Sensitivity: General

Beca

Penlink Toll Modelling Report

Prepared for Waka Kotahi NZ Transport Agency - Auckland
Prepared by Beca Limited

8 September 2021

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Revision History

Revision Nº	Prepared By	Description	Date
1.0	Caleb Deverell	First DRAFT report for Client comments	28/06/21
2.0	Caleb Deverell	Draft following Client and peer review comments	23/08/21
3.0	Caleb Deverell	Final Report	08/09/21

Document Acceptance

Action	Name	Signed	Date
Prepared by	Caleb Deverell		08/09/21
Reviewed by	Nyan Aung Lin		08/09/21
Approved by	Andrew Murray		08/09/21
on behalf of	Beca Limited		

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Executive Summary

Purpose and Scope

This report describes an analysis of the transport system effects of tolling on the proposed Penlink corridor between Whangaparaoa Peninsula and State Highway 1 in Auckland. The purpose of this work is to provide information to Waka Kotahi to inform their decision making on any tolling strategy for Penlink. The base case for this assessment assumes an un-tolled Penlink scenario, and as such this assessment addresses the specific impact of tolling, and not the effects of constructing Penlink itself.

This analysis is based on existing traffic models (albeit refined and updated to current conditions) and driver willingness to pay (WtP) parameters from other studies. Detailed market research into WtP has not been undertaken specifically for this work, however the effects of uncertainties in WtP and other key inputs and assumptions have been estimated via sensitivity tests and risk-profiling. While this work provides estimates of network demands and revenue suitable for network planning, the revenue estimates are not considered 'investment grade' such as might be required for private-sector investment.

The Penlink project is currently in the planning and design phase, with completion expected in late 2025. Tolling the corridor influences the level of service of the corridor and can therefore influence the design requirements of the corridor. As such, a decision on tolling needs to be made in 2021 to allow sufficient time for design of the corridor and a tolling Order in Council to be completed before opening of the new road.

Approach and Methodology

This analysis has focused on the transport network impacts and revenue potential of tolling of the corridor. The specific transport impacts that were requested to be assessed include:

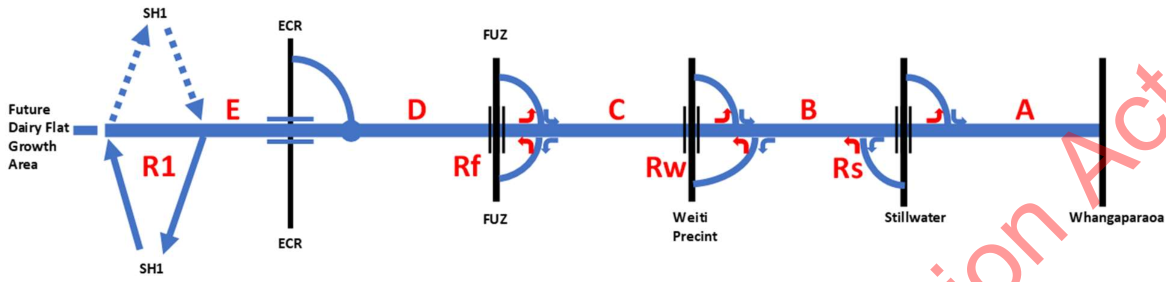
- Road safety, specifically any change in crash costs of diverting traffic from the new corridor back to the existing roads
- Accessibility, measured via estimated travel times along key corridors and the consistency in this travel time across the day
- Environmental impacts of changes in traffic patterns, measured by estimates of the likely changes in vehicle CO_2 emissions
- Total travel demand impacts, such as reduced amount of vehicle travel from higher travel costs
- Equity (fairness) of pricing across the different users of the corridor

The traffic flow and network outcomes were primarily derived from a traffic assignment model built from the Macro Strategic Model (MSM) owned by the Auckland Forecasting Centre (AFC). Key refinements made to the assignment model included a finer zone system, more detailed road networks, rebasing and calibrating the model to 2018 conditions and updating the toll diversion response. The existing Silverdale Aimsun model (a detailed simulation model) owned by AFC was also used to help inform network outcomes, in particular potential congestion points. Although a refined assignment model was developed for this work, the methodology agreed with Waka Kotahi included use of the AFC's regional demand model and land use inputs for estimating growth and travel demand patterns. Assumptions on specific local land use development and network upgrades were agreed via a workshop with Waka Kotahi subject matter experts.

An initial assessment of various potential toll strategies was considered, resulting in a short-list of scenarios agreed with Waka Kotahi for explicit testing. Detailed testing was undertaken for the forecast year 2028 to identify a preferred strategy and range of toll tariffs. From the network impacts assessed for the short-list options, a technically preferred strategy was agreed with Waka Kotahi that sought a balance between the various measures. Representative traffic flow and associated revenue estimates were then developed for the project from opening year to 2048, including risk-adjusted factors provide 5th, 50th and 95th percentile estimates.

Penlink Toll Strategy

A range of potential toll gantry locations were identified for this project:



Gantry	Description
A	Mainline on Weiti Bridge
B	Mainline between Stillwater and Weiti (Access 2)
C	Mainline between Access 2 and Access 1
D	Mainline between Access 1 and ECR
E	Mainline between ECR and SH1
Rs	Ramps, east-facing at Stillwater
Rw	Ramps, east-facing at Weiti (access2)
Rf	Ramps, east-facing at access1
R1	Ramps, south-facing on SH1

Under current legislation a free alternative route must be available for users, which is available for the Whangaparaoa and Stillwater communities using existing roads. However, the Weiti Precinct only has access to Penlink so the tolling strategy must allow for an un-tolled route. The Future Urban Zone (FUZ) area has not been planned in detail, so its proposed land use and transport network is not known. While it has a proposed access onto Penlink, it could also have local (un-tolled) access routes to East Coast Road.

From these potential toll gantry locations, a range of toll strategies were developed comprising various combinations of those tolling points. From an initial filtering process, a strategy comprising three tolling points (A+Rs+R1) was agreed with Waka Kotahi for further analysis due to its balance of outcomes between revenue potential, fairness, efficiency (transaction cost vs. revenue) and likely capital cost.

The subsequent modelling and analysis of that strategy identified the following key outcomes:

- Tolling introduces additional travel costs resulting in less vehicle trips or constraining trips to closer destinations. This effectively has the potential to mitigate the induced traffic from building Penlink
- This 'suppression' effect on travel is however somewhat offset by diverting some traffic back to the longer alternative routes
- The net effect of the suppression and diversion effects is expected to be a small reduction in daily Vehicle Kilometres of Travel (VKT)
- This reduced VKT from tolling is predicted to reduce transport externalities such as crash costs and CO_2 emissions
- The model predicts that an un-tolled scenario has peak-hour flows that are likely to result in poor levels of service, both along the rural sections of the route and at the entry/exit from SH1. Tolling was found to reduce traffic flows on Penlink and hence significantly improve its levels of service
- Tolling Penlink was found to have only a minor impact on travel times on the alternative corridor, assuming no significant change in the form of that route
- The resulting tolled traffic flows on the Stillwater west-facing movements were predicted to be very low (<1,000 vpd). While the revenue from such movements would be unlikely to economically justify the capital cost of the tolling system, tolling was recommended for fairness reasons and to gain the 'suppression' effects (that is, to mitigate induced traffic effects of Penlink)

- An alternative toll strategy (mainline gantry A + mainline gantry B) could be used to impose similar tolls to the preferred option (Mainline gantry A + ramp gantry Rs), but would require the ability to track and discount vehicles using both gantries, with potentially higher transaction costs
- The Stillwater movements (Rs) were modelled with the same toll levels as users of the Weiti Bridge (A), however, a lower rate could be considered for the Stillwater movements as they are likely to use a shorter length of Penlink than those from Whangaparaoa. The additional complexity of communicating such a strategy to drivers would need to be considered further
- Tolling the SH1 ramps was found to aide SH1 performance through reduced peak-period ramp flows and to mitigate induced traffic flows from the adjacent areas. However, high toll rates were found to divert high levels of traffic to East Coast Road, which is a longer and less safe route than SH1 for some users
- The corridor primarily serves local rather than inter-regional travel, resulting in traffic flow profiles that have dominant commuter peaks. This would make time-varying tolls a viable option, with relatively clear transition points
- Truck tolls are recommended to be 2 times that for light vehicles for consistency with other toll roads in the region
- Toll revenue was found to increase with increasing tolls, up to the maximum toll scenario tested of an end-to-end $4 tariff
- The strategy of tolls varying by destination and time of day would be more complex to communicate to drivers through road-side signage

From the assessment the following strategy was agreed with Waka Kotahi for final assessment:

- Tolling applied all day (to achieve suppression effect), but with higher tolls during commuter peaks to improve corridor levels of service (defined as 6am – 9am and 4pm – 7pm)
- A light-vehicle tariff on the Weiti Bridge (A) of $2-$3
- A light-vehicle tariff on the SH1 south-facing ramps (R1) of approximately $1
- A light-vehicle tariff on the Stillwater west-facing movements (Rs) the same as for Gantry A of $2-$3
- A heavy vehicle toll ratio of 2 times that for light vehicles
- No toll on buses
- Consideration could be given to reduced tolls for other high productivity vehicles (such as high occupant vehicles), but this would depend on the feasibility of administering and enforcing such a strategy

The feasibility and safety implications of the signage system required to communicate this strategy to drivers would need to be considered by Waka Kotahi, as it involves different levels of toll by both destination and time of day. An alternative, simple strategy may be a viable option (such as a single mainline Gantry at A or B), although it would lose some elements of perceived fairness and some potential revenue.

Final Toll Strategy and Estimated Traffic Flows and Revenue

The following representative toll strategy was agreed with Waka Kotahi to estimate the traffic flows and revenue potential:

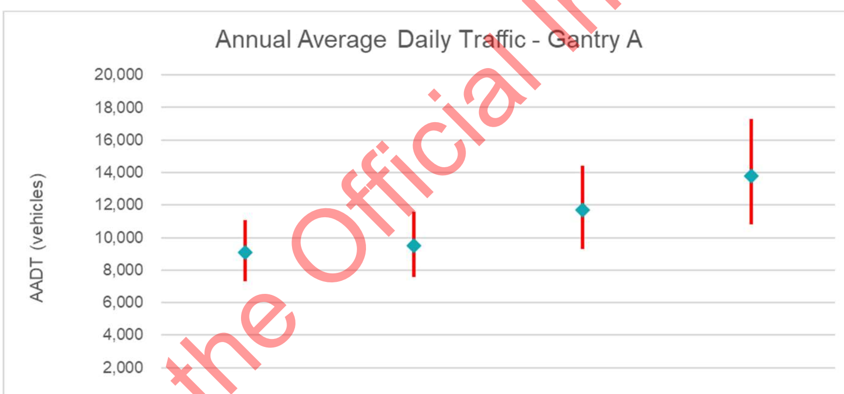
- Differential tolling for the commuter peaks, defined as 6am – 9am and 4pm – 7pm
- A light-vehicle tariff at A and Rs of $3 in the commuter peaks
- A light-vehicle tariff at R1 of $1 in the commuter peaks
- A light-vehicle tariff at A and Rs of $2 in the off-peak
- A light-vehicle tariff at R1 of $1 in the off-peak
- A heavy vehicle toll ratio of 2 times that for light vehicles

- No toll on buses

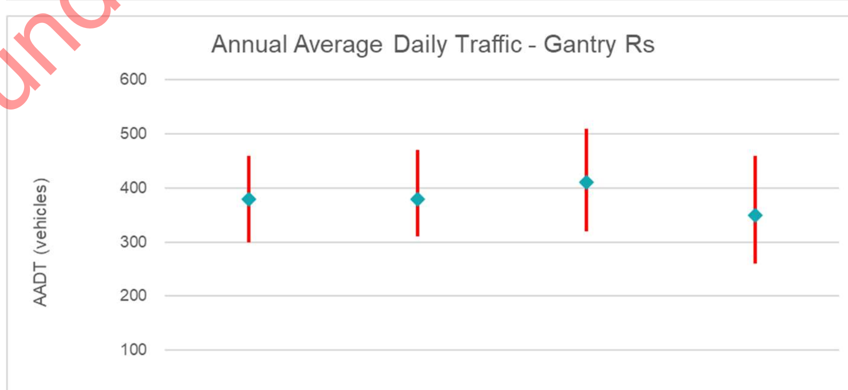
In the long-term, north-facing ramps and a western connection are expected at the SH1 Redvale interchange to serve the Dairy Flat future urban growth area, with the interchange then taking on a wider function in the network. Tolling of the south-facing ramps could be reviewed at the time such additional functions were added.

Forecasting traffic flows on major new transport infrastructure has inherent uncertainty, which is increased due to uncertainties in how motorists will respond to specific tolling proposals. While standard modelling methods were used along with key assumptions agreed with Waka Kotahi subject matter experts, an assessment of the uncertainties in the key inputs was undertaken to gauge the likely range of uncertainty in the model predictions. Sensitivity testing on key assumptions was used with Monte-Carlo simulation of the multiple outcomes to provide a risk-profile for the resulting traffic flows.

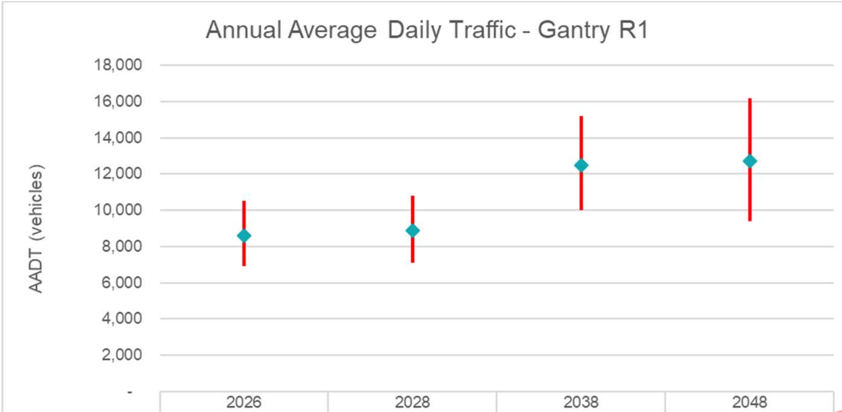
The estimated annual average daily traffic flows and combined net revenue are shown in the following figures. These traffic flows are estimated to generate gross revenue of some $12.1m in 2026, increasing to $17.6m in 2048. With an assumed toll transaction cost of 70c per vehicle (as advised by Waka Kotahi), the combined net revenue of the toll strategy is estimated to be between $5.7m (5th %ile) and $9.5m (95th %ile), with an expected value of $7.4m in 2028.



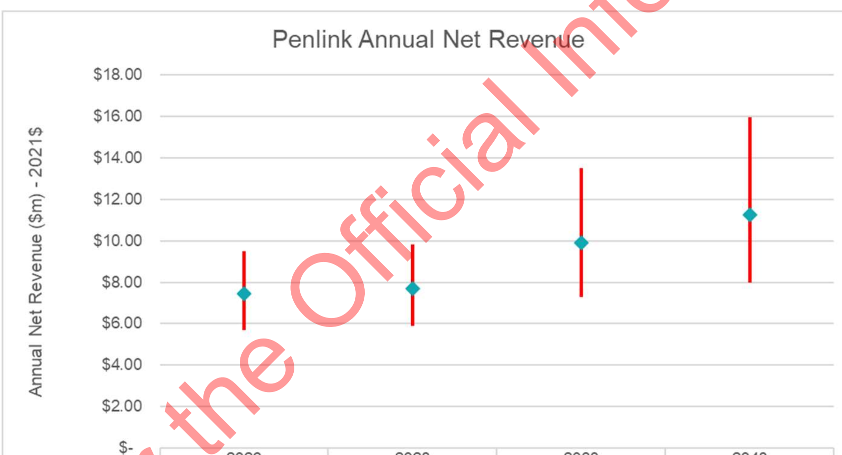
	2026	2028	2038	2048
5th Percentile	7,300	7,600	9,300	10,800
50th Percentile	9,100	9,500	11,700	13,800
95th Percentile	11,100	11,600	14,400	17,300



	2026	2028	2038	2048
5th Percentile	300	310	320	260
50th Percentile	380	380	410	350
95th Percentile	460	470	510	460



	2026	2028	2038	2048
5th Percentile	6,900	7,100	10,000	9,400
50th Percentile	8,600	8,900	12,500	12,700
95th Percentile	10,500	10,800	15,200	16,200



	2026	2028	2038	2048
5th Percentile	$5.70	$5.91	$7.29	$7.98
50th Percentile	$7.44	$7.71	$9.89	$11.24
95th Percentile	$9.48	$9.83	$13.50	$15.98

Conclusion

This analysis has identified the transport system effects of imposing a toll on the Penlink project, including assessment of potential changes in total crash costs, vehicle tail-pipe emissions and travel times on both Penlink and the surrounding network. The modelling indicated that without tolls, The Penlink project would induce new vehicle travel between Whangaparaoa and areas south, with levels of peak-period traffic flows likely to result in poor traffic levels of service along the route and queues at the entry/exit from SH1. Relative to this base case, tolling was found to:

- reduce daily vehicle travel (effectively mitigating the induced traffic)
- reduce transport effects associated with vehicle travel, such as crash costs and vehicle emissions
- Improve traffic levels of service on Penlink but with only minor impact on the alternative route
- Generate revenue

The preferred toll strategy from this analysis includes three tolling points, namely the Weiti Bridge, the SH1 south-facing ramps and the Stillwater west-facing movements. The preferred strategy includes tolls varying by destination and by time of day, although the feasibility of communicating such a strategy to drivers would need to be confirmed by Waka Kotahi.

Forecasting traffic flows for a new toll road contains inherent uncertainty. While this report has attempted to quantify the potential scale of the key uncertainties, the risks associated with traffic forecasts should be considered in design and policy decisions for this project.

1 Introduction

1.1 Purpose

Beca Ltd was commissioned by Waka Kotahi – New Zealand Transport Agency (Waka Kotahi) to investigate the effect of tolling the Penlink project on the transport network, to assist in recommending a suitable toll strategy. This work considered various different tolling strategies and assessed the likely toll revenue and key operational impacts on the transport network, being crash costs, vehicle emissions and network travel times and congestion. This scope of work does not include an assessment on the transport network of building Penlink.

1.2 Scope and Limitations

The purpose of this report is to assess the transport network impacts and potential revenue from tolling the Penlink corridor, in accordance with the parameters of our agreed scope as set out in our proposal. Further analysis may be required in order to support more detailed financial analysis. Specifically, this work does not provide 'investment-grade' revenue estimates.

Although in this report, Beca offers professional advice and may express opinions on likely or possible outcomes, we cannot guarantee any particular outcome and any decision to proceed with the next phase of investigation is a commercial decision for Waka Kotahi.

It should be noted that the toll revenue estimates provided as part of the Services are not a statement of absolute revenue suitable for detailed investment decisions, rather they will have an accuracy range commensurate with various factors such as the extent of relevant information provided, the certainty of data and assumptions and the level of detail available at the time of preparation.

Assessment of the transport network impacts is limited to the following outcome measures:

- Safety – as measured by the social crash cost difference between a tolled and un-tolled scenario
- Accessibility – as measured by the travel time and travel time consistency along key corridors in the network
- Environmental – as measured by the change in vehicle CO_2 emissions between a tolled and un-tolled scenario
- Value for Money – as measured by the potential revenue generated from tolling the Penlink corridor
- Equity (fairness) – as simplistically considered in terms of pricing across the different users of the corridor
- Influencing Demand – as measured by the changes in vehicle demand patterns

This assessment has included the transport system effects noted above, and has not included a wider assessment against Waka Kotahi or other Government policies or frameworks.

Forecasting traffic flows for a new toll road contains inherent uncertainty. While this report has attempted to quantify the potential scale of the key uncertainties, the risks associated with traffic forecasts should be considered in design and policy decisions for this project.

In preparing this assessment we have relied on the inputs and assumptions provided by or agreed with Waka Kotahi as outlined in this report, including:

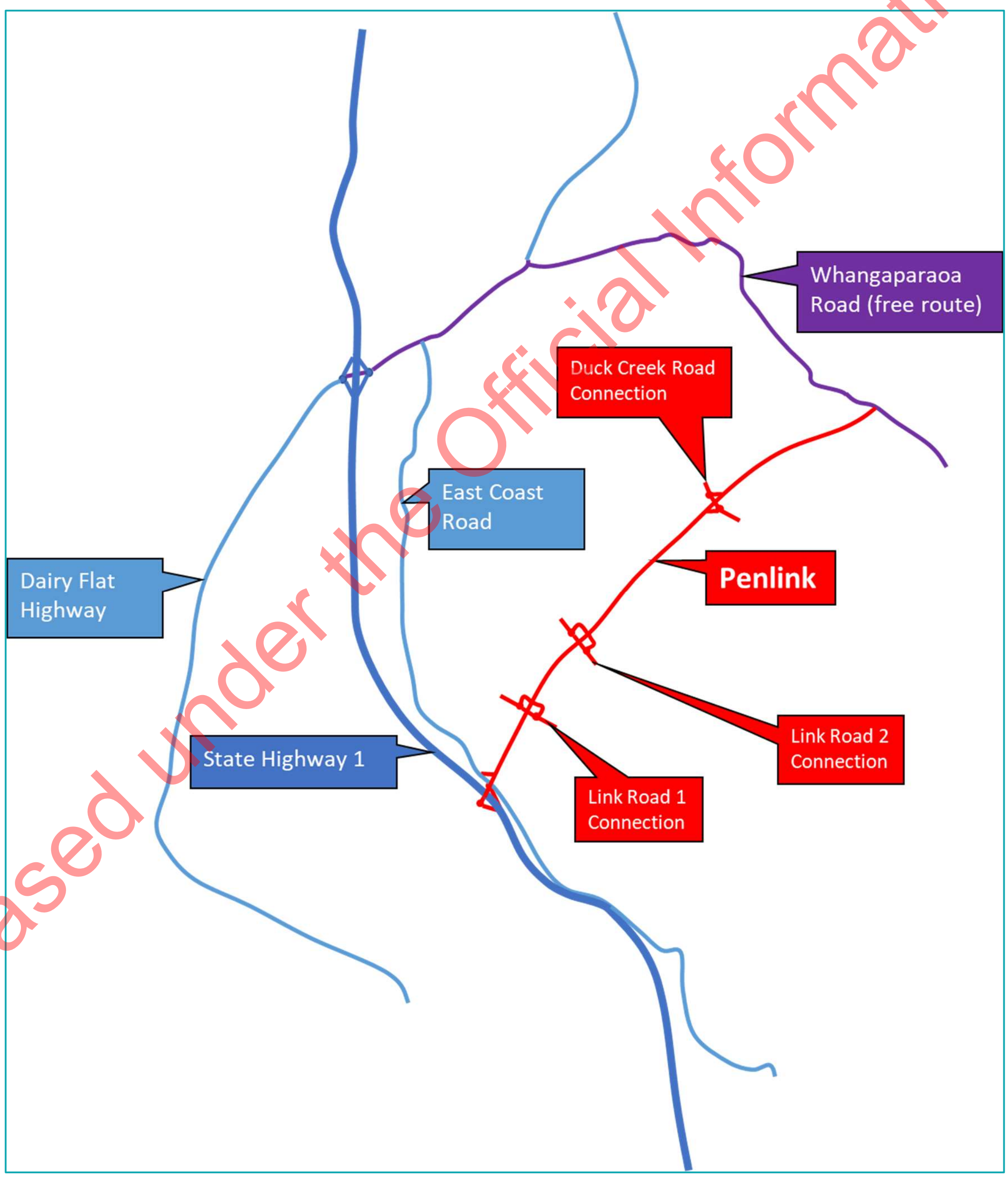
- Design of Penlink project
- Land use inputs
- Wider network project assumptions
- Toll system transaction costs
- Waka Kotahi's Vehicle Emission Prediction Model

1.3 Penlink Project

The project study area is shown in **Figure 1-1**. The Penlink project involves a new connection between the Whangaparaoa peninsula and the existing State Highway 1 corridor. The corridor is currently designed as a two-lane road with a wire-rope barrier separating each direction. Proposed connections along the corridor include 'Link Road 1', that provides access to the planned Future Urban Zone, 'Link Road 2', that provides access to the planned Weiti Precinct and the Duck Creek Road connection that provides access to the Stillwater community.

The Penlink project is currently in the planning and design phase. Tolling has the potential to significantly change the level of service along the corridor, and therefore can have design implications. Hence a decision on tolling must be made during the planning and design phase. The Penlink project is expected to open in late 2025.

Figure 1-1: Project Study Area



1.4 Study Approach

The broad approach adopted for the assessment was as follows:

- Undertake preliminary testing of a range of toll levels on the Penlink project for a single forecast year (2028) to understand the impact of tolling and suggested toll range
- Select a preferred toll strategy for the Penlink project and provide a fuller set of forecasts based on the preferred strategy, including more detailed risk analysis of forecasting uncertainties

1.5 Independent Peer Review

An independent peer review of this work was undertaken by Flow Transportation Ltd. This included:

- a review of the modelling methodology and base model validation
- review of forecasting assumptions
- a review of the draft report

The comments on the draft report and the responses are included as **Appendix B** of this report.

1.6 Report Structure

The remainder of this report is structured as follows:

Chapter 2	Describes the assessment methodology used in this assessment
Chapter 3	Describes the outcome measures used to assess each toll strategy
Chapter 4	Describes the elements of a toll strategy and a preliminary assessment of options
Chapter 5	Describes the Preliminary modelling and analysis of the toll strategies
Chapter 6	Details the refined outcomes from the agreed preferred strategy for Penlink
Chapter 7	Summary and Conclusions

2 Modelling Methodology

2.1 Approach

The assessment of traffic flows, revenue and network performance is based on a series of models and assessments, comprising:

- A regional multi-modal **demand model** to estimate future travel demands from land use and network inputs
- A more detailed, regional **traffic assignment model** that predicts toll road traffic flows and wider network performance
- A detailed **simulation model** that predicts local network operating performance
- An **annualization process** to expand weekday, peak period model predictions into daily then annual flows
- A **revenue model**, that estimates potential toll revenue from the traffic flows, allowing for revenue leakage and transaction costs
- A **risk-analysis process**, that considers the key forecasting uncertainties to provide a range of forecasts that reflect those uncertainties

These elements are described in the following sections.

2.2 Modelling Input Assumptions

A workshop was held with Waka Kotahi subject matter experts to agree project input assumptions. The following assumptions were agreed for the land use adopted and the projects within the study area to include:

2.2.1 Land Use

The regional base forecast adopted the i11.6 land use, with the following adjustments:

- Local Weiti Precinct with 550 households by 2028
- Highgate to include 1,350 employees by 2048

2.2.2 Network Assumptions

The network starting point for regional projects was agreed as the latest available Auckland Transport Alignment Project (ATAP).

Table 2-1 shows the project assumptions in the study area:

Table 2-1: ATAP Projects Assumptions

No.	Project	Description	2028 ATAP	2038 ATAP	2048 ATAP
1	Bus lane	Bus shoulder lanes on SH1 from Silverdale to Oteha Valley Rd	✓	✓	✓
2	Red vale interchange	Redvale interchange with South facing Ramps	✓	✓	
3		Redvale full interchange			✓
4	Penlink	Penlink Arterial Rd- 1 lane each direction	✓	✓	✓
5	Wilks Interchange	New wilks road interchange with south facing ramps			✓
6	Mildale NS Arterial	New arterial roads - one lane each direction (Milldale NS arterial and Highgate SH1 Crossing)	✓	✓	✓
7		Mildale NS arterial upgarded to 2 lanes (Dairy Flat to Highgate crossing)		✓	✓
8		Mildale NS arterial upgarded to 2 lanes (Dairy Flat to Wainui Road)		✓	✓
9	SH1	SH1 widened NB between Oteha valley and Redvale		✓	✓
10		SH1 widened to 3 lanes between Oteha Valley and Silverdale			✓
11	Jackson way	Jacksonway extension-1 lane each direction			✓
12	LRT	LRT on western side of SH1			✓
13	ECR	Widening of ECR between Hibiscus Coast Hwy and Bawden Rd			✓
14	Dairy Flat	Dairy Flat widening between Durey Rd and Post man Rd - 2 lanes			✓
15	Postman-Bawden Rd connection (E-W)	New connection between Postman Rd and Bawden Rd-1 lane each direction			✓
16	Postman Rd	New NS Arterial from Dairy flat to Wilks Rd Postman Rd extension- 2lane		✓	✓
17		Postman Rd upgraded to 2 lanes			✓
18	Dairy Flat - Postman Rd connection (E-W)	Connection between Dairy Flat (Kahikatea Flat Rd) to postman Rd - 1 lane each dir			✓

For more local projects the following was agreed to be incorporated in sensitivity testing:

- Hibiscus Coast Highway environment
- Silverdale St / HBC Highway signals
- Whangaparaoa Road dynamic lanes
- Speed on Penlink
- At-grade intersections on Penlink

2.3 Regional Demand Model

The Auckland Macro Strategic Model (MSM) is owned and operated by the Auckland Forecasting Centre (AFC), and estimates future travel patterns (via origin-destination trip patterns by period, purpose year and mode). Key inputs to that model are future land use and demographic forecasts, future network assumptions and policy and economic inputs. For this study those key inputs have been adopted from recent models developed by the AFC for the update of the Auckland Transport Alignment Project (ATAP). These include:

- Land use forecasts based on Scenario I-11.6
- Project assumptions from ATAP in the wider network

The regional model covers both this corridor as well as the Whangaparaoa Road corridor and alters the travel patterns in response to travel costs such as tolls. The model was run for un-tolled and tolled scenarios to inform the demand response, which includes changes in trip distribution, mode shift and route choice to Whangaparaoa Road / Hibiscus Coast Highway.

2.4 Penlink Traffic Assignment Model

The Penlink Traffic Assignment Model (PTAM) was developed from the MSM. The base year assignment model has been developed and is discussed in Appendix A.

For this work, the MSM was refined within the study area (from Constellation Drive in the south to the Northern Gateway Toll road in the north). The refinement included refinement of the zone system to match the North Aimsun model and a more detailed road network. A validation exercise was undertaken to validate the model against traffic count data (focussing on the key corridors of Whangaparaoa Road, Hibiscus Coast Highway, State Highway 1, Dairy Flat Highway and East Coast Road). Mobile phone and census 2018 journey-to-work sector-to-sector movement patterns were used to calibrate sector-to-sector trip patterns. The model reflects average weekday AM, interpeak and PM peak periods.

The traffic assignment model used a 12-class assignment as part of the toll diversion model described below, following the same structure as the MSM.

Model demands were directly sourced from the MSM for the years 2028, 2038 and 2048. The demands are disaggregated to the finer zone system and then adjusted based on the matrix adjustment process described in the base year model development report (Appendix A).

2.5 North Aimsun Model

The North Aimsun model was originally developed by AFC for the Transport for Urban Growth (TfUG) project. This included development and calibration of a base year (2016) model and preparation of reference forecast models. The original model sourced travel demands from the now superseded regional multi-modal (ART3) model. The Supporting Growth Alliance (SGA), which built on the TfUG work, created a demand process to generate forecast year travel demands from the MSM by using the growth between the base year (2016) and a forecast year (e.g. 2028) and applying this growth to the already calibrated 2016 demand matrices. This process has been maintained for this study, however instead of sourcing the travel demands from the MSM, they are sourced from the Emme Traffic Assignment Model.

The North Aimsun model has three demand segments, light vehicles – low occupancy, light vehicles – high occupancy and heavy vehicles. The consequence of this is that there are not enough demand segments to rely on the toll diversion from this model. Therefore, the North Aimsun model is set up to get the toll diversion directly from the PTAM.

2.6 Toll Diversion Model

This study adopted a multi-class route choice form of toll response model. This involves segmenting the traffic demand matrices into different segments, which is assigned a Willingness to Pay (WTP) value. The toll is then included in the route choice model, where the model seeks to find the least-cost paths through the network.

- Segmentation of the travel demands into 12 user classes[1]. These classes reflect the same classes used in the WTP module available in MSM.
- Allocation of WTP parameters to each user class

This methodology was adopted directly from the MSM, albeit with modified values of time as described below.

2.6.1 Willingness to Pay

In this modelling, WTP comprises three elements:

- The Value of Time (VoT) in $/hour. This parameter converts the monetary toll into equivalent minutes of travel. User classes with higher VoT will have a high WtP.
- Road perception factors, that reflect perceptions of the relative safety, convenience, amenity or reliability of the competing routes.
- Escalation of VoT. This accounts for a change in value of time based on income growth.

A key uncertainty in toll modelling are the VoT values. Two key sources were used for this study:

1. The values included for the same 12 user classes in the MSM[2]
2. The values used in the Tauranga demand models

Stated Preference surveys were undertaken in Tauranga in 2005 to assess VoT values for the proposed eastern motorway toll road. However progressive modelling of the existing Takitimu Drive toll road in Tauranga found those values underestimated usage of the toll road. They were also found to over-predict reductions in traffic with successive increases in tolls. The VoT values were therefore progressively increased over various model updates to better reflect observed behaviour. Those revised values were found to provide good prediction of usage when the Eastern Motorway toll road opened in 2015.

Data collection carried out for the Puhoi to Wellsford Toll Assessment project demonstrated that the through traffic diversion from the Northern Gateway Toll Road was approximately 5%. With an uncongested travel time saving of approximately 8 minutes; 95% of drivers have a value of time equal to or greater than $18/hour. Therefore, for this study the VoT was adopted as follows:

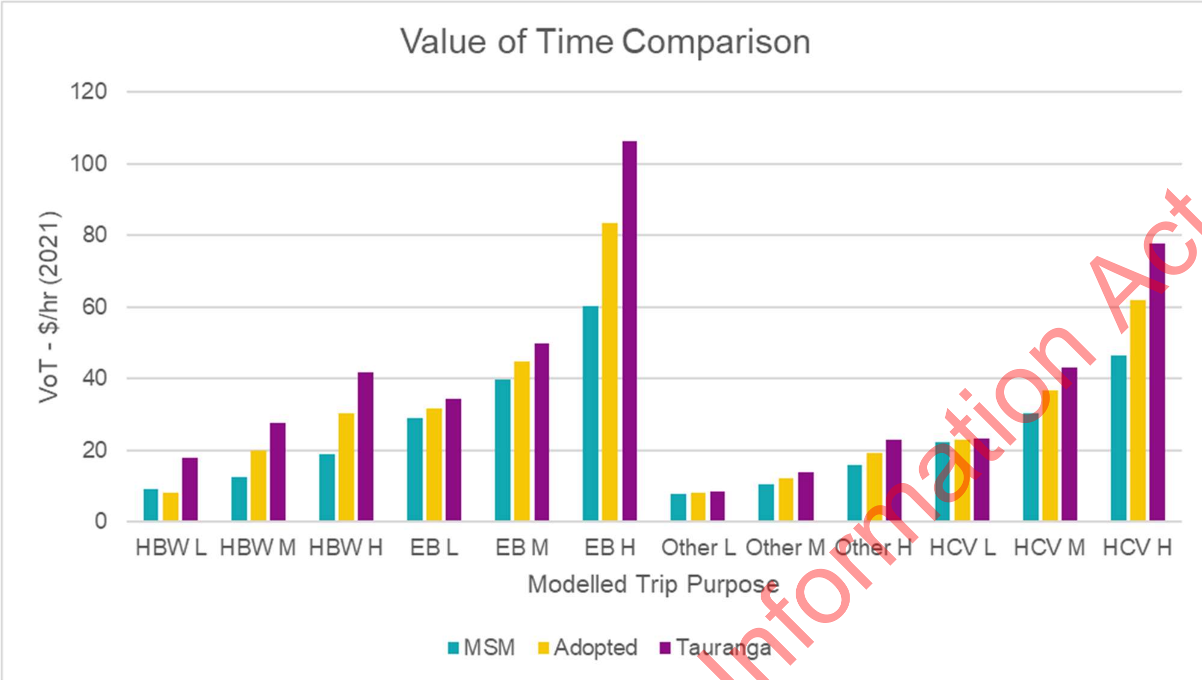
- A 'central' estimate that was a simple average of the Auckland (MSM) and Tauranga (TTSM) values
- Sensitivity testing with the lower MSM values and the higher full Tauranga values

The VoT adopted is shown in **Figure 2-1**.

[1] Refer to Appendix A for detail on user class segmentation

[2] The MSM VoT is based on the Economic Evaluation Manual VoTs and adjusted for the Auckland region

Figure 2-1: Value of Time (2021$)



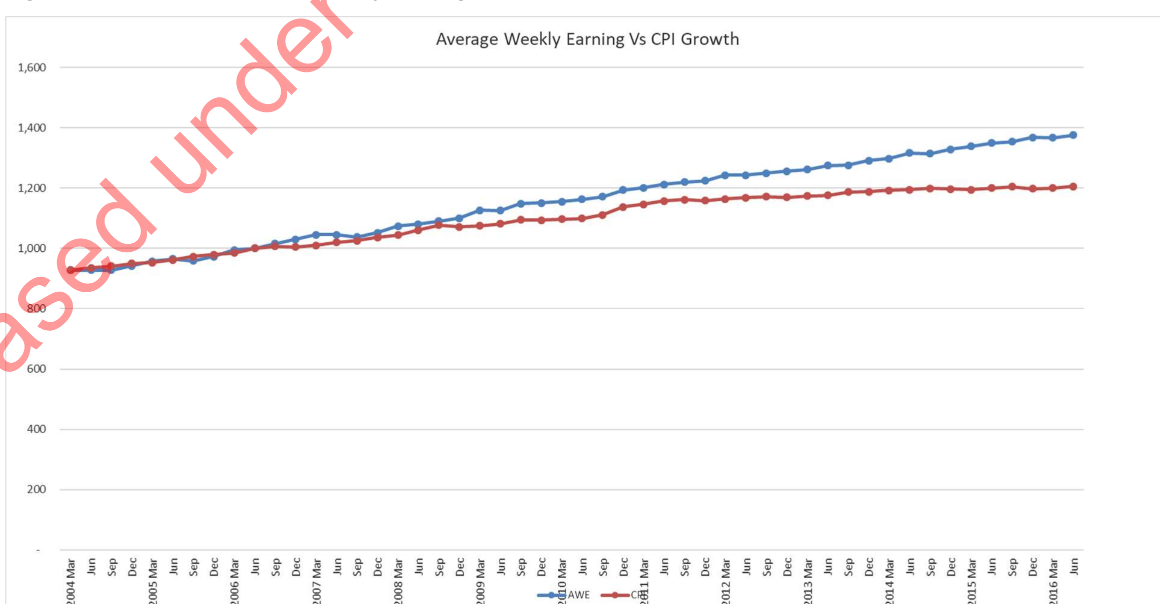
2.6.2 Escalation of VoT

Previous tolling studies have assumed the following:

- Tolls will be escalated, on average at the rate of inflation (CPI)
- VoT is likely to escalate based on income growth
- Average weekly earnings have historically been found to grow at some 1%-1.1% faster than CPI
- This means that the WtP is expected to increase over time in real terms

Figure 2-2 below shows the indexed growth in CPI versus average weekly earnings, which suggested earnings growing at 1.1% faster than CPI.

Figure 2-2: Indexed Growth in Weekly Earnings and CPI



Within the models all tolls were applied in $2021 terms and the 2021 VoT values retained[3]. To account for the difference in CPI growth and VoT growth a 1% WtP escalation effect was applied to the representation of toll costs in the models.

2.6.3 Cumulative Effect

Toll roads in New Zealand have typically served longer distance and less frequent trips. The Penlink corridor is predicted to serve shorter, more frequent trips, such as commuters. There is limited research available to indicate the scale of effect that regular travel has on a user's willingness to pay. However, it is estimated that the cumulative effect would reduce the willingness to pay and therefore increase the diversion away from Penlink. Therefore, it is reasonable to adopt a central estimate for VoT that is lower than the values adopted in Tauranga. Further to this, sensitivity testing and hence the risk adjustment factors have been weighted towards the lower value of time, reducing the 50th and 95th percentile estimates.

2.7 Demand Response

Tolling is expected to alter both the travel routes (diversion) as well as the travel patterns (mode share, destination choice etc.). The diversion is the primary response; however, the demand response is also important. The source of demand response was the MSM, from which the effect on corridor traffic flows with differing toll levels was determined.

2.8 Annualization Factors

Annualization factors are required to convert the modelled traffic volumes for each modelled peak (AM, IP, PM) into average weekday daily traffic (ADT) and annual average daily traffic (AADT).

The factors have been determined by following the steps described below. TMS data on the south-facing ramps at the Silverdale interchange and tube counts on Whangaparaoa Road have been used in the calculations. The Whangaparaoa Road count covers one full week in February of 2018, while the TMS data covers the full 2018 calendar year.

Initial modelling confirmed that in the interpeak the Penlink corridor has much greater proportions of Home-Based Work (HBW) and Employees Business (EB) trips compared to other locations. For example, on Penlink the percentage of HBW trips is 16% and EB is 15%, while on Whangaparaoa Road it is 11% for both HBW and EB individually. Due to the characteristics of this corridor, a methodology was developed to generate factors specific to the trip purposes in the model, Home-Based Work, Other, Employees Business and Heavy Commercial Vehicles. With a potential toll strategy including differential tolling for the commuter peaks of 6am – 9am and 4pm – 7pm, a decision was made to use the annualization factors to cover these periods using the AM and PM peak (as modelled periods are 7am – 9am and 4pm – 6pm)

The steps taken to develop the factors were as follows:

- Matrices were extracted from the MSM to determine the proportion of each purpose for each peak, including the School Peak (SP) and Off-peak (OP)
- Factors were derived to convert IP purpose proportions to SP and OP proportions
- From the count data, factors were developed to scale IP volume to SP and OP volumes and AM and PM peak volumes to cover 6am – 9am and 4pm – 7pm respectively
- The factors developed were used to determine the average daily weekday traffic
- Assume a purpose percentage split for weekend car traffic of 5% HBW, 90% Other and 5% EB[4]

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[3] 2018 was used as this is the base calibrated model.

[4] Estimate based on report 'A Comparison of Weekend and Weekday Travel Behaviour Characteristics in Urban Areas', May 27, 2004

- Factors were derived to convert IP purpose proportions to weekend proportions
- From the count data, factors were developed to scale IP volume to weekend volumes
- Determine the factor between the volume of a standard week (no school holidays, no public holidays) and the annual average
- Use the factors developed to determine the annual average daily traffic volumes

The factors determined are shown in **Table 2-2** for the ADT and **Table 2-3** for AADT.

Table 2-2: ADT Factors

Peak	HBW	Other	EB	HCV
AM	1.30	1.30	1.30	1.41
IP	8.52	4.45	3.96	4.35
PM	1.33	1.33	1.33	1.27

Table 2-3: AADT Factors

Peak	HBW	Other	EB	HCV
AM	0.95	0.95	0.95	1.04
IP	7.23	5.32	3.87	4.17
PM	0.98	0.98	0.98	0.93

2.9 Revenue Calculation

The following steps were taken in order to calculate the annual net toll revenue for each toll tariff level tested:

- Multiply the toll tariff by the annual traffic using the toll road to get gross revenue
- Deduct the revenue leakage, i.e. users of the toll road that either do not pay the toll or are exempt from paying
- Deduct the transaction cost for each vehicle, set at $0.70 per transaction to get net revenue

2.9.1 Annual Traffic

The annual traffic on the toll road is determined by running the Emme Traffic Assignment model for each modelled peak, extracting the volume on the toll road for each peak and then using the annualization factors to convert this to an annual traffic volume.

2.9.2 Transaction Cost

The transaction cost of $0.70 per transaction has been provided by Waka Kotahi. This has been assumed to be an average transaction cost that covers all transaction types and circumstances, for example toll payment notices for non-payers. It is possible the transaction cost reduces over time as more toll roads are added to the national system and other reasons. No information on this is available, however this has been addressed in the risk analysis.

2.9.3 Revenue Leakage

The revenue leakage has been determined by analysing the Northern Gateway Toll Road (NGTR) gantry data. This represents the percentage of traffic that does not pay for the toll road, either through non-compliance or are exempt from paying the toll. The revenue leakage is summarised in **Table 2-4**:

Table 2-4: Revenue Leakage

Vehicle Class	Percent of Vehicles Not Paying
Motorcycle	10%
Car / Light Truck	3%
Heavy Truck / Bus	2%

The percent of vehicles not paying was calculated using data from 2018 and 2017.

2.10 Risk Analysis Process

This process is detailed more fully in later chapters for the preferred toll strategy. It involves the following key steps:

- Prepare model forecasts using agreed inputs
- Identify key areas of uncertainty that influence the forecasts
- Test or assess the potential scale of the uncertainty
- Set potential probability functions for the uncertainty
- Run Monte-Carlo type simulation that combines the effects of all the uncertainties to give adjustment factors to apply to model results at differing levels of certainty (e.g. 5th, 50th and 95th percentile adjustments)
- Apply factors to the model results to provide ranges in forecasts

3 Outcome Measures

3.1 Approach

This section describes the key outcome measures used to assess the impact of tolling on the network.

The outcome measures include the following:

- Safety
- Accessibility
- Environmental
- Value for Money (including revenue)
- Equity
- Influencing Demand

These outcome measures have considered both the Government Policy Statement (GPS 2018) and outcomes used in similar studies. The traffic volumes on the toll road are of particular interest for this study not just for the revenue analysis, but for the performance of the road under a two-lane design.

3.2 Safety Measures

Traffic flows were measured on the toll road, roads in the vicinity of the toll road and the wider road network in the Emme Traffic Assignment model in order to estimate the potential social cost of deaths and serious injuries (DSIs). The crash costs and rates were based on crash rates calculated from existing crash history data.

Scenarios with a high toll will encourage more use of the free, alternative routes. The alternative route has some sections with a higher predicted crash rate, while others (e.g. SH1) have a lower predicted crash rate and also a longer route travelled. In addition to this, scenarios with a high toll reduce the amount of travel due to higher travel costs, which would reduce the social crash cost.

3.3 Accessibility Measures

Four measures are proposed for accessibility:

- Point-to-point travel time through the corridor
- Impact on travel costs between communities (a simple summary of additional costs imposed on key movements)
- Changes in mode share (as a measure of travel choice)
- Travel consistency, based on any variability between the modelled travel time over the three modelled peaks; AM, IP and PM.

3.4 Environmental Measures

Two measures are proposed for environmental impacts:

- Estimated vehicle emissions using the Vehicle Emissions Prediction Model (VEPM version 6.1), and measured over the full extent of the Emme Traffic Assignment Model
- Changes in traffic volumes in sensitive environments including Whangaparaoa Road, Hibiscus Coast Highway, Silverdale Ramps at SH1, SH1 at Silverdale, SH1 at Penlink, Dairy Flat Highway, East Coast Road, Spur Road, Penlink Ramps at SH1 and Penlink

3.5 Value for Money

The 'value for money' is measured by:

- the potential annual toll revenue and associated transaction costs

3.6 Equity

Equity is proposed to be a measure of the 'fairness' of the proposed toll system. This will be assessed subjectively based on two simple indicators:

- Whether users of each section of Penlink have similar paid/free access (i.e., can some users use parts for free)
- Whether payment is similar on a per-km basis
- Whether tolling is consistent with similar toll road corridors in NZ

3.7 Influencing Demand

This was assessed by how the toll influences demand through:

- Mode shift
- Change in travel (VKT)

4 Tolling Strategies

The current Penlink design includes six access points: State Highway 1, East Coast Road Link, Local Connection 1, Local Connection 2, Duck Creek Road and Whangaparaoa Road as indicated in **Figure 4-1**. These access points to each part of the corridor are critical to the development of the toll strategy, and are assumed as follows:

- State Highway 1: south facing ramps in the short-medium term, with potential to include north-facing ramps and a connection to the west in the long term
- East Coast Road Link: entry for eastbound direction only, with exit possible for eastbound and westbound traffic

- Local Connection 1: full grade separated connection for all movements
- Local Connection 2: full grade separated connection for all movements
- Duck Creek Road: full grade separated connection for all movements
- Whangaparaoa Road: at-grade signalised intersection at Beverley Place

It is noted that individuals are required to have a free alternative route to the toll road or be exempt from paying the toll. This is particularly important for the Weiti precinct at Local Connection 2, where there is currently no alternative route possible. Therefore, the toll strategy must allow access to some or all of Penlink for those individuals with no free alternative.

4.1 Toll Strategy Elements

The key elements considered with the toll strategy include:

- The toll collection and payment methods
- The location of toll points/gantries
- The toll tariff
- Any discounting or capping
- Any differentials by vehicle type
- Any differentials by time of day
- How toll tariffs are escalated over time

4.1.1 Existing Toll Roads

The attributes of the three existing NZ toll roads are shown in **Table 4-1**. Given those are also State Highways, it is assumed that similar attributes would be expected.

Table 4-1: Attributes of Existing Toll Roads

Attribute	SH1 Northern Gateway Auckland	SH2 Eastern Link Tauranga	SH2 Takitimu Drive Tauranga
Toll Collection	Free-flow electronic toll gantry		
Payment Methods	Waka Kotahi automated Toll account Pay on-line Cash (at selected service stations)		
Toll Tariff (as at October 2019) Light Vehicle Heavy Vehicle (over 3.5t) Trailer	 $2.40 $4.80 $0	 $2.10 $5.20 $0	 $1.90 $5.00 $0
Heavy Vehicle toll relative to light vehicle	2 times	2.5 times	2.6 times
Length of toll road	7km	15km	5.4km
Distance saving relative to alternative route Typical time saving (uncongested)	5km 8 min	2.8km 7 min	1-2km 4 min
Equivalent light vehicle toll/km of toll road	$0.34/km	$0.14/km	$0.35/km
Equivalent light vehicle toll/minute saved	$0.3/min	$0.3/min	$0.95/min
Collection points	One mainline gantry per project		
Discounting or capping	none		
Escalation	Generally CPI, but to nearest 10c		

Table 4-2 demonstrates the toll pricing for the full corridor when following the equivalent light vehicle toll / km and light vehicle toll / minutes saved:

Table 4-2: Toll Pricing Equivalence

Attribute	Value
Length	~7km
Alternative Route Length	~12.75km
Estimate Time Saving	~7min
Toll (with $0.34/km)	$2.40
Toll (with $0.14/km)	$1.00
Toll (with $0.3/min)	$2.10

4.1.2 Assumptions and Options

For the purposes of this analysis it is assumed that a consistent approach to existing toll roads would be adopted in this corridor, including:

- All toll collection will use the same kind of free-flow electronic toll gantries
- All toll payment methods will be as per the existing toll roads
- Escalation of tolls will be as per the existing toll roads

This means that the following attributes need to be considered in this corridor:

- The toll collection points
- Any associated discounts or caps where there are multiple collections
- Heavy vehicle differential (although it is assumed it would be in the similar ratio of 2-3 times the light vehicle toll)
- Any time of day differential

4.2 Approach to Corridor Assessment

4.2.1 Toll Tariffs

Various levels of tolls have been explicitly tested.

4.2.2 Vehicle and Time of Day Differentials

For consistency with existing toll roads, it has been assumed for this modelling that heavy vehicles will be tolled at two times the light vehicle toll tariff.

For the time of day differentials, several scenarios have been tested:

- Consistent 24/7 tolls
- Tolls only in the AM and PM peak periods
- Reduced toll outside of the peak periods

The commuter centric nature of this corridor indicates that time-varying tolls may be applicable and could provide potential Travel Demand Management (TDM) benefits.

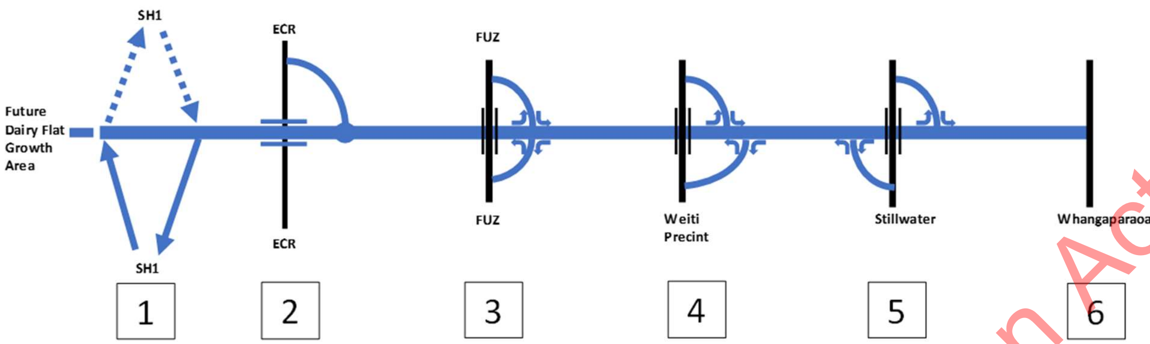
4.3 Toll Gantry Location Strategies

4.3.1 Access Points and Movements

The key access points and potential movements using the full corridor are indicated in **Figure 4-1**. There are six possible access points along the corridor (including eastern and western end).

The following sections consider the potential location strategies.

Figure 4-1: Corridor Access Points

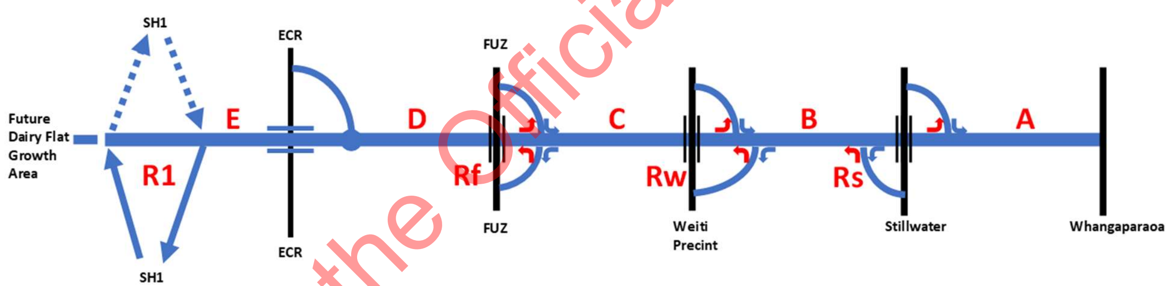


Location	Description
1	SH1 Motorway Ramps
2	East Coast Road - at grade roundabout
3	Local Connection 1 (FUZ) - grade separated
4	Local Connection 2 (Weiti) - grade separated
5	Stillwater - grade separated
6	Whangaparaoa Road - at grade signals

4.3.2 Toll Gantry Locations

With multiple access points along the corridor, a number of toll gantry locations have been considered. The toll gantry locations considered as part of this study are shown in **Figure 4-2**:

Figure 4-2: Potential Toll Gantry Locations



Gantry	Description
A	Mainline on Weiti Bridge
B	Mainline between Stillwater and Weiti (Access 2)
C	Mainline between Access 2 and Access 1
D	Mainline between Access 1 and ECR
E	Mainline between ECR and SH1
Rs	Ramps, east-facing at Stillwater
Rw	Ramps, east-facing at Weiti (access2)
Rf	Ramps, east-facing at access1
R1	Ramps, south-facing on SH1

A preliminary assessment of a number of toll gantry strategies is included in **Table 4-3**, based on the following assessment criteria:

- Equity / Fairness: number of free sections along the corridor
- Revenue Potential: potential revenue for each strategy
- Efficiency: revenue potential vs. transaction cost
- Indicative capital cost: estimate of the gantry cost for each strategy

For each of the criteria, a score between one and five is given based on the gantry strategy. A negative score is given for capital cost.

Table 4-3: Preliminary Toll Strategy Assessment

Strategy	Gantries	Comment	Fairness	Rev	Efficiency (transaction cost vs rev)	Capital Cost
1	A	Low transaction cost but only peninsula and eastbound trips tolled	2	3	5	-2
2	A + B	Stillwater revenue captured but double transaction cost on through traffic	3	3	3	-3
3	A + Rs	West facing ramps at Stillwater - lower transaction cost but extra gantries - allows progressive implementation when wanted	3	3	5	-3
4	A+Rs+C	C adds no revenue gain as Weiti must be free	3	3	2	-4
5	A+Rs+C+ Rw	Rw is to discount those using C so Weiti don't pay toll. Hence these cancel out so not efficient.	3	3	1	-5
6	A+Rs+D+ Rw	Allows tolling of FUZ - but they will need free alternative access. Without alternative access there is no value in D. Creates extra transaction cost for through traffic	4	4	1	-5
7	A+Rs+Rf	Allows tolling of FUZ - but they will need free alternative access, hence likely low usage. Allows progressive implementation	4	4	2	-4
8	A+B+C+ D	Very high transaction cost and would need Rw for free Weiti	4	4	1	-5
9	A+Rs+Rf	Efficient version of Quad strategy (8) becomes same as 7	4	4	2	-4
10	A+Rs+Rf +R1	Free access to ECR, but not to SH1. Helps with TDM on ramps	4	4	1	-5
11	A+Rs+R1	Drop Rf for efficiency as likely low value. Free for Weiti <--> FUZ	3	4	3	-4
12	A+R1	Drop Rs for efficiency as likely low usage to ECR (A and R1 capture travel to SH1 and Whangaparaoa)	3	4	4	-3

It should be noted that the above strategies are not an exhaustive list of potential ramp gantry location combinations. Further to this, some of the traffic volumes and diversion levels at some locations may mean that some sections do not justify being tolled.

Based on this preliminary assessment; strategies 1, 3, 11 or 12 could all be taken forward for further consideration. A preferred strategy is likely to depend on the different weighting given to each of the assessment criteria.

For this toll modelling study, strategy 11 (A+Rs+R1) has been the primary strategy test, but strategy 3 (A+Rs) has also been tested to understand the impact of a toll on R1.

5 Preliminary Toll Outcomes

The purpose of this section is to investigate the options and recommend a toll strategy. Refined flow and revenue results are reported later in this report. These preliminary results are all for a 2028 forecast year.

Early testing of the models indicated that time-varying tolls (e.g. no toll in the off-peak periods) had a negligible impact on the alternative peak periods. For example, having no toll during the inter-peak had negligible impact on the traffic volumes in the AM and PM peaks.

The following toll tariff levels were tested for each peak period:

- No Toll
- A+Rs=$1.00, R1=$1.00
- A+Rs=$1.50, R1=$1.00
- A+Rs=$2.00, R1=$1.00
- A+Rs=$2.50, R1=$1.00
- A+Rs=$3.00, R1=$1.00
- A+Rs=$2.00, R1=$2.00
- A+Rs=$2.00

Note that the toll tariff values quoted are in $2021.

5.1 Demand and Diversion Response

A critical influence on the outcome measures, especially the emissions and crash cost outcomes, is the trade-off between the demand response and the diversion response.

Under a tolled scenario, cost of travel for those heading south from Whangaparaoa (or vice versa) increases compared to the un-tolled scenario. Therefore, the MSM will predict that some people may decide to change their destination of travel. For example, if an individual previously travelled to Albany for shopping under an un-tolled scenario, they may change their destination to shop more locally, such as in Silverdale, when a toll is introduced. The result of this is a decrease in vehicle kilometres travelled. This is the model predicted demand response. The reverse of this is true when Penlink is built, creating a lower cost of travel to and from the south and therefore inducing more trips between Whangaparaoa and the south. Not including the impact of a shorter route, this will increase the vehicle kilometres travelled.

The diversion response relates to the model prediction of route choice. For example, for those people that are heading south from Whangaparaoa peninsula, two primary route choice options are available, using Penlink or using Whangaparaoa Road / Hibiscus Coast Highway. Using Whangaparaoa Road / Hibiscus Coast Highway is approximately 6km longer than using Penlink (depending on exact origin and destination). Under a tolled scenario, the cost of using Penlink increases, so the model will predict a higher proportion of drivers using Whangaparaoa Road / Hibiscus Coast Highway, therefore increasing the vehicle kilometres travelled. Again, the reverse is true when Penlink is built, shifting drivers from the longer route along Whangaparaoa Road / Hibiscus Coast Highway on to the shorter Penlink route, therefore decreasing the vehicle kilometres travelled.

Both responses push the vehicle kilometres travelled (VKT) in opposite directions. Therefore, the scale of each of these will influence the outcome measures.

In order to understand the resulting change in VKT, a comparison between the No Toll scenario and the A+Rs=$1.00, R1=$1.00 is made.

5.1.1 Overall Network Results

Table 5-1 shows the VKT for each scenario and peak for the full Auckland network.

Table 5-1: Modelled Vehicle Kilometres Travelled

Modelled Period	No Toll	ARs$1_R1$1	ARs$2_R1$1	ARs$3_R1$1
AM	6,317,500	6,317,100	6,319,200	6,319,100
IP	5,194,500	5,185,500	5,186,600	5,188,000
PM	6,727,000	6,723,400	6,727,900	6,726,900

The AM peak shows some fluctuation between slight reductions or increases in overall network VKT when tolling. The IP consistently shows reduced VKT when tolling, albeit at slightly fluctuating amounts depending on the toll. The PM peak is similar to the AM peak, with some fluctuation between increasing and reducing VKT from tolling.

To understand this response and focus more specifically on the study area rather than network wide, a comparison of the sector-to-sector movements has been made in the following section.

5.1.2 Sector-to-Sector Results

The following tables demonstrate the demand change for sector-to-sector movement for the interpeak under a range of toll scenarios and also the do minimum (i.e. no Penlink). The change in demand is in comparison to a no-toll, with Penlink scenario. The sector system used in this analysis is shown in **Figure 5-1**.

Figure 5-1: Sector System

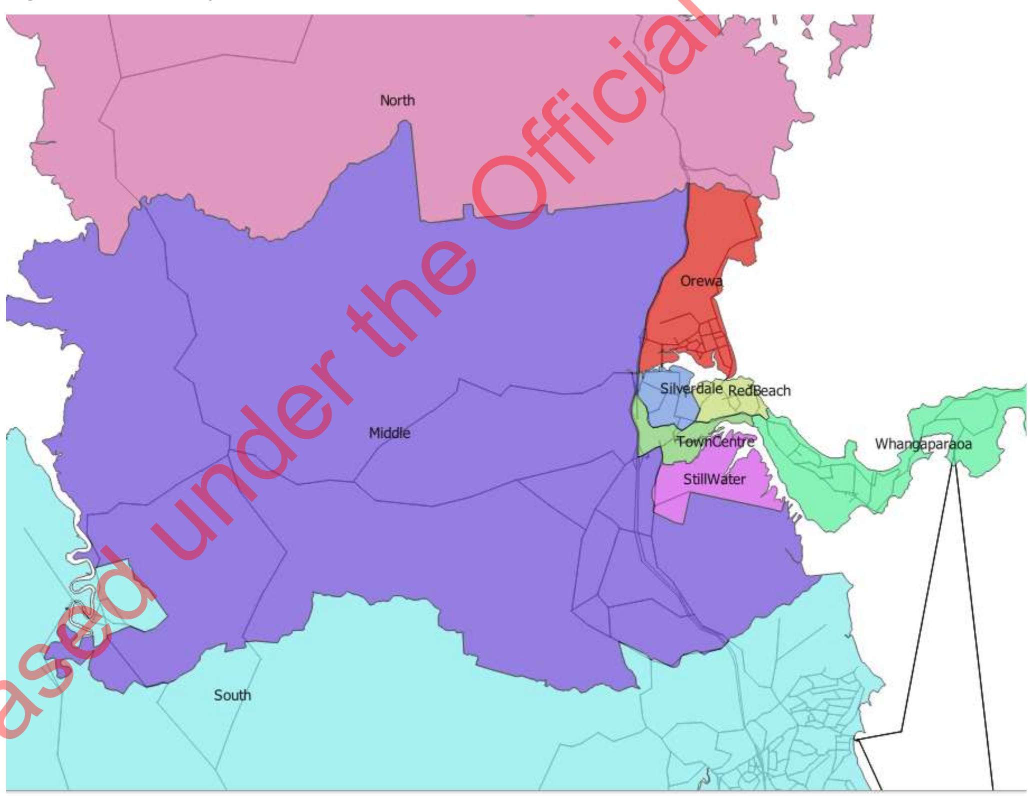


Table 5-2: Do Minimum to No Toll Demand Change

	North	Middle	Orewa	Silverdale	RedBeach	Whangaparaoa	TownCentre	StillWater	South
North	7	0	1	0	0	-1	0	0	-1
Middle	0	-11	7	4	8	17	7	-43	9
Orewa	1	4	14	2	-1	-14	4	-9	-1
Silverdale	0	2	2	0	4	-6	1	-12	0
RedBeach	0	6	0	4	0	-9	7	-8	0
Whangaparaoa	-2	14	-12	-5	-9	-353	-6	51	331
TownCentre	0	5	5	2	7	-7	4	-14	5
StillWater	0	-44	-9	-13	-8	47	-14	10	23
South	-1	21	-4	-1	-1	311	4	17	-364

Table 5-3: No Toll to $1 Demand Change

	North	Middle	Orewa	Silverdale	RedBeach	Whangaparaoa	TownCentre	StillWater	South
North	-4	0	0	0	0	0	0	0	0
Middle	0	19	-1	0	-1	-14	-1	-4	-5
Orewa	-1	2	-6	-1	-1	4	-1	-1	2
Silverdale	0	1	-1	0	-2	2	-1	-2	1
RedBeach	0	0	0	-1	0	2	-2	-2	1
Whangaparaoa	1	-7	9	4	5	176	6	-7	-270
TownCentre	0	1	-2	-2	-2	3	0	-2	0
StillWater	0	-3	-1	-2	-2	-7	-2	12	-10
South	0	-24	1	0	0	-222	0	-7	158

Table 5-4: No Toll to $2 Demand Change

	North	Middle	Orewa	Silverdale	RedBeach	Whangaparaoa	TownCentre	StillWater	South
North	-4	4	1	5	-2	-8	0	0	1
Middle	2	25	-2	0	-2	-17	-1	-9	-3
Orewa	1	1	-8	-1	1	6	0	-1	2
Silverdale	4	1	-1	0	-2	5	0	-3	5
RedBeach	-1	-1	2	-2	2	4	-2	-4	-1
Whangaparaoa	-5	-13	8	4	4	272	7	-23	-343
TownCentre	0	0	-2	0	-2	8	0	-5	-1
StillWater	0	-8	-1	-3	-3	-20	-6	33	-9
South	1	-15	3	5	0	-325	1	0	83

Table 5-5: No Toll to $3 Demand Change

	North	Middle	Orewa	Silverdale	RedBeach	Whangaparaoa	TownCentre	StillWater	South
North	-5	4	0	5	-2	-8	0	0	1
Middle	2	27	-2	0	-3	-18	-1	-8	1
Orewa	0	0	-10	-1	4	7	0	0	2
Silverdale	4	1	-1	2	-2	4	1	-2	6
RedBeach	-1	-2	3	-3	4	5	-2	-3	0
Whangaparaoa	-6	-15	7	3	5	317	6	-39	-359
TownCentre	0	0	-1	1	-2	7	1	-5	0
StillWater	1	-7	0	-2	-3	-35	-5	38	-1
South	1	-13	4	6	1	-336	1	5	97

The tables demonstrate the following:

- Building Penlink shifts traffic from more local trips (e.g., within Whangaparaoa) to longer trips such as between Whangaparaoa and the South sector
- Tolling Penlink reduces travel to and from Whangaparaoa and the South sectors

- Tolling Penlink increases local travel within and around the peninsula, e.g., within Whangaparaoa, or to/from Orewa, Silverdale, Red Beach and the Town Centre
- At a toll tariff of approximately $3, the induced travel from building Penlink is largely mitigated

Investigating the trip distances for the sector-to-sector pairs in the model provides the following insights:

- The average trip length for those travelling to and from Whangaparaoa and the South sector is 32-34km with Penlink and 39-40km without Penlink
- The average trip length for those travelling within Whangaparaoa is 4km
- The average trip length for those travelling to/from Whangaparaoa and the adjacent sectors (e.g., Orewa) is 7-10km

With both the demand response and the trip length information, it can be seen that when drivers switch from travelling to/from Whangaparaoa and the South sector to more local trips, the distance travelled significantly decreases from approximately 32-34km to between 4-10km, which is a decrease of 22-30km. Therefore, this can offset the increase in trip length when switching from using Penlink to Whangaparaoa Road / Hibiscus Coast Highway, which is approximately a 6km increase in trip length. This can result in a net decrease in VKT when tolling Penlink. Net reductions in VKT contribute to reductions in emissions and crash costs.

5.1.3 Penlink Volumes

To further assist in understanding the different aspects of demand response and diversion, a comparison of volumes on Penlink (between Whangaparaoa and Stillwater) is made. Several scenarios have been run, as shown in **Table 5-6**. The final assignment of all the scenarios uses the 2028 network that includes Penlink.

Table 5-6: Demand Scenario Testing

Scenario	Year - Demand	Penlink – Induced Traffic	Toll – Suppressed Traffic	Toll - Diversion
1	2028	✗	✗	✗
2	2028	✓	✗	✗
3	2028	✓	✓	✗
4	2028	✓	✓	✓

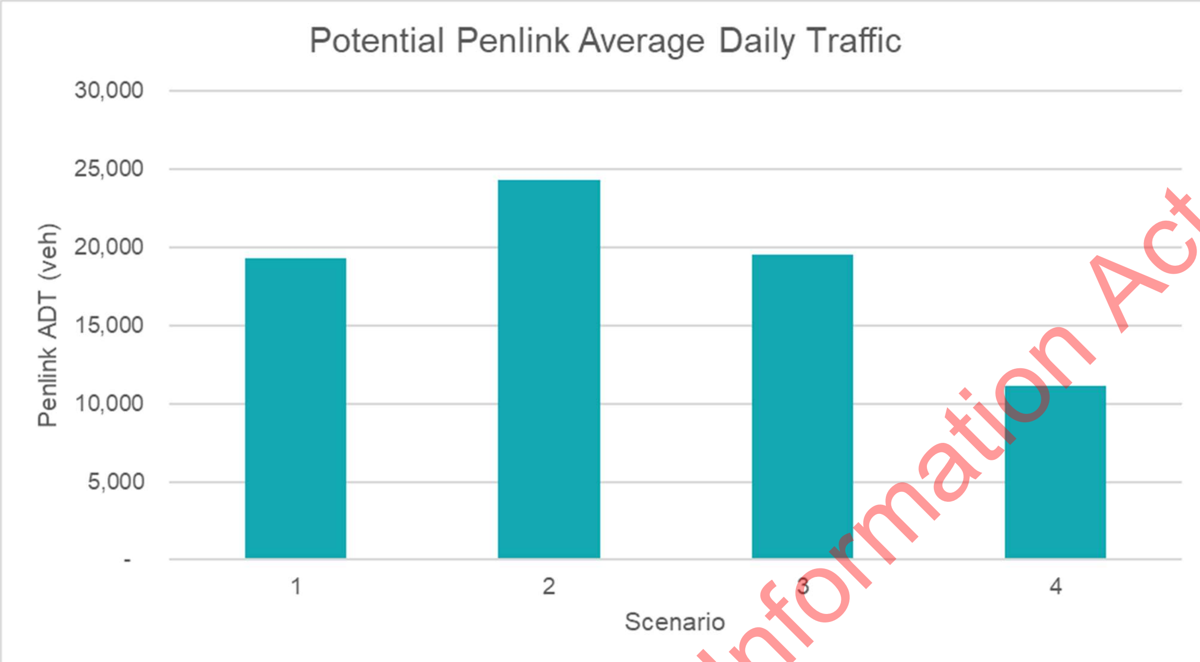
The difference between each scenario can be used to understand the different aspects of the demand. The following table indicates what can be measured between each scenario.

Table 5-7: Demand Component Indicators

Scenarios Compared	Demand Component
1-2	Penlink induced traffic
2-3	Toll suppressed traffic
3-4	Toll diversion

The following figure shows the potential demand for Penlink under each scenario:

Figure 5-2: Penlink Potential Demand



The figure demonstrates the following:

- The induced traffic from building Penlink is approximately ~5,000 vehicles per day
- The suppression effect from tolling Penlink is approximately ~4,800 vehicles per day
- Tolling Penlink largely mitigates the induced traffic demand effect from building Penlink
- The diversion effect from tolling Penlink is approximately ~8,400 vehicles

5.2 Corridor Traffic Flows

This section provides information on the average daily traffic (ADT) for the purpose of comparing performance. However, in the assessment of the preferred strategy, annual average daily traffic (AADT) has been used due to its relation to annual revenue.

Figure 5-3 shows the daily traffic volumes on the toll road between Whangaparaoa Road and Stillwater and between Local Connection 1 and East Coast Road for the various toll strategies tested.

Figure 5-3: 2028 Penlink Average Daily Traffic Volumes

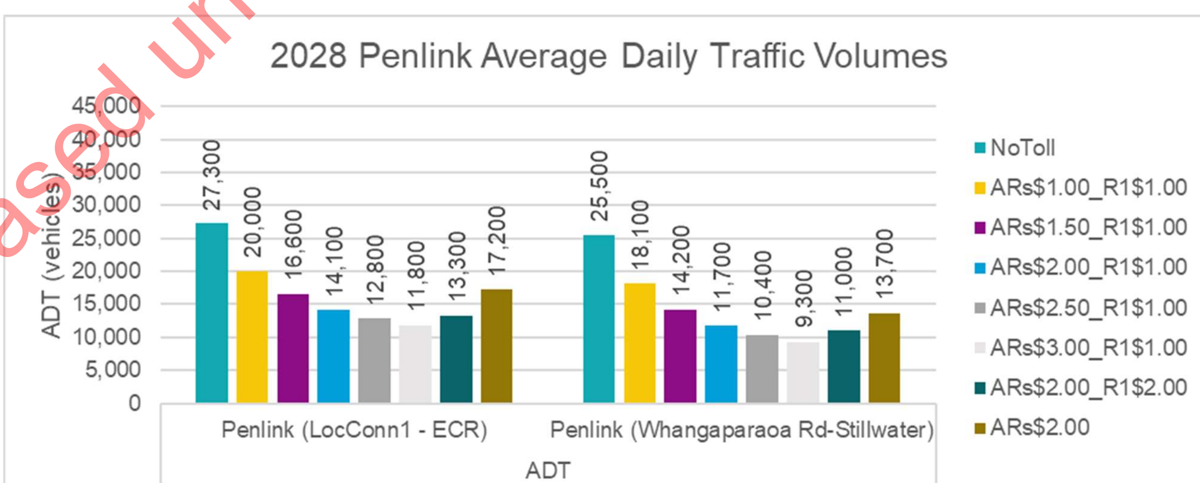
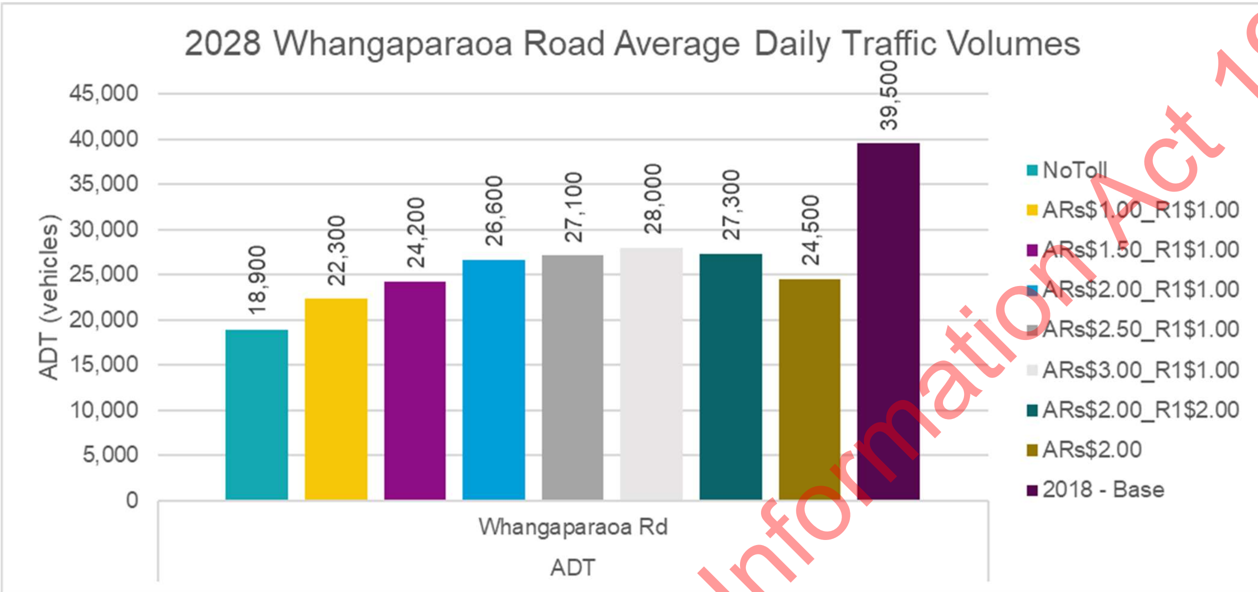


Figure 5-4 shows the daily traffic volumes on Whangaparaoa Road between Vipond Road and Marellen Drive for the various toll strategies tested. The modelled 2018 traffic volume is also included for context.

Figure 5-4: 2028 Whangaparaoa Road Daily Traffic Volumes



The following observations have been made:

- Introducing a toll reduces the daily traffic volume on Penlink by approximately 8,000 vehicles
- With no toll, the volume on Penlink is approximately 40% higher than on Whangaparaoa Road
- At a toll between $2.50 and $3.00 end-to-end, the daily traffic volume is approximately half the un-tolled volume
- The 2028 volume of traffic on Whangaparaoa Road is not estimated to reach the 2018 levels under any of the toll scenario tested
- A $2.00 toll at A and Rs only produces a similar volume on Penlink and Whangaparaoa Road as the A, Rs=$1.50 and R1=$1.00 scenario (or $2.50 end-to-end)

  - *Tolling Penlink has the potential to reduce traffic flows by over 50%, from 25,500 ADT to 9,300 ADT; and*
  - *Tolling Penlink diverts traffic back on to Whangaparaoa Road (up to 28,000 ADT), however this isn't estimated to exceed the 2018 traffic flows (39,500 ADT).*

5.3 Safety

Safety has been measured by determining a crash cost and Death and Serious Injury (DSI) per vehicle kilometres travelled for the following corridors:

- Dairy Flat Highway and Durey Road
- East Coast Road
- Grand Drive
- Hibiscus Coast Highway
- SH1 Motorway
- Whangaparaoa Road

5 years of crash data was analysed to determine the crash rate and therefore the crash cost for each corridor. As Penlink will be a brand-new road with no existing data available a prediction of the crash cost

has been made using Waka Kotahi's Monetised Benefits and Costs Manual and the Crash Estimation Compendium. The crash rates for these corridors are shown in **Table 5-8**.

Table 5-8: Crash Cost and DSI by Corridor

Road	Avg Speed	Cents Per Veh Km	DSIs per 100m Veh Km
Dairy Flat Highway and Durey Road	80	17.3	15.3
East Coast Road (Hibiscus Coast Highway to Oteha Valley Road)	80	11.4	8.0
Grand Drive (Interchange to Hibiscus Road)	50	6.1	6.8
Hibiscus Coast (Interchange to West Hoe Road)	60	6.2	4.2
SH1 Motorway (Grand Drive to Oteha Valley Interchange)	100	1.2	0.9
Whangaparaoa Road	50	4.6	4.4
Penlink	80	2.2	1.9

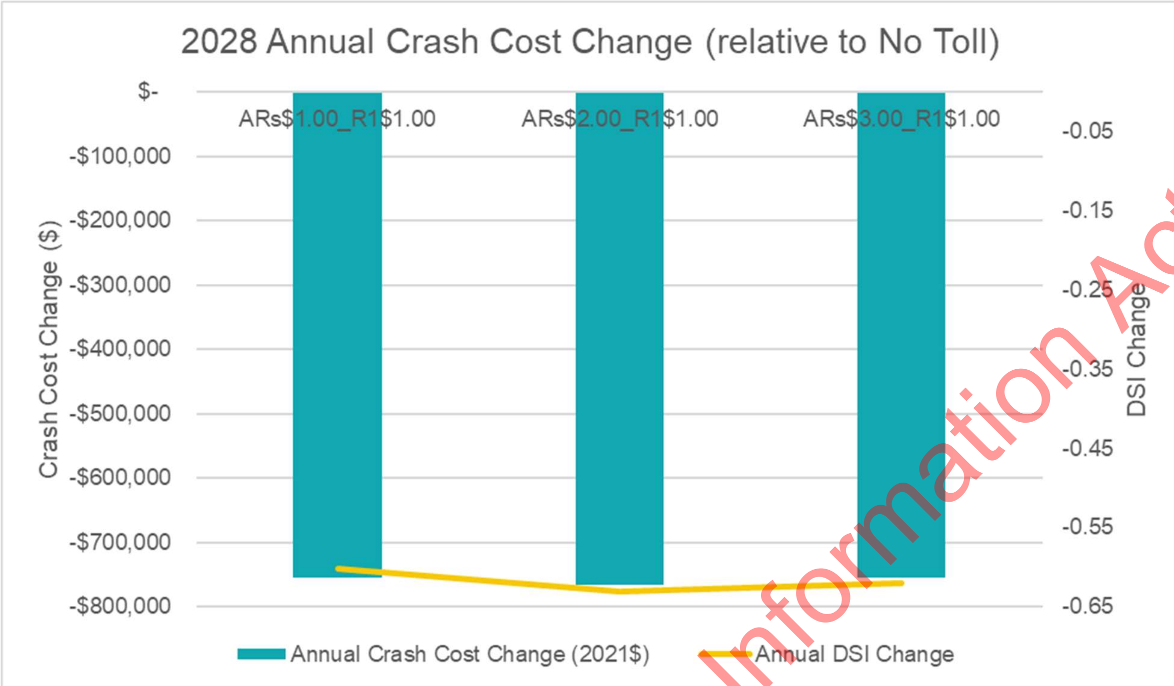
For road sections outside of these corridors average crash costs have been based on the road type and speed environment. The classification of these and the associated crash rates are shown in **Table 5-9**.

Table 5-9: Standard Crash Cost and DSI by Road Type

Road Type	Avg Speed	Cents Per Veh Km	DSIs Per 100m Veh Km
Motorway	<=60	6.32	3.0
	<80	0.30	0.3
	>=80	2.79	1.7
Arterial	<=60	11.81	12.6
	<80	1.36	1.0
	>=80	14.56	9.3
Local	<=60	9.96	8.7
	<80	0.32	0.3
Rural	<=60	0.95	0.7
	<80	5.64	4.6
	>=80	17.46	13.4

Figure 5-5 shows the change in crash cost and DSI for the core toll scenarios tested compared to the un-tolled scenario. The un-tolled scenario has a total crash cost of $235 million per annum and DSIs of 214, which has been measured within the area shown in **Figure 5-6**.

Figure 5-5: 2028 Annual Crash Cost Change (relative to No Toll)



The figure demonstrates that tolling Penlink has the potential to reduce the annual social crash cost by approximately $750,000 and annual DSIs by approximately 0.6. Although this is a seemingly minor reduction (~0.3%) compared to the total cost and total DSIs, it is still a positive outcome that improves the safety outcomes of tolling Penlink.

- *Tolling Penlink has the potential to reduce the annual social crash cost by up to $750,000 and DSIs by approximately 0.6 per year, hence improving safety outcomes in the area.*

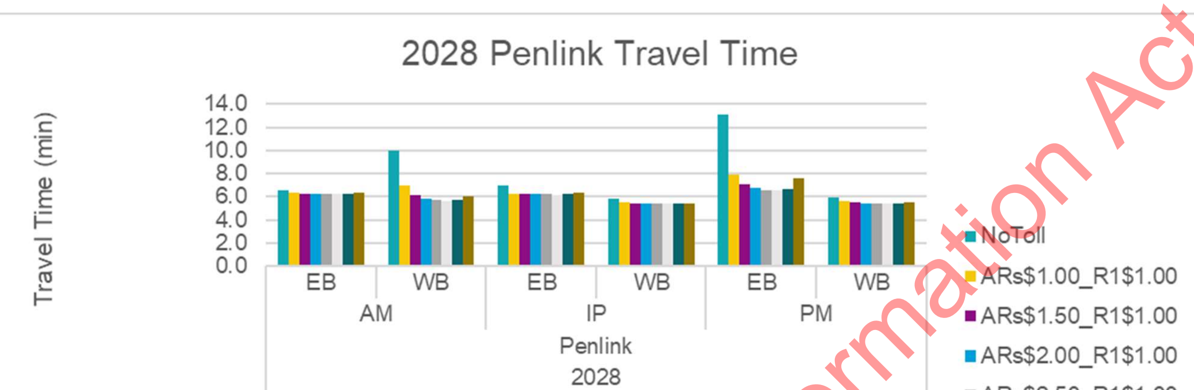
Figure 5-6: Crash and Emissions Focus Area

5.4 Accessibility

5.4.1 Travel Time

The travel time along key corridors have been measured for each toll scenario modelled. **Figure 5-7**, **Figure 5-8**, **Figure 5-9** and **Figure 5-10** summarise the travel time between each location:

Figure 5-7: 2028 Penlink Travel Time



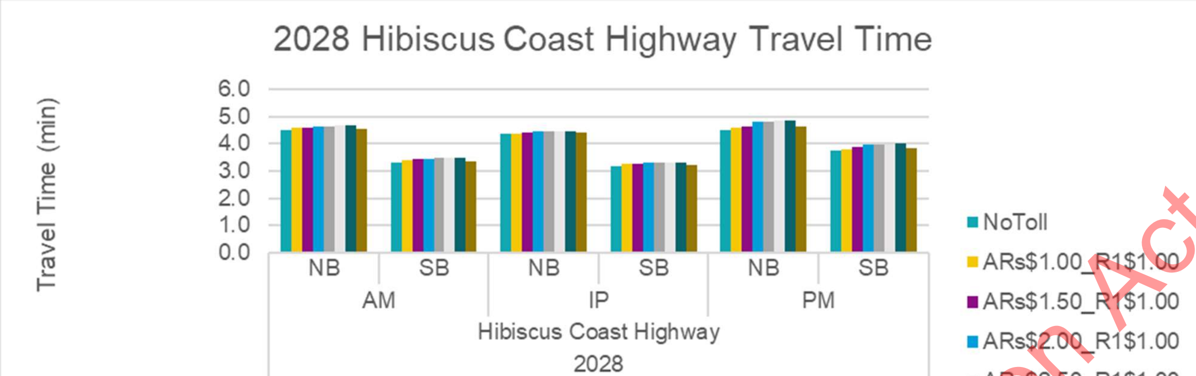
	AM EB	AM WB	IP EB	IP WB	PM EB	PM WB
NoToll	6.6	10.0	7.0	5.9	13.1	5.9
ARs$1.00_R1$1.00	6.3	7.0	6.3	5.5	7.9	5.6
ARs$1.50_R1$1.00	6.3	6.1	6.2	5.4	7.1	5.5
ARs$2.00_R1$1.00	6.2	5.8	6.2	5.4	6.7	5.5
ARs$2.50_R1$1.00	6.2	5.7	6.2	5.4	6.6	5.4
ARs$3.00_R1$1.00	6.2	5.7	6.2	5.4	6.5	5.4
ARs$2.00_R1$2.00	6.2	5.7	6.2	5.4	6.7	5.4
ARs$2.00	6.3	6.1	6.3	5.5	7.6	5.5

The following observations have been made regarding the travel time along Penlink:

- An un-tolled scenario is predicted to have a poor level of service with high travel times in the peak directions for the commuter peaks
- Introducing a toll is predicted to significantly reduce the peak direction travel time in the AM and PM peak
  - The majority of the reduction in delay is at the East Coast Road / Penlink roundabout
- The AM peak, westbound direction sees a reduction in travel time of up to 4.3 minutes
- The PM peak, eastbound direction sees a reduction in travel time of up to 6.6 minutes
- The inter peak travel time improvement is lower than the peaks, with a reduction of up to 0.8 minutes
- Introducing a toll at the Penlink ramps (R1) improves the Penlink / East Coast Road performance in the PM peak, with travel time between the off-ramp and East Coast Road (~0.4km) reducing by 0.7 minutes between the $2 toll at A+Rs only and adding a $1 toll at R1 to this strategy
  - The AM peak does not generate the same benefit on Penlink when adding the toll at R1 as the Penlink Ramps cannot be accessed when travelling from East Coast Road (right turn from ECR into Penlink banned in current design)

The modelling suggests that the current design for the Penlink corridor will result in a poor level of service without a toll. Tolling is expected to divert traffic away from Penlink and therefore improve the level of service.

Figure 5-8: 2028 Hibiscus Coast Highway Travel Time

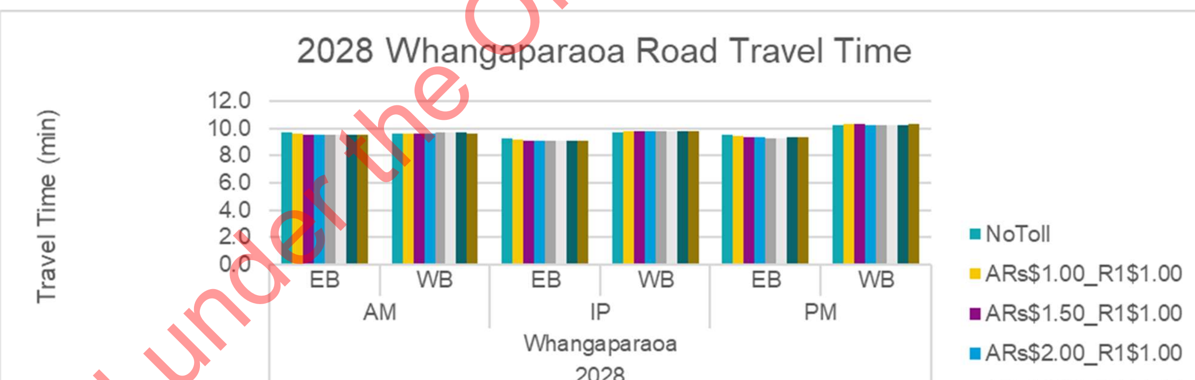


	AM NB	AM SB	IP NB	IP SB	PM NB	PM SB
NoToll	4.5	3.3	4.4	3.2	4.5	3.7
ARs$1.00_R1$1.00	4.6	3.4	4.4	3.3	4.6	3.8
ARs$1.50_R1$1.00	4.6	3.4	4.4	3.3	4.7	3.9
ARs$2.00_R1$1.00	4.6	3.5	4.4	3.3	4.8	4.0
ARs$2.50_R1$1.00	4.7	3.5	4.4	3.3	4.8	4.0
ARs$3.00_R1$1.00	4.7	3.5	4.5	3.3	4.9	4.0
ARs$2.00_R1$2.00	4.7	3.5	4.5	3.3	4.9	4.0
ARs$2.00	4.6	3.4	4.4	3.2	4.7	3.8

The following observations have been made regarding the travel time along Hibiscus Coast Highway (between SH1 and Whangaparaoa Road):

- There is limited impact on the travel time along Hibiscus Coast Highway, assuming there is no change in capacity)

Figure 5-9: 2028 Whangaparaoa Road Travel Time

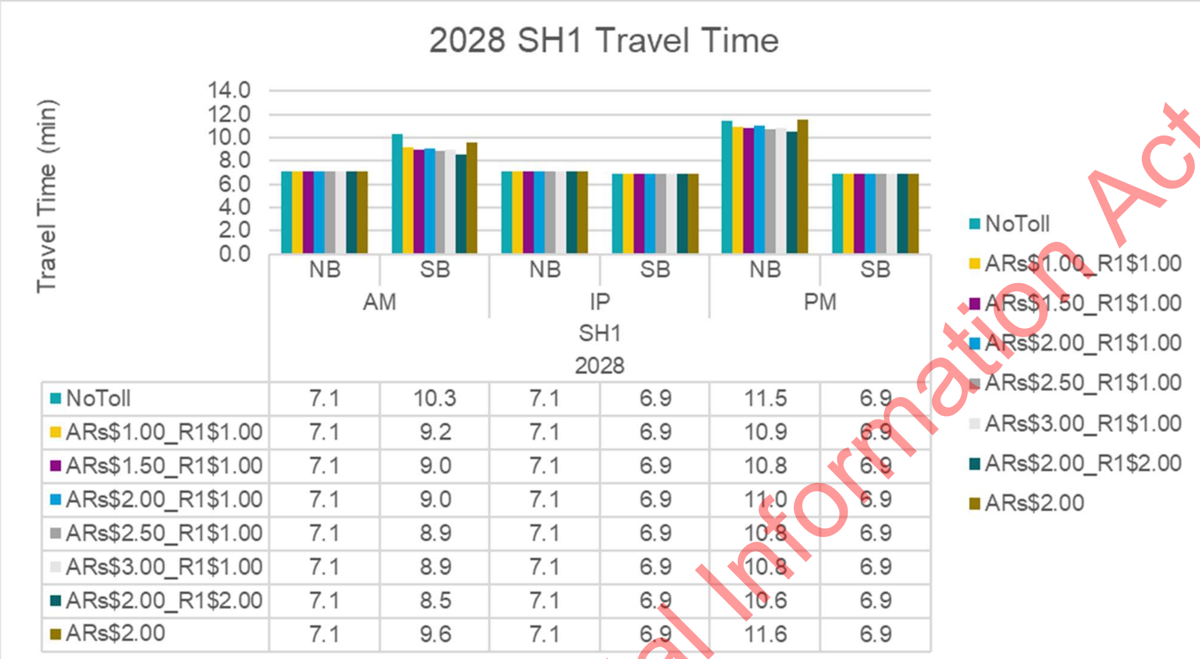


	AM EB	AM WB	IP EB	IP WB	PM EB	PM WB
NoToll	9.7	9.7	9.3	9.8	9.6	10.3
ARs$1.00_R1$1.00	9.6	9.6	9.2	9.8	9.4	10.3
ARs$1.50_R1$1.00	9.5	9.6	9.1	9.8	9.4	10.3
ARs$2.00_R1$1.00	9.5	9.7	9.1	9.8	9.4	10.3
ARs$2.50_R1$1.00	9.5	9.7	9.1	9.8	9.3	10.2
ARs$3.00_R1$1.00	9.5	9.7	9.1	9.8	9.3	10.2
ARs$2.00_R1$2.00	9.5	9.7	9.1	9.8	9.4	10.3
ARs$2.00	9.5	9.7	9.1	9.8	9.4	10.3

The following observations have been made regarding the travel time along Whangaparaoa Road (between Hibiscus Coast Highway and Stanmore Bay Road):

- There is a marginal improvement on Whangaparaoa Road with tolling, especially immediately east of Penlink in the eastbound direction

Figure 5-10: 2028 SH1 Travel Time



	AM NB	AM SB	IP NB	IP SB	PM NB	PM SB
NoToll	7.1	10.3	7.1	6.9	11.5	6.9
ARs$1.00_R1$1.00	7.1	9.2	7.1	6.9	10.9	6.9
ARs$1.50_R1$1.00	7.1	9.0	7.1	6.9	10.8	6.9
ARs$2.00_R1$1.00	7.1	9.0	7.1	6.9	11.0	6.9
ARs$2.50_R1$1.00	7.1	8.9	7.1	6.9	10.8	6.9
ARs$3.00_R1$1.00	7.1	8.9	7.1	6.9	10.8	6.9
ARs$2.00_R1$2.00	7.1	8.5	7.1	6.9	10.6	6.9
ARs$2.00	7.1	9.6	7.1	6.9	11.6	6.9

The following observations have been made regarding the travel time along State Highway 1 (between Hibiscus Coast Highway and Oteha Valley Road):

- Tolling improves the travel time in the peak direction in the peak periods (southbound in the AM, northbound in the PM)
  - Travel time reduces by up to 1.8 minutes in the AM peak and 0.9 minutes in the PM peak
- Including the toll at R1 improves the travel time in the peak direction in the peak periods

➢ *Tolling generally improves network performance, with improvements in the peak and off-peak, albeit higher in the peak. The Penlink corridor sees travel times improve by up to 4.3 minutes in the AM peak direction and 6.6 minutes in the PM peak direction*

➢ *Toll should be applied all day, but could be higher during the commuter peaks*

➢ *Tolling is recommended at R1 (but see discussion on long-term effects below)*

5.4.2 Travel Toll Cost

The toll cost for vehicles using the toll road between communities have been summarised in **Table 5-10** for the toll strategy A,Rs = $3, R1 = $1.

Table 5-10: Travel Toll Cost

Origin / Destination	Whangaparaoa	Stillwater	Local Connection 1	Local Connection 2	East Coast Road	SH1
Whangaparaoa	$ -	$3.00	$3.00	$3.00	$3.00	$4.00
Stillwater	$3.00	$ -	$3.00	$3.00	$3.00	$4.00
Local Connection 1	$3.00	$3.00	$ -	$ -	$ -	$1.00
Local Connection 2	$3.00	$3.00	$ -	$ -	$ -	$1.00
East Coast Road	$3.00	$3.00	$ -	$ -	$ -	$ -

SH1	$4.00	$4.00	$1.00	$1.00	$1.00	$ -

- *For the people who do choose to use the toll road, their monetary costs of travel will generally increase. Cost of travel can increase by up to $4 each journey for an end-to-end trip. The overall impact of this will depend on the frequency of their travel.*

5.4.3 Mode Share

Changes in mode share come directly from the MSM. Running un-tolled and tolled scenarios have a limited impact on the mode share, with up to approximately 150 new public transport trips being made on a daily basis. However, some of the PT users switch from driving to the park and ride station at Silverdale to taking the bus directly from the Whangaparaoa peninsula and across Penlink.

5.4.4 Travel Time Consistency

Travel time consistency has been measured by comparing the travel time between each modelled peak, AM, IP and PM, on the key corridors.

a. Penlink

Without tolling, the peak direction in the peak periods have travel times that are significantly higher than the opposite direction or outside of the peaks. Tolling significantly improves the consistency in travel time between each direction and over the modelled periods.

b. Hibiscus Coast Highway

The travel time along Hibiscus Coast Highway is reasonably consistent across the modelled periods, however there is some inconsistency between both directions. Tolling does not materially impact this trend.

c. Whangaparaoa Road

The travel time along Whangaparaoa Road is reasonably consistent across both the modelled periods and between both directions. Tolling has limited impact on this trend.

d. State Highway 1

The travel time along SH1 is inconsistent for the peak direction in the peak periods (i.e. southbound in the AM peak and northbound in the PM peak). Tolling slightly improves this inconsistency, however the travel time in the peak direction in the peak period will still be higher than the off-peak direction or off-peak period.

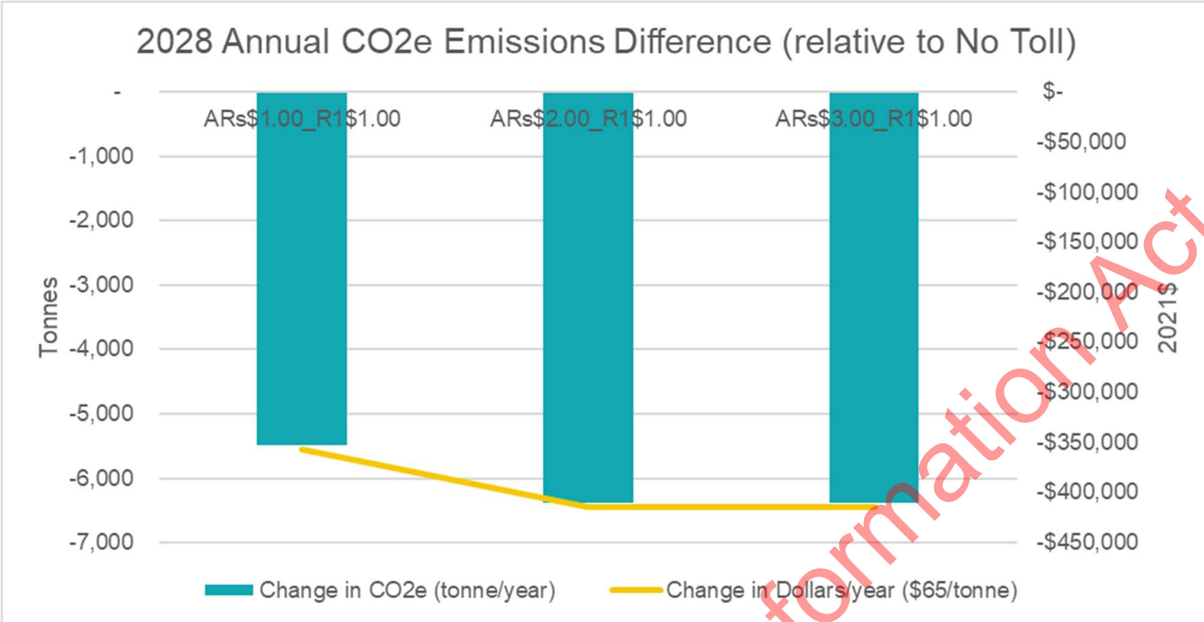
5.5 Environment

5.5.1 Vehicle Emissions

The Waka Kotahi vehicle emissions prediction model (VEPM6.2) has been used to determine the emissions for each toll scenario tested. The VEPM assumes a vehicle fleet mix and uses the vehicle kilometres travelled to determine the level of emissions.

Figure 5-11 summarises the annual emissions for the core toll scenario level tested. The graph shows the change in annual vehicle CO_2-e emissions compared to the un-tolled scenario, both in terms of tonnes and dollars. The total emissions in the un-tolled scenario within the study area shown **Figure 5-6** is 843,560 tonnes, equivalent to approximately $54.8m.

Figure 5-11: 2028 Annual CO_2 Emissions Difference (relative to No Toll)



The figure demonstrates that tolling Penlink reduces emissions compared to the No Toll scenario. The reduction in emissions between the $2 toll at A and Rs and a $3 toll is negligible.

Figure 5-12, **Figure 5-13** and **Figure 5-14** show the annual emissions for the AM, IP and PM peak periods respectively.

Figure 5-12: 2028 AM Annual CO2 Emissions Difference (relative to No Toll)

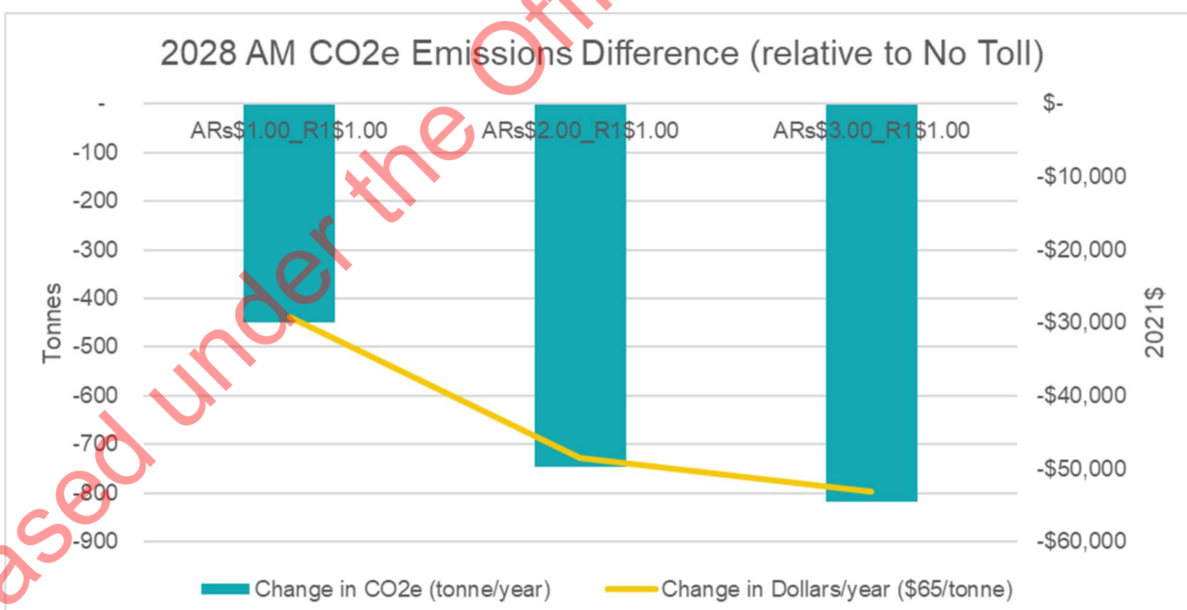


Figure 5-13: 2028 IP Annual CO_2 Emissions Difference (relative to No Toll)

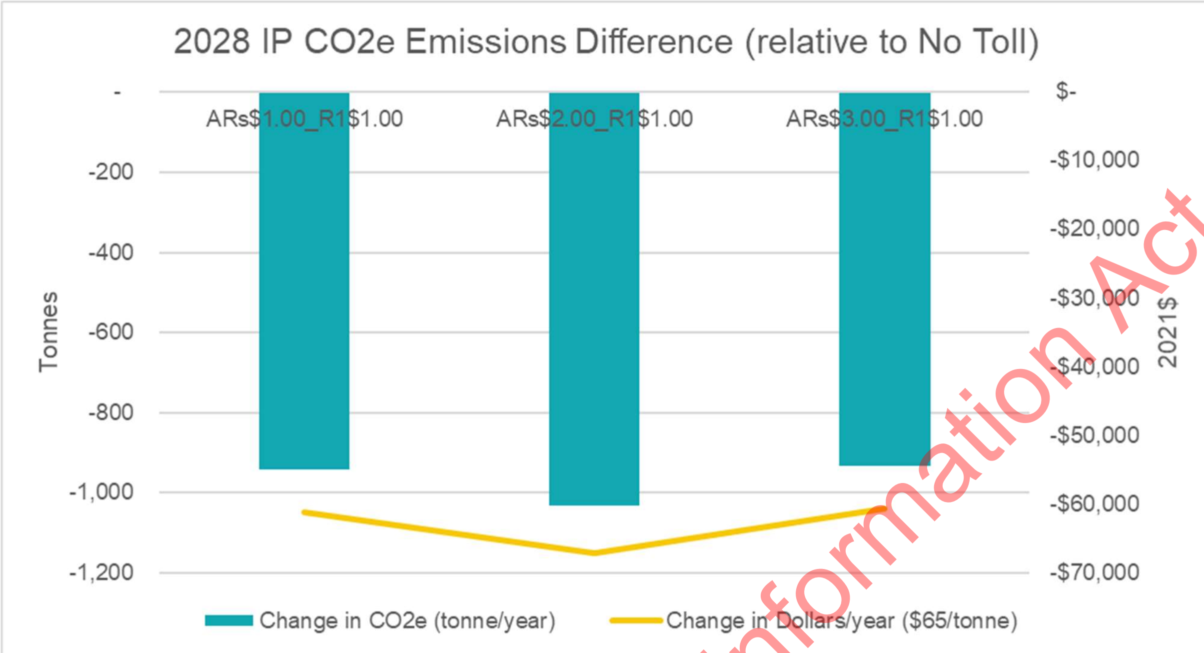
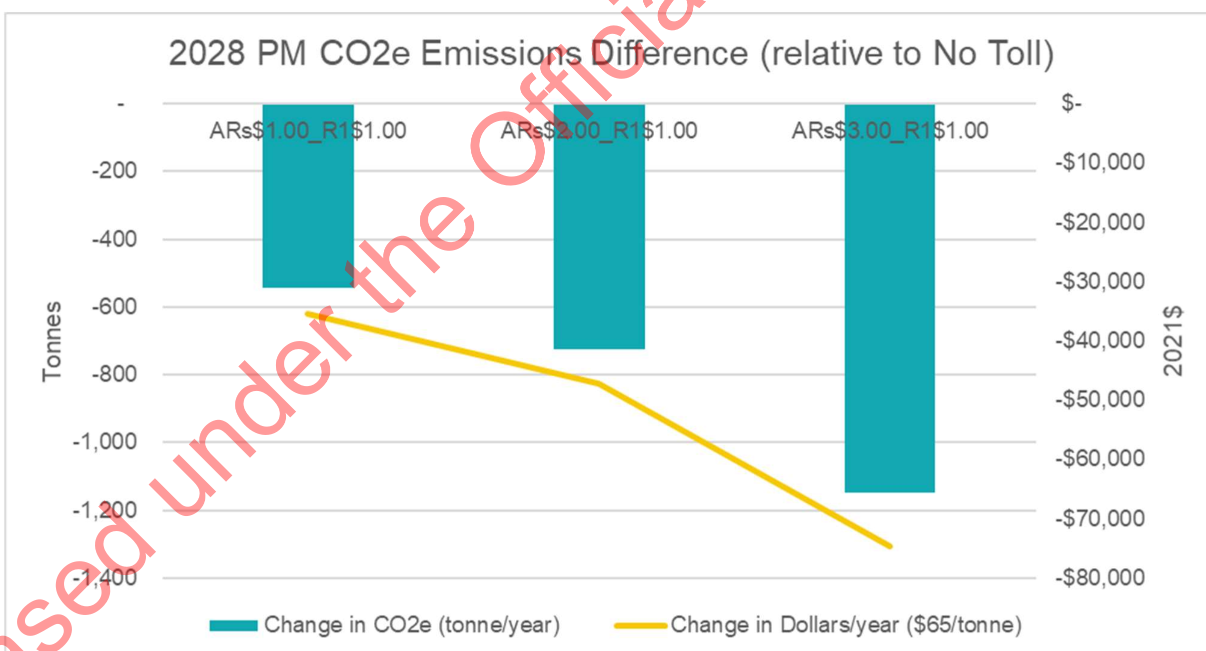


Figure 5-14: 2028 PM Annual CO_2 Emissions Difference (relative to No Toll)



The figures demonstrate that the peak periods have higher reductions in emissions for a $3 toll at A and Rs, while the interpeak has the highest reduction in emissions for a $2 toll at A and Rs.

- *Tolling is expected to cause a reduction in emissions, by up to ~6,000 tonnes annually. Higher toll values in the peaks further reduces emissions compared to the interpeak.*
- *Toll values of $2 at A and Rs produce the best outcome for the interpeak, while $3 at A and Rs produce the best outcome for the peak periods.*

5.6 Value for Money

5.6.1 Toll Revenue

Figure 5-15 shows the gross and net revenue curve for the Penlink toll road with increasing A and Rs toll tariff. **Figure 5-16** shows the gross and net revenue for the tool road with increasing R1 toll tariff. The net revenue is the gross revenue less the transaction costs of $0.70 per vehicle at each toll gantry.

Figure 5-15: 2028 Penlink Annual Revenue (Increasing A, Rs)

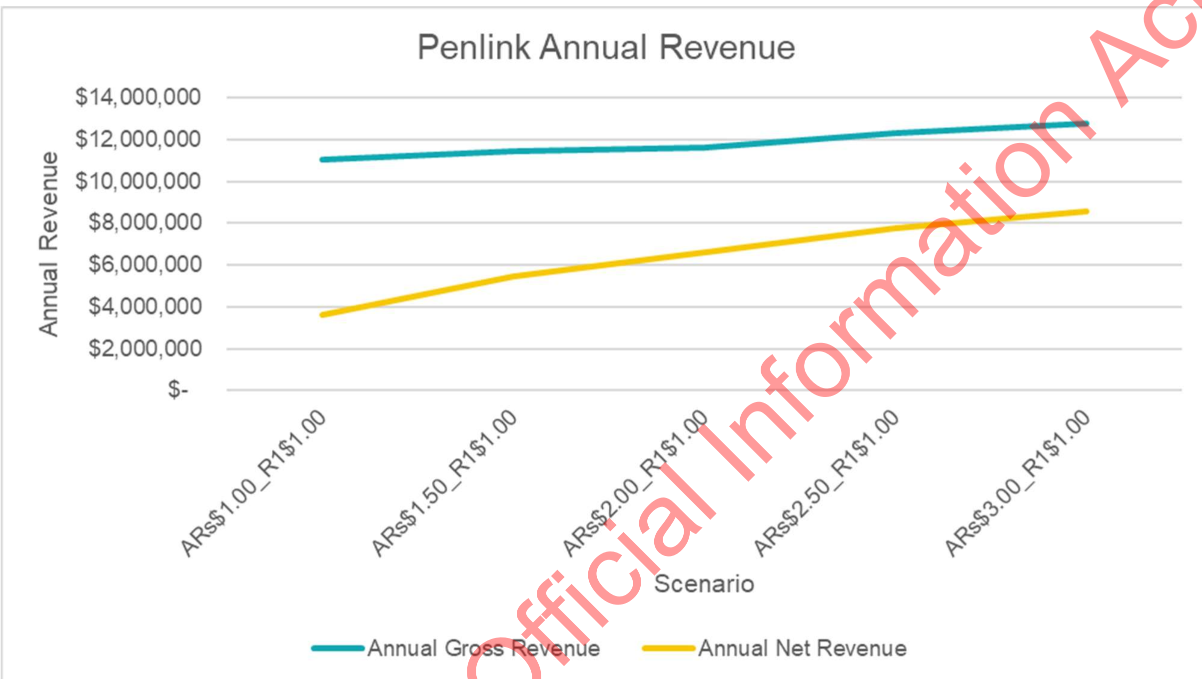
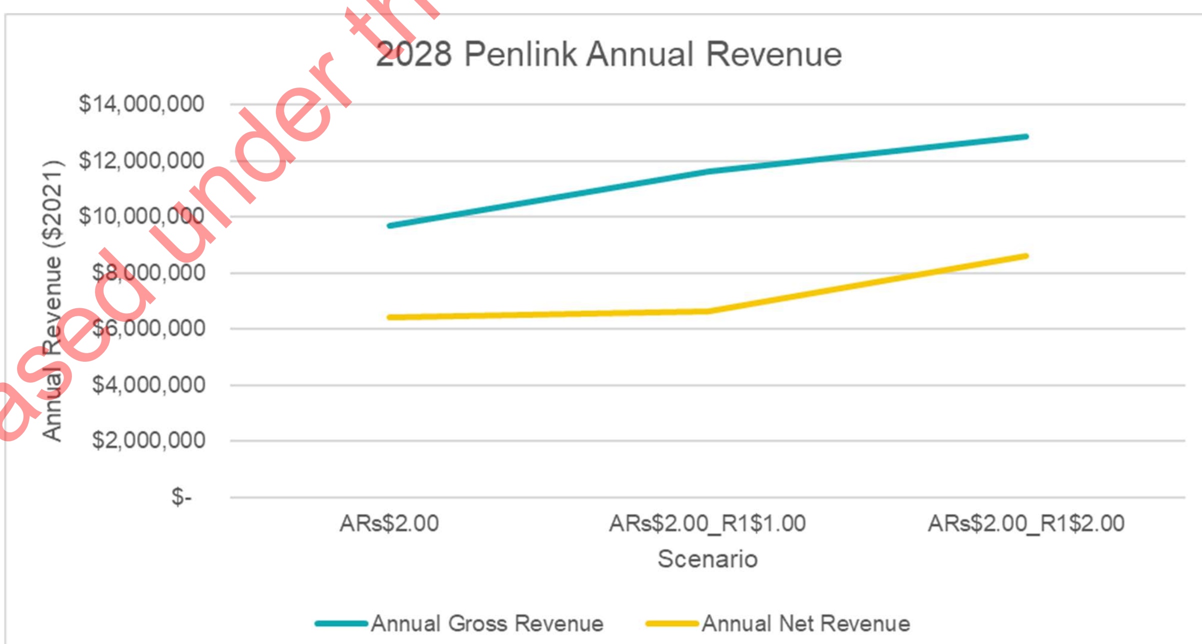


Figure 5-16: 2028 Penlink Annual Revenue (Increasing R1)



The figures show:

- The annual gross and net revenue continue to increase with increasing A and Rs toll tariff
- At a toll tariff of A,Rs=$3 and R1=$1 the gross revenue is estimated to be over $12m per annum.
- Introducing a toll at R1 decreases the net revenue, due to the reduction in total traffic volume and increase in transaction costs
- Increasing the R1 toll tariff provides a negligible increase in gross and net revenue

Although specific capital costs of installing a tolling system were not directly assessed here, based on previous studies this revenue is expected to significantly exceed the installation and maintenance costs.

- ➢ *A higher toll at A and Rs compared to R1 is recommended*
- ➢ *Tolling the new road has potential to generate net revenue of $3.6 – $8.6m per annum.*

5.7 Equity

Equity has been simplistically considered in terms of pricing across the different users of the corridor.

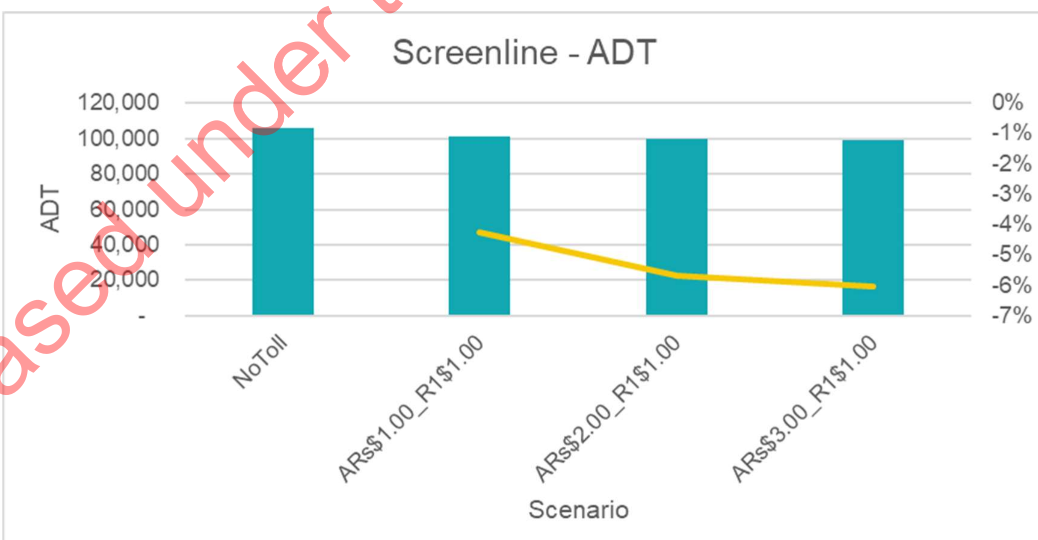
Under current legislation a free alternative route must be available for users, which is available for the Whangaparaoa and Stillwater communities using existing roads. However, the Weiti Precinct only has access to Penlink so the tolling strategy must allow for an un-tolled route. The Future Urban Zone (FUZ) area has not been planned in detail, so its proposed land use and transport network is not known. While it has a proposed access onto Penlink, it could also have local (un-tolled) access routes to East Coast Road.

Therefore, tolling strategies proposed capture users that have a confirmed free alternative for each of their destinations, while the addition of toll gantry R1 captures users from those locations without alternative access to East Coast Road.

5.8 Influencing Demand

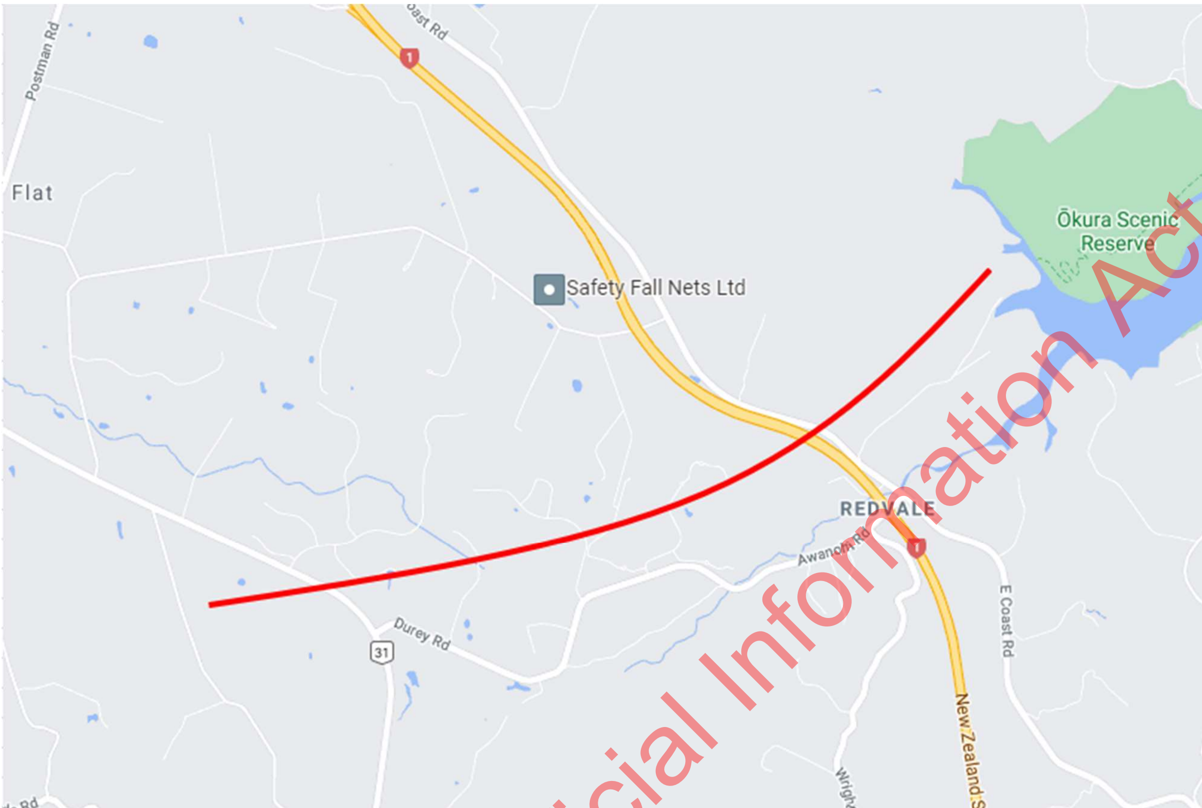
Tolling Penlink is expected to marginally improve the mode share in the area while also reducing the travel between Whangaparaoa and south of the Penlink connection. **Figure 5-17** shows the reduction in average daily traffic volumes through the screenline illustrated in **Figure 5-18**.

Figure 5-17: Screenline Average Daily Traffic



The figure demonstrates a reduction in average daily traffic of up to 6% at the selected screenline.

Figure 5-18: Demand Response Screenline



5.9 Consideration of Vehicle Differentials

The consideration of toll tariff for heavy vehicles against light vehicles is as follows:

- The higher VoT associated with heavy vehicles could mean an ability to generate greater revenue through larger heavy vehicle differentials
- However, high truck tolls could result in more trucks on local roads and have an economic impact on economic growth
- However, Penlink is not expected as a major freight route, with the percentage of heavy vehicles using Penlink estimated by the model to be relatively low at approximately 4% daily un-tolled
- It could be perceived as perverse to have to different heavy vehicle differentials between the existing toll road and new toll road

Penlink is a potential bus route, therefore treatment of tolls for buses will need to be considered. It is recommended to consider free access for buses in order to continue to promote mode shift to high occupancy modes.

There is potential to encourage higher vehicle occupancy through discounted tolling for high occupancy vehicles (e.g., T2 / T3), however this would likely be difficult to enforce.

➢ *It is recommended to adopt the same ratio (2) for heavy vehicles as the adjacent Northern Gateway Toll Road.*

➢ *It is recommended to consider free access for buses*

➢ *High occupancy vehicle discounts could be considered if technically feasible.*

5.10 Consideration of Stillwater Toll

The consideration of a toll at the Stillwater is as follows:

- Tolling Stillwater west-facing ramps provides marginal revenue and is unlikely to cover capital and operating costs
- Tolling will contribute to suppression effect (mitigates induced travel from building Penlink)
- Provides more equitable use of Penlink

  - ➢ *Tolling of the Stillwater ramps is recommended for equity (fairness) and trip suppression effects*

5.11 Consideration of Alternative Strategy (A+B vs. A+Rs)

There are two possible locations for capturing traffic heading to/from the west to/from Stillwater; west-facing ramp gantries at Rs or a mainline gantry at B. Either strategy can achieve the same effective tolling for Whangaparaoa and Stillwater users (assuming that Whangaparaoa users are discounted and not paying double from the gantry at A and B). However, a gantry at B will incur significantly higher transaction costs due to traffic to/from Whangaparaoa being detected at gantry A and B. This is based on the assumption that every vehicle detected incurs a consistent transaction cost of 70c.

  - ➢ *Gantries at A+Rs is preferred over at A+B due to the lower transaction costs, however this is subject to confirmation through detailed design feasibility*

5.12 Consideration of Penlink Ramp Tolling (R1)

The consideration for a toll at the Penlink ramps identified the following:

- Negligible increase in revenue (the small extra ramp revenue is offset by reduced flow at the other gantry)
- R1 improves SH1 performance in peak periods / peak direction by reducing merge flows
- R1 improves Penlink / East Coast Road roundabout performance in the PM peak by reducing turning flows at the intersection
- Will contribute to the suppression effect (mitigates induced travel) for the East Coast Road catchment
- Arguably increases fairness equity in the short term by tolling this element of Penlink
- Long term (with full diamond and wester connection) arguably in-equitable as this would be the sole community tolled for ramp access in Auckland

The fairness/equity issue is therefore more complex as it changes over time and differs between a local versus regional perspective. Regarding the long-term strategy for tolling at R1, three approaches could be considered:

1. Everyone who uses the ramps pays, regardless of where they are from/going i.e., anyone from Weiti, Whangaparaoa, Dairy Flat etc. would pay (this is what has been modelled)
2. Only some users of R1 pay, e.g. only users from Whangaparaoa or Stillwater pay, with everyone else being free
3. No-one pays at R1 in the long-term

Option 1 could be considered 'equitable' as everyone using the ramps pays, similar to how equity for the gantries along Penlink has been treated. However, it could be considered 'regional inequitable' when compared to all other motorway access points in Auckland, i.e. this would be the only motorway access tolled, with no other community being tolled to access SH1.

Option 2 seems inequitable as it is not clear why Weiti or Dairy Flat should have free access when Whangaparaoa and Stillwater do not.

Option 3 is arguably the most 'equitable', both locally and regionally. However, the travel time benefits on Penlink of tolling R1 would be lost.

Therefore, the role of the ramps and whether they are defined and remain part of Penlink needs to be considered. The ramps have three roles that change over time:

- Access to SH1 from Penlink
- Access to SH1 from East Coast Road
- Long-term access to SH1 from Dairy Flat

If the ramps are considered part of Penlink, then options 1 or 3 remain equitable and possible (i.e., everyone or no-one is tolled). If the ramps are not defined as part of Penlink, but the eastern access to the ramps is, then shifting gantries from R1 to E (see **Figure 4-2**), now or later would be possible. However, as noted above this raises the regional issues about why only those from the east of SH1 pay to use the ramps, but not those from the west. It could also create perverse routing via Bawden Road to avoid the toll at E.

➢ *It is recommended to toll the R1 ramps in the short term but consider removing in the long term when the role of the interchange changes (or regional road pricing is introduced to the whole system to address regional fairness)*

5.13 Consideration of Time-Varying Tolls

There is potential to apply different toll tariffs by time of day. The following points are considered with respect to this option:

- Consistency of toll would be desirable for driver legibility, operating costs, enforcement etc.
- There are clear commuter peaks which means that the toll tariff can be switched at discernible and logical points of switching tolls
- Pricing commuter peaks is beneficial to manage demand and level of service on Penlink
- The emissions outcome measure sees diminishing returns with increased tolling in the interpeak compared to the commuter peaks

➢ *Therefore, it is recommended to adopt a 24/7 toll system, but with higher toll tariffs in the peaks*

5.14 Recommended Strategy

Based on the preliminary assessment, the following is recommended:

- Gantries at A, Rs and R1
- Consider removing R1 in the long term
- All day toll, but higher in the peaks
- Higher toll at A and RS than R1
  - Off-peak Approximately: $2 at A and Rs, $1 at R1
  - Peak Approximately: $3 at A and Rs, $1 at R1
- Toll trucks at 2x car (as per Northern Gateway)
- Free for buses
- Consider discount for HOVs if technically feasible

Although tolls varying by time and destination is recommended due to the expected outcomes, it is noted that this makes for a more complex toll communication / signage that should be confirmed during the signage design process.

6 Assessment of Preferred Strategy

6.1 Approach

This chapter provides more detailed forecasts for the recommended toll strategy. The strategy proposed was agreed with Waka Kotahi for the purposes of this report.

6.2 Modelled Scenarios

For undertaking the assessment of the preferred strategy, both un-tolled and tolled scenarios were run for 2028, 2038 and 2048.

6.3 Penlink Preferred Toll Strategy

A number of toll strategies have been considered for the Penlink project.

The preferred strategy is for toll gantries at A (gantry between Whangaparaoa and Stillwater), Rs (Ramp gantries on the Stillwater west-facing ramps) and R1 (ramp gantries at the SH1 / Penlink motorway ramps).

The traffic and revenue analysis is therefore based on the following:

- Differential tolling for the commuter peaks, defined as 6am – 9am and 4pm – 7pm
- A recommended light-vehicle tariff at A and Rs between $2 and $3 in the commuter peaks, modelled at $3
- A recommended light-vehicle tariff at R1 of approximately $1 in the commuter peaks, modelled at $1
- A recommended light-vehicle tariff at A and Rs between $1 and $2 in the off-peak, modelled at $2
- A recommended light-vehicle tariff at R1 of approximately $1 in the off-peak, modelled at $1
- A heavy vehicle toll ratio of 2 times that for light vehicles
- No toll on buses

6.4 Opening Year Traffic Estimates on Penlink

The Penlink project is expected to open in late 2025, however the earliest available model is for 2028. Allowing for a ramp up period, we have estimated 2026 annual average daily traffic flows. This has been assessed as follows:

- Interpolation between the 2018 (no project) corridor flow and the 2028 modelled corridor flow
  - An assignment has been run of the 2018 demands with the 2028 network (i.e. Penlink project included). This gives the anticipated corridor traffic flow that does not include growth or induced traffic.

Using the interpolation method AADT flows at each of the toll gantry locations are as shown in **Table 6-1** for the preferred toll strategy.

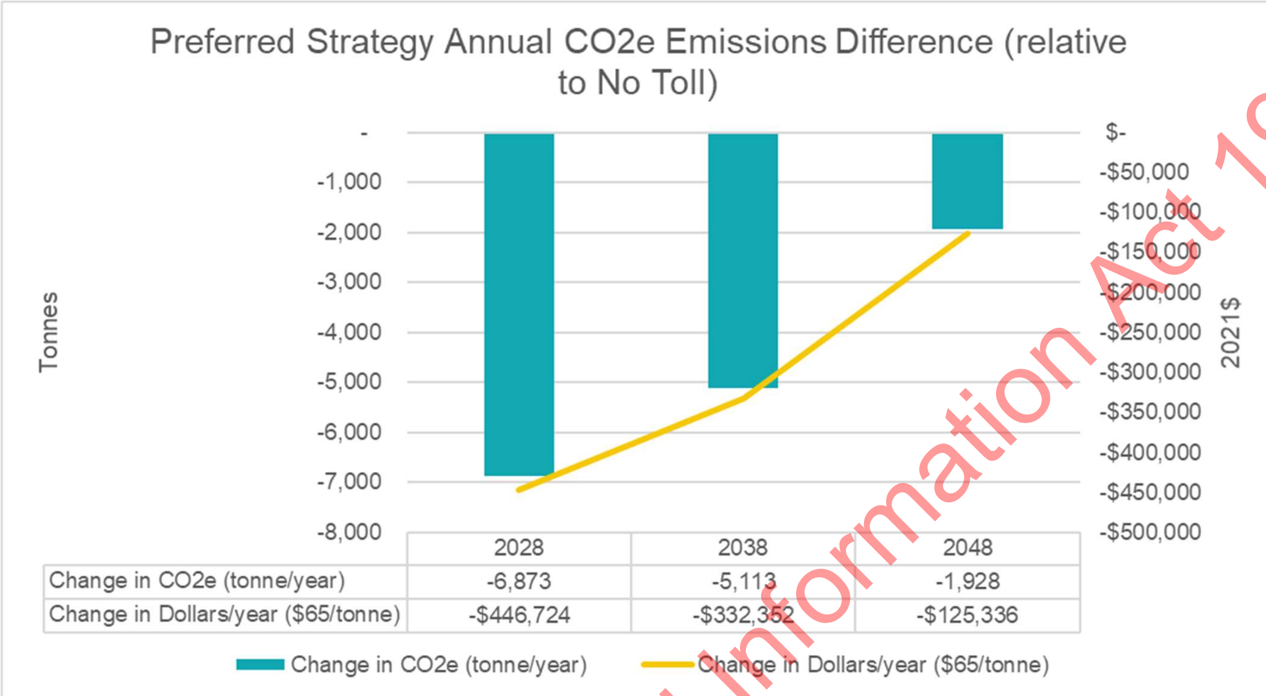
Table 6-1: Opening Year AADT Estimate

Gantry	Opening Year AADT (2026)
A (between Whangaparaoa and Stillwater)	9,000
Rs (west-facing ramps at Stillwater)	400
R1 (south-facing ramps at SH1)	8,500

6.5 Emissions

Figure 6-1 shows the annual emissions for the preferred toll scenario and compared to the no toll scenario for the modelled years 2028, 2038 and 2048.

Figure 6-1: Preferred Strategy Annual CO_2 Emissions Difference



The figure demonstrates that the benefit to emissions due to tolling reduces over time, however there is still an overall reduction in emissions compared to the No Toll scenario for all modelled years. The reduced benefit is due to the changing fleet composition to lower emitting vehicles in the future, reducing the overall emissions for all scenarios.

6.6 Travel Time

As seen in the Preliminary testing, tolling has the potential to relieve congestion along Penlink in the 2028 forecast year.

The following figures show the Penlink travel time for the preferred scenario for each modelled peak of AM, IP and PM over the forecast years 2028, 2038 and 2048.

Figure 6-2: Penlink Travel Time - AM

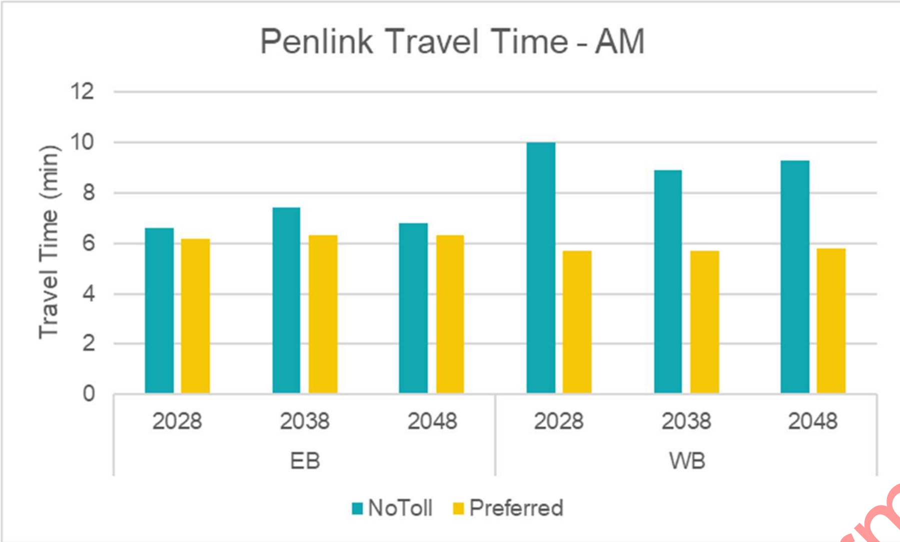


Figure 6-3: Penlink Travel Time - IP

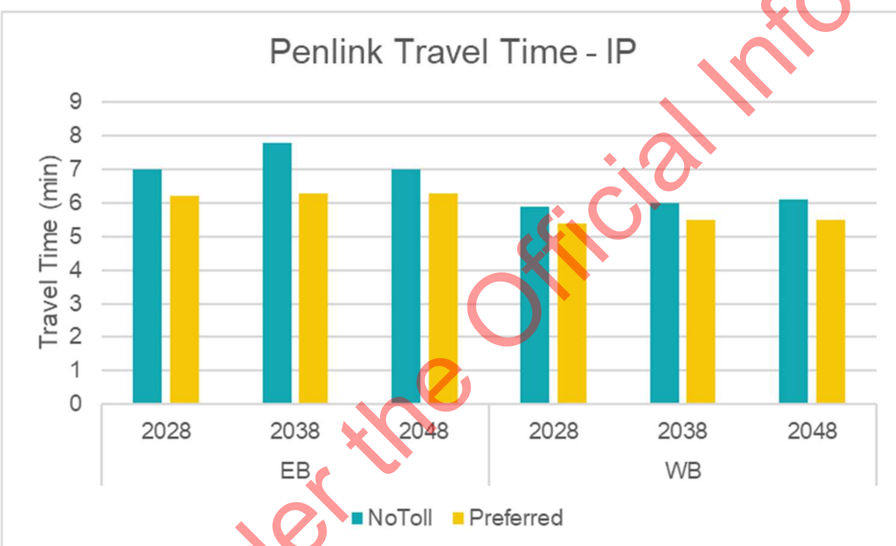
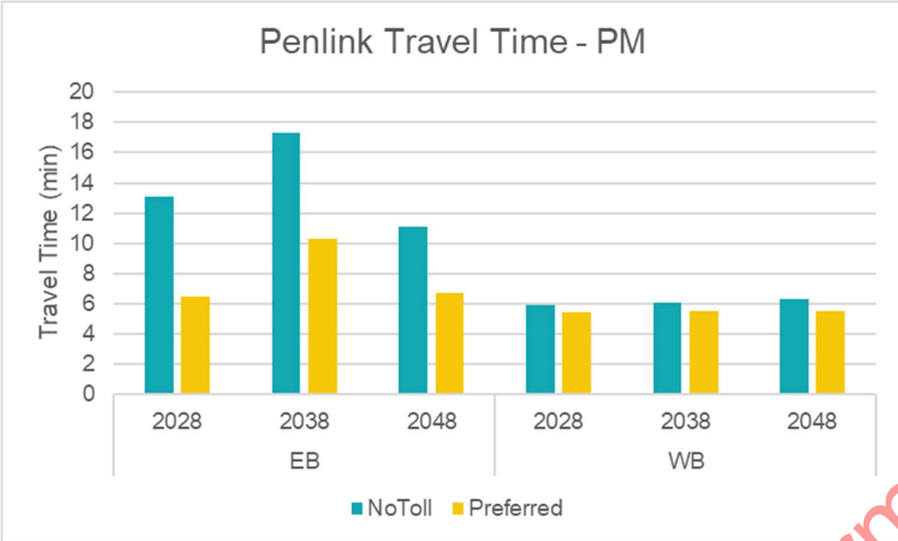


Figure 6-4: Penlink Travel Time - PM



The figures again demonstrate that tolling has the potential to relieve congestion and provide an improved travel time along Penlink across all forecast years. With the design used in the modelling, it is predicted that the un-tolled scenario would operate at a poor level of service, particularly at the approaches to the East Coast Road roundabout and at the SH1 ramps.

It is noted that some travel times improve in 2048 compared to 2038, despite higher traffic volumes. Most notably for the eastbound direction in the PM peak. This is due to the completion of the full diamond interchange at State Highway 1 and the completed access from the Penlink interchange over to the Dairy Flat area. This enables Penlink users to use SH1 northbound or directly access Dairy Flat as opposed to turning into East Coast Road at the Penlink / ECR roundabout, which causes additional delay to the Penlink through movements.

6.7 Risk Analysis

Key risks and uncertainties have been identified that could influence the predicted outcomes. Probabilities and the scale of impact of these effects were then estimated, followed by a Monte-Carlo-type simulation that combined all the risks. The risks are summarised in **Table 6-2** below. Items 1-11 have impacts on the traffic volumes on the toll road and hence the revenue, items 12 and 13 only impact the net revenue of the toll roads. **Table 6-3** demonstrates the 5th, 50th and 95th percentile values for each item.

Table 6-2: Risk Analysis

No	Item	Discussion	Assumed Distribution	Distribution Parameters			
					2028	2038	2048
1	Growth	The forecast growth in land use is limited on the Whangaparaoa Peninsula and Stillwater and therefore has more limited levels of uncertainty than areas with high growth planned / predicted. However, future growth areas such as Weiti, Dairy Flat and the Future Urban Zone adjacent to the Penlink corridor have some level of uncertainty in growth. The lower bound estimate has assumed that there is no growth from the base year 2018 forecasts.	Triangular	Low: Likely: High:	0.98 1.0 1.03	0.97 1.0 1.03	0.83 1.0 1.03
2	WtP -VoT	The key VoT values are uncertain and difficult to determine. Sensitivity tests use the lower MSM values and the higher Tauranga VoT. In order to account for some uncertainty in the impact of cumulative use of the toll road, the distribution parameters have been weighted towards the lower MSM values.	Triangular	Low: Likely: High:	0.8 1.0 1.2	0.8 1.0 1.2	0.8 1.0 1.2
3	WtP - Escalation	The assessment assumes that the tolls are escalated at the rate of inflation but that WTP will escalate 1% faster. This is tested with the 1% margin removed and also with it increased to 1.5% (assumed increase in the MSM)	Triangular	Low: Likely: High:	0.97 1.0 1.03	0.93 1.0 1.07	0.89 1.0 1.09
4	WtP – Road perception factors	Road perception factors are used to distinguish road characteristics such as safety, comfort and gradient. There is uncertainty in how drivers perceive these characteristics, particularly for a toll road. The low and high estimates are based on +/-50% on the modelled perception factors.	Triangular	Low: Likely: High:	0.95 1.0 1.05	0.95 1.0 1.05	0.95 1.0 1.05
5	Demand Response – Toll suppression	The models include a demand response to tolling, where demand is suppressed. The high estimate is based on a no toll scenario – however slightly moderated to recognise that it is highly unlikely to have no demand response. The low estimate assumes a small likelihood of demand response being bigger.	Triangular	Low: Likely: High:	0.95 1.0 1.2	0.95 1.0 1.2	0.95 1.0 1.2
6	Demand Response – Induced traffic	The models include a demand response to Penlink being built (induced traffic). The low estimate assumes half the induced traffic occurs, while the high estimate assumes half the low estimate to account for models generally being too sensitive for large changes in travel cost.	Triangular	Low: Likely: High:	0.9 1.0 1.05	0.9 1.0 1.05	0.9 1.0 1.05
7	Alternative Route speed / capacity treatments	No specific speed / capacity treatments have been assumed on the alternative routes for the core scenarios. Speed / capacity management plans could lower the attractiveness of the un-tolled	Binary	Probability: Result:	80% 1.00	80% 1.00	80% 1.00

		route, resulting in higher flows on Penlink. The alternative route treatments could include removal of the Whangaparaoa Road tidal lanes and signalisation of the Silverdale / HBC Highway intersection.		Alternative Result:	1.06	1.06	1.06
8	Penlink Speed	The Penlink corridor is currently designed as an 80km/h road and modelled to reflect this. However, there is a possibility of a 60km/h speed limit being adopted. This could reduce the attractiveness of Penlink and therefore lower the traffic volumes.	Binary	Probability: Result: Alternative Result:	85% 1.0 0.94	85% 1.0 0.94	85% 1.0 0.94
9	Penlink Speed+At-grade	The Penlink access points to Penlink along the corridor are modelled as grade-separated intersection, however at-grade intersections may still be considered for the design in combination with a lower speed limit. This will increase the travel time along Penlink and likely reduce the attractiveness, hence reducing the flows.	Binary	Probability: Result: Alternative Result:	70% 1.0 0.88	70% 1.0 0.88	70% 1.0 0.88
10	2018 Base Patterns	The base 2018 calibration process produced factors that adjusted the distribution of trips to better match observed data. A sensitivity test has been undertaken where these factors were taken out due to uncertainty in their application in the future given the significant impact building Penlink has.	Binary	Probability: Result: Alternative Result:	70% 1.0 0.97	70% 1.0 0.97	70% 1.0 0.97
11	Annualisation	The model has used available count data to determine annualization factors. The counts and model may have bias in the count location and time of year observed. A distribution is developed to account for this uncertainty.	Triangular	Low: Likely: High:	0.9 1.0 1.05	0.9 1.0 1.05	0.9 1.0 1.05
12	Revenue Leakage	The assessment assumed a 3% loss of revenue from non-payments. This was tested at 2% and 5%	Triangular	Low: Likely: High:	0.95 0.97 0.98	0.95 0.97 0.98	0.95 0.97 0.98
13	Transaction Costs	The assessment has assumed a transaction cost of $0.70 per vehicle, as advised by NZTA. It could be expected that this value reduces as more toll projects are included in the system, so this was tested with: $0.65 in 2028, $0.50 in 2038 and $0.45 in 2048	Triangular	Low: Likely: High:	0.65 0.7 0.75	0.5 0.7 0.75	0.45 0.7 0.75

Table 6-3: Risk Adjustment Values – Gantry A

	2026			2028			2038			2048		
Item	5th	50th	95th	5th	50th	95th	5th	50th	95th	5th	50th	95th
1	0.99	1.00	1.02	0.99	1.00	1.02	0.98	1.00	1.02	0.87	0.96	1.01
2	0.86	1.00	1.14	0.86	1.00	1.14	0.86	1.00	1.14	0.86	1.00	1.14

3	0.98	1.00	1.02	0.98	1.00	1.02	0.95	1.00	1.05	0.92	0.99	1.06
4	0.97	1.00	1.03	0.97	1.00	1.03	0.97	1.00	1.03	0.97	1.00	1.03
5	0.97	1.04	1.15	0.97	1.04	1.15	0.97	1.04	1.15	0.97	1.04	1.15
6	0.93	0.99	1.03	0.93	0.99	1.03	0.93	0.99	1.03	0.93	0.99	1.03
7	1.00	1.06	1.06	1.00	1.06	1.06	1.00	1.06	1.06	1.00	1.06	1.06
8	0.94	1.00	1.00	0.94	1.00	1.00	0.94	1.00	1.00	0.94	1.00	1.00
9	0.88	1.00	1.00	0.88	1.00	1.00	0.88	1.00	1.00	0.88	1.00	1.00
10	0.97	1.00	1.00	0.97	1.00	1.00	0.97	1.00	1.00	0.97	1.00	1.00
11	0.93	0.99	1.03	0.93	0.99	1.03	0.93	0.99	1.03	0.93	0.99	1.03
Combined	0.81	1.01	1.23	0.81	1.01	1.23	0.80	1.00	1.23	0.74	0.95	1.19
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.96	0.97	0.98	0.96	0.97	0.98	0.96	0.97	0.98	0.96	0.97	0.98

Table 6-4: Risk Adjustment Values – Gantry Rs

	2026			2028			2038			2048		
Item	5th	50th	95th	5th	50th	95th	5th	50th	95th	5th	50th	95th
1	0.99	1.00	1.02	0.99	1.01	1.02	0.90	0.97	1.01	0.75	0.92	1.01
2	0.86	1.00	1.14	0.86	1.00	1.14	0.86	1.00	1.14	0.86	1.00	1.14
3	0.98	1.00	1.02	0.96	0.99	1.03	0.89	0.98	1.04	0.83	0.96	1.06
4	0.97	1.00	1.03	0.97	1.00	1.03	0.97	1.00	1.03	0.97	1.00	1.03
5	0.97	1.04	1.15	0.97	1.04	1.15	0.97	1.04	1.15	0.97	1.04	1.15
6	0.93	0.99	1.03	0.93	0.99	1.03	0.93	0.99	1.03	0.93	0.99	1.03
7	1.00	1.06	1.06	1.00	1.06	1.06	1.00	1.06	1.06	1.00	1.06	1.06
8	0.94	1.00	1.00	0.94	1.00	1.00	0.94	1.00	1.00	0.94	1.00	1.00
9	0.88	1.00	1.00	0.88	1.00	1.00	0.88	1.00	1.00	0.88	1.00	1.00
10	0.97	1.00	1.00	0.97	1.00	1.00	0.97	1.00	1.00	0.97	1.00	1.00
11	0.93	0.99	1.03	0.93	0.99	1.03	0.93	0.99	1.03	0.93	0.99	1.03
Combined	0.81	1.01	1.23	0.80	1.00	1.23	0.74	0.94	1.18	0.64	0.86	1.13
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

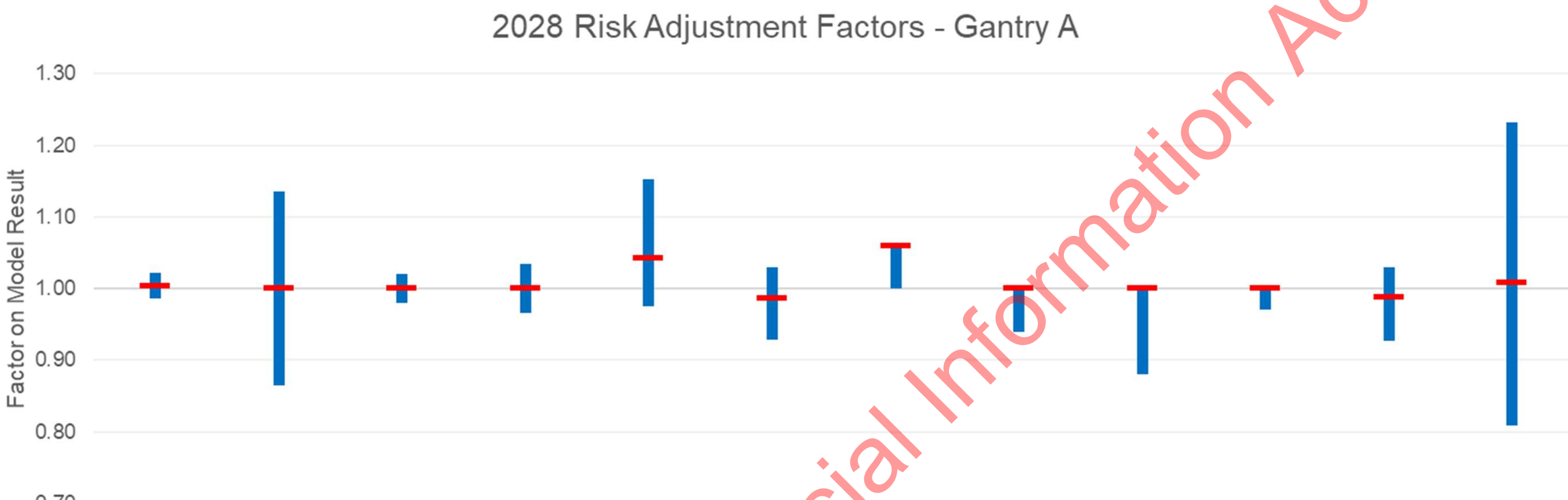
13	0.96	0.97	0.98	0.96	0.97	0.98	0.96	0.97	0.98	0.96	0.97	0.98

Table 6-5: Risk Adjustment Factors - Gantry R1

	2026			2028			2038			2048		
Item	5th	50th	95th	5th	50th	95th	5th	50th	95th	5th	50th	95th
1	0.99	1.00	1.02	0.99	1.00	1.02	0.97	1.00	1.02	0.71	0.90	1.01
2	0.86	1.00	1.14	0.86	1.00	1.14	0.86	1.00	1.14	0.86	1.00	1.14
3	0.98	1.00	1.02	0.99	1.00	1.01	0.99	1.01	1.03	0.99	1.01	1.04
4	0.97	1.00	1.03	0.97	1.00	1.03	0.97	1.00	1.03	0.97	1.00	1.03
5	0.97	1.04	1.15	0.97	1.04	1.15	0.97	1.04	1.15	0.97	1.04	1.15
6	0.93	0.99	1.03	0.93	0.99	1.03	0.93	0.99	1.03	0.93	0.99	1.03
7	1.00	1.06	1.06	1.00	1.06	1.06	1.00	1.06	1.06	1.00	1.06	1.06
8	0.94	1.00	1.00	0.94	1.00	1.00	0.94	1.00	1.00	0.94	1.00	1.00
9	0.88	1.00	1.00	0.88	1.00	1.00	0.88	1.00	1.00	0.88	1.00	1.00
10	0.97	1.00	1.00	0.97	1.00	1.00	0.97	1.00	1.00	0.97	1.00	1.00
11	0.93	0.99	1.03	0.93	0.99	1.03	0.93	0.99	1.03	0.93	0.99	1.03
Combined	0.81	1.01	1.23	0.81	1.01	1.24	0.81	1.01	1.24	0.67	0.90	1.15
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.96	0.97	0.98	0.96	0.97	0.98	0.96	0.97	0.98	0.96	0.97	0.98

For illustration purposes, the risk adjustment distribution for 2028 Gantry A is shown in **Figure 6-5**.

Figure 6-5: Risk Adjustment Factors

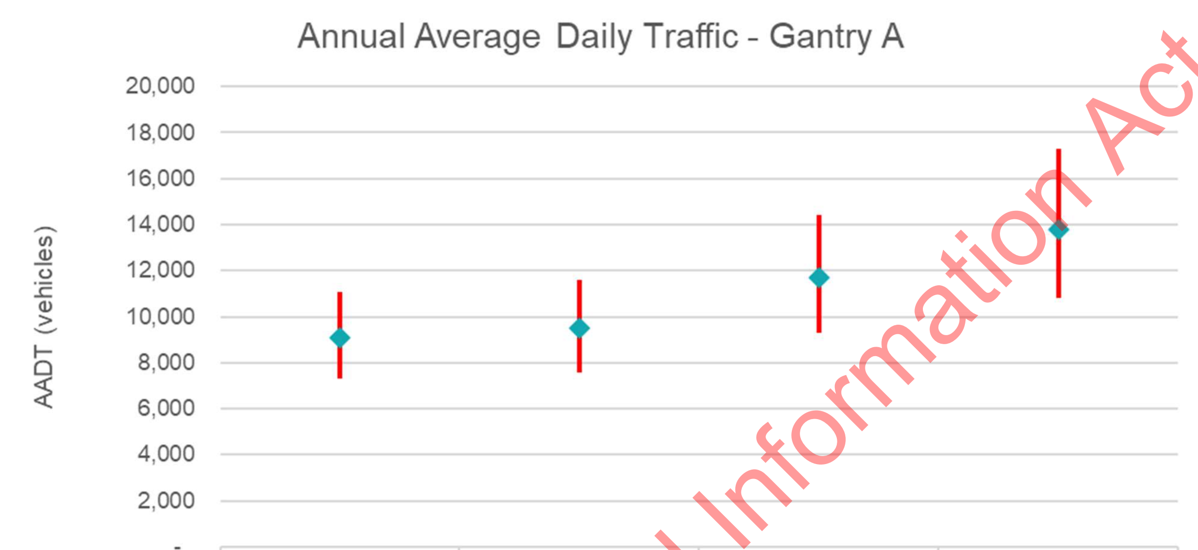


	Land Use Growth	WtP - VoT	WtP - Escalation	WtP - Road Perception Factors	Demand Response - Toll Supression	Demand Response - Induced Traffic	Alternative Route Speed / Capacity Treatments	Penlink Speed	Penlink Speed+At-grade	2018 Base Patterns	Annualisation	Combined
95th	1.02	1.14	1.02	1.03	1.15	1.03	1.06	1.00	1.00	1.00	1.03	1.23
5th	0.99	0.86	0.98	0.97	0.97	0.93	1.00	0.94	0.88	0.97	0.93	0.81
50th	1.00	1.00	1.00	1.00	1.04	0.99	1.06	1.00	1.00	1.00	0.99	1.01

6.8 Forecast Traffic Volumes

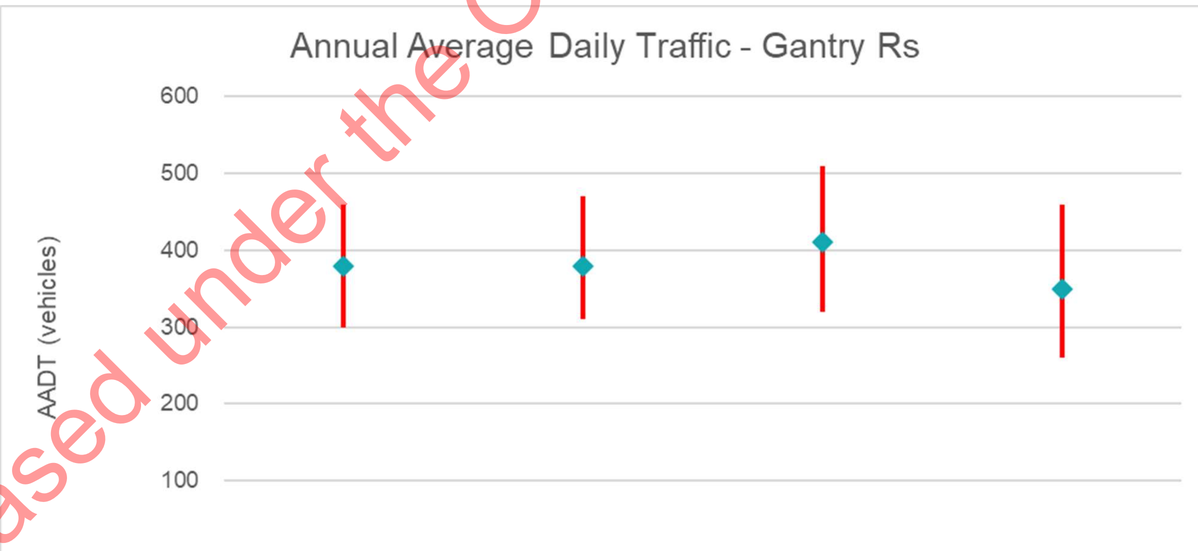
The AADT on the Penlink toll road at each gantry location is reported for three levels: 5th, 50th and 95th percentile. The AADT shown is for the recommended toll strategy described above.

Figure 6-6: AADT - Gantry A



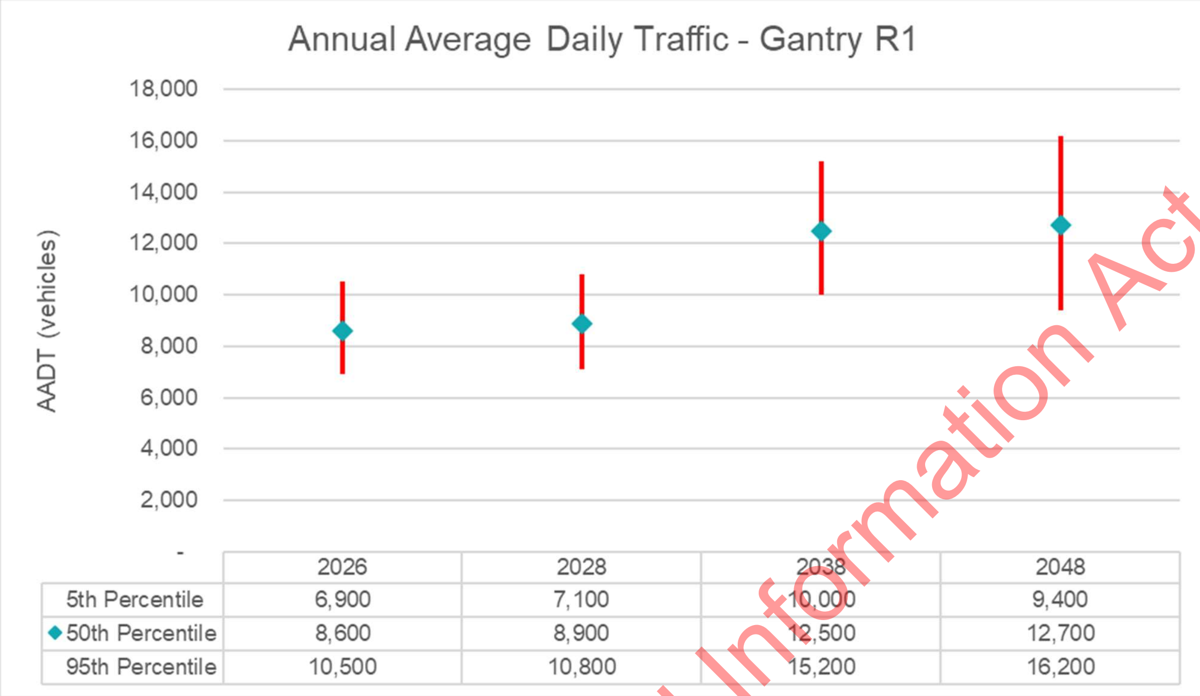
	2026	2028	2038	2048
5th Percentile	7,300	7,600	9,300	10,800
◆ 50th Percentile	9,100	9,500	11,700	13,800
95th Percentile	11,100	11,600	14,400	17,300

Figure 6-7: AADT - Gantry Rs



	2026	2028	2038	2048
5th Percentile	300	310	320	260
◆ 50th Percentile	380	380	410	350
95th Percentile	460	470	510	460

Figure 6-8: AADT - Gantry R1



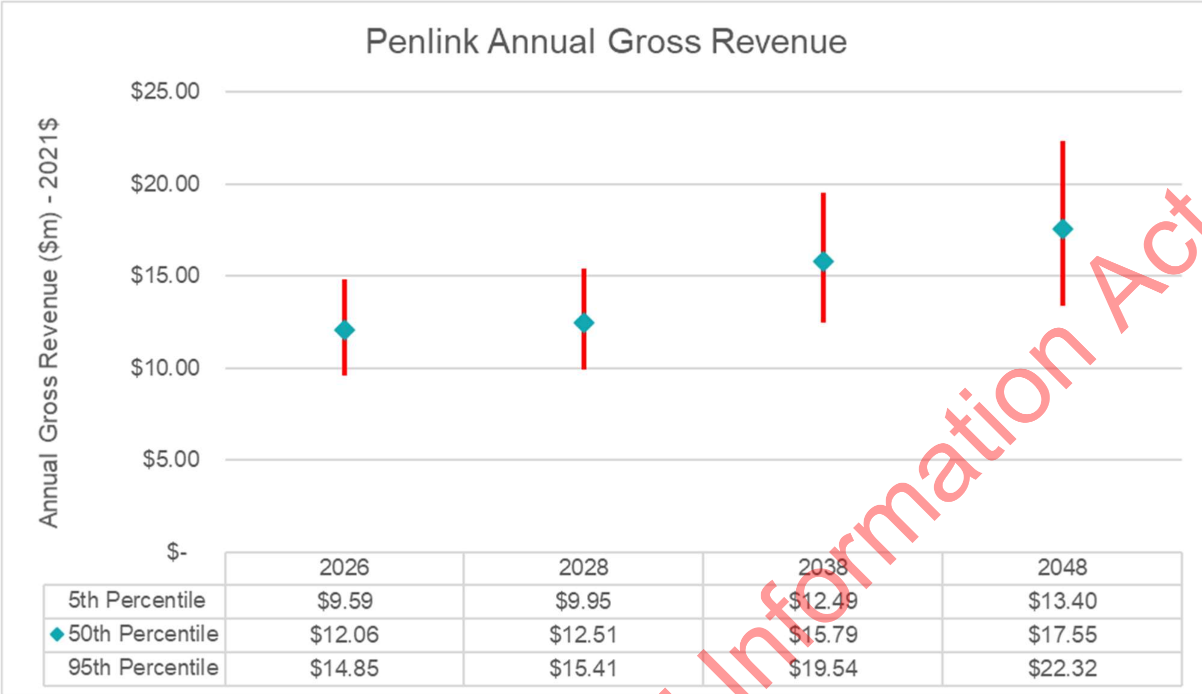
The following observations can be made from the figures:

- Gantry A has an upper estimated two-way AADT of 17,300 vehicles in 2048
- Gantry Rs has limited change in volume between the 5th and 95th percentile estimates, therefore will have very limited material impact on the performance or revenue of Penlink
- Gantry R1 has an upper estimated two-way AADT of 16,200 vehicles in 2048

6.9 Estimated Revenue

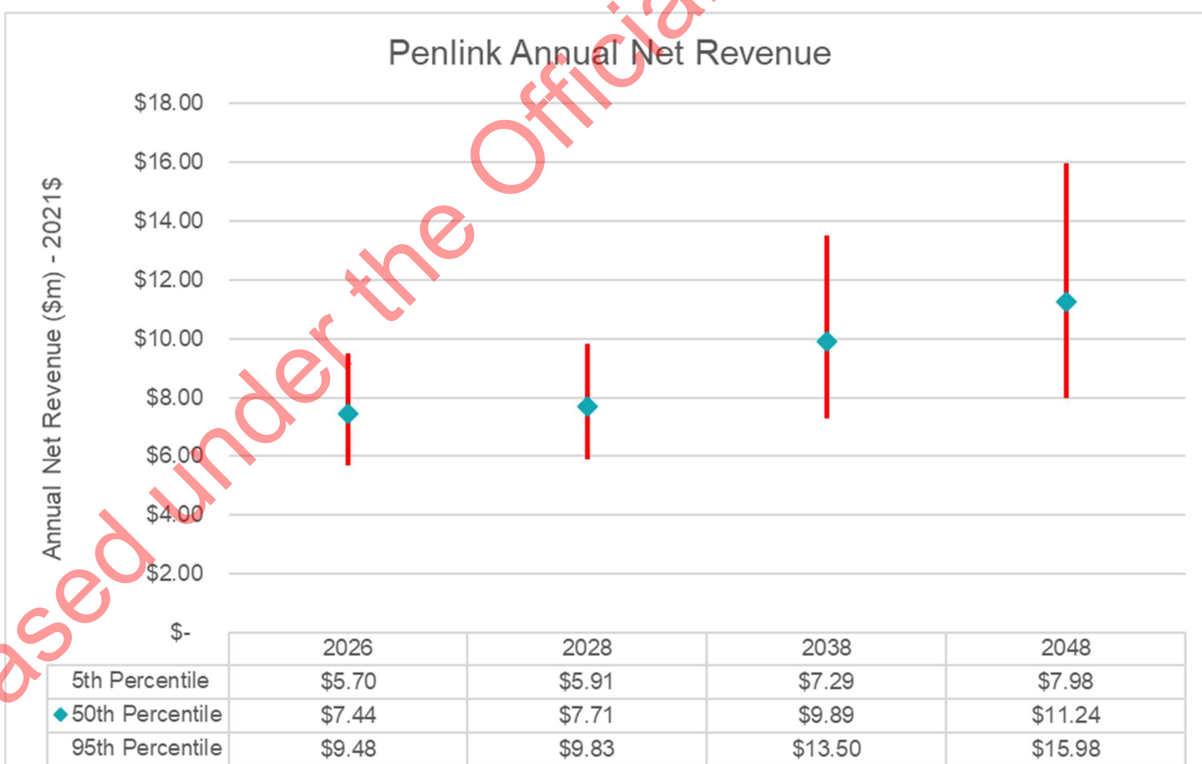
The estimated annual revenue for each modelled year and opening year is shown in **Figure 6-9** and **Figure 6-10** for the gross revenue and net revenue (less transaction costs). The figures show the 5th, 50th, and 95th percentile revenues based on the AADT traffic flow volumes.

Figure 6-9: Penlink Annual Gross Revenue Estimate



	2026	2028	2038	2048
5th Percentile	$9.59	$9.95	$12.49	$13.40
◆ 50th Percentile	$12.06	$12.51	$15.79	$17.55
95th Percentile	$14.85	$15.41	$19.54	$22.32

Figure 6-10: Penlink Annual Net Revenue Estimate



	2026	2028	2038	2048
5th Percentile	$5.70	$5.91	$7.29	$7.98
◆ 50th Percentile	$7.44	$7.71	$9.89	$11.24
95th Percentile	$9.48	$9.83	$13.50	$15.98

The following observations have been made:

- Annual gross revenue ranges from $9.95m to $15.41m in 2028, with a 50th percentile estimate of $12.51m
- Annual net revenue ranges from $5.91m to $9.83m in 2028, with a 50th percentile estimate of $7.71m

6.10 Operational Traffic Assessment

The operational traffic performance for the 2028 preferred scenario was assessed in greater detail using the existing Aimsun simulation model. That model uses traffic demands and toll road flows from the Traffic Assignment model.

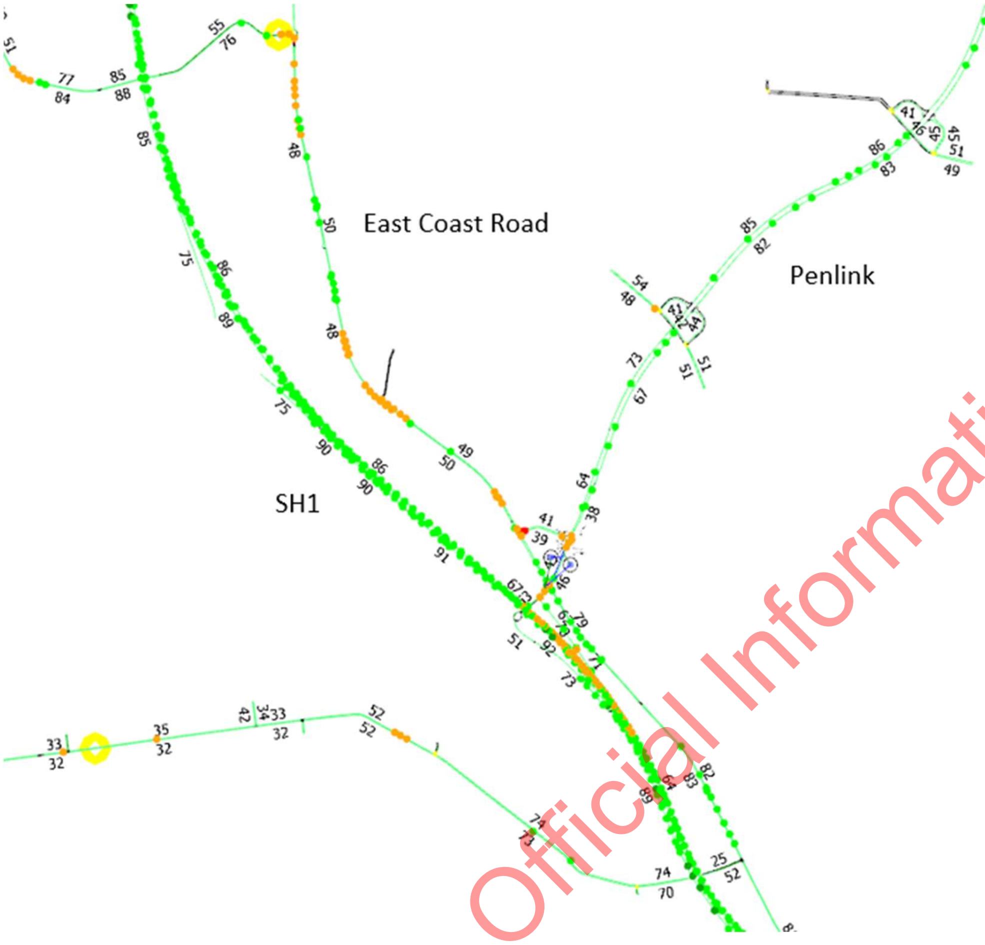
Two scenarios have been modelled, the preferred toll scenario and a no toll scenario. The assessment focused on the performance of the Penlink corridor in the 2028 commuter peaks.

AM Peak

Figure 6-11 and **Figure 6-12** show a plot of the vehicle speeds in the Aimsun model. The speeds are classified as follows:

Figure 6-11: AM - No Toll - Speed Plot

Figure 6-12: AM - Toll - Speed Plot



The following observations have been made:

- With no toll on Penlink, and therefore higher traffic flows, queues form and cause delays on Penlink at the East Coast Road roundabout
- With no toll on Penlink congestion and queueing occurs on SH1 around the southbound on-ramp merge
- Adding a toll reduces the volumes on Penlink and significantly reduces the queuing and delays on both Penlink at the East Coast Road roundabout and on SH1 at the southbound on-ramp

PM Peak

Figure 6-13: PM - No Toll - Speed Plot

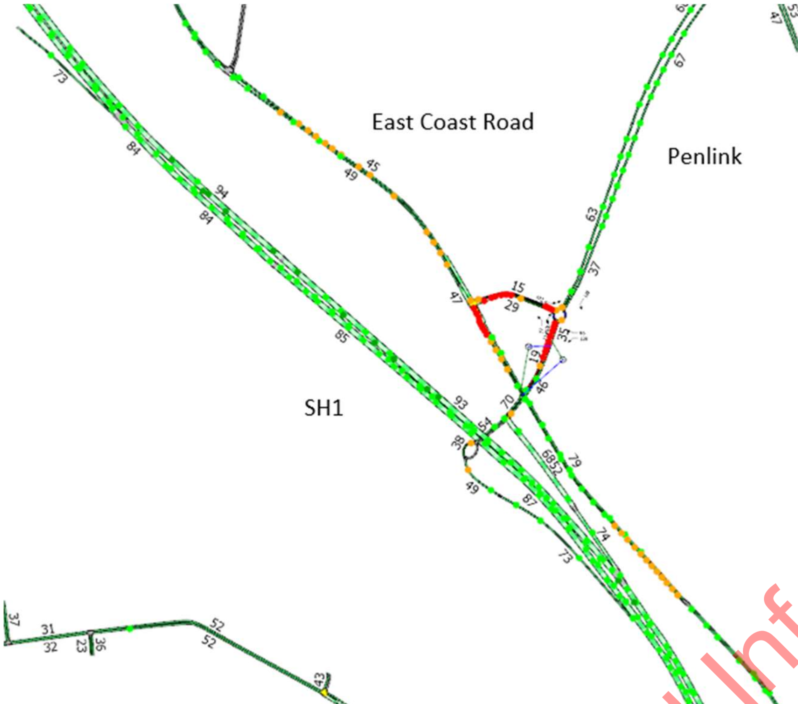
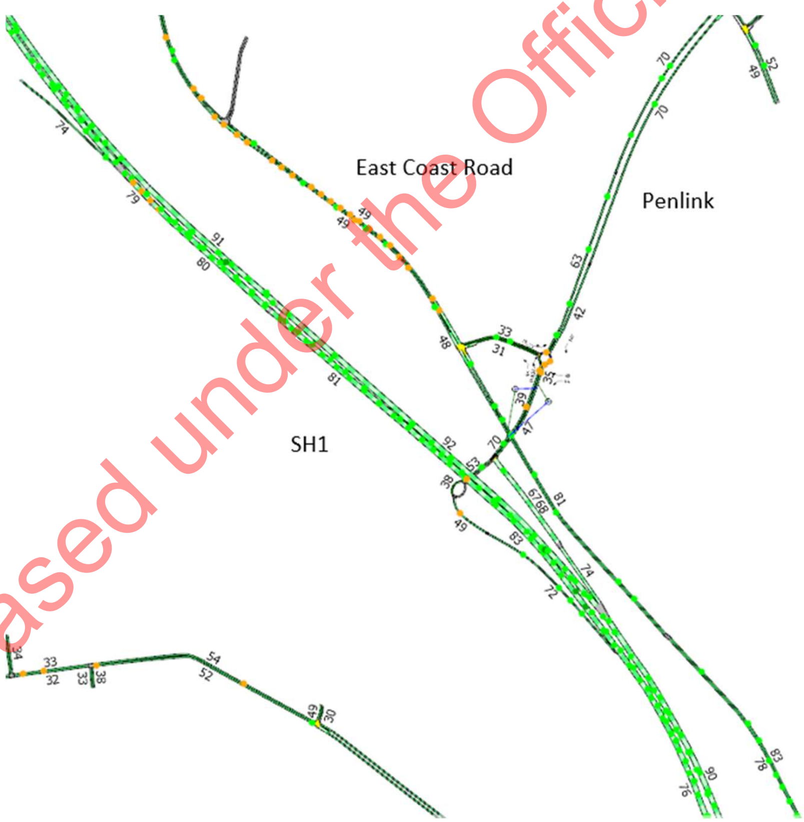


Figure 6-14: PM - Toll - Speed Plot



The following observations have been made:

- With no toll on Penlink, and therefore higher traffic flows, queues form and cause delays on Penlink and East Coast Road at the East Coast Road roundabout
- Adding a toll reduces the volumes on Penlink and significantly reduces the queuing and delays on both Penlink at the East Coast Road roundabout and at the southbound on-ramp

The findings from the operational model are generally consistent with those in the MSM and Penlink Traffic Assignment model. This further highlights that with the current design of the East Coast Road and Penlink roundabout, a low level of service is predicted under an untolled scenario. Tolling helps to relieve the congestion at this location and could help to avoid capacity design changes.

7 Summary and Conclusions

This report described an analysis of the effects of tolling on the Penlink corridor in Auckland. The purpose of this work is to provide information to Waka Kotahi to support their decision making on whether to proceed to public consultation of tolling. While this work provides estimates of network demands and revenue suitable for network planning, the revenue estimates are not considered 'investment grade' such as might be required for private-sector investment.

The analysis focused on the revenue potential and network impacts of tolling the corridor. The measured network impacts were derived from the specific project objectives, key transport priorities (such as from the GPS) and items specific to tolling. These included:

- Road safety, specifically any change in crash costs of diverting traffic form the new road back to the existing road network
- Accessibility, measured via estimated travel times along key corridors
- Environmental impacts such as estimated changes in CO_2 emissions
- Travel demand impacts, such as reduced amount of vehicle travel from higher travel costs
- Equity of pricing different users

The traffic flow and network outcomes were primarily derived from a new Emme traffic assignment model developed for this assessment. The Penlink Traffic Assignment Model was built from the Auckland Macro Strategic Model, with refinements to the network, zone system and values of time. The demands were sourced from the MSM and then adjusted based on observed sector-to-sector journey to work data and mobile phone data. Model counts and travel times were then validated against observed data.

An initial assessment of potential toll strategies was considered, resulting in a short-list of scenarios for testing. More detailed testing for the Penlink project was then undertaken for the forecast year 2028 to identify a preferred range of toll tariffs. This preferred range was determined by balancing between increasing revenue potential, diminishing returns on outcome measures and costs to users. Representative revenue estimates were then developed for the Penlink project from opening year to 2048, including risk-adjusted factors to provide 5^{th}, 50^{th} and 95^{th} percentile estimates.

This analysis has identified potential of significant revenue from tolling Penlink. Further to this, tolling can provide improvements in the expected outcomes of the projects, such as improved travel time, reduced emissions and reduced crash costs. Further to this, tolling can achieve suppression of trips that largely mitigates the induced trips from building Penlink. The following strategy is considered to represent a balance between increasing revenue, diminishing returns on outcome measures and the costs to users:

- Differential tolling for the commuter peaks, defined as 6am – 9am and 4pm – 7pm
- A recommended light-vehicle tariff at A and Rs between $2 and $3 in the commuter peaks, modelled at $3
- A recommended light-vehicle tariff at R1 of approximately $1 in the commuter peaks, modelled at $1
- A recommended light-vehicle tariff at A and Rs between $1 and $2 in the off-peak, modelled at $2
- A recommended light-vehicle tariff at R1 of approximately $1 in the off-peak, modelled at $1
- A heavy vehicle toll ratio of 2 times that for light vehicles
- No toll on buses

Unlike other toll roads in Auckland, this corridor is likely to be primarily used by commuters, with cumulative impacts on travel costs due to repeated trips. Therefore, this corridor needs to consider the uncertainty of motorist's cumulative willingness to pay.

The emerging preferred strategy includes varying tolls for both time of day and destination. This may be difficult to effectively communicate to drivers compared to the simple toll strategy of other toll roads in New

Zealand. The transition times from commuter peak to off-peak toll tariffs may also produce some undesirable driver behaviour, such as slowing or stopping before a toll gantry to wait for the off-peak period. The complexity in communicating and managing time and destination varying tolls and the potential for undesirable driver behaviour should be considered.

The executive summary contains a more detailed overview of the analysis and outcomes.

A

Appendix A – Model Development

Introduction

A previous, preliminary study on the effects of tolling Penlink was undertaken using the Macro Strategic Model (MSM). This study identified some limitations with the model used and therefore some recommendations to consider for subsequent studies, such as this study. The limitations were as follows:

- Simplified representation of the road network, including intersections and motorway interchanges, weaving and merging
- No local model calibration / validation targeted specifically to the toll study. The OD patterns specifically remain a key uncertainty of this analysis
- No refinement of the MSM toll response module targeted at the specific toll study
- Simplistic representation of Penlink, without explicit representation of topography or local connections
- Assumptions on the long-term upgrades to SH1 based on the SGA IBC
- Land use and growth used at the time of initial study adopted in early 2020 and hence pre-COVID19

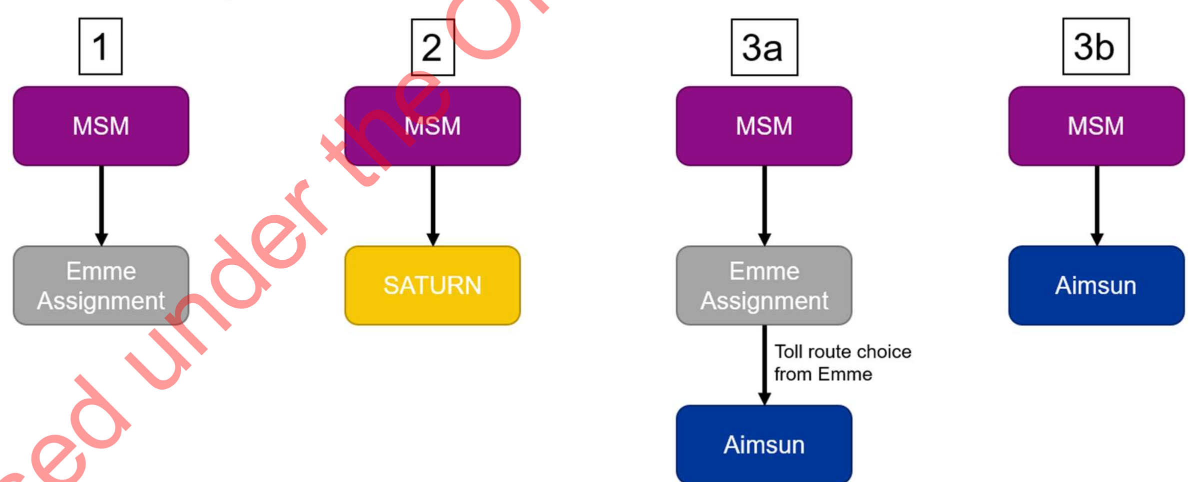
Therefore, for this study, a modelling system / structure is required that addresses some or all of the limitations noted above.

The following sections will describe the modelling systems considered, the adopted system and the development of this system.

Model System

Several model systems were considered for the Penlink Toll Modelling Assessment. These are shown in Figure X

Figure 7-1: Considered Model Structures



Each option was considered against the following set of criteria:

- Toll choice model
- Demand response
- Asset is re-useable (beyond this toll study)
- Stable / plausible results
- Time / cost efficient

The following table summarises each option against each of the criteria:

Table 7-1: Model System Criteria Analysis

Objective	1. Emme	2. SATURN	3a. Aimsun w/o toll choice	3b. Aimsun w/ toll choice
Toll choice model	Proven stability Used extensively in other studies	Successfully used on P2W toll study	Relies on Emme toll choice May need to work through congestion discrepancy between models	Concern about stochastic nature, particularly in combination with attempting to measure low toll tariff impacts and secondary analysis
Demand response	Demand response from MSM	Demand response from MSM	Demand response from MSM	Demand response from MSM
Asset is re-useable	Some refinements in the Emme project may be able to be carried over into MSM	Potentially least re-useable as multiple projects using existing Aimsun model May cause confusion for existing studies	Project teams / modellers already have familiarity with the model Forecast flows / travel times will still change due to base year refinements	
Stable / plausible results	Proven stability Used extensively in other studies	Proven stability Issues can be quickly fixed / worked through thanks to quick run times	Generally less stable Can be difficult to interpret results Often takes several runs to reach a result that is plausible / modellers are comfortable with **Toll route choice will have stability from Emme model**	Generally less stable Can be difficult to interpret results Often takes several runs to reach a result that is plausible / modellers are comfortable with **Toll route choice potentially unstable – do we need multiple DUE runs with different random seeds?**
Time / cost efficient	Efficient to run Existing network and processes ready to be used / refined	Efficient to run Existing process / structure available in P2W model Requires rebuild of network	Existing network and processes ready to be used / refined Much longer run times, stability issues etc. can cause significant issues for time / cost efficiency May be able to improve run time by simplifying the road network (particularly in the Albany area) Current run times: 2028 AM / IP ~ 1.5 hours, PM ~ 7 hours	

Based on the above assessment and in discussion with Auckland Forecasting Centre (AFC), Option 3a was selected to take forward. The major component of Option 3a was building a new Emme Assignment model.

The key features of the Emme Assignment model are as follows:

- 12 class assignment
- Network and zone refinement
- Sector-to-sector demand adjustment
- Toll Value of Time parameters adopted from the Puhoi to Warkworth toll study

- Travel time and link flow validation

Model Development

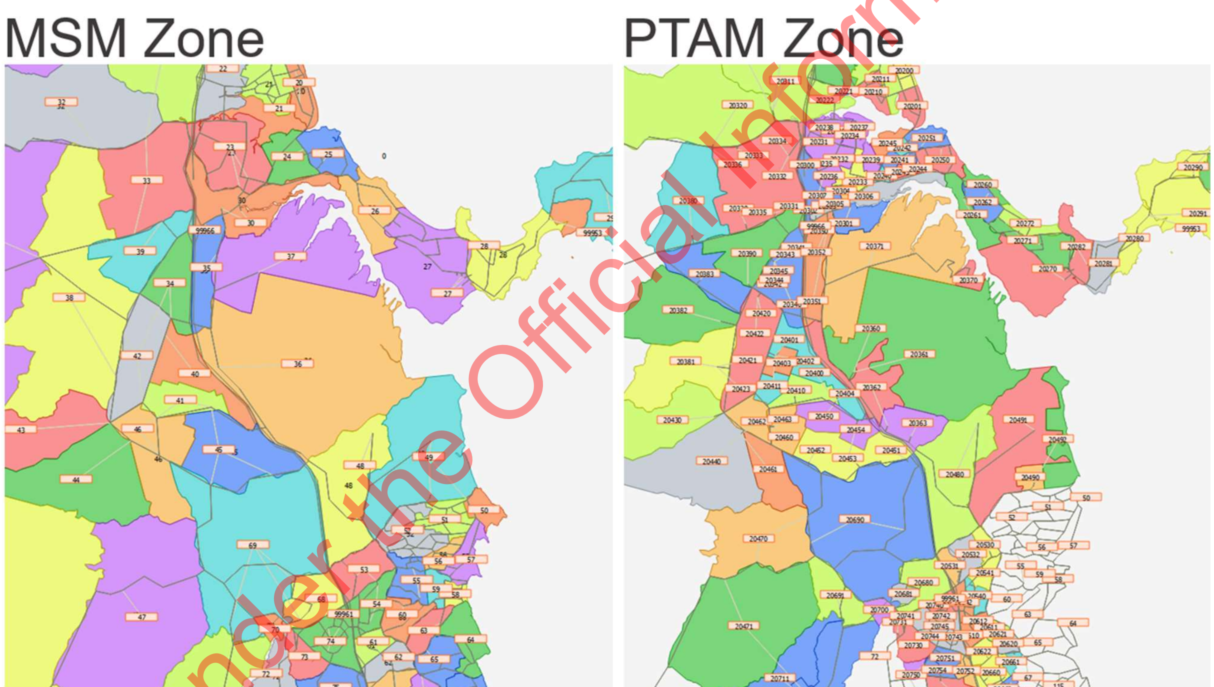
Zone / Network Refinement

The Penlink Traffic Assignment Model (PTAM) refines both the network and the zone system compared to the MSM.

The zone system takes 44 MSM and disaggregates them to 148 Traffic Assignment Zones. The zone system for the PTAM is identical to the Aimsun model. The MSM and PTAM zone systems can be seen in **Figure 7-2**.

With the inclusion of additional zones, the network has been refined to incorporate the loading point of these zones. Further to this, some missing local roads and intersections have been added to the model. Through the calibration process, some of the network parameters were updated, such as free speed and capacity.

Figure 7-2: Model Zone Systems



Demand Development

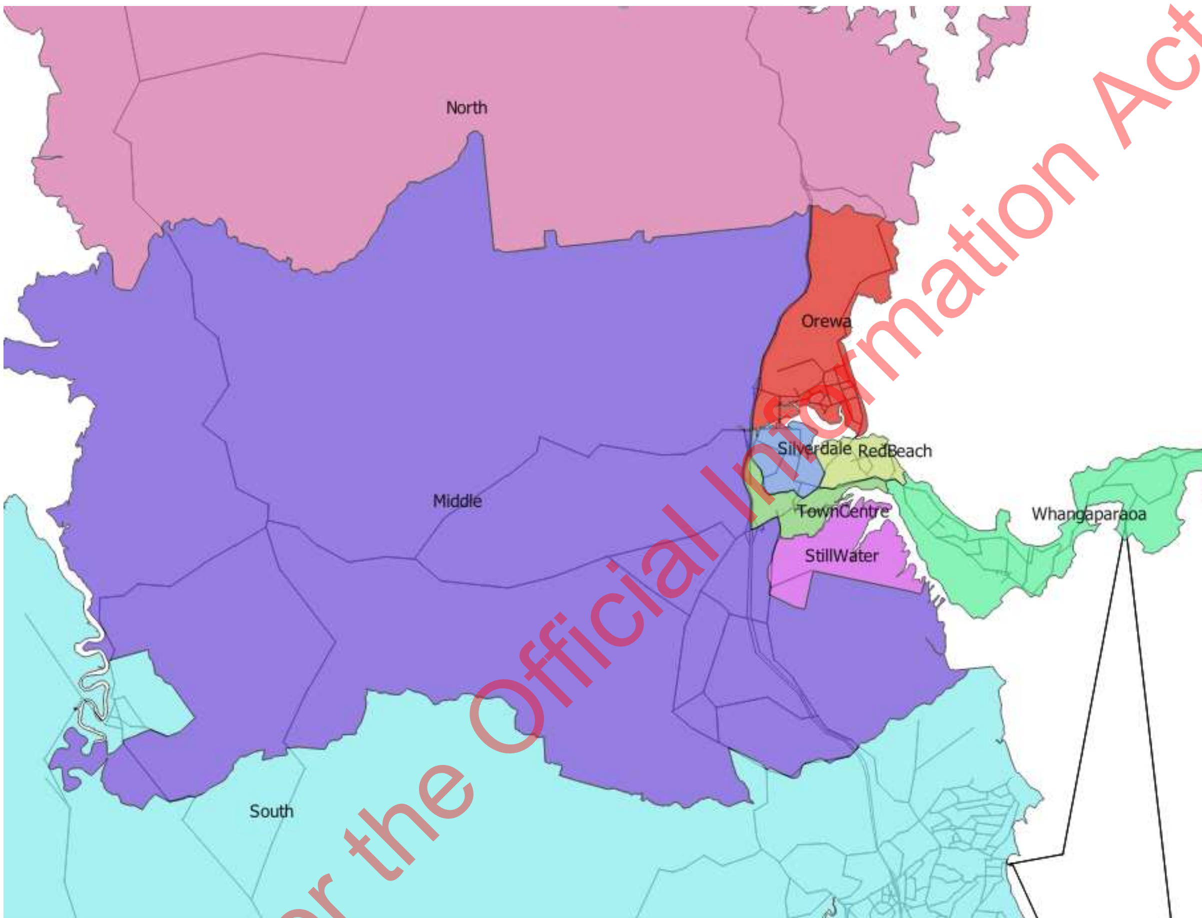
Analysis performed in preliminary studies identified differences in observed trip distribution from the Whangaparaoa peninsula between the MSM and observed data (e.g., journey to work data).

As part of this study, the trip distribution patterns were revisited and also included an investigation of trip matrices derived from mobile phone data that was provided by Auckland Forecasting Centre (AFC). The mobile phone matrices included trips taking both private vehicles and public transport. The mobile phone data does not distinguish trip purpose. The census 2018 journey to work data was also used to give an indication of the home-based work (HBW) trip distribution, with the mobile phone matrices used to inform all other trip purposes. As a result, the process for demand adjustment is as follows; adjust the HBW distribution according to the JTW data, adjust the other purposes (excluding heavy vehicles) so that the total trips distribution.

The methodology for adjusting the demand was as follows:

- Use a sector-sector system to make demand adjustments (sector system shown in Figure 7-3)
- Use a multiplicative factoring approach to adjust the demand, while attempting to minimise the scale of the factors
- Limited adjustment to the 'middle' sector, where a significant amount of development occurs in the forecast years

Figure 7-3: Demand Adjustment Sector System



7.1.1 Demand Adjustment Factors

The adjustment factors for the home-based work purpose, based on the JTW data, are shown in **Table 7-2** to **Table 7-4** for AM, IP and PM respectively:

Table 7-2: AM HBW Demand Factors

HBW	North	Middle	Whangaparaoa	South	Silverdale	TownCentre	RedBeach	Orewa	Stillwater	PnR
North	1	1	1	1	1	1.3	1	1	0.6	0.6
Middle	1	1	1	1	1	1.3	1	1	0.6	0.6
Whangaparaoa	1.1	0.7	0.7	1.25	1.3	1.4	1	1	0.6	0.6
South	1	0.8	1	1	1.4	1.4	1	1	0.6	0.6
Silverdale	1	0.8	1	1.2	1	0.7	1	1	0.6	0.6
TownCentre	1	1	1	1	1	1	1	1	0.6	0.6
RedBeach	1	1	1	0.8	1	1	1	1	0.6	0.6
Orewa	1	1	1	1	1	1	1	1	0.6	0.6
Stillwater	0.6	0.6	0.6	0.6	1	1	0.6	0.6	1	0.6
PnR	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1

Table 7-3: IP HBW Demand Factors

HBW	North	Middle	Whangaparaoa	South	Silverdale	TownCentre	RedBeach	Orewa	Stillwater	PnR
North	1	1	1	1	1	1	1	1	0.6	0.6
Middle	1	1	1	1	1	1	1	1	0.6	0.6
Whangaparaoa	1	1	0.8	1.3	1	1.3	1	1	0.6	0.6
South	1	1	1.3	1	1.2	1.2	1	1	0.6	0.6
Silverdale	1	1	1	1.2	1	1	1	1	1	0.6
TownCentre	1	1	1.3	1.2	1	1	1	1	1	0.6
RedBeach	1	1	1	1	1	1	1	1	0.6	0.6
Orewa	1	1	1	1	1	1	1	1	0.6	0.6
Stillwater	0.6	0.6	0.6	0.6	1	1	0.6	0.6	1	0.6
PnR	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1

Table 7-4: PM HBW Demand Factors

HBW	North	Middle	Whangaparaoa	South	Silverdale	TownCentre	RedBeach	Orewa	Stillwater	PnR
North	1	1	1	1	1	1	1	1	0.6	0.6
Middle	1	1	0.8	0.9	1	1	1	1	0.6	0.6
Whangaparaoa	1	1	0.65	1	1	1	1	1	0.6	0.6
South	1	0.9	1.3	1	1	1	1	1	0.6	0.6
Silverdale	1	1	1	1	1	1	1	1	0.6	0.6
TownCentre	1.2	1	1.3	1	1	1	1	1	1	0.6
RedBeach	1	1	1	1	1	1	1	1	0.6	0.6
Orewa	1	1	1	1	1	1	1	1	0.6	0.6
Stillwater	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1	0.6
PnR	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1

The adjustment factors for the Other and EB purposes, based on the mobile phone matrices, are shown in **Table 7-5** to **Table 7-7** for AM, IP and PM respectively:

Table 7-5: AM Other/EB Demand Factors

EB/Others	North	Middle	Whangaparaoa	South	Silverdale	TownCentre	RedBeach	Orewa	Stillwater	PnR
North	1	1	1	1	1	1.3	1	1	0.6	0.6
Middle	1	1	1	1	1	1.3	1	1.2	0.6	0.6
Whangaparaoa	1	1.3	0.9	0.6	1.2	1.4	1.2	1.4	0.6	0.6
South	1	1.3	1	1	1.2	1.4	1	1.2	0.6	0.6
Silverdale	1	1	1	0.8	1	1	1	1	0.6	0.6
TownCentre	1	1	1	1	1	1	1	1	0.6	0.6
RedBeach	1	1	1	1	1	1	1	1	0.6	0.6
Orewa	1	1	1	1	1	1	1	1	0.6	0.6
Stillwater	0.6	0.6	0.6	0.6	1	1	0.6	0.6	1	0.6
PnR	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1

Table 7-6: IP Other/EB Demand Factors

EB/Others	North	Middle	Whangaparaoa	South	Silverdale	TownCentre	RedBeach	Orewa	Stillwater	PnR
North	1	1	1	1	1	1	1	1	0.6	0.6
Middle	1	1	1.1	1.1	1	1	1	1	0.6	0.6
Whangaparaoa	1	1.1	0.9	1	1	1	1.1	1	0.6	0.6
South	1	1.2	1.2	1	1.2	1.4	1.2	1.2	0.6	0.6
Silverdale	1	1	1	1.1	1	1	1	1	1	0.6
TownCentre	1	1	1	1.4	1	1	1	1	1	0.6
RedBeach	1	1	1.1	1.1	1	1	1	1	0.6	0.6
Orewa	1	1	1	1.1	1	1	1	0.9	0.6	0.6
Stillwater	0.6	0.6	0.6	0.6	1	1	0.6	0.6	1	0.6
PnR	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1

Table 7-7: PM Other/EB Demand Factors

EB/Others	North	Middle	Whangaparaoa	South	Silverdale	TownCentre	RedBeach	Orewa	Stillwater	PnR
North	1	1	1	1	1	1	1	1	0.6	0.6
Middle	1	1	1	1.1	1	1	1	1	0.6	0.6
Whangaparaoa	1	1	0.8	1	1	1	0.8	1	0.6	0.6
South	1	1.1	1	1	1	1.2	1	1	0.6	0.6
Silverdale	1	1	1	1	1	1	1	1	0.6	0.6
TownCentre	1.1	1	1.1	1.2	1	1	1	1	1	0.6
RedBeach	1	1	1	1	1	1	1	1	0.6	0.6
Orewa	1	1	0.9	1	1	1	1	1	0.6	0.6
Stillwater	0.6	0.6	0.6	0.6	0.6	1	0.6	0.6	1	0.6
PnR	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1

Model Validation

Link Count Validation

Figure 7-4 shows the locations of link counts used for the link count validation:

Figure 7-4: Link Count Locations

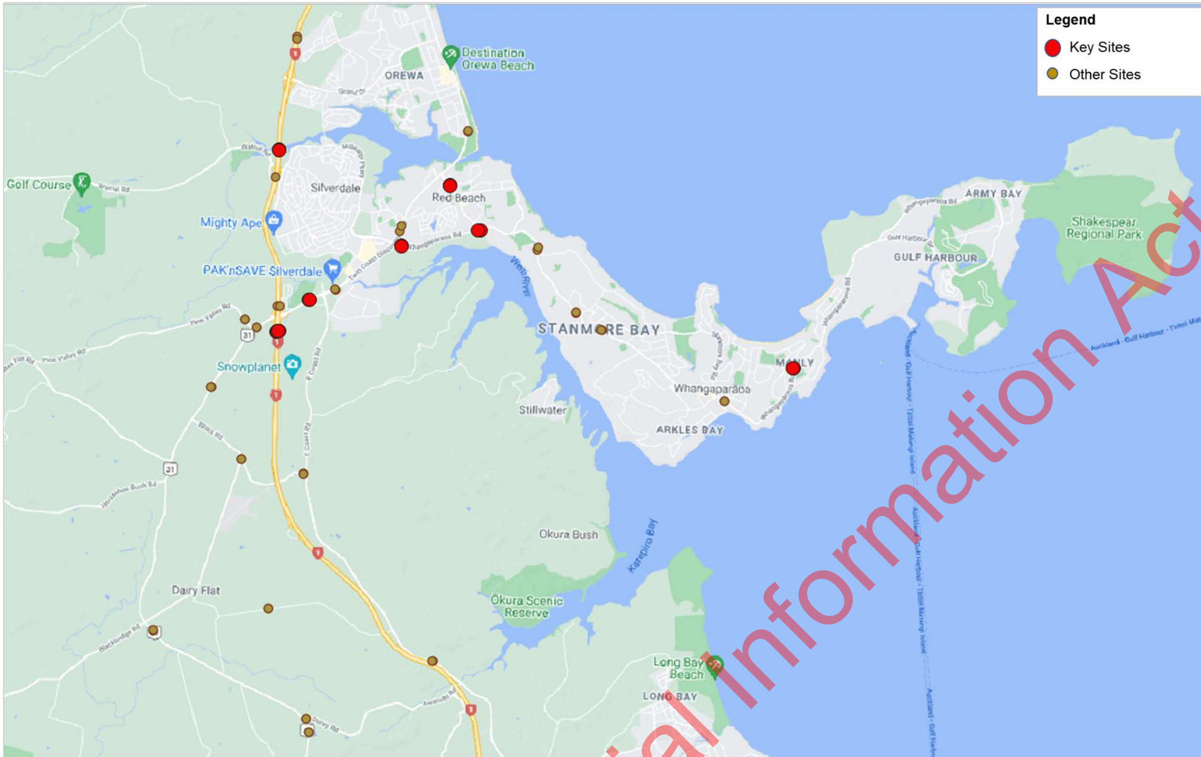


Table 7-8 shows the validation results for these link counts and the target criteria for a strategic network:

Table 7-8: Link Count Validation Summary

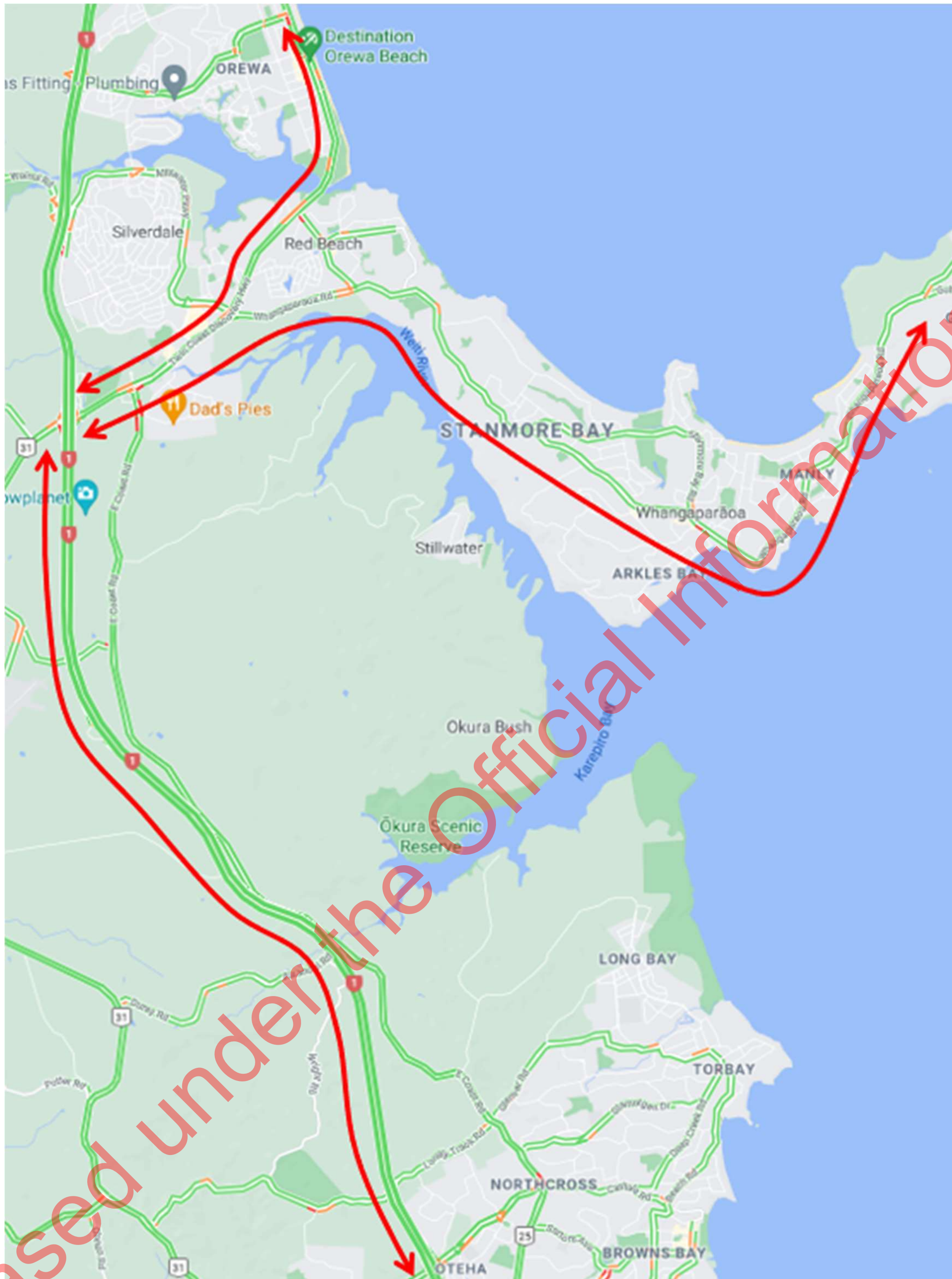
Set	Measure	AM	IP	PM	Target
Set 1 (key sites)	GEH<5	81%	81%	88%	>75%
	GEH<7.5	100%	94%	94%	>80%
	GEH<10	100%	100%	100%	>85%
	GEH<12	100%	100%	100%	NA
Set 2 (other sites)	GEH<5	75%	87%	69%	>75%
	GEH<7.5	87%	92%	87%	>80%
	GEH<10	97%	100%	97%	>85%
	GEH<12	100%	100%	100%	NA
All sites	GEH<5	76%	85%	75%	>75%
	GEH<7.5	91%	93%	89%	>80%
	GEH<10	98%	100%	98%	>85%
	GEH<12	100%	100%	100%	NA
	RMSE	21%	24%	20%	<25%
	R^2	0.95	93%	96%	>0.9

The table demonstrates that each of the criteria for all peaks are met.

Travel Time

Figure 7-5 shows the travel times routes used in the validation of this model:

Figure 7-5: Travel Time Routes



The validation for these travel time routes is as follows:

Peak	Route	Start	End	Direction	Observed	Modelled	Diff	Diff%
AM	HBC/Whangaparaoa	SH1	Gulf Harbour	EB	20.54	21.81	1.27	6%
	Whangaparaoa/HBC	Gulf Harbour	SH1	WB	23.26	23.4	0.14	1%
	Hibiscus Coast Highway	SH1	West Hoe Rd	NB	9.02	9.93	0.91	10%
	Hibiscus Coast Highway	West Hoe Rd	SH1	SB	9.78	10.28	0.5	5%
	SH1	OtehValley	Silverdale	NB	7.31	7.09	-0.22	-3%
	SH1	Silverdale	OtehValley	SB	8.41	8.04	-0.37	-4%

Peak	Route	Start	End	Direction	Observed	Modelled	Diff	Diff%
IP	HBC/Whangaparaoa	SH1	Gulf Harbour	EB	20.49	20.88	0.39	2%
	Whangaparaoa/HBC	Gulf Harbour	SH1	WB	20.08	21.43	1.35	7%
	Hibiscus Coast Highway	SH1	West Hoe Rd	NB	9.69	9.61	-0.08	-1%
	Hibiscus Coast Highway	West Hoe Rd	SH1	SB	9.8	9.35	-0.45	-5%
	SH1	OtehValley	Silverdale	NB	7.3	7.09	-0.21	-3%
	SH1	Silverdale	OtehValley	SB	7.82	7.32	-0.5	-6%

Peak	Route	Start	End	Direction	Observed	Modelled	Diff	Diff%
PM	HBC/Whangaparaoa	SH1	Gulf Harbour	EB	23.32	25.71	2.39	10%
	Whangaparaoa/HBC	Gulf Harbour	SH1	WB	19.94	22.55	2.61	13%
	Hibiscus Coast Highway	SH1	West Hoe Rd	NB	11.53	10.91	-0.62	-5%
	Hibiscus Coast Highway	West Hoe Rd	SH1	SB	10.27	10.03	-0.24	-2%
	SH1	OtehValley	Silverdale	NB	10.3	10.16	-0.14	-1%
	SH1	Silverdale	OtehValley	SB	7.5	7.31	-0.19	-3%

The travel time criteria for a strategic network is that at least 85% of routes are within 15% or 1 minute of observed travel time. The table above demonstrates that 100% of routes are within 15% or 1 minute.

Conclusions

In order to address limitations of previous toll modelling studies for Penlink, a new modelling system was developed. This included the development of a new Emme traffic assignment model. The model underwent the following enhancements compared to the MSM:

- 12 class assignment (for refined toll response)
- Network and zone refinement
- Sector-to-sector demand adjustment
- Toll Value of Time parameters adopted from the Puhoi to Warkworth toll study

The model was validated against link counts and travel time data in the study area and deemed to meet all the criteria for a strategic network assignment model. Therefore, the model is appropriate for undertaking the Penlink toll modelling study.

B

Appendix B – Peer Review Comments

This report has been independently peer reviewed by Flow Transportation Specialists. The comments and responses (*red italic text*) are provided here:

- The report focuses on the effects of tolling, rather than the effects of the project itself. This may be acceptable, but it is a very important distinction which I return to on a few occasions in the comments below.

Agreed – will clarify that the report is intended to only inform the decision on tolling and is not intended to provide a detailed assessment of PENLINK itself.

- On initial inspection I found some of the forecast outcomes surprising. In particular, tolling the project is predicted to reduce overall emissions (Sections 5.1.1 and 5.5) and to reduce crash costs (Section 5.3). I found this surprising as tolling could be expected to lead to greater volumes of traffic using the longer route (via Whangaparaoa Road/Hibiscus Coast Highway/SH1), increasing VKT and to require traffic to use some roads with higher crash costs (Whangaparaoa Road and Hibiscus Coast Highway).
- However, the answer is clearly that tolling is predicted to lead to an element of trip suppression/trip shortening, as well as trip reassignment. This is clearly set out in the Figure at the top of page 20 of the report, and the subsequent information in Figures 5-2 and 5-3:
    - The untolled Penlink would attract around 24,300 vehicles/day in 2028
    - The tolled Penlink would attract between 8,800 and 17,100 vpd, depending on the toll scenario
    - Tolling Penlink would increase flows on Whangaparaoa Road by between 3,400 and 8,700 vpd
    - The differences in the above two bullets are interesting in that the increases in flows on Whangaparaoa Road do not match the decreases on Penlink. This may depend on the location selected along Whangaparaoa Road, as presumably there will be secondary changes in flows. As an example, there won't just be decreases in westbound flows on Whangaparaoa Road in the morning peak (west of Penlink) due to tolling – there could also be increases in eastbound flows at that point, as traffic from, say, Red Beach may use a section of Whangaparaoa Road to reach Penlink.

Agreed – the ability of tolls to impact on travel patterns were identified as an important outcome.

- This situation clearly indicates the importance of the modelled predictions relating to changes in travel behaviour due to tolling. The report correctly acknowledges the uncertainties around toll modelling in NZ (Section 2.6.1), with few toll roads currently operating and very few willingness to pay surveys. This indicates that the accuracy of the demand response needs to be considered to be a fairly high risk. In addition, while a fairly significant amount of trip suppression is predicted, modest mode change to PT is predicted, indicating a reduction in accessibility.

Agreed – the increased costs to travel by car are expected to reduce the relative attractive of car (relative to PT) and reduce the trip lengths.

- Section 5.4 notes the poor level of service at the East Coast Road/Penlink roundabout, with an untolled scenario. This may be a reasonable conclusion, or it may be that if an untolled scenario was to progress, consideration could be given to a different design for that intersection, suggesting that this conclusion may not be totally justified at this stage, in isolation.

Agreed that the model results are influenced by the design used in the models. The report does explicitly note (S5.4.1) that the conclusion is based on the current design, and also that the tolling information could be used to influence the design (Exec Summary). It is also noted that while different intersection designs could potentially reduce the delay in the un-tolled scenario, it is likely that this would in turn increase flows on the motorway ramps, creating additional delays at those locations.

- That said, it is apparent that any increase in southbound traffic on SH1 in the morning peak will exacerbate congestion on the Northern Motorway, as any extra traffic will add to the queue that currently extends back to somewhere between Oteha Valley Road and Lonely Track Road. The trip suppression associated with tolling will reduce this issue (i.e. queues will still occur, but the project will lead to a lesser increase).

Agreed – the models indicate that tolling would reduce southbound on-ramp flows and therefore reduce delays on SH1 from merging vehicles

- I note that Section 6.10 is not yet completed. This may shed further light on the points above, or it could lead to a requirement for further clarification around any differences in forecast travel time savings between the various transport models being used for this assessment, and feedback between the model tiers on this issue may influence the demand response.

This section now completed. The operational modelling shows queuing/delay in the AM peak untolled scenario westbound on PENLINK approaching the East Coast Road roundabout and on SH1 approaching the ramp merge. The tolled scenarios show reductions in both of these locations. Both of these outcomes are consistent with the project traffic model.

- As noted above, Section 5.3 considers safety effects. This has focussed on total crash costs, and I wonder if similar conclusions were to be drawn if one was to consider only deaths and serious injuries, or if one was to consider the effects of tolling against a “Road to Zero” lens.

DSI indicators now added – and demonstrate the same kind of reduction indicated by total crash costs. The key influence on ‘road to zero’ outcomes will be the design of the facility, with tolling only directly influencing the perceived attractiveness. However, the expected reduction in queueing on PENLINK and SH1 and the overall reduction in VKT are both considered to contribute positively to desired safety outcomes.

- Section 5.6 considers value for money. This is based on annual revenue, but it does not consider the overall value for money to build the project. Presumably a forecast flow of 9,500 vehicles/day (the central value assumed in Section 6) would lead to low overall value for money, as the cost to build the project is presumably similar for a tolled v untolled scenario (in fact the tolled scenario is likely to lead to higher costs, with these being mitigated by the revenue).

As noted above, this assessment relates only to a decision to apply tolls (or not). As such, the value for money of the overall PENLINK project has not been considered in this report. We note the estimated revenue is expected to exceed the capital and operating costs of tolling, and as such would represent good value for money for the ‘investor’.

- The consideration around equity considers “fairness”, but does not consider the equity issue of tolling adversely affecting the accessibility of persons with lower income.

Noted. The assessment agreed this measure of ‘fairness’ with Waka Kotahi. In terms of impact on different income groups, this depends on the baseline considered. That is, the extra user costs of tolling compared to an untolled project would likely impact on lower-income households. However, given the ready access to the (existing) untolled route, the impact on household costs can be managed by users choosing which route to use.

- The considerations around environmental issues have focussed on emissions costs, as is commonly the case. However, again the assessment focuses on the effects of tolling, with the reduction in emissions concluded as being desirable. When viewing the project solely through a climate change/environmental lens (as is now becoming increasingly important), presumably not proceeding with the project would lead to greater environmental gains (not just emissions).

As noted above, this assessment relates only to a decision to apply tolls and does not include an environmental assessment of the PENLINK project itself.

- This then leads to an important point, that the positive effects of the project relate to improving accessibility of the existing residents/employees within the Whangaparaoa/Silverdale area and to facilitate future additional residents/employees. If the project does not proceed, this may adversely affect the potential for future development within these areas, or it may adversely affect the ability to provide greater priority for other modes, eg to get greater numbers of people to the Silverdale Park and Ride station. Similar comments could be considered comparing the tolled v untolled scenarios. While there has been stakeholder buy in to the model assumptions regarding land use and transport networks, the potential for land use and other effects may require further consideration. Indeed the NZ Up web site refers to the justification for the Penlink project being as follows:
  - "Penlink is one of the important first steps to providing people in north Auckland with real choice in the way they travel and help improve climate outcomes by providing for public transport capacity and for people to travel on foot or by bike.
  - Substantial growth is forecast in the Whangaparāoa Peninsula, Weiti, Orewa, Silverdale and surrounding areas. As an example, in Silverdale-Dairy Flat, around 15,000 new homes are expected to be built over the next 30 years, with 6,000 of these built over the next decade.
  - The two-lane transport connector will also provide transport capacity for housing developments in the area and support:
    - planned development in Dairy Flat and Silverdale
    - more travel choices for people walking and on bikes
    - improved public transport services with more reliable journey experiences
    - a more co-ordinated transport network in north Auckland along with more transport initiatives to come."

In regard to growth assumptions:

The modelling of tolls has been undertaken for three horizons (2028, 2038 and 2048), and as such the assessment as considered different levels of growth in the wider area. The conclusions were drawn from all three horizons. The potential for different growth rates were also included in the risk-adjusted flow and revenue projections. While the rate and scale of growth will evolve of time and may differ from current forecasts, it is not expected that such uncertainties would likely alter the conclusions of the tolling assessment.

In regard to project outcomes, the key indicators used in the assessment were agreed with Waka Kotahi as suitable to reflect the intended (or unintended) outcomes. In regard to the outcomes noted on the project website:

- The two-lane transport connector will also provide transport capacity for housing developments in the area and support:
  - planned development in Dairy Flat and Silverdale *– only minor impact expected for this due to tolling diverting some traffic back to the existing route (but still less than under a no-penlink scenario)*
  - more travel choices for people walking and on bikes *– the range of travel choices offered by the PENLINK project will not be affected by tolls (although the relative perceived attractiveness of car travel will be reduced by tolls)*
  - improved public transport services with more reliable journey experiences *– the reduced traffic and congestion on PENLINK from tolling is expected to assist bus reliability, as well as increase the relative perceived attractiveness of PT relative to car travel)*
  - a more co-ordinated transport network in north Auckland along with more transport initiatives to come." *– no impact from tolling*