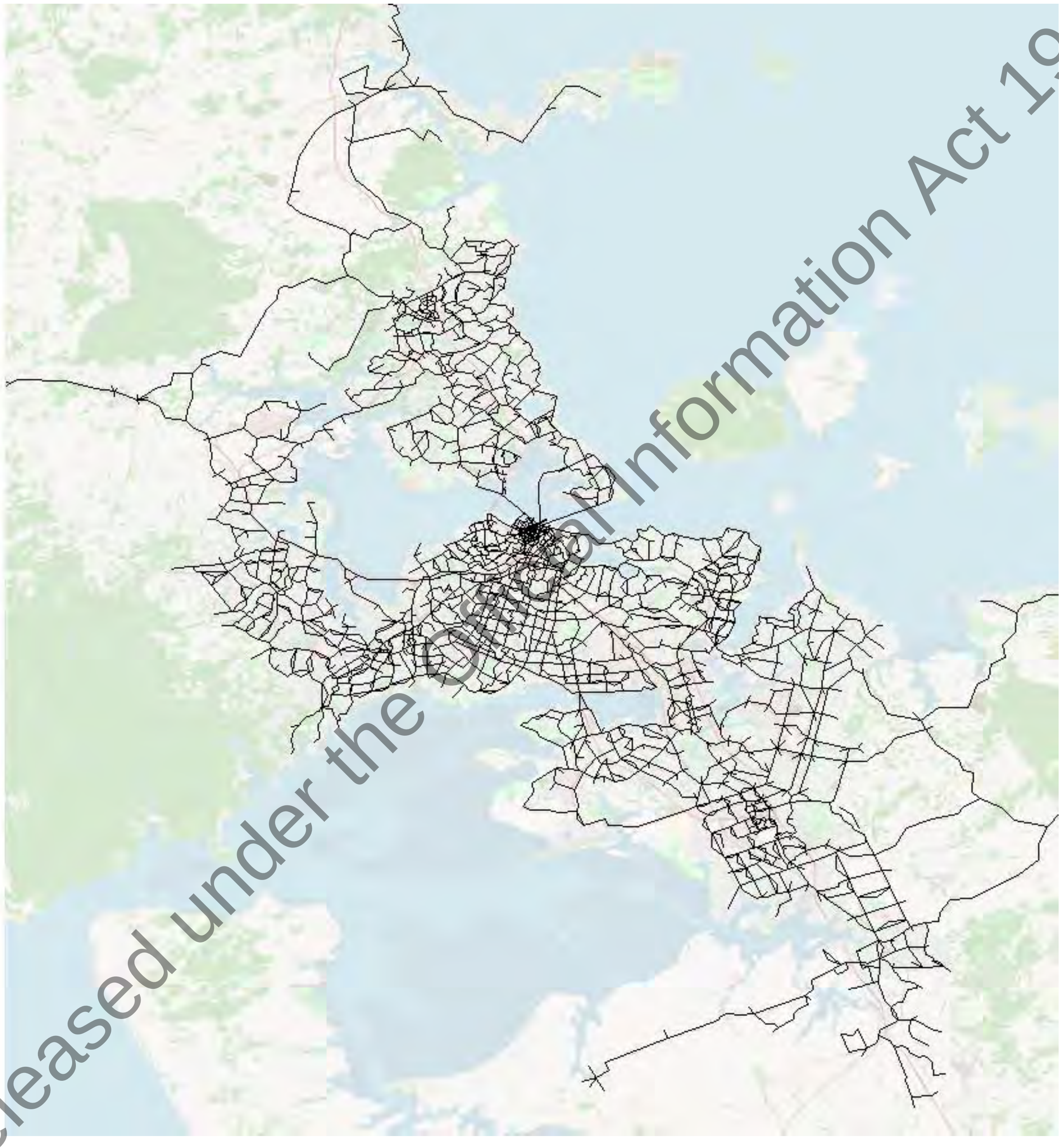
This inherent variability in cyclist numbers has made the development of the Auckland Cycle Model particularly challenging, and the evaluation of the model that follows must therefore be considered in light of this variability.

3 MODELLED NETWORK

The Auckland Cycle Model was originally developed to include only central Auckland and the lower North Shore, but has subsequently been extended to represent all major cycling routes within urban Auckland, with a greater level of detail within the city centre, Auckland's Metropolitan centres, and within the inner suburbs that have the target of increased cycle investment in recent years. The model generally includes all arterial and collector type routes, cycleways and shared paths, some ferry routes as well as footpaths through parks and reserves that are significant to cycle trips.

Figure 1 below illustrates the extent of the model.

Figure 1: Extent of the Auckland Cycle Model



The model represents two-hour morning (7 to 9 am) and evening (4 to 6 pm) peak periods. Insufficient cycle count data was available for the additional development of an interpeak model.

Estimates of daily cyclists have been derived by summing and factoring the morning and evening peak period models. The daily factors used in this process have been obtained from automated cycle count sites across Auckland, and range from 1.4 (am + pm) for routes that are used predominantly by commuter users during the peak periods, to 2.4 or more for routes which experience a high use by recreational users outside the peak periods. The Auckland average is 1.9 (am + pm).

Zones within the modelled area relate to the ART model zone structure, but have been disaggregated into a finer zone structure within the Auckland city centre, Metropolitan Centres, and within Central Auckland and the lower North Shore. There are presently 695 zones within the modelled network.

The model interface uses traditional SATURN[1] traffic modelling software, however the majority of the model mechanism is through a series of spreadsheet based matrices and algorithms. The network has been coded using what SATURN refers to as 'buffer' network. This form of coding excludes capacity considerations and omits all detail at intersections; it allows a large network to be quickly and simply developed and is suitable for cycling networks where capacity constraints are not commonly an issue.

Links within the network have been categorised according to the link categories defined in Table 1. Each link category has then been assigned a 'Relative Attractiveness' (RA) index value, based on the relative level of comfort, safety and inclusiveness that each type of link provides to people on bicycles.

Table 1: Link Categories

Infrastructure Type		Relative Attractiveness Index
Cycleways and off road cycle paths	Iconic (for example LightPath and SkyPath)	19
	High standard – cyclist only, or shared path uninterrupted by vehicle crossings or side streets	15
	Average standard – shared use path interrupted by vehicle crossings or side streets	14
	Low standard – a pedestrian footpath	13
	Very low standard – a poor quality pedestrian footpath	12
On road cycle infrastructure	Protected cycle lanes	15
	Painted cycle lanes on a minor/two-lane arterial	14
	Painted cycle lanes on a major/multi-lane arterial	13
Transit lanes	Transit mall	14
	Arterial road with bus lanes	13
No specific cycle infrastructure	Quiet route with local area traffic management – Greenways	14
	Quiet route	13
	Minor/two-lane arterial	12
	Major/multi-lane arterial	11
Rural roads	Rural road	11

[1] A traffic modelling program for the Simulation and Assignment of Traffic to Urban Road Networks developed by Atkins-ITS Transport Software. http://www.saturnsoftware.co.uk

As a general rule, a Relative Attractiveness rating of 15 has been applied to routes that meet current best practice. The iconic rating has been developed to represent the LightPath cycleway, which due to its combination of colourful design, interactive lighting, harbour and city views, width and media attention, has received an exceptionally high number of cyclists since opening (see forecast model calibration, Section 5.4).

Modelled routes have also been assigned a Relative Attractiveness rating one classification higher where they are considered to be scenic routes that attract significant numbers of recreational cyclists, such as Tamaki Drive. Conversely, routes have been shifted down on classification where they are considered to be of a lower standard or less safe than other facilities of the same type, or where they climb a significant uphill gradient.

Broadly, the Relative Attractiveness scale of 10 to 19 aligns with the Relative Attractiveness scale applied in Simplified Procedures 11 (SP11) of the NZ Transport Agency's Economic Evaluation Manual (EEM), of 1.0 for a route with no dedicated cycle infrastructure to 2.0 for an off-road route.

Relative Attractiveness has been represented within the model by the speed on each modelled link. It is important to recognise that this is not an actual speed, as the model does not consider travel times, delays or congestion. It does however allow the Relative Attractiveness classification assigned to each link to affect route assignment within the model: modelled trips assign not necessarily via the most direct route, but via an optimal route based on a weighting of each route's comfort, safety, inclusiveness and gradient (its Relative Attractiveness) and its distance. This reflects known cyclist behaviour, where user tend to be willing to cycle a slightly longer distance in order to access a safe and comfortable route, or to avoid a particularly dangerous route.

It is noted that the assignment within the model is 'all or nothing', rather than stochastic distribution.

The Relative Attractiveness classification is also important in the derivation of forecast demands for each route (refer Section 5).

In addition to physical cycling infrastructure, links have been included within the model representing the Devonport, Bayswater and Birkenhead/Northcote ferries. These links have been assigned lengths that correspond to a $5 ferry fare[2], plus the respective journey times and wait/transfer times (depending on the frequency of sailings), converted to distance by assuming a 15 km/h average cycle speed and standard EEM values for travel time[3].

4 2013 BASE MODEL

4.1 Methodology

A base model has been developed to represent March 2013 network conditions. March 2013 has been used as it aligns with both:

- The 2013 Census, carried out in March that year, and

[2] Noting that the 2013 adult cash fare for each ferry was $6 and the AT Hop fare was $4.20
[3] $22.78/hour, including EEM update factors appropriate in 2013

- Auckland Transport's annual cycle count programme, also carried out in March.

The number of cyclists within the base model has been derived from the 2013 census journey to work data. This data includes 5,904 one-way bicycle trips to work within the Auckland region that was first reduced to 5,679 trips by removing trips in areas outside the model extent. This has been transposed to develop a matrix of the journeys home from work, used to develop evening peak demands.

The census data represents daily trips to work (or from work when transposed). These matrices were factored down to represent two-hour peak periods using the UK DoT's National Travel Survey statistics for commute trip types. Factors applied were 0.6 and 0.49 in the morning and evening peaks, respectively[4], resulting in a morning peak matrix total of 3,407 trips and 2,783 evening peak trips.

These matrices represented only those cycle trips that were undertaken as trips to or from work, so have been factored up to reflect all trip types undertaken by bicycle. For the morning peak, this factor (1.25) has been obtained by comparing data from the Household Travel Survey, which provided the number of cycle-to-work trips undertaken per person in Auckland with the number of cycle trips per person for all purposes. The resulting all-trip matrix contained 4,259 morning peak trips. A higher factor (1.43) was applied to the evening peak, reflecting the higher proportion of trips being undertaken for purposes other than commuting in the evening period, and resulting in 3,975 evening peak trips.

The above procedures have been used as a part of the calibration process, to scale the March 2013 cycling demands to match observed March 2013 cycle count data.

The census travel to work data contains a small number of cycle trips across the Waitemata Harbour, despite there being no existing cross harbour walking or cycling facility. This corresponds to cyclists who cycle to ferry (or bus) terminals or those who cycle 'the long way around' via the Upper Harbour Bridge. Cross harbour census trips have been calibrated to better reflect the observed cycle counts on the Devonport, Bayswater and Northcote/Birkenhead ferries, as well as those across the Upper Harbour Bridge.

While the census home-to-work trip data was manipulated as above to include all trip types, the modelled number of cyclists predicted to educational institutions and major schools was notably lower than observed. To correct for this, school trips have been manually added to the model for schools that recorded 50 or more daily cycle trips according to 2013 Auckland Transport cycle count data[5]. These trips have been distributed equally among residential zones within each school's enrolment area. This correction has been made to the morning peak period model only, as the return school trips will generally occur before the evening peak period. Similarly, inbound cycle trips into the University of Auckland and Auckland University of Technology city campuses in the morning peak, and outbound cycle trips in the evening peak, have been factored up to better reflect observed count data.

[4] Factors of 0.50 and 0.45 could alternatively have been applied, using data from the NZ Transport Agency's Research Report 340. This would have then required higher factors when building the matrices to include all trip types, in order to achieve appropriate matrix calibration outcomes.

[5] Nine schools included, being: Belmont Intermediate, Takapuna Intermediate, Takapuna Grammar, Remuera Intermediate, Orewa College, St Cuthbert's, Western Springs College, Auckland Grammar and Westlake Boy's. All other Auckland schools had surveyed cycle volumes of less than 50 students

The final pre-estimation matrices contained 4,856 and 3,952 trips, in the morning and evening peak periods, respectively.

Recreational cyclists are a noticeable occurrence on the network, particularly during daylight saving months (typically October to March). It was noted that the model was under-representing cyclist trips on key recreational corridors along Auckland's waterfront, particularly Tamaki Drive, and particularly in the contra-peak directions (away from the city in the morning, and the reverse in the evening). To account for these trips, a series of fixed route trips have been manually added to the model between various inner west suburbs (such as Pt Chevalier and Westmere) and various inner east suburbs (Orakei, St Heliers and Glen Innes), via Quay Street and Tamaki Drive. This calibration factor has allowed a more acceptable comparison of observed and modelled cyclist numbers on Tamaki Drive, Quay Street and through the Wynyard Quarter.

The recreational trip process above is supported by Strava cycle heat maps for Auckland, which show trips undertaken by cyclists using smartphone apps and fitness equipment that logs their trips. The Strava data is not a representative sample of all cycle trips, being instead weighted towards recreational/fitness cyclists. The heat maps however show a concentration of such trips on Auckland's central waterfront that the base model did not fully represent without the above corrections.

4.2 Matrix Estimation

The process above has developed a 'prior' matrix for each peak period that was a fairly coarse approximation of actual cycle trips in March 2013, and which did not align with cycle count data from that period as well as it could. To better improve this fit, the prior matrices were run through a matrix estimation process. This process used approximately 410 cycle count data points from across Auckland, for each modelled period. The process used predominantly data from fine days in March 2013, but additional data collected in 2012, 2013 and 2014 were used, with these latter data points corrected for seasonality and annual growth as appropriate. Individual counts have also been corrected for weather as appropriate.

The estimation process was tempered by applying the following controls:

- Preventing the estimation process from 'seeding' demands in origin-destination pairs that had zero trips in the prior matrix. This prevented the estimation process from generating cycle trips to and from unlikely origin-destination pairs, such as Albany to Manukau.
- Limiting the factoring that the estimation process could apply to individual origin-destination pairs, and to each link, to five times the value in the prior matrix.

The changes in trip totals due to the estimation process are shown in Table 2, which details the total cycling demands in the prior matrices and the final estimated matrices.

Table 2: Matrix Totals, Before and After Estimation

	Morning Peak Period	Evening Peak Period
Prior Matrix Demand	4,856	3,952
Final Estimated Matrix Demand	4,644 (-4%)	3,739 (-5%)

The above table illustrates that the estimation process has reduced demands across the modelled network by 4% to 5%.

Plots showing comparisons of the prior and post estimation matrices are included in Appendix A. In these plots, green bands represent links where the estimation process has increased modelled demands, while blue bands represent reductions. The plots show that the estimation process has increased demands on Tamaki Drive in the morning peak and on Great North Road through Grey Lynn in the evening peak, but to have generally reduced demands overall.

As a second check of the estimation process, the trip length distribution has been compared between the prior and post estimation process. These distributions are also shown in Appendix A, and show a good level of agreement between the two demand sets. The process has resulted in an increase in trips of three to four km in length, which is a sensible result. The average trip length in the prior matrix was 5.9 km, and that in the post estimation process was 5.7 km.

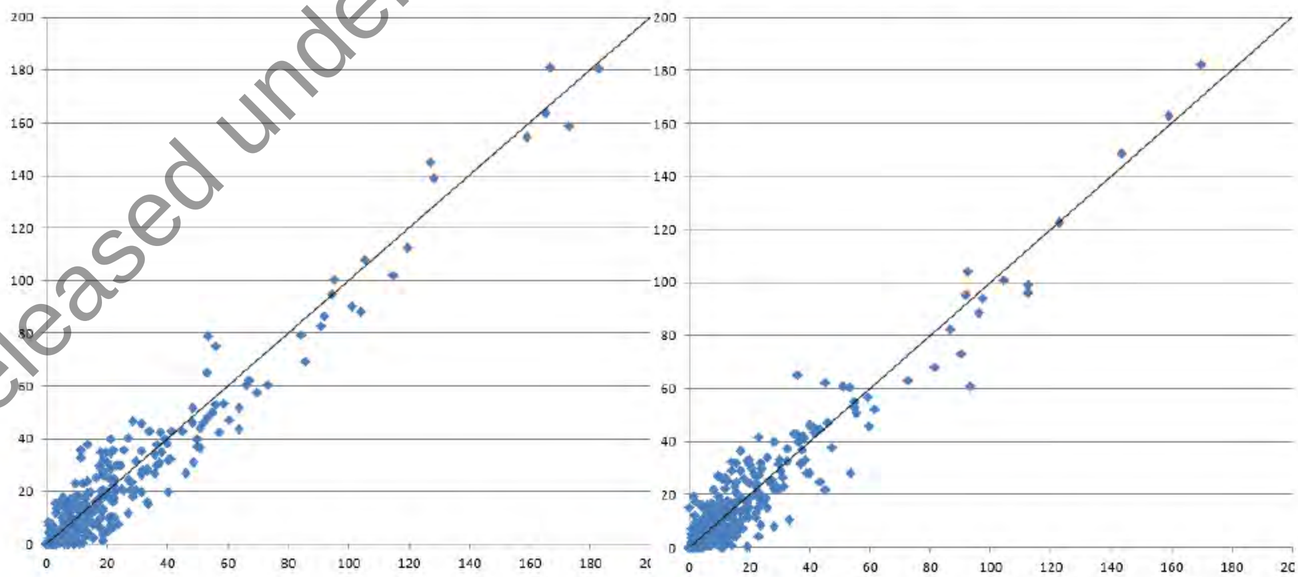
As a final check, a sector analysis has been carried out on the pre and post estimation matrices, with this process documented in Appendix A.

4.3 Model Validation

The March 2013 post estimation cycle trip matrices were applied to the 2013 base network model to enable sensibility checks to be undertaken on the model outputs at key locations, comparing these with existing weekday cycle count data. Count data was again predominantly taken for the month of March 2013, with additional data from 2012 to 2014 corrected as appropriate. The validation process used approximately 340 data points for each modelled period, each independent of the data used in the matrix estimation process.

Plots of the observed counts against the modelled volumes are shown in Figure 2 below.

Figure 2: Observed Counts (X axis) versus Modelled (Y axis), Morning (left) and Evening Peak Periods (right)



It is noted at this stage that a traditional traffic model would be validated against criteria from the NZ Transport Agency's Transport Model Development Guidelines. The criteria within this document were developed for application to traditional traffic models and have not generally been found to be appropriate to the cycle model. The criteria relating to GEH statistics[6] for example were found to be a poor measure of cycle model validity, as GEH criteria are too easy to meet when dealing with low value data points (over 40% of counts used in the validation are under 10 cyclists per two-hour period).

Model validation criteria applied to the model include those listed below. The Transport Agency's validation criteria relate to the 'Type B – Strategic Network Traffic Assignment Model' classification, which the Auckland Cycle Model most resembles. The Percent Mean Absolute Error is also provided in the table below, which is not a validation criterion documented in the NZ Transport Agency's Transport Model Development Guidelines.

Table 3: Link Count Validation Criteria

Link Count Criteria	Transport Agency Model Validation Guidelines	Auckland Cycle Model Morning Peak Period	Auckland Cycle Model Evening Peak Period
Coefficient of determination (R^2)	0.90	0.94	0.93
Line of best fit	Y = 0.9x to 1.1x	Y = 0.96x	Y = 0.97x
Percentage-Root-Mean-Square Error (RMSE)	◆ Acceptable: <25% ◆ Requires clarification: 25-35% ◆ Unlikely to be appropriate: >35%	35%	39%
GEH statistic	◆ >75% GEH <5.0 ◆ >80% GEH <7.5 ◆ >85% <10.0	◆ 99% GEH <5.0 ◆ 100% GEH <7.5 ◆ 100% GEH <10.0	◆ 99% GEH <5.0 ◆ 100% GEH <7.5 ◆ 100% GEH <10.0
Percent Mean Absolute Error	n/a	27%	30%

The comparisons for R^2 and the line of bets fit are generally very good, while the RMSE and GEH criteria are considered potentially unsuitable for cycle models.

Plots showing the locations of validation count data are included in Appendix B, as is a full tabulation of count data versus model outputs.

5 FORECAST MODEL DEMANDS

5.1 Methodology

The forecast demand methodology has considered two fundamental drivers of increases (or decreases) in cycle demands between any two zones:

[6] The GEH statistic is a form of Chi-squared statistic, commonly used to compare observed and modelled count data.

- Changes in cycle demands as a result of future changes in land use, and
- Changes in cycle demands as a result of future cycle infrastructure improvements.

The first of the above may be considered 'organic' growth that would occur if the physical cycle network remained unchanged from its March 2013 state (ie the base model). The second relates to mode shift and behaviour change resulting from investment. This process is summarised in Equation 1 below.

Equation 1: Future Demand Calculation

Future demands	=	Existing demands, factored to reflect land use growth	+	Mode shift in response to cycle infrastructure investment

Each of the factors used in the above equation are explained in more detail below.

5.2 Accounting for Land Use Growth

The base model's demand set represents March 2013 cycle demands, while each of the forecast years represent annual average daily cyclists. To correct this, the base model demand set has been factored down by 26%, to convert to average annual daily cyclists. This factor was obtained by comparing March 2013 count data to annual count 2013 data from six Auckland automated cycle count locations[7].

The annualised 2013 demand sets were then factored up to account for land use growth from Auckland Council's most recent land use forecasts (Scenario I11). This factoring has been carried out on a zonal basis, to ensure the growth has an appropriate geographic distribution. For the morning peak demand set, the growth applied to each origin-destination pair is the average of the forecast population growth for the origin zone and the forecast employment growth for the destination zone. The reverse has been applied to the evening peak demand set.

The fixed recreational trips documented in Section 4.1 have been factored up at this stage, by the forecast regional population growth.

This process of factoring base model demands has in effect developed future 'Do Nothing' demand sets that represent a hypothetical future scenario where there is no improvement in cycle infrastructure compared to the March 2013 network.

Some manual corrections have been made to the resulting future 'Do Nothing' demand sets, most notably in the Whenuapai area. This area had a large number of cycle trips in the 2013 base model, due to a high cycle to work mode share among employees of the Whenuapai Airforce Base. This semi-rural area is currently being urbanised however, with very high land use growth predicted. If the high cycle mode share was factored up by the high land use growth, disproportionately high cyclist demands would result. Existing cycle demands within the Whenuapai area have been zeroed accordingly.

The 'Do Nothing' demands consider the background growth in cyclist numbers through population and employment growth, and inherently assume that cycle mode share will remain the same; that is, they

[7] Lagoon Drive, SH20 cycleway at Dominion Road, Upper Harbour Bridge, Tamaki Drive, Northwestern Cycleway at Te Atatu and Northwestern Cycleway at Kingsland

do not reflect any increased cycle trips due to people choosing to change mode, particularly where new infrastructure is introduced. Taking cross-harbour trips as an example, the March 2013 demand matrices include relatively few cross-harbour cycling trips, as currently these trips are difficult, being via the Upper Harbour Bridge or requiring a transfer to ferry. Upon completion of SkyPath however, there will clearly be some existing cross-harbour trips by non-cycling modes converting to cycling trips. It would not be appropriate to factor up the existing cross-harbour cycling trips to represent this mode shift, as their distributions would likely differ significantly. These mode shift trips have been added in to the 'Do Nothing' forecast trips, and the methodology used to estimate these trips is documented below.

5.3 Accounting for Mode Shift

5.3.1 General Methodology

The methodology for representing future mode shift resulting from investment in cycle infrastructure has followed the process summarised in Equation 2:

Equation 2: Future Mode Shift Calculation

Mode shift in response to cycle infrastructure investment = 'Potential Cycle Trips' from ART model x Distance Conversion Factor, based on distance between O-D pairs x Improvement Conversion Factor, based on improvements to cycle network between O-D pairs

Each term is addressed in turn below.

5.3.2 Potential Cycle Trip Matrices

Future 'potential cycle trip' matrices have been developed by summing forecast person trips from each of the ART forecast models. The ART model is based on seven trip types however, and not all of these are suitable for conversion to cycle trips (such as heavy vehicle trips). Accordingly, only some trip types have been included in the process. Table 4 documents those trips types that have been included within this process, for the 2026 morning peak period. The same proportions have been applied to the evening peak period, but the trip totals differ.

Table 4: Trip Types Included in Pool of 'Potential Cycle Trips', 2026 Morning Peak Period

Trip Types	Total Trips	Proportion Included	Trips Included
Home-based work trips	221,500 car trips 59,400 public transport trips	100% of car trips 100% of public transport trips	280,900 trips
Home-based education trips	96,500 car trips 28,500 public transport trips	1000% of car trips 100% of public transport trips	125,000 trips
Home-based shopping trips	28,300 car trips 5,500 public transport trips	25% of car trips 100% of public transport trips	12,600 trips
Home-based other trips	198,500 car trips 11,600 public transport trips	25% of car trips 100% of public transport trips	61,200 trips
Employer's business trips	82,400 car trips 2,500 public transport trips	0% of car trips 100% of public transport trips	2,500 trips

Table 4: Trip Types Included in Pool of 'Potential Cycle Trips', 2026 Morning Peak Period

Trip Types	Total Trips	Proportion Included	Trips Included
Non home-based other trips	102,400 car trips 5,600 public transport trips	0% of car trips 100% of public transport trips	5,600 trips
Medium/heavy commercial vehicle trips	35,300 heavy commercial vehicle trips	No trips	0 trips
Totals	**878,000 trips**		**487,700 trips (56% of all trips)**

While trips associated with employers' business may be an area where short trips could be made by bicycle, the likely change is not considered to be significant compared to the other types of trips and therefore for this modelling has not been included. Similarly, cargo bicycles may replace certain heavy vehicle movements given appropriate future conditions, but this has been assumed not to be significantly so.

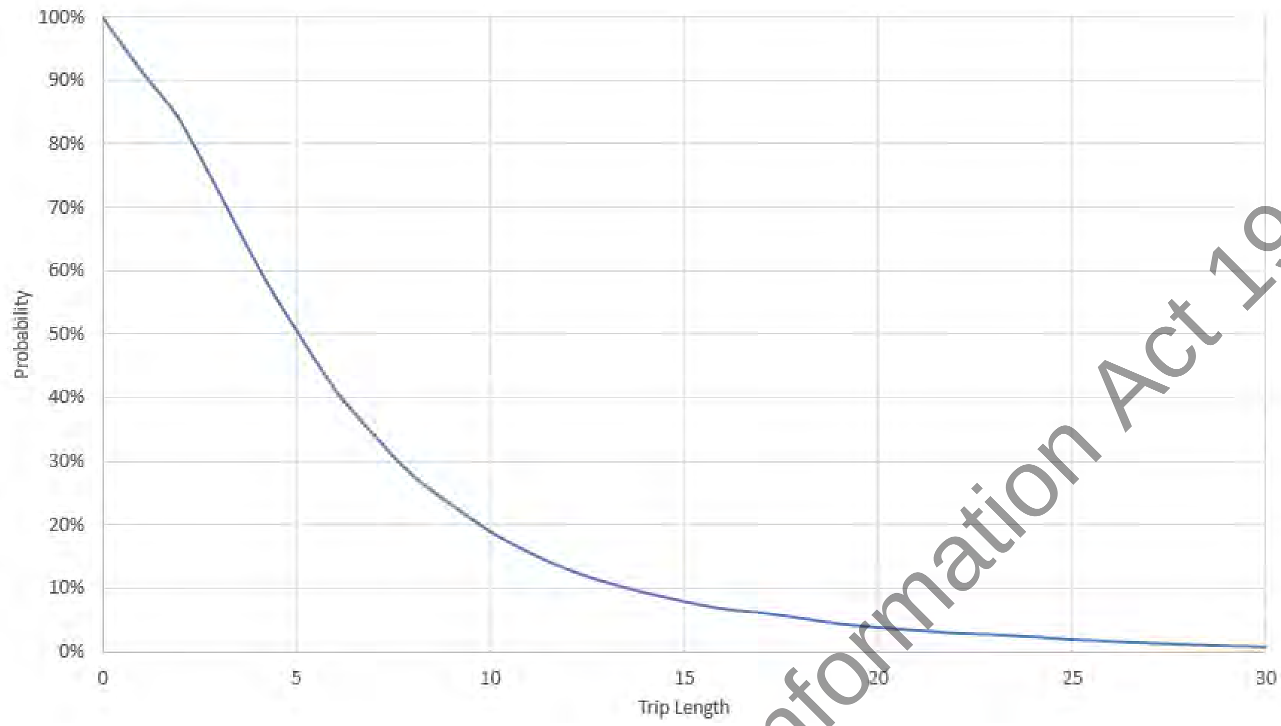
The resulting future morning and evening period trip matrices include most of the car and public transport person trips within the modelled area that might potentially convert to cycling. Their likelihood of shifting to bicycle depends however on a number of factors, most significantly the distance between each origin and destination, and the provision of cycle infrastructure between each origin and destination.

5.3.3 Distance Conversion Factor

As noted above, the likelihood of each potential trip being converted to cycling will depend on the distance between each origin-destination pair, with shorter trips being more conducive to cycling than longer distance trips. To account for this, a trip length probability function has been applied to the future potential cycle trips.

To estimate this underlying function, the census data trip length distribution has been converted to a probability function, which is best illustrated by way of an example. Taking the census cycle trip length distribution, 84% of cycle trips are of 2 km length or longer. It has been assumed then that 84% of trips of length 2 km might potentially be converted to bicycle. Similarly, 72% of cycle trips are 3 km or longer, so by extension a 72% conversion factor has been applied to each trip of 3 km length. This function is shown in Figure 3.

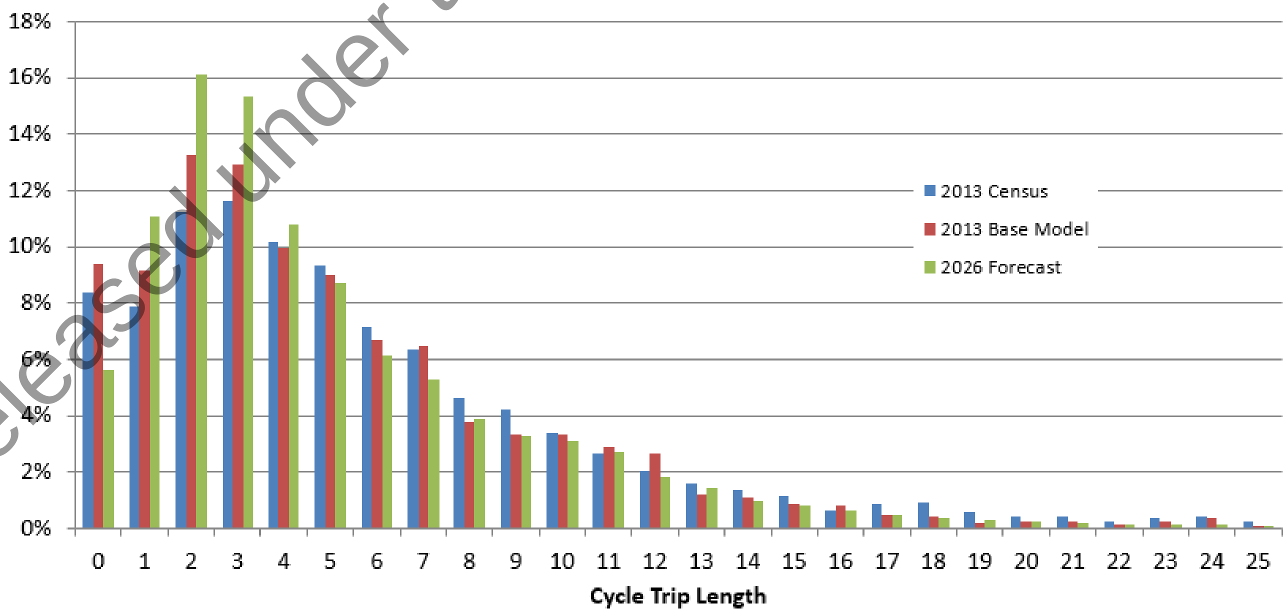
Figure 3: Trip Length Probability Function



This process has been applied to the 'potential trip' matrices, based on the distance between each origin-destination pair within the modelled network. This has in effect dampened down trips between more distant pairs of zones, while trips between two very close zones have remained relatively unchanged.

As a sensibility check, the final 2026 modelled morning period cycle trip length distribution has been plotted alongside the 2013 census data in Figure 4 below. The comparison shows that the forecast 2026 trip length distribution follows the census data distribution appropriately.

Figure 4: Cycle Trip Length Distribution



5.3.4 Improvement Conversion Factor

An improvement conversion factor has been applied to the future potential cycle trip matrices. This acknowledges that conversion from motorised modes to bicycle will only occur in areas where cycle infrastructure is improved, either in terms of reduced cycle distance or improved Relative Attractiveness. This conversion factor has been based on demand elasticity principles, and has been determined according to Equation 3.

Equation 3: Improvement Conversion Factor

$$\text{Improvement Conversion Factor} = \frac{\text{Change in distance between O-D pair (due to infrastructure improvements)}}{\text{Distance between O-D pair}} \times \text{Distance Elasticity} + \frac{\text{Change in average Relative Attractiveness between O-D pair (due to infrastructure improvements)}}{\text{Average Relative Attractiveness between O-D pair}} \times \text{Relative Attractiveness Elasticity}$$

Elasticity factors of 0.35 have been applied in relation to distance changes, and 0.65 in terms of Relative Attractiveness changes. These factors were calibrated during the initial 2014 model build to result in forecast demands that align with international research and result in a sensible long term mode share should the full Auckland Cycle Network (ACN) be built. They were then recalibrated in 2016 against post-implementation data from several major cycleway projects. This calibration process is documented further in Section 5.3.5.

As a simple example, the route between a particular origin-destination pair may be 10 km long via a minor arterial road without cycle infrastructure in 2013; this would correspond to a Relative Attractiveness of 12 if applying the Relative Attractiveness scale documented in Section 3. If a new dedicated cycleway of Relative Attractiveness 15 was built along this route, additionally shortening the distance to 8 km, the resulting Improvement Conversion Factor would be 0.23, as shown below:

Equation 4: Example Improvement Conversion Factor

$$\begin{aligned}\text{Factor} &= (10-8)/10 \times 0.35 + (15-12)/12 \times 0.65 \\ &= 0.23\end{aligned}$$

Conversely, an origin-destination pair with an unimproved route (in terms of both distance and Relative Attractiveness) would be assigned an Improvement Conversion Factor of zero.

In reality, trips between any given origin-destination pair will generally assign via a series of different roads with varying levels of cycle infrastructure, and a weighted average of the Relative Attractiveness along the route has been used to reflect this. This means that most origin-destination pairs are only partially affected by improvements by a given project. As a result, most conversion factors applied to the model are very low, typically in the order of 0.01 to 0.05.

This process has been applied to each origin-destination pair, resulting in non-cycle trips from the ART model being converted to cycle trips only if that trip has been improved by new or improved infrastructure. Further, the level of conversion is proportional to the degree of improvement on that route (in terms of shortened distance, improved route attractiveness, or both).

5.3.5 Initial Development of Elasticity Factors

As documented above, elasticity factors of 0.35 and 0.65 have been adopted, with regard to changes in route distance and Relative Attractiveness, respectively. The higher latter rate acknowledges that improvements in route attractiveness (eg cycle route safety) are likely to have a greater impact on cyclist demands than reductions in cycle distances. This reflects cyclists' priorities for more safe cycle routes[8], and aligns with the fundamental premise of the model network build, which assumes cyclists are willing to cycle somewhat greater distances in order to use a more favourable route.

The elasticity factors were originally developed for the evaluation of the Auckland Urban Cycleways Programme (UCP) in 2015, and were set at 0.35 for distance and 0.75 for Relative Attractiveness. These values were calibrated to result in sensible cycle demand predictions, and this calibration is documented in the following section. It should be recognised that the current elasticity factor for Relative Attractiveness of 0.65 results in more conservative demand estimates than those documented below from the 2015 process. It should also be appreciated that the international experience referenced below may no longer represent the most up to date research, as it did during the model's early development in 2015.

The first means of determining values for the elasticity factors compared the modelled effects of the Auckland UCP to international case studies on the effects of cycle infrastructure improvements on cycle mode share. Studies reviewed have included:

- Research from 35 US cities with populations over 250,000, which concluded that every mile of on road bicycle lane per square mile of city corresponds to a 1% increase in cycle mode share among commuters[9]
- In Montreal, improved cycle infrastructure investment including 67 km of separated cycle facilities has been matched by a 35 to 40% increase in cycle use between 2008 and 2010[10]
- The Minneapolis Greenway project, which is an 8.8 km shared path on a former rail corridor linking employment and residential areas, resulted in an 89% increase in cycle trips among residents living within three miles, and a 33% increase among those living within six miles[11]
- Sydney recorded a 132% increase in the number of cycling trips in the city centre, between 2010 and 2014, led by separated cycleway and shared path infrastructure improvements.

Table 5 below compares the outputs from the 2026 Auckland UCP model (relative to a 2026 Reference Case without the Auckland UCP) with the relevant international study.

[8] Auckland Transport Cycling Research, 2013 https://at.govt.nz/media/981846/AT-Active-Modes-Research-Report-June-2013.pdf
[9] Dill, J and Carr, T. Bicycle Commuting and Facilities in Major US Cities: If You Build Them, Commuters Will Use Them – Another Look. Portland State University. 2003
[10] http://old.cycleto.ca/protected-bike-lanes/safety-ridership
[11] http://www.prnewswire.com/news-releases/study-shows-bicycle-friendly-city-infrastructure-in-us-significantly-increases-cycling-to-work-by-residents-which-can-improve-health-of-locals-281451471.html

Table 5: Comparison of Model Outputs and International Experience

Measure	Modelled Outcome from 2026 Auckland UCP Model	International Comparison
Auckland cycle to work mode share	0.32% increase predicted as a result of the 28 km of Project infrastructure	0.16% increase expected if applying research from 35 US cities where a 1% increase in mode share was seen for every mile of bicycle lane per square mile of city. This research is thought to underestimate the effects of the Project as it: 1) Relates to on-road cycle lanes, whereas the Project generally consists of facilities separated from traffic 2) Represents the average effects of cycle infrastructure across an urban area, whereas the Project is focussed on the CBD, where a greater effect on mode share per mile of bicycle facility can be expected.
Increases in cycle trips across Auckland urban area	16% increase in cycle trips across the Auckland urban area predicted due to the 28 km of cycle infrastructure assessed	35 to 40% increase in cycle trips in Montreal, due to significant investment including 67 km of separated cycle facilities
Local increases in cycle trips	51% increase in cycle trips predicted among origin-destination pairs with improved routes (generally within 3 km of infrastructure improvements)	89% increase in cycle trips among those living with three miles of Greenway project, Minneapolis; 33% increase among those living within six miles
City centre increases in cycle trips	51% increase in cycle trips to/from the city centre predicted	132% increase in cycle trips within Sydney city centre

The second means of determining values for the elasticity factors involved developing a hypothetical set of 2026 cycle demands that represent a scenario where a complete cycle network has been constructed Auckland wide. This has been approximated by converting all urban arterials into routes with separated cycle facilities, and it represents a network similar to a completed ACN. The resulting ACN demand set resulted in an Auckland wide cycle mode share for commute to work trips of 6.5% (compared with 1.2% in 2013[12]). This is considered an appropriate, if conservative, estimate of Auckland's long term cycling potential, should a complete network be built (see comparator cities, following section5.3.6).

Finally, the model outputs were compared to the forecast reference case 2026 model demands across SkyPath documented in the Transportation Assessment Report for this project[13]. This document gives an annual demand for SkyPath of 1.385 million trips in its fifth year of operation, counting both cyclists and pedestrians, corresponding to a daily average of 3,800 trips. Many of these trips are predicted to

[12] New Zealand Census data
[13] Traffic Design Group. SkyPath Transport Assessment Report. October 2014

be outside the commuter peaks however, and the SkyPath Patronage Research[14] upon which SkyPath demands are based on estimates that 60% of weekly SkyPath use will be on weekends, with weekday making up 8% each. This 8% factor has been applied to result in a weekday daily demand on SkyPath of 2,130 trips. The SkyPath Transportation Assessment goes on to estimate that 85% of SkyPath users will be cyclists, giving a total weekday daily cycle demand of 1,810 trips.

The elasticity factors assumed in the model have resulted in modelled 2026 demands on SkyPath of 1,840 weekday daily cyclists[15], which agrees well with the estimated 1,810 daily cyclists derived from the SkyPath Transportation Assessment.

A discussion on elasticity factors can be found in the US National Cooperative Highway Research Program's "Estimating Bicycling and Walking for Planning and Project Development: A Guidebook". This study refers to distance elasticities for cycling trips of between 0.41 and 0.75. These elasticities are higher than the 0.35 applied to the Auckland Cycle Model, and would result in significantly greater forecast demands if they were applied. The Guidebook offers no suitable elasticities for application to route quality (ie Relative Attractiveness).

The elasticity factors and overall demand process have resulted in a maximum conversion of non-bicycle mode trips to cycling trips of 29%. This has been achieved in the case of closely spaced origin-destination pairs with the greatest improvement in distance and infrastructure. This 'trader factor' agrees well with the Christchurch Strategic Cycle Model[16], where a factor of 30% was applied, following a review of international stated preference literature quoting factors between 9% and 80%.

5.3.6 Network Effects

It is important to recognise that the demand forecast process documented above is linear. For a given cycle infrastructure improvement, say a cycleway, the demand process will generate a number of new cycle trips, say x. For a second piece of connecting infrastructure, the demand process may generate y new trips and if the two cycleways are assessed collectively, the demand process will generate x+y new trips.

This differs from expectations however, where the effects of cycle network investment are thought to be non-linear: the demand responses from incremental improvements to the cycle network are expected to accelerate as the network approaches completion. This 'network effect' phenomenon is related to the 'safety in numbers' and 'critical mass' effects, where increasing numbers of visible cyclists encourage more users to take up cycling, and is documented by Macmillan et al (2014)[17].

As such, provision of a complete cycle network would likely generate more new trips than the sum of its individual parts, and the cycle demand elasticities are unlikely to be linear. Recognising this, a 'Network

[14] Angus & Associates. Patronage Research for the Auckland Harbour Bridge Pathway Project. June 2014
[15] Applying a weekday Annual Daily Traffic (ADT) factor of 2.8 to the morning and evening peak period demands (summed), based on automated cycle count data across six Auckland locations
[16] Quality Transport Planning; Christchurch Strategic Cycle Model Background Report, August 2012
[17] The Societal Costs and Benefits of Commuter Bicycling: Simulating the Effects of Specific Policies Using System Dynamics Modelling; *Macmillan, Connor, Witten, Kearns, Rees and Woodward*; April 2014

Factor' has been applied to the demand elasticities documented in Section 5.3.4. This Network Factor has been developed by:

- Assessing the average Relative Attractiveness from each zone to all other zones with a cycle-able distance of 5 km
- Where the above average Relative Attractiveness is 12 or less, the Network Factor has been set at 1.0 (ie. There are no network effects at this level of network development)
- Where the above average Relative Attractiveness is 15 or more, the Network Factor has been set at 2.0 (ie. Where all possible trips within a 5 km trip length from a given zone can be carried out on 'best practice' cycle infrastructure, 'network effects' are assumed to apply to that zone)
- For average Relative Attractiveness ratings of 12 to 15, a sliding scale has been used.

In practice, the above process has no effect on forecast cycle demands when applied to Auckland's existing cycle network, as there are no areas of Auckland where the average Relative Attractiveness threshold of 12 to 15 is met. That is to say, the existing demand response to cycle infrastructure investment in Auckland continues to be linear. Similarly, when evaluating individual future cycle investment projects, such as SkyPath or the Glen Innes to Tamaki Drive cycleway, the Network Factor has no effect. Only when evaluating a significant long term investment programme such as the completed Auckland Cycle Network, does the Network Factor have an impact.

It has not been possible to calibrate the Network Factor process, as this is not a phenomenon currently experienced on Auckland's existing cycle network, and nor is it a process that has been well documented internationally. However, when assessing a 'complete network' of 'best practice' cycle infrastructure across the extent of Auckland (eg separated cycle infrastructure on all Auckland arterial roads), the model predicts an approximate 14% mode share for cycle trips to work. In terms of comparator cities against which this forecast may be benchmarked:

- Christchurch has an existing cycle to work mode share of 7%[18], despite having a far from complete network
- Portland has a comparable geography, climate and land use density and has a 6% cycle mode share, with a target mode share of 25%[19]
- Munich and Tokyo have comparable climates, partially complete cycle networks, and 17% and 14% mode shares[20], respectively.

5.4 2016 Forecast Model Calibration

The initial development of the elasticity factors applied in the Auckland Cycle Model were developed in 2015, but subsequent modifications have been made to the process to better align the model's performance with observed trends. Chiefly among these, a model calibration process was carried out in February 2017[21].

[18] Sustainable Cities; Benchmarking Cycling and Walking in Six New Zealand Cities, Pilot Study; 2015
[19] Portland 2035 Transportation System Plan; May 2018
[20] Auckland Transport; Auckland Cycling Programme Business Case; 2017
[21] Michael Jongeneel; Evaluating the Auckland Cycle Model; February 2017

In the three years since the network represented by the 2013 base model, a significant investment had been made in cycle infrastructure in Auckland to the end of 2016, including the:

- Grafton Gully and Beach Road cycleways
- Westhaven Promenade
- Nelson Street cycleway and Te Ara I Whiti (LightPath)
- Carlton Gore Road protected/buffered cycle lanes
- Improvements to the existing Northwestern cycleway
- Upper Harbour Drive buffered cycle lanes
- Mt Roskill Safe Routes
- Dominion Road parallel cycle route
- Quay Street cycleway.

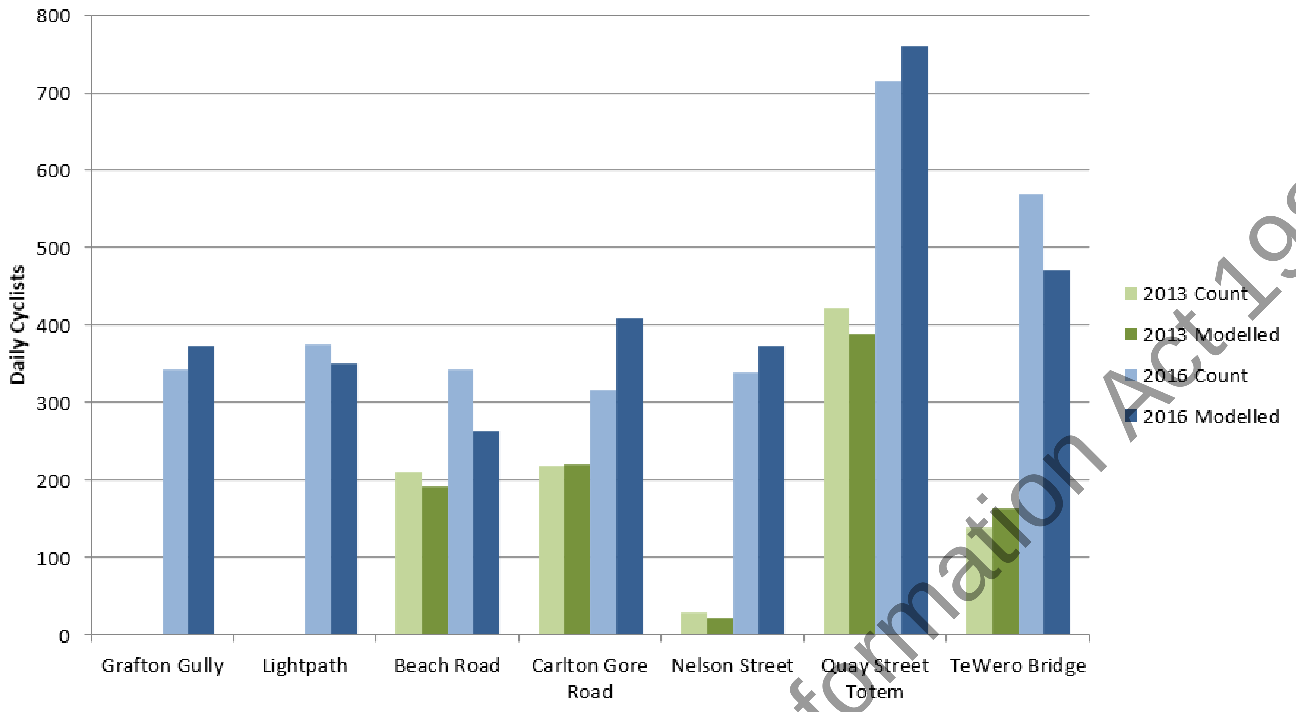
The calibration process allowed outputs from the 2016 Auckland Cycle Model to be compared to post implementation count data on the above routes, and others. In total, data was available from 21 automated cycle count sites across Auckland, providing 41 separate data points with which to compare. The comparison sites included a mixture of new routes, improved routes, and routes that had remain unchanged.

As a result of the forecast calibration process, three adjustments were made to the model process to better align the model forecasts with the observed trends:

- The Relative Attractiveness elasticity was reduced from 0.75 to 0.65
- Evening peak period growth was dampened down by 10%
- A new Relative Attractiveness category was applied to routes that have an exceptionally high appeal to cyclists, such as LightPath.

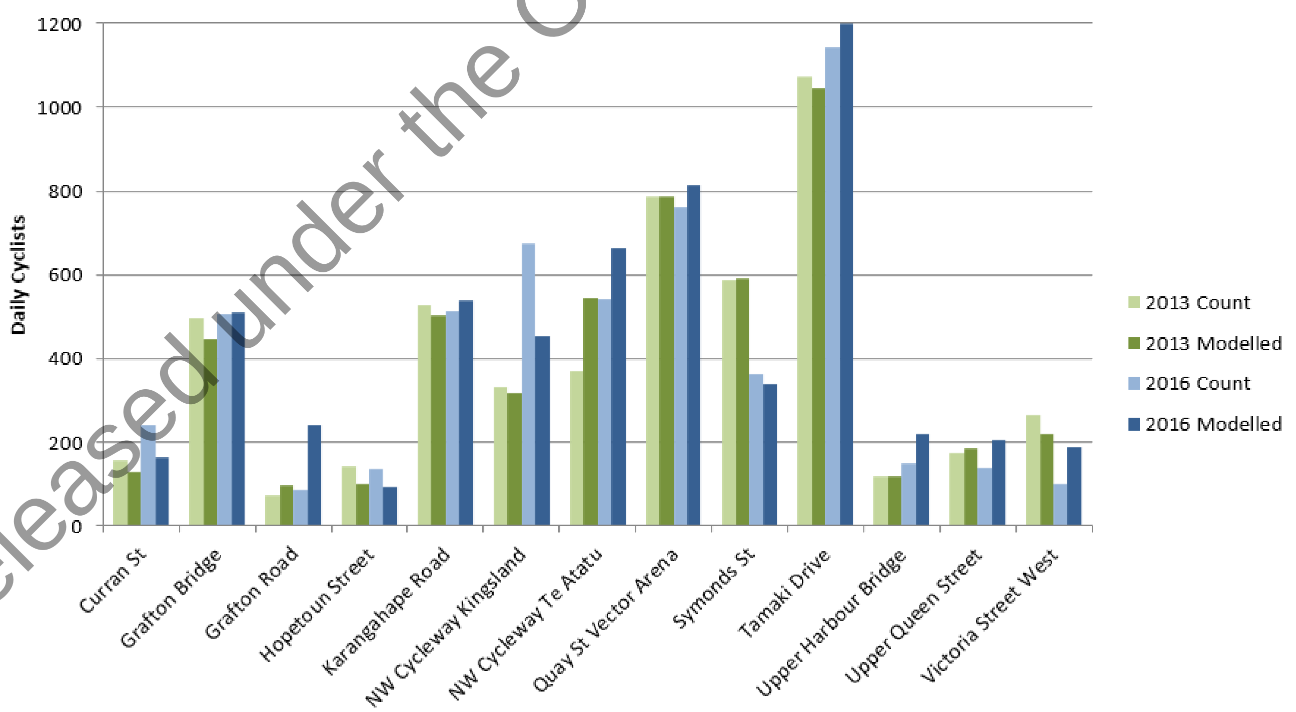
Figure 5 and Figure 6 show comparisons of the Auckland Cycle Model's 2016 forecasts (after the above adjustments were made) against the observed 2016 data, for new/improved routes and unimproved routes, respectively. A comparison of 2013 observed and modelled cyclists is also shown for completeness.

Figure 5: Observed vs Modelled Daily Cyclists, New and Improved Routes



The above comparison shows how daily cycle demands on Auckland's improved cycle routes had increased significantly between 2013 and 2016, with for example 300 more daily cyclists recorded on Nelson Street after the completion of stage 1 of this facility. The model forecasts generally agree well with these increases. In the case of the new routes, again the model agrees well with the observed data.

Figure 6: Observed vs Modelled Daily Cyclists, Unimproved Routes



In the case of the above routes that were not improved between 2013 and 2016, again the model generally agrees well with the observed data. Notably in the case of Symonds Street where the construction of the parallel Grafton Gully cycleway has resulted in a 38% reduction in daily cyclists, the model has produced a comparable reduction.

A final stage in the 2017 model calibration was to compare the Auckland Cycle Model's 2016 forecasts to the two alternative existing methods of forecasting cycle demands. This comparison is summarised below.

Table 6: Comparison of 2016 Cycle Demand Predictions – Three Methods (two-way, average annual daily cyclists)

Route	Observed Cyclists (2016)	2016 Auckland Cycle Model		Research Report 340		EEM Simplified Procedures 11	
		Cyclists	Error	Cyclists	Error	Cyclists	Error
Beach Road	343	263	-23%	392	+14%	1,158	+237%
Carlton Gore Road	317	410	+29%	423	+33%	1,067	+237%
Grafton Gully	344	373	+8%	465	+35%	1,660	+383%
Nelson Street	340	373	+10%	64	-81%	1,535	+352%
LightPath	375	351	-6%	248	-34%	1,594	+325%
Quay Street	715	761	-6%	628	-12%	956	+34%
Average Error		**±14%**		**±35%**		**±261%**	

6 MODEL LIMITATIONS

The Auckland Cycle Model represents a broad range of cycle trip types including commuter trips, trips to education (schools and higher education), shopping trips and 'other trips'. This final trip type category in particular will include some reasonable number of future recreational trips. However, the model is unable to represent any significant future change in recreational use on key routes, such as those that may be specifically drawn to future infrastructure such as SeaPath, SkyPath or improvements to Tamaki Drive. While the daily effect of these recreational trips can be estimated by using an appropriate daily cyclist factor (refer Section 3), the routes used by these recreational cyclists are unable to be accurately forecast.

Similarly, while the fixed recreational routes that have been manually added to the 2013 base model have been factored up to reflect forecast population growth, the model does not reassign these trips to new routes following infrastructure change.

SkyPath in particular is expected to attract a very high proportion of both recreational and tourist trips, with many of these trips taking place outside of the commuter peak periods. As a result, care must be taken when factoring the commuter peak model outputs to generate estimates of daily demands on this facility.

The model includes background growth in cyclist numbers reflecting both forecast population growth and also future infrastructure improvements. It does not however predict other factors that may influence road users' future travel choices, such increasing general traffic congestion, fuel costs, road pricing, or the impact of increasing uptake in electric bicycles.

The mode shift component of forecast cycle trips within the model are developed using person-trips from the ART model. The zones within the ART model are relatively large and many short trips such as trips to primary schools and to local shops will be intra-zonal trips in this regional model. These short, intra-zonal trips will not be accurately represented within the Auckland Cycle Model, and consideration should be given to manually evaluating these trips for projects where the focus is short trips to schools or local destinations.

The ART model version on which the Auckland Cycle Model is based does not exclusively consider trips to park and ride facilities; as a result, the current version of the Auckland Cycle Model will also exclude possible short cycle trips to public transport. It should be noted however that a recent update to the ART model (now the Macro Strategic Model, MSM) does incorporate car trips to park and ride facilities. Should the Auckland Cycle Model be updated to reflect the MSM's outputs, it too will incorporate these trips accordingly (at least in the case where the public transport facility has a park and ride component).

APPENDIX A matrix estimation

Figure 7: Matrix Estimation Count Locations

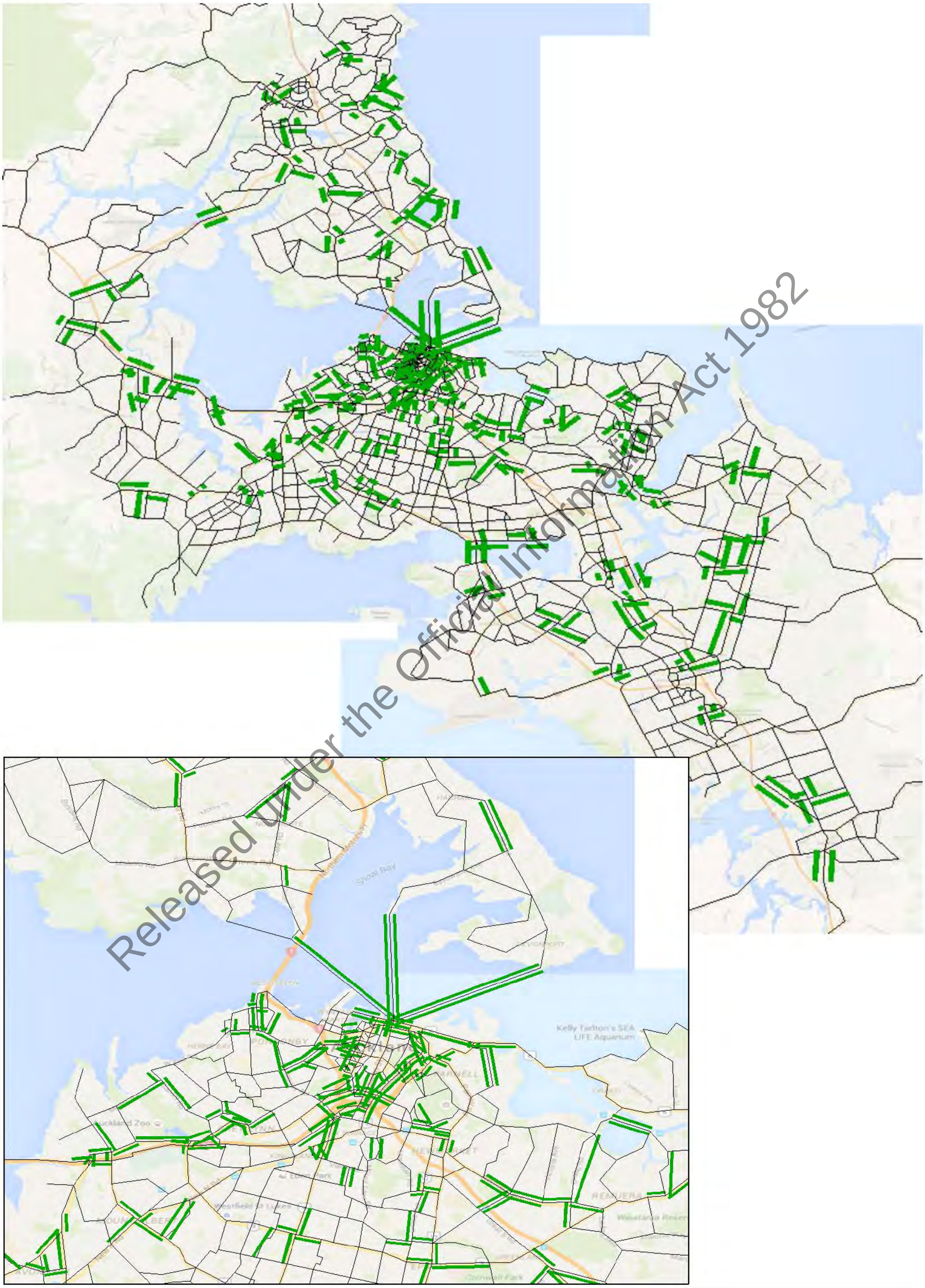
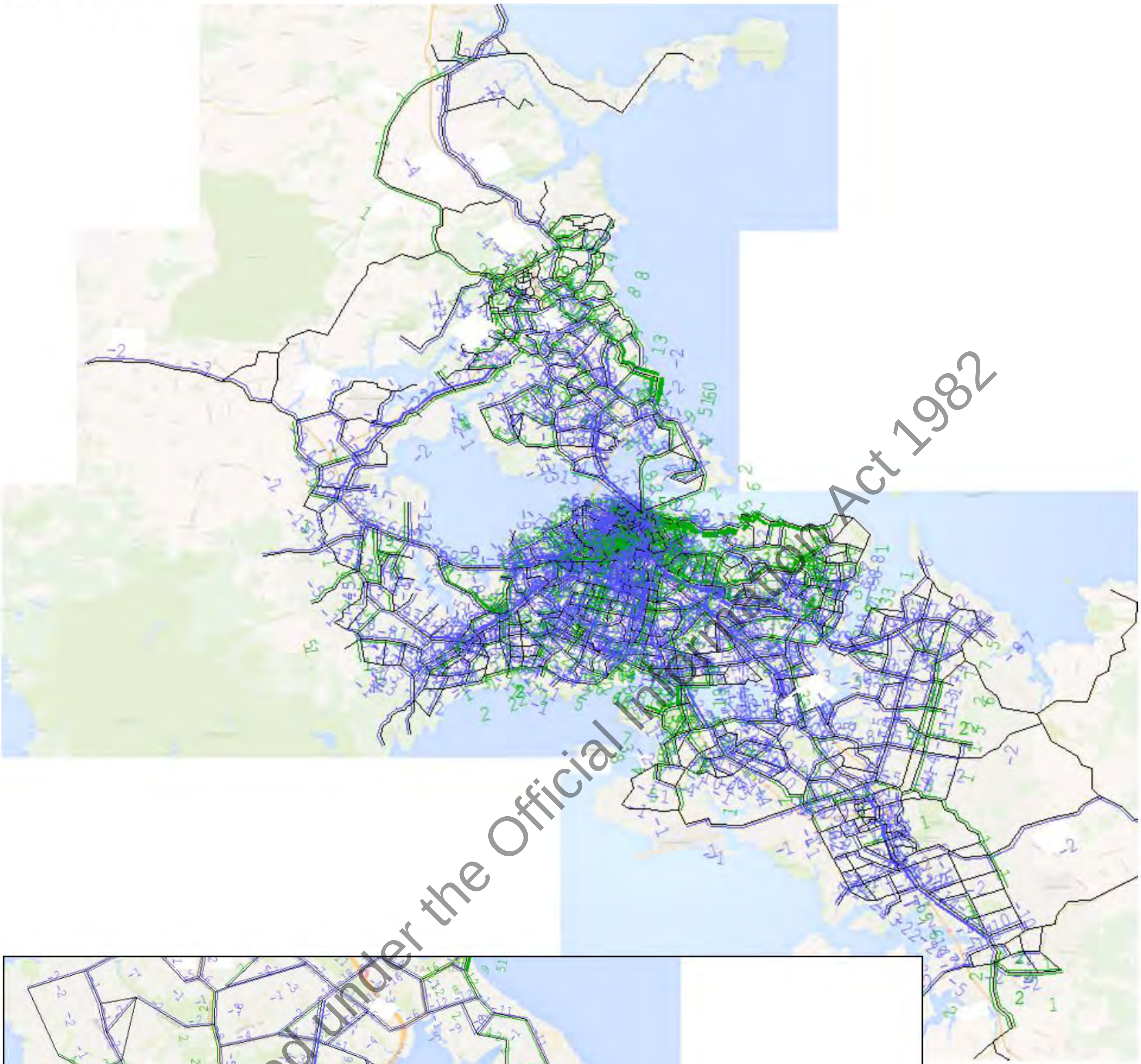


Figure 8: Prior vs Post Estimation Matrices, 2013 Morning Peak Period



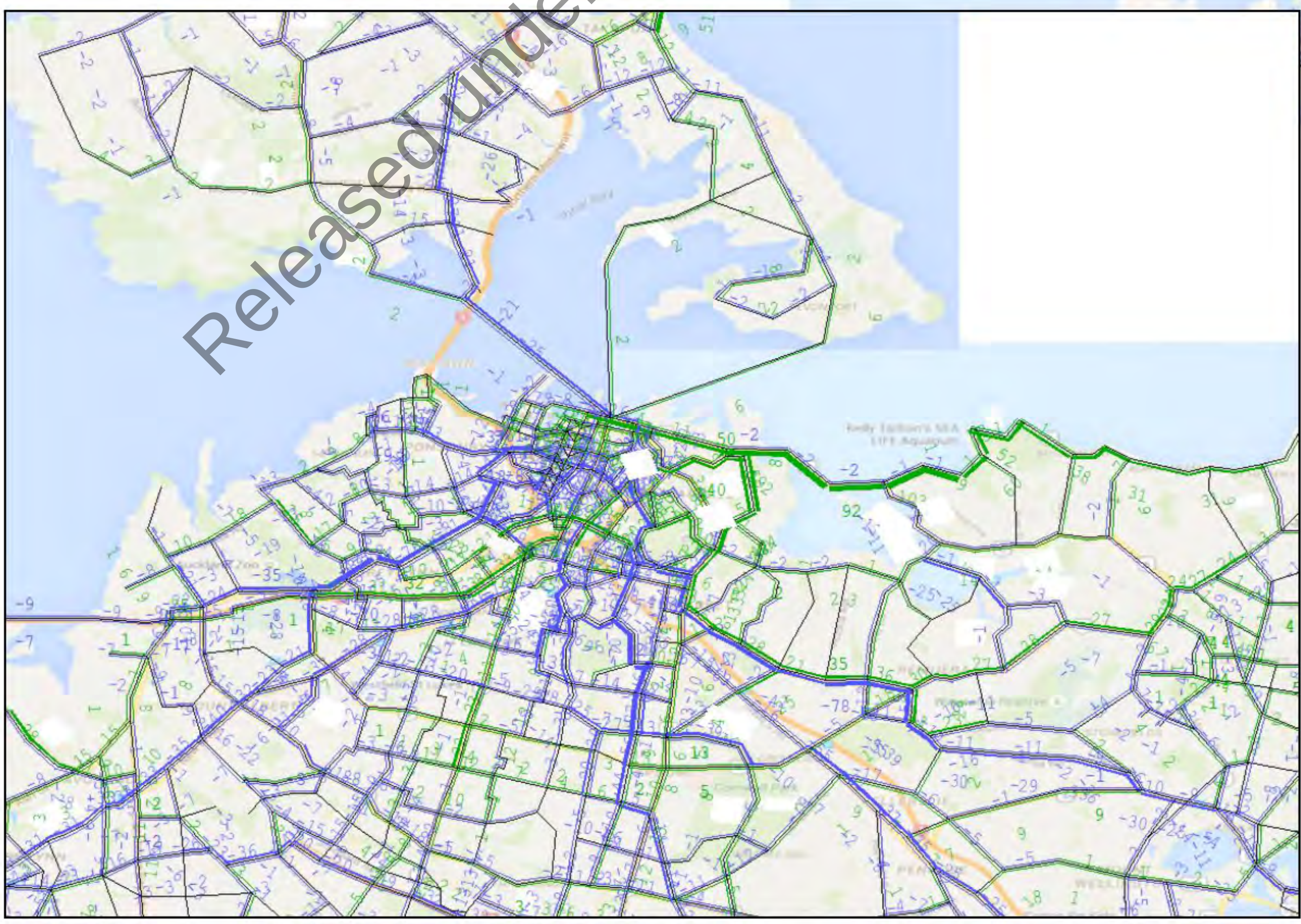


Figure 9: Prior vs Post Estimation Matrices, 2013 Evening Peak Period

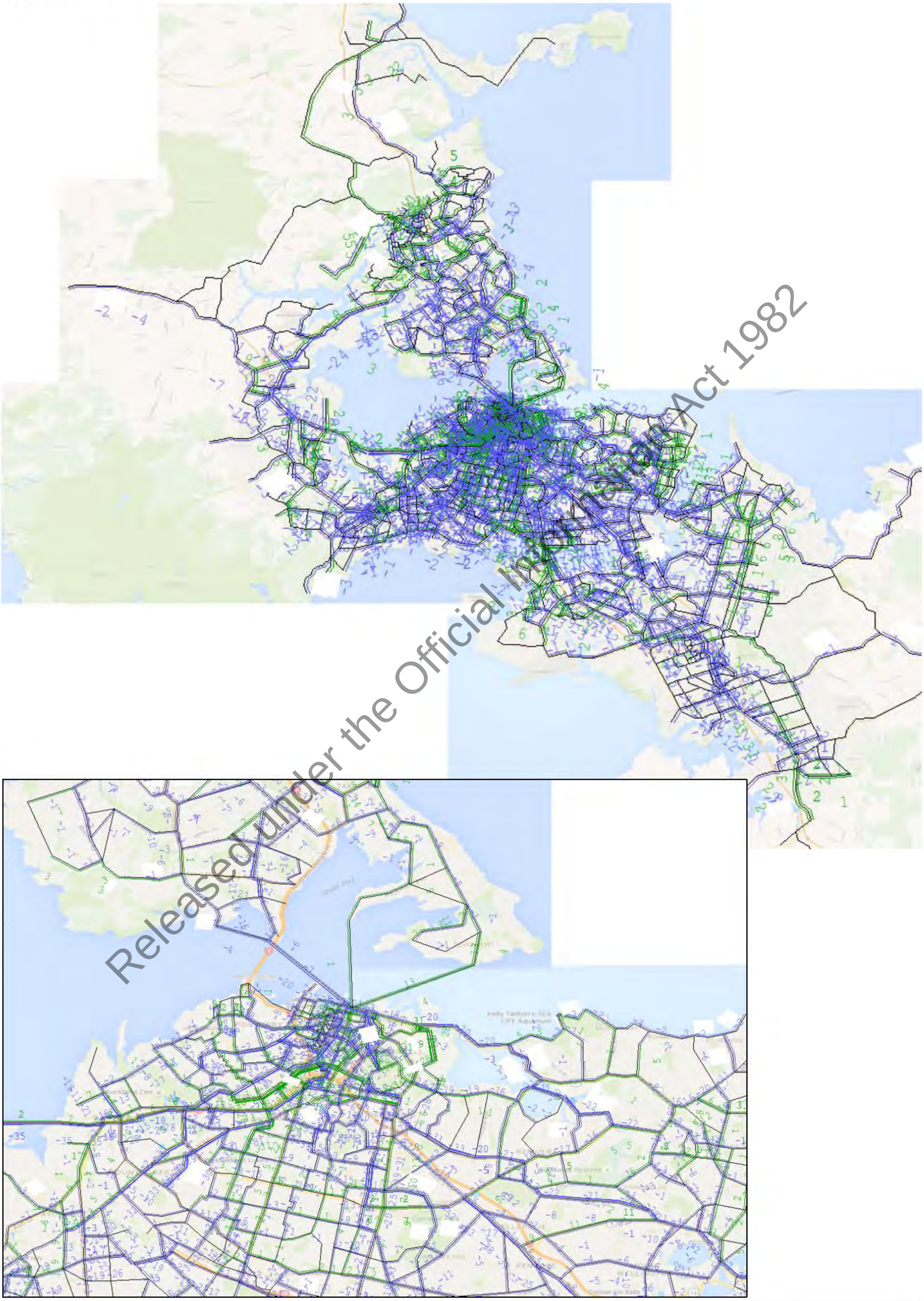


Figure 10: Prior vs Post Estimation Trip Length Distribution, 2013 Evening Peak Period

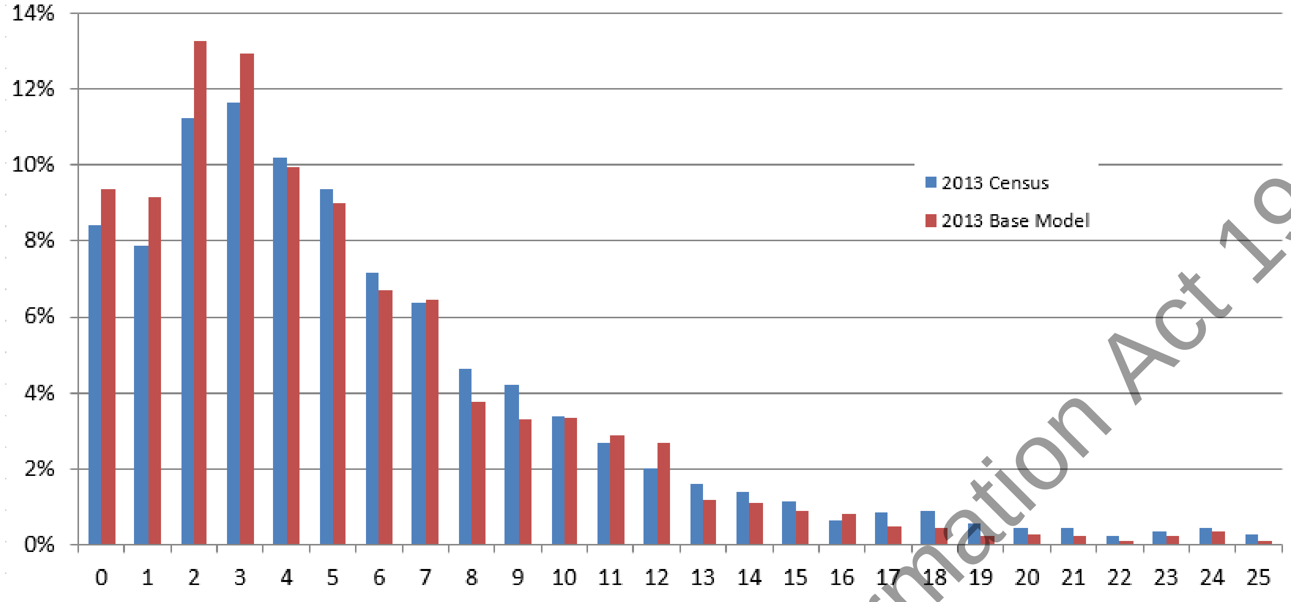


Table 7: 2013 Morning Peak Pre-Estimation Matrix Sectors

	North	West	Central	CBD	East	South
North	992	9	54	42	1	9
West	40	304	169	71	7	5
Central	9	46	1,611	722	36	83
CBD	0	7	31	36	0	0
East	0	0	49	11	137	45
South	0	2	75	10	28	215

Table 8: 2013 Morning Peak Post-Estimation Matrix Sectors

	North	West	Central	CBD	East	South
North	1,043	10	42	47	0	3
West	13	281	143	43	1	0
Central	12	49	1,530	693	27	70
CBD	1	12	31	62	0	0
East	0	0	30	5	127	45
South	0	0	95	5	16	209

Table 9: 2013 Morning Peak Estimation Sector Changes

	North	West	Central	CBD	East	South
North	51	1	-12	6	-1	-6
West	-27	-23	-26	-28	-6	-4
Central	3	3	-81	-29	-9	-13
CBD	1	5	-1	26	0	0
East	0	0	-19	-6	-10	-1
South	0	-2	20	-5	-12	-6

Table 10: 2013 Evening Peak Pre-Estimation Matrix Sectors

	North	West	Central	CBD	East	South
North	565	37	9	0	0	0
West	8	284	43	6	0	2
Central	50	158	1,283	29	45	70
CBD	39	66	674	34	10	9
East	1	6	34	0	128	26
South	8	4	78	0	42	200

Table 11: 2013 Evening Peak Post-Estimation Matrix Sectors

	North	West	Central	CBD	East	South
North	546	11	9	1	0	0
West	14	288	39	18	0	1
Central	41	144	1,255	60	27	93
CBD	47	34	585	56	1	2
East	0	4	16	0	123	17
South	4	0	65	0	38	197

Table 12: 2013 Evening Peak Estimation Sector Changes

	North	West	Central	CBD	East	South
North	-20	-26	0	0	0	0
West	6	4	-4	12	0	-1
Central	-9	-14	-28	30	-18	23
CBD	8	-32	-89	23	-9	-7
East	-1	-3	-18	0	-5	-9
South	-4	-4	-12	0	-4	-3

APPENDIX B Model validation

Figure 11: Base Model Validation Count Locations