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Upper North Island Supply Chain Strategy

CBA technical notes

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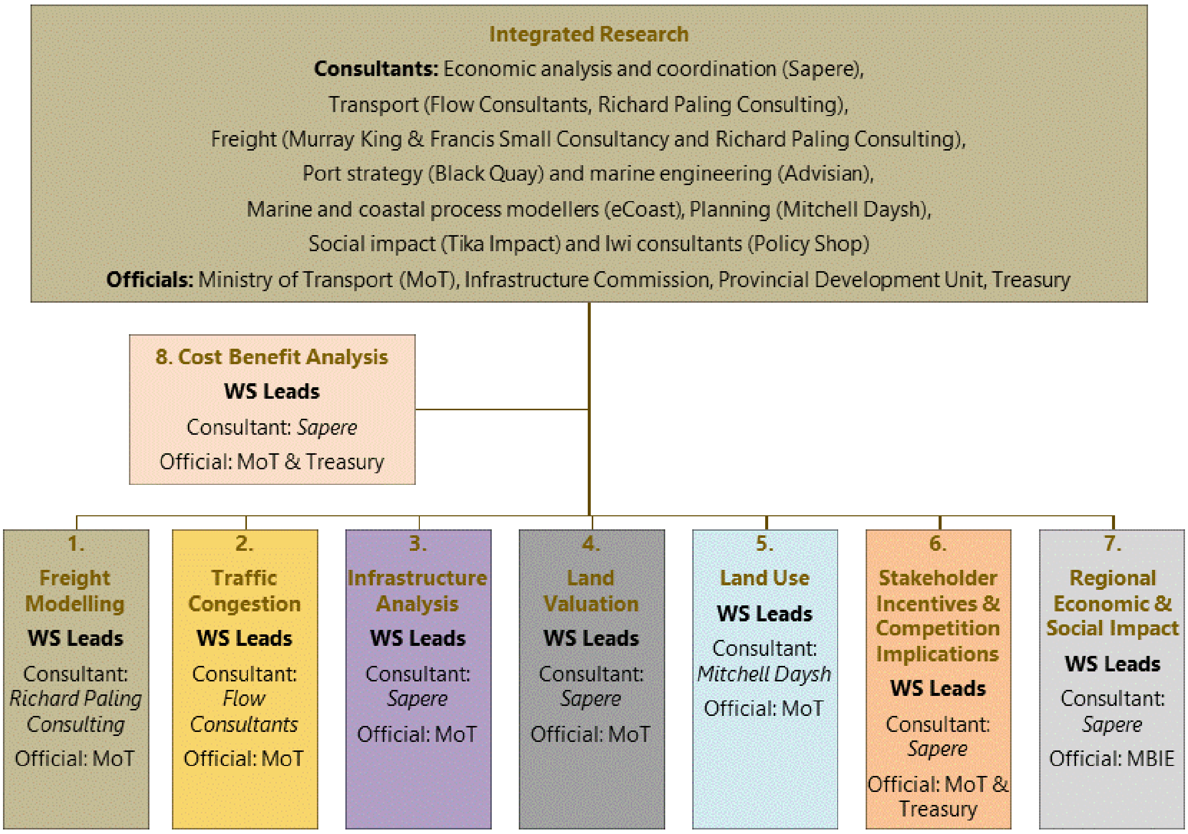
1. Introduction

This note is part of a work programme to inform an officials-led assessment of the options for a full move of the freight operations of the Ports of Auckland Ltd.

Sapere was engaged as the lead consultancy to prepare a cost benefit analysis (CBA) of the options. The approach and results of the CBA were summarised in an integrative report, which is the main output of the work programme.

This note is one of a range of supporting reports across the eight other workstreams forming the work programme (see Figure 1). It sets out in more detail the components, assumptions, sources and ultimately the treatment of inputs integral to the derivation of costs and benefits.

Figure 1 Workstreams making up work programme



The note starts by rehearsing the description of costs and benefits included in the CBA and then illustrating the correspondence between the relevant programme workstreams and those costs and benefits. The next section details broad assumptions. We then outline the composition of each of the major cost and benefit categories, including specific assumptions used.

2. Taxonomy of costs and benefits

Table 1 lists the impacts (costs and benefits) estimated in the analysis and maps those to workstreams to outline the contributions of the relevant workstreams. Not all work streams feed into the CBA.

Table 1 Cost and benefit categories

Category (workstream)	Impact	Content	Contribution to CBA
Freight operations (Freight modelling, Traffic Congestion)	Road use, direct	Road freight moving cost	**Base case:** • existing and future volume and nature of freight handled at Auckland port • estimate of when capacity would appear to be reached at Auckland site • distances involved in transporting freight to and from the Auckland port by road • existing rail capacity at Auckland and alternative locations • existing and future share of freight travelling by road in Auckland and alternative locations **Move:** • number of additional truck loads, truck numbers and truck capacity • extent to which extra capacity is needed • extent of increase in freight operations in alternative locations • expected modal shift at alternative port locations
	Rail use, direct	Rail freight moving cost	**Base case:** • existing and future volume and nature of freight handled at Auckland port • estimate of when capacity would appear to be reached at Auckland site • distances involved in transporting freight to and from the Auckland port by rail • existing rail capacity at Auckland and alternative locations • existing and future share of freight travelling by rail in Auckland and alternative locations **Move:** • number of additional wagon loads, train numbers and train capacity • extent to which extra capacity is needed • extent of increase in freight operations in alternative locations • expected modal shift at alternative port locations
	Road use, indirect	Congestion, emissions, safety	**Base case:** • estimate of total time spent traveling and vehicle kilometres travelled in Auckland, Northland, and Tauranga at present • existing total carbon dioxide emissions, NOx and SO_2 from moving freight by road over all the years in consideration

			• total truck volumes currently on relevant routes **Move:** • estimate of total time spent traveling and vehicle kilometres travelled in Auckland, Northland, and Tauranga under the Tauranga and Northland options • total truck volumes likely on relevant routes following the relocation (for accident avoidance purposes) • effect on congestion in Auckland CBD from land redevelopment • estimated future total carbon dioxide emissions, NO_x and SO_2 from moving freight by road from alternative locations
	Rail use, indirect	Emissions	**Base case: t**otal carbon dioxide emissions, NO_x and SO_2 from moving freight by rail over all the years in consideration **Move:** Total carbon dioxide emissions, NO_x and SO_2 from moving freight by rail from alternative locations
Supply chain investment (Infrastructure)	Port development	Planning, capital works and equipment costs	**Base case:** • cost estimate for each piece of infrastructure equipment required at the current Auckland site to best cope with future capacity **Move:** • incremental cost estimate for each piece of infrastructure required at the Northport and Tauranga sites • full cost estimate for each piece of infrastructure required at the Manukau and Firth of Thames sites • deadweight costs associated with potential central government funding
	Road investment	Planning, construction costs, deadweight costs	**Base case:** Cost estimate for road network upgrades related to activity from Auckland ports including upgrades on motorway network and State Highway network **Move:** Cost of road network upgrades required to accommodate freight task at other locations
	Rail investment	Planning, construction costs, deadweight costs	**Base case:** Cost of a third main from Westfield Junction to Quay Park **Move:** • cost estimate for Manukau and Firth of Thames options to connect to the rail network • cost estimate a new rail line from Avondale to Southdown and capacity improvements Avondale to Swanson

			• estimates should also include the cost of any new rail rolling stock required • deadweight costs associated with potential central government funding
Land redevelopment (Land Value)	Net economic gain from alternative use of Auckland site	Amenity value, welfare gains to consumers and producers, agglomeration benefits	**Base case:** The average value of the current Auckland site in dollars per square metre under current use **Move:** Additional economic welfare gains from redevelopment[1]

[1] We do not cover the estimation of these impacts in this paper as that detail is contained in a separate report supporting the Alternative Land Use Value workstream.

3. Assumptions

The major assumptions and inputs used in the analysis are contained in Table 2. Most of the assumptions are based on published guidance material (e.g. discount rate, deadweight cost rate) but others we have adjusted to fit the nature of the project (i.e. the analysis, planning, construction and freight transition periods).

On the discount rate assumption, we did consider the use of a declining discount rate, to reflect nascent practice and account for the long-term nature of the proposal.

Table 2 Assumptions and inputs

Factor	Source	Core value	Alternative tested
Analysis period	Officials	60 years	N/A
Base year for analysis and values	Sapere	2019	N/A
Discount rate	Treasury, NZTA EEM	6% real	4%, 8% real
Deadweight cost of taxation	Treasury Sapere	20% Central government 0% Local government	N/A
Planning period	Expert advice, Sapere	10 years, from 2020	N/A
Construction period	Expert advice	10 years, from 2030	5 years, from 2030
Transition of freight period	Sapere	5 years, from 2039	3 years, from 2034
Optimism bias	Sapere	N/A	N/A
Contingency costs for capital expenditure	Sapere	N/A	15%
Economic life of asset	Sapere	Road, rail, port hardstand, 100 years Other equipment, N/A	N/A

3.1 Base case

In the base case, POAL is assumed to remain and expand on the Waitematā Harbour for 60 years for the purpose of estimating a counterfactual infrastructure cost. Previous studies have concluded that POAL is constrained on a number of fronts, with respect to handling the future freight task. The assessment of the incremental costs of the options for a full move of the freight operations requires that those constraints be put aside.

A series of freight forecast scenarios for container volume growth at POAL have been prepared by transport consultants, using the Ministry of Transport (MoT) Freight Futures Model.[2] The forecasts also assume that POAL is able to remain and expand on the Waitematā Harbour to accommodate the

[2] Work undertaken by Richard Paling (transport planner and economist) and Murray King (transport consultant)

increasing volume of freight over 60 years. The purpose is to size the future freight task, to inform the required infrastructure capacity for the port options under consideration.

The POAL 30-year plan provides for yard capacity at Fergusson Container Terminal to increase from 1.0 million TEU to 2.1 million TEU in two stages: (1) construct a third berth, automate the yard and finish reclamation; and (2) relocate the administration block and extend the reefer space, construct rail-mounted gantry and automate the rail yard. The 30-year plan also provides for the Freyberg Wharf to be converted to container terminal operations, to increase yard capacity to 2.7 million TEU.

Two sets of port consultants, Advisian and Black Quay, were asked to independently review the planned capacity and to offer a view on yard capacity. The overall conclusion is that the planned development will enable sufficient operating capacity for approximately 30 years from 2020, with the range being 28 to 35 years of capacity (i.e. until 2048 or 2053), depending on the freight forecast scenario and the estimate of operating capacity.[3] This conclusion assumes that other constraints, such as channel dredging to enable larger vessels to access the harbour entrance, will be addressed (i.e. that the necessary consents will be obtained).

Accommodating the forecast increase in container volumes out to 2077/78 would require expansion to the port precinct beyond that allowed for in the 30-year masterplan. Advisian have concluded that this would involve substantial reclamation into the Waitematā Harbour, although not necessarily extending beyond the north face of the Fergusson Wharf. It could potentially involve extending the container terminal an estimated 800 m east of the existing Fergusson North Wharf and associated 24 hectares of reclamation to maintain sufficient berth capacity to service vessels until 2077/78.

Advisian acknowledge that reclamation is a controversial topic and that this level of reclamation may prove difficult to consent, particularly as expansion eastward will have coastal impacts on the sediment flow through the harbour, potentially causing siltation around Mechanics Bay and Judges Bay. Such an expansion would also like require the relocation of the facilities at Judges Bay and Mechanics Bay.

The cost of port infrastructure in the base case is estimated to be $1.27 billion.

[3] The Infrastructure workstream report provides more detail

4. Derivation of road user impacts

4.1 Truck trips forecast

The key input into the road costs model is the number of truck trips occurring per year. Hence, we will elaborate on the inner workings of the truck trips forecast before moving on to how the road freight costs are calculated.

4.1.1 Overview of the key equation

In the CBA, the definition of a "trip" is a leg of the journey. For example, if a truck goes from Northport to its destination in Penrose, that would be one truck trip. If the truck makes a return trip from Penrose to Northport (so it can pick up the next freight load in Northport), we would consider that to be another trip.

We use the following equation to derive the total number of truck trips per year for a given freight type from the freight forecast.

$$TruckTrips = \frac{FreightAmountForYearX \times RoadShare}{\left(\frac{FreightAmountPerTruck}{ReturnFactor}\right)}$$

$$= \frac{FreightAmountForYearX \times RoadShare}{FreightAmountPerTruck} \times ReturnFactor$$

Although, the first equation is what we use in the CBA, but for ease of understanding we suggest readers focus on the second equation. The numerator of the above fraction is the amount of freight, for a given freight type such as cars, TEU etc. which must travel by road, while the denominator is how much of that freight type a truck can carry, on average.

In simple terms, the fraction represents the amount of trucks which must be loaded at the port to carry all the freight required. If trucks never had to make return trips, then this would be equal to the amount of truck trips. However, often trucks need to make a return trip back to the port so they can pick up the next load. Because of this, it is necessary to adjust by a return factor. In the case of TEU cargo, the return factor is 1.75, which indicates that 75% of the time an empty return trip must be made (i.e. there is a load for 25% of return trips).

4.1.2 Inputs into the truck trip forecast

The key inputs into the truck trip forecast are the freight forecast, the road share for a given port, the amount of freight per truck (for a given freight type), and the return factor.

The amount of TEUs per truck and cars per truck were provided to us by POAL directly. The tonnes of bulk per truck was derived from analysis done by Murray King on the amount of bulk a truck could carry for various types of bulk. The return factors were also inputs sourced from expert opinion, the TEU return factor in particular was sourced from an analysis of BECA data by Richard Paling. An overview of the freight per truck and return factor inputs is given below. These inputs are constant across all port options.

Table 3 Freight Forecast Input Parameters

	Value
TEUs per truck	1.94
Return factor for TEU trucks	1.75
Tonnes of bulk per truck	28.14
Return factor for bulk trucks	2
Cars per truck	4.43
Return factor for car trucks	2

Source: Murray King, Sapere analysis

We have assumed road shares for cars and bulk are 100% for all options, meaning all car and bulk traffic travels by road. We were given some evidence that select types of bulk could potentially go by rail in the future, but it represented only a small portion of the bulk trade and was highly uncertain. Therefore, we chose to keep the assumption that all bulk will go by road as is currently the case at POAL.

The assumption that all cars will go by road is based on expert opinion by Murray King for the POAL, Manukau and Firth of Thames options. In short, the reasoning behind this is that POAL, Manukau and Firth of Thames are too close to Auckland for it to be economical to take cars by rail. For the Northport and Tauranga options, we still assume all cars travel by road, as this was the result of analysis done in Section 8.2.1.

Since car and bulk traffic has been assumed to travel exclusively by road in all cases, differences between the port options only arise with respect to the TEU rail/road shares. A road share of 75% indicates that 75% of TEU traffic will travel by road. This also implies that 25% of TEU traffic will travel by rail. The rail and road shares used in the CBA are given below. Section 7.5 describes the derivation of the rail shares in more detail, and to avoid significant repetition here, we direct readers to that section.

Table 4 Road and Rail Shares

	Rail share	Road share
POAL (Base Case)	25%	75%
Northport	50%	50%
Tauranga	70%	30%
Firth of Thames	50%	50%
Manukau	10%	90%

Source: Murray King, Richard Paling

4.2 Road costs

4.2.1 Truck vehicle km travelled

The key input into the road costs model is the vehicle km travelled by truck, as all emission costs and truck operating costs are given in terms of cost per km travelled. This vehicle km travelled by truck figure is derived with the following equation.

$$TruckVKT = TruckTrips \times AverageDistanceFromPort$$

The resulting TruckVKT figure represents the total km travelled by truck in a given year.

The $AverageDistanceFromPort$ parameter is the average weighted distance from the port to the regions of Auckland where the weights are the share of traffic destined to/originating from that region of Auckland. Distance information was sourced from Google Maps, and the share of traffic to/from each region was sourced from a Beca report on truck movements in Auckland.[4] This same report was used in the 2019 and 2016 EY studies. We made a small modification to the Beca shares by removing the "South Beyond Auckland" share. This was done because our analysis suggested that previous EY studies had significantly misinterpreted the meaning of the "South Beyond Auckland" share, and we had concerns about changes in this region since 2009.[5]

The average weighted distance from each port option's location to the relevant locations in Auckland is given below.

Table 5 Average Weighted Distances from Port Options to destinations in Auckland

	Average Weighted Distance (km)
POAL (Base case)	20.77
Northport	154.25
Port of Tauranga	208.51
Firth of Thames (Kawakawa Bay)	46.12
Manukau (Puhinui)	13.74

Source: Sapere analysis

4.2.2 Trucking costs (non-externality costs)

For each port option, Richard Paling estimated a different truck cost per km for each of the port options. The distances used here do not quite align with the distances used in table 4 above because in his analysis Richard Paling made a simplifying assumption that all traffic was travelling to/from Penrose. Truck costs are made up of driver time and truck operating costs (i.e. the actual gasoline and other costs required to operate the truck).

[4] Beca (2009) *"Truck Movement And Access Time Research for Ports of Auckland"*
[5] Sensitivity analysis was conducted to see if removing "South Beyond Auckland" had a material impact on the results. It did not.

Costs per km vary between the options because the average speed of travel between the options varies significantly. The roads between POAL/Firth of Thames/Manukau and Penrose are significantly more congested and have lower actual speeds than the roads between Northport/Tauranga and Penrose. Hence, the truck costs per km considers any congestion benefits to truck operators from moving truck traffic to a less congested area.

Costs per km also vary because Richard Paling has assumed driver wages will be $4 per hour more for the Northport and Tauranga options. This is because longer trips have additional costs associated with scheduling to ensure all drivers return to their bases at the end of the day.

Below we give the key inputs/assumptions used to derive the cost per km. These inputs are distance, trips per day, VOC, driver wages, fixed costs (i.e. vehicle depreciation) and average speed.

Table 6 Inputs for Trucking Cost per km Calculation

	POAL	Northport	Tauranga	FoT	Manukau
Distance to Penrose (km)	14	152	197	57	15
Round trips per day	14	4	3	7	15
Average speed (km/h)	40	65	74	49	55
VOC per km ($)	1.9	1.9	1.9	1.9	1.9
Driver wage per hour ($)	40	44	44	40	40
Fixed costs ($)	227,429	227,429	227,429	227,429	227,429

Source: Richard Paling

Below are the costs per km derived by Richard Paling using the inputs above.

Table 7 Cost per km by Truck for Each Port Option

	POAL	Northport	Tauranga	FoT	Manukau
Cost per km ($)	6.26	3.35	3.22	3.93	5.65

Source: Richard Paling

From here, the total km travelled between the relevant destination locations in Auckland and one of the port options is multiplied by the respective cost per km above, to derive total road costs for that port option in a given year. Rail trips usually have a final truck trip to deliver the goods from the train station to the final destination. The costs of those truck trips are included in rail costs model not the road costs model.

4.2.3 Externality costs

In the CBA, we account for 3 different categories of truck externalities:

- Truck CO_2 emissions
- Truck pollution costs – these are pollutants which are generally directly harmful to humans
- Truck safety costs – if there are more trucks on the road, there is an increased chance of a serious truck crash that would not have happened otherwise.

4.2.3.1 CO_2 Emission Costs

A truck's CO_2 emissions vary depending on the loading of the truck. Because of this, we use different emissions factors for fully loaded truck trips and empty return trips. Our internal consultants have derived two rates of CO_2 emissions per km, one for fully loaded trips and another for empty return trips. These figures were constructed using national averages from the MoT Vehicle Fleet Emission Model and NZ National Fleet Statistics. Given a cost of carbon dioxide of $71.19[6], we can easily calculate a CO_2 emissions cost per km as shown in the table below.

Table 8 Emission Costs Parameters and Final Emissions Factor

	CO_2 emissions per km (tonnes)	Cost of CO_2	Cost of CO_2 emissions per km
Fully Loaded	0.001436	$71.19	$0.1022
Empty (return trip)	0.001030	$71.19	$0.0733

Source: Sapere analysis

We refer to the cost of CO_2 emissions per km figure as an emissions factor. Since these emissions factors are in per km terms, the total cost of CO_2 emissions for a given year can be calculated as shown below.

$$CO2EmissionsCost = TotalVKTLoaded \times LoadedEmissFactor + TotalVKTReturn \times ReturnEmissFactor$$

4.2.3.2 Truck pollution costs

In the CBA, we include the cost of truck emissions for PM10, NO_X, CO, and HC in the truck pollution costs figure. The pollution emission rates for HCV per km are sourced from the 2018 EEM (NZTA, 2018). The EEM requires an average speed and gradient to determine the emission rates of these pollutants. The average speeds used were those given in table 5 and the gradients were estimated using Google Maps elevation data. All gradient data is estimated for the route from the port location to Penrose. Kawakawa Bay and Puhinui are used as the locations of the Firth of Thames and Manukau ports respectively.

Table 9 Assumptions Used to Determine Pollutant Emission Rates

	POAL	Northport	Tauranga	FoT	Manukau
Average speed (km/h)	40	65	74	49	55
Gradient – incline	1.16%	2%	1.1%	0.64%	1.4%
Gradient – decline	0.89%	2%	1.2%	0.64%	1.4%

[6] This figure is from the NZTA EEM and was updated to 2019 dollars. See section 7.4.1.

Source: Richard Paling, Sapere analysis

Since the average speed and gradient is different for each option, each option has a slightly different emissions rate for the four pollutants. The EEM prescribed different emissions rates per km depending on if the trip was an incline or decline trip. We used an average of these two emissions rates as our overall emissions rate.

The cost of the pollutants per tonne was sourced from the EEM and updated to 2019 values by assuming a 2.8% annual growth in the social cost of these pollutants[7].

Table 10 Cost of Pollutants per Tonne Updated for 2019

	Cost per tonne
PM10	$499,374.46
NO_x	$17,745.79
CO	$4.48
HC	$1,422.09

Source: NZTA EEM

The rate of emissions per km (in tonnes) multiplied by the cost per tonne (above) gives us our cost per km travelled, which we can multiply by the total vehicle km travelled in a given year to get the total pollution costs for that year. This is shown in the equation below.

$$PollutionCost = TotalVKT \times (PM10CostPerKm + NO_XCostPerKm + COCostPerKm + HCCostPerKm)$$

Since the emissions rate changes for each port, the costs per km are slightly different for each port. Below is a schedule of the total pollutant costs per km used for each port (i.e. this corresponds to adding all the pollutant costs per km as shown in the equation above).

Table 11 Total Pollutant Cost per Km

	POAL	Northport	Tauranga	FoT	Manukau
Cost of all pollutants per km ($)	0.182479331	0.14680096	0.13905196	0.162327402	0.153326186

Source: Ministry of Transport, Sapere analysis

4.2.3.3 Truck safety costs

We estimate truck safety costs in the same way as EY did in their 2019 analysis, the only difference is that we use updated crash statistics and value of life/injury figures.

Truck crashes are split into those that which result in a death, those which result in a serious injury, and those which result in a minor injury. To calculate deaths/serious injuries/minor injuries per truck km travelled, we sourced the number of deaths/serious injuries/minor injuries in 2018 involving trucks

[7] The 2.8% annual growth rate assumption was made because the social cost of emissions is determined on the basis of the value of statistical life, which has increased from $4.1m in 2016 to $4.34m in 2018, i.e. 2.8% annual change.

from MoT's annual crash statistics[8] and divided this by MoT's 2018 estimate of national truck kilometres travelled[9]. The cost of a death, serious injury, and minor injury was sourced from the updated NZTA EEM (NZTA, 2018).

Table 12 Safety Costs Parameters and Final Safety Factors

	Rate per truck km	Cost	Cost per km travelled
Death	0.000000024	$4,369,700	$0.105316103
Serious Injury	0.000000066	$458,400	$0.030228841
Minor Injury	0.000000243	$24,700	$0.006002667

Source: Ministry of Transport, Sapere analysis

Hence, total safety costs for a given year can be calculated as follows.

$$SafetyCosts = TotalVKT \times (DeathCostPerKm + SeriousInjCostPerKm + MinorInjCostPerKm)$$

[8] https://www.transport.govt.nz/mot-resources/new-road-safety-resources/truck-crashes/truck-crashes-and-casualties/

[9] https://www.transport.govt.nz/mot-resources/transport-outlook/transport-outlook-future-state-model-results/

5. Derivation of traffic (congestion) impacts

5.1 Background to the estimates and why HCV costs were not used by the CBA

Using a series of complex traffic models, Flow estimated the impact of a port move on total HCV and car costs. The models used were:

- The Auckland Macro Strategic Model (MSM)
- The Tauranga Transport Strategic Model
- A SATURN traffic model which covers State Highway 1 in Northland, from north of Wellsford to Whangarei.

There exist topological gaps between the Auckland and Tauranga models and the Auckland and Northland models. The effect of these gaps was manually corrected by Flow (i.e. by using the model's average speed it is possible to estimate what occurs between the gaps in the model). Flow output the costs for the year 2048 and then suggested that future (past) values could be derived by assuming a 3% growth (discount) rate. The car costs were exclusively congestion costs (as passenger cars aren't involved in carrying freight) but the truck/HCV costs were a mix of congestion costs and actual transport freight costs.

Flow's HCV/truck costs were not used in the CBA largely because it was very impractical to do so. Running the models took a considerable amount of time (several days) and given the tight timeframe of the project, it was not feasible to wait for this output after each sensitivity test. Using our own internal road costs model also allowed us to be more transparent about the assumptions being made, which was often unclear in the transport models. Therefore, congestion costs in the CBA only refers to car congestion costs from Flow's models. This does not mean that the effect of congestion on trucks was ignored, as we explain in Section 4.2.2, truck congestion costs are implicitly included in the road costs.

Flow's car and HCV costs were estimated using the Officials' agreed freight forecast and the rail shares given below. Refer to section 5.2 below for further detail.

Table 13 Rail Share Assumptions Used by Flow Modelling

	POAL	Northport	Tauranga	FoT	Manukau
Rail Share	13.5%	35%	35%	13.5%	13.5%

Source: Flow

The car congestion costs included in the CBA are given below for the year 2048. Travel time costs (i.e. time wasted in traffic or travelling), VOC and CO2 emission costs were all included as part of the congestion costs. The car congestion costs for the split option was not given to us by Flow, and instead we have estimated it as an average of the congestion costs for the Northport and Tauranga options.

Table 14 Car Congestion Costs in Millions

$, Millions	Travel Time	VOC	CO2	Total	Diff. to Base

POAL (Base case)	9502.783841	5069.743108	202.7897243	14775.31667	0
Northport	9514.159773	5077.150926	203.086037	14794.39674	19.08006238
Tauranga	9503.778044	5071.601973	202.8640789	14778.2441	2.927422008
FoT	9491.213755	5071.827181	202.8730873	14765.91402	-9.402649791
Northport and Tauranga	9508.968908	5074.376449	202.975058	14786.32042	11.00374219
Manukau	9487.005228	5062.495241	202.4998096	14752.00028	-23.31639469

Source: Flow, Sapere analysis

5.2 Assumptions made to integrate congestion costs into the CBA model

As mentioned before, the CBA uses an internal road costs model instead of the Flow HCV costs to model truck costs. However, the car congestion costs from Flow are still used in the CBA as "congestion costs". These congestion costs were not modified from what Flow provided us, even though we do not make the same rail share assumptions as they do, and in our Calibrated model we do not make the same freight forecast assumptions either. This is because, in the CBA, we assume that car congestion costs are not impacted significantly by the number of trucks on the road.

In discussions with Flow and Richard Paling, they advised us that most of the impact from congestion costs (in the event of a port move) originated from increased traffic in the Auckland CBD (since many more people will work and live in the POAL site once it is vacated). Since the vast majority of freight trucks are not bound for destinations in the Auckland CBD, an increase in the number of trucks should not impact CBD congestion in a significant way (as the port trucks are bound for other destinations like Penrose or the port itself i.e. Manukau, Northport etc.). Therefore, a change in the number of port related trucks will not impact Auckland CBD congestion.

However, some congestion originates from traffic near the port as well, or else there would be no difference between the port move options (as they all have the exact same scenario occurring in the Auckland CBD). Our assumption is that this is largely due to fixed effects on congestion in combination with infrastructure effects, both of which are not affected by a marginal increase in the number of trucks.

The idea behind the port's congestion effect being fixed is that, people will need to slow down and be careful of trucks near the port, and this effect doesn't significantly change if the number of trucks changes. An example of fixed infrastructure effects could be the benefits of new road infrastructure (built as a result of the port) which saves people time on their morning and evening peak commutes. Trucks generally wouldn't necessarily all travel at peak commute times, so any change in the number of trucks would not significantly impact this benefit.

Therefore, because we assume that car congestion costs are not affected by changes in the number of trucks, we do not adjust car congestion costs for changes in road/rail shares or for changes in the freight forecast, as these variables can only impact car congestion through changes in the number of trucks on the road. As a result, the car congestion costs are the same under the Officials' agreed and

Calibrated freight forecasts and why car congestion costs do not change for our rail share sensitivity analysis.

6. Derivation of infrastructure impacts

6.1 Port

Inputs from Advisian, Black Quay and Mitchell Daysh indicated the earliest that major new port capacity could be planned and built would be over a 10-year period. This assumes a decision about the location of future port capacity is made immediately, the approvals process takes 5 years, and construction the next 5 years. As timeframes for the consenting process and construction phase could be materially longer than expected we have taken a conservative approach, outlined in Table 14. This follows the principle of avoiding using best-case assumptions when planning for the long term. These conservative assumptions are applied to all options, for modelling simplicity and to enable comparability.

We expect some duplication of capacity is required to enable the smooth transition of the freight task so we have allowed a gradual shift of 20 per cent of volume per year, for five years across all options.

Table 15 Time frames for port infrastructure

	Planning	Construction	Utilisation
Preferred assumptions	10 years	10 years	5 years
Sensitivity testing	10 years	5 years	3 years

Source: Sapere analysis

In sensitivity testing we reduce the time frame for construction and the utilisation lag but keep the planning time period to enable comparison across new and existing port options.

6.1.1 Planning costs are spread evenly over the decade beginning in 2020

The planning report prepared by Richard Turner (Mitchell Daysh) considered the timeframes involved in gaining approval for new capacity, at existing ports and the potential sites for a new port. Allowing for a design phase, lead-in time to prepare technical reports, and the consenting process, the conclusion is that gaining the necessary approvals could take up to seven years at an existing port and up to a decade for a new port.

For modelling simplicity, we assumed planning costs are spread evenly across the 2020s.

Table 16 Estimation of timeframes for the approvals process

Port option	Planning feasibility (years)	Modelling assumptions (years)
Northport and Port of Tauranga	5-7	10
Manukau Harbour	7-9	10
Firth of Thames	8-10	10

Source: Mitchell Daysh 2020

For the existing ports the upper end of the Mitchell Daysh range provided was used. Calculations for the new ports included a 2016 high level Black Quay estimate of $100 million for consulting and design. This was adjusted to 2019 dollars using the NZTA structures index, to calculate a 8.47 per cent increase.

Table 17 Planning costs spread evenly over 2020s ($ millions)

Option	Planning cost	Source
Tauranga	3	Mitchell Daysh
Northport	3	Mitchell Daysh
Northport-Tauranga split	6	Mitchell Daysh
Manukau Harbour (Puhinui)	116	Black Quay/ Mitchell Daysh
Firth of Thames	116	Black Quay/ Mitchell Daysh

Source: Sapere analysis

6.1.2 Construction costs are spread evenly over the decade beginning in 2030

While the port consultants generally assumed that construction of major new port capacity would occur across a five-year period we have allowed for 10 years of construction with costs evenly spread over the decade for each option.

The costs outlined in Table 17 were provided by Advisian, and Black Quay. These included provision for equipment and capital works. The Black Quay original estimates were for a port with capacity of 10 million TEU, these were scaled down to allow for 5 million TEU capacity. The 2040 figure for Tauranga includes a provision of $758 million to relocate a highway, marina and airport.

Table 18 Option development cost Calibrated freight forecast ($ millions)

Decade	2020	2030	2040	2050	2060	2070
Ports of Auckland	-	-	174	434	188	188
Tauranga	3	408	1,191	518	224	289
Northport	3	1,474	164	216	298	299
Northport-Tauranga split	6	1,230	472	330	247	311
Manukau Harbour (Puhinui)	116	5,810	85	138	188	188
Firth of Thames	116	5,254	85	138	188	188

Source: Advisian, Black Quay, Sapere analysis

The figures are scaled down for the Officials' agreed case to allow for 2 million TEU capacity.

Table 19 Option development cost Officials' agreed freight forecast ($ millions)

Decade	2020	2030	2040	2050	2060	2070
Ports of Auckland	-	-	174	-	-	-
Tauranga	3	408	224	518	112	-
Northport	3	1,474	82	-	-	-
Northport-Tauranga split	6	1,230	390	168	9	-
Manukau Harbour (Puhinui)	116	4,977	-	-	-	-
Firth of Thames	116	4,006	-	-	-	-

Source: Advisian, Black Quay, Sapere analysis

6.1.3 Utilisation lags construction and is assumed to take five years for the full transition of freight task to a new location

Freight volume begin to shift to the new port options in 2040 at a rate of 20 per cent a year until the transition is complete. This allows for the necessary duplication of some infrastructure as the shift of the freight task occurs

6.1.4 Avoided base case costs are those scheduled to occur beginning 2040

The Ports of Auckland costs incurred in the 2020s and 2030s are considered sunk and therefore excluded from analysis.

Table 20 Avoidable port infrastructure costs ($ million)

Ports of Auckland	2040	2050	2060	2070
Calibrated	174	434	188	188
Officials' agreed forecast	174	-	-	-

Source: Advisian, Sapere analysis

6.1.5 Capacity adjusted for forecast freight volumes

New ports designed to take 10 million TEU, costs scaled to accommodate 5 million TEU for the Calibrated forecast and 2 million TEU for the Officials' agreed forecast.

6.2 Road

Road costs were estimated by combining previous forecasts and analysis. No net avoided roading costs are included in analysis. Costs are the same for the Calibrated and Officials' agreed freight forecasts. Negative costs represent projects brought forward, that is they occur earlier than otherwise due to the port relocation. For consistency we spread road costs evenly across the decade in which they occur and allow for some planning and consenting to be done in the 2020's. Our treatment of road costs has some curious results, such as negative terminal values due to discounting, explained in detail in the section below.

Table 21 Road infrastructure costs ($ million)

	2020	2030	2040	2050	2060	2070
Ports of Auckland	-	-	-	-	-	-
Tauranga	15	1,476	-1,090	-	-	-
Northport	31	3,110	-3,141	-	-	-
Northport-Tauranga split	46	4,585	-4,232	-	-	-
Manukau Harbour (Puhinui)	8	762	-	-	-	-
Firth of Thames	27	2,660	-	-	-	-

Source: NZTA, AT, Flow Consultants, Sapere analysis

6.3 Rail

Inputs come from; RIC NZ Ltd, NAL business case, Kiwirail and Murray King

Rail infrastructure include costs for a planning and implementation phase that is spread evenly across the 2020's decade. The majority of construction is undertaken in the 2030's with some further development in the 2050's. Unlike road there are avoidable costs for the Calibrated forecast (the third main line from Westfield to Quay Park), planning costs in the 2030's and construction in the 2040's.

Table 22 Rail infrastructure costs Calibrated freight forecast ($ millions)

	2020	2030	2040	2050	2060	2070
Ports of Auckland	-	21	1,278	-	-	-
Tauranga	6	586	-	1,436	-	-
Northport	50	4,952	-	2,465	-	-
Northport-Tauranga split	53	5,222	-	250	-	-
Manukau Harbour (Puhinui)	35	1,938	-	-	-	-
Firth of Thames	160	8,545	-	-	-	-

Source: RIC NZ Ltd, NAL business case, Kiwirail, Murray King, Sapere analysis

The costs are unchanged for the new port options under the MoT freight scenario with costs scaled for the existing ports.

Table 23 Rail infrastructure costs Officials' agreed freight forecast ($ millions)

	2020	2030	2040	2050	2060	2070
Ports of Auckland	-	-	-	-	-	-
Tauranga	5	473	-	25	-	-

Northport	48	4.820	-	29	-	-
Northport-Tauranga split	51	5,099	-	27	-	-
Manukau Harbour (Puhinui)	35	1,938	-	-	-	-
Firth of Thames	160	8,545	-	-	-	-

Source: RIC NZ Ltd, NAL business case, Kiwirail, Murray King, Sapere analysis

6.4 Terminal values

Terminal values are included as the road, rail and port infrastructure is fully costed but some of this infrastructure will continue to provide value beyond the analysis period. The remaining value of assets at the end of the analysis period (i.e. terminal values) are deducted from the total capital costs.

Several simplifying assumptions were required:

- We assume that all long-term assets have a 100-year lifespan.
- The life of the asset begins upon construction and the asset's value decays linearly throughout its lifespan.
- We excluded all equipment such as cranes, straddles and rolling stock. Other capital expenditure excluded from terminal values includes; dredging, demolition, planning and consenting costs.

The costs were spread out evenly over the decades and so are the terminal values meaning each year of expenditure has a different remaining lifespan. The costs considered are outlined in table 22, these costs are times by the remaining lifespan at the end of analysis 2079.

The stylised formula is,

$$Terminal\ value = \%\ of\ asset\ life\ remaining \times\ asset\ value$$

And for the percentage of life remaining,

$$\%\ of\ asset\ life\ remaining = \frac{Asset\ life - (Final\ year\ of\ analysis - ConstructionYear)}{100}$$

These values are calculated, then summed and discounted in the final year of analysis.

Table 24 Initial capital included in terminal value Calibrated calculations ($ millions)

		2030	2040	2050	2060	2070
Ports of Auckland	Port	-	88	366	-	-
	Road	-	-	-	-	-
	Rail	20	1,199	-	-	-
Tauranga	Port	105	890	240	-23	39
	Road	1,475	-1,091	-	-	-
	Rail	393	-	1,264	-	-
Northport	Port	748	22	28	38	39

	Road	3,110	-3,141	-	-	-
	Rail	4,722	-	2,215	-	-
Northport-Tauranga split	Port	574	307	119	-2	39
	Road	4,585	-4,231	-	-	-
	Rail	5,010	-	38	-	-
Manukau Harbour (Puhinui)	Port	3,136	-	-	-	-
	Road	762	-	-	-	-
	Rail	1,908	-	-	-	-
Firth of Thames	Port	4,854	-	-	-	-
	Road	2,660	-	-	-	-
	Rail	8,375	-	-	-	-

Source: Sapere analysis

Table 25 Initial capital included in terminal value MoT calculations ($ millions)

		2030	2040	2050	2060	2070
Ports of Auckland	Port	-	88	-	-	-
	Road	-	-	-	-	-
	Rail	-	-	-	-	-
Tauranga	Port	105	224	240	-11	-
	Road	1476	-1,091	-	-	-
	Rail	355	-	8	-	-
Northport	Port	748	-	-	-	-
	Road	3,110	-3,141	-	-	-
	Rail	4,675	-	12	-	-
Northport-Tauranga split	Port	574	73	100	-51	-
	Road	4,585	-4,232	-	-	-
	Rail	4,968	-	10	-	-
Manukau Harbour (Puhinui)	Port	2,329	-	-	-	-
	Road	762	-	-	-	-
	Rail	1,908	-	-	-	-
Firth of Thames	Port	3,606	-	-	-	-
	Road	2,660	-	-	-	-
	Rail	8,375	-	-	-	-

Source: Sapere analysis

6.5 Deadweight costs

As funding is expected to come from general taxation 20 percent cost is added to the road and rail infrastructure cost, to account for potential distortionary effects from use of the taxation system. The deadweight cost looks higher for rail in the Officials' agreed base case, this is because the costs are relative to the base case and in the Officials' agreed scenario rail investment is not required whereas significant rail investment is required in the Calibrated scenario.

Table 26 Deadweight costs from taxation funding of infrastructure ($ NPV millions)

Freight forecast	Calibrated		Officials' agreed	
Infrastructure type	Road	Rail	Road	Rail
Ports of Auckland	-	64	-	-
Tauranga	78	27	78	43
Northport	123	442	123	428
Northport-Tauranga split	201	406	201	453
Manukau Harbour (Puhinui)	68	110	68	174
Firth of Thames	236	705	236	769

Source: Sapere analysis

6.6 Maintenance cost

Maintenance costs are not included as a direct line item. The treatment is slightly different across infrastructure aspects.

For ports we considered the equipment required to undertake the freight task to be relatively consistent and the different options just shift location. This ignores some pertinent factors that may alter significantly at different location like dredging maintenance costs.

For road to be consistent with no avoided roading infrastructure costs we assume maintenance costs are unchanged under the various scenarios.

For rail the costs provided by Murray King include a provision for maintenance. "The capital costs included are those in the nature of operating costs, such as rail replacement, track grinding, and destressing."

6.7 Contingency

A 15 per cent contingency is added to all infrastructure costs in sensitivity testing. We did not include in the preferred assumptions as the costings are high level and port consultants Black Quay noted a possible plus or minus 50 per cent to their estimates.

7. Derivation of rail impacts

7.1 Tonnes of Freight by Rail Derivation

The key input into the rail costs model is the amount of freight in tonnes travelling by rail. Although it is possible for the CBA to calculate the number of rail trips, rail trips are not actually used anywhere in the rail costs.

The CBA has assumed that bulk and cars will travel exclusively by road across all the options. The justification for this assumption has already been outlined in detail in Section 4.1.2. Therefore, only TEUs travel by rail in our analysis.

We have not been able to include consideration of transporting empty containers in the CBA. We considered the effect of transhipments (in particular, the potential for transhipments between ports in the base case that would result in additional rail trips in the alternative option/s). The impact was just over one half of one per cent for the Tauranga-Auckland case and even lower for Northport-Auckland. Thus, the CBA does not account for such impacts.

To convert TEUs to tonnes, we use a conversion factor which varies between 11.313 and 10.341 tonnes per TEU. These figures are largely based on analysis done by Murray King. Murray King derived two separate TEU-to-tonnes conversion factors for import and export TEU freight (shown below). This was done by analysing Statistics NZ customs data on weight and mapping that to TEU traffic data from MoT (FIGS) and POAL to arrive at the weight per TEU figures for imports and exports.

Table 27 Average Weight per TEU Calculation

	Import TEU	Export TEU
Weight per TEU (including tare weight)	9.427	13.562
Import/export share at POAL in 2018	0.544	0.456
Average weight per TEU in 2018	11.313	11.313
Import/export share at POAL in 2079 (Calibrated forecast)	0.779	0.221
Average weight per TEU in 2079 (Calibrated forecast)	10.341	10.341

Source: Murray King, Sapere analysis

The weights per TEU used include tare weight (i.e. the weight of the actual container). The calculation for the tonnes of TEU freight travelling by rail is given below. Note that the $TEUtoTonnes$ parameter changes over time as import/export shares change.

$$TonnesOfFreightByRail = AmountOfTotalTEUFreight \times TEUtoTonnes \times RailShareForPort$$

Where the rail shares for each port are given below.

Table 28 Rail Shares

	POAL	Northport	Tauranga	FoT	Manukau
Rail Share	25%	50%	70%	50%	10%

Source: Sapere analysis

7.2 Freight Tonne Km Travelled

Rail operating costs and rail emissions costs are given on a net tonne km basis. Therefore, it is necessary to convert the tonnes of freight by rail figure (derived in the previous section) to a net tonne km by rail figure.

All rail trips are assumed to stop in Southdown (as is currently the case). Hence, the distance travelled by rail depends on the port's distance from Southdown. These distances are given in the table below.

Table 29 Distances to Southdown from Port Location By Rail

	Distance to Southdown (km)
POAL (Base case)	22
Northport	214
Tauranga	223
Firth of Thames (Kawakawa Bay)	55
Manukau (Puhinui)	22

Source: Murray King, Kiwirail

To derive tonne km travelled by rail, we use the following equation.

$$TonneKmTravelledByRail = TonnesOfFreightByRail \times DistanceFromPortToSouthdown$$

7.3 Rail Operating Costs

7.3.1 Derivation of Rail Operating Costs per Tonne Km Travelled

Using data provided by Kiwirail, Murray King derived the costs per TEU and net tonne km travelled per TEU for the trip from each port to Southdown. The costs per TEU included capital costs that were operating costs in nature, such as rail replacement, track grinding, and destressing. Therefore, the final costs per net tonne km that we derive from these figures, will include typical operating costs such as fuel and wages along with capital costs that are related to rail maintenance.

The costs per TEU also assume that trains are 80% utilised under the Northport, Tauranga, and Firth of Thames options and 70% utilised under the POAL and Manukau options. This means that many of the TEU slots on a train are not filled. POAL uses a 70% utilization rate because that is what the rail line at POAL currently shows, and we assume Manukau will be the same due to the similarity between the two ports. The utilisation assumptions were made on the advice of Murray King.

When some cargo arrives at Southdown a truck will need to pick up the cargo to transport it to the final destination (i.e. a store warehouse or factory). Because of this, it is not sufficient to only consider the costs of the train trip from the port to Southdown, we also need to consider the cost of the truck trip from Southdown to the final destination.

Richard Paling estimates that on average this is a 30km round trip by truck. Also, we know that Richard Paling's and Murray King's previous analyses showed that the cost per km for truck travel in Auckland is $6.261 per km and the load per truck is 1.94 TEUs. Additionally, Murray King estimates that trucks have a 25% return load on average. Therefore, the total load for the round trip is 2.425 TEUs and the total cost of the round trip is $187.83. Hence, the cost per TEU of the final truck trip is $77.46 per TEU.

Total costs per TEU divided by net tonne km per TEU yields our cost per net tonne km figure which we use to cost rail in the CBA. The table below shows the parameters we have explained in the paragraphs above and the final cost per tonne km that we derive using those figures. [redacted]

Information withheld as it would be likely unreasonably to prejudice the commercial position of the person who supplied or who is the subject of the information.

Table 30 Cost per Net Tonne Km Parameters and Final Figure

	POAL	Northport	Tauranga	FoT	Manukau
Cost per TEU (70-80% utilization)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Final truck trip cost per TEU	$77.46	$77.46	$77.46	$77.46	$77.46
Net tonne km travelled per TEU	200	1855	1933	474	200
Cost per net tonne km travelled	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Source: Murray King, Richard Paling, Sapere analysis

The final truck trip cost per TEU can be thought of as a fixed (i.e. universal and unavoidable) cost that must be incurred for every TEU transported. Hence, when we incorporate the final truck trip cost into the "Cost per net tonne km travelled" figure, we do so on a cost per net tonne km basis, for ease of modelling purposes. To be clear, there is no assumption here that if the rail trip was longer (i.e. the rail lines are diverted to take a longer route to Southdown) that the final truck trip cost would increase in proportion to that.

7.3.2 Calculating Rail Operating Cost

Since we have already derived the cost per net tonne km travelled in the section above, by using the tonne km travelled by rail (derived in section 7.2) and the equation below, we can calculate the total operating cost of rail (i.e. cost of using rail - not considering externalities).

$$TotalRailCost = TonneKmTravelledByRail \times CostPerTonneKmTravelledForPort$$

Information withheld as it would be likely unreasonably to prejudice the commercial position of the person who supplied or who is the subject of the information.

7.4 Rail Externalities Cost

7.4.1 Carbon Dioxide Emissions

Carbon dioxide emissions were estimated at 28g of CO2 emissions per tonne km. This figure was sourced from MfE (2019). This value is an average for all freight and does not distinguish between bulk/packed cargo and container freight. Currently, there is no publicly available data that would allow estimating more granular emission factors for rail transport, distinguishing between loads and types of cargo.

Carbon dioxide emissions are costed at $71.19 per tonne. This figure was updated from the 2016 value of $65.58, given in the 2018 EEM, and assuming a 2.8% annual growth rate in cost (NZTA, 2018). The 2.8% annual growth rate assumption was made because the social cost of emissions is determined on the basis of the value of statistical life, which has increased from $4.1m in 2016[10] to $4.34m in 2018,[11] i.e. 2.8% annual change.

Therefore, to calculate the cost of rail CO_2 emissions, we use the following formula.

$$TotalCO2Cost = TonneKmTravelledByRail \times CO2CostPerKm$$

Where $CO2CostPerKm$ is the CO_2 emissions rate (adjusted to tonnes) multiplied by the cost of emissions per tonne, which are both given above.

7.4.2 Final Truck Trip Emissions

The final 30km truck trip required to move goods from Southdown to their final destination in Auckland, also carries emissions costs. Since the effect is small, to avoid a complex implementation of this in the CBA, we have taken the approach used by Flow and assumed the cost of all pollutants (CO_2 and other pollutants) is equal to 5% of truck operating costs. From Richard Paling's analysis we know truck operating costs are $1.9 per km, therefore, the total cost of emissions for the 30km truck round trip is $2.85. Since the load of the truck round trip is 2.425 TEU, the emissions cost per TEU is $1.175. Dividing through this emissions cost per TEU by the net tonne km per TEU, results in the truck pollutants cost per net km travelled as shown below.

Table 31 Truck Emissions Cost per Net Tonne Km Parameters and Final Value

	POAL	Northport	Tauranga	FoT	Manukau
Truck emissions cost per TEU	$1.175	$1.175	$1.175	$1.175	$1.175
Net tonne km per TEU	200	1855	1933	474	200
Truck emissions cost per net tonne km	$0.00588	0.00063	0.00061	0.00248	$0.00588

[10] As per (NZTA, 2018)

[11] https://www.transport.govt.nz/mot-resources/road-safety-resources/roadcrashstatistics/social-cost-of-road-crashes-and-injuries/

Source: Richard Paling, Murray King, Sapere analysis

Like the final truck trip cost, we can think of the "Truck Emissions cost per TEU" above as a fixed (i.e. universal and unavoidable) cost which must be incurred for every TEU. Hence, when we calculate the "Truck emissions cost per net tonne km travelled", we do so on a per net tonne km basis for ease of integration into the CBA model. There is no assumption here that a longer rail trip would incur more truck emission costs.

In the same way as the CO_2 emissions costs were estimated in the prior section, to calculate the total cost of truck trip emissions from rail, we use the following equation:

$$FinalTruckTripEmissions = TonneKmTravelledByRail \times CostOfTruckEmissionsPerNTKM$$

7.5 Rail share derivation

Below we describe the process used by Murray King and Richard Paling to derive the rail shares used in the CBA. Most of this analysis relies on expert judgement around the extent to which certain factors could impact use of rail.

7.5.1 Share of Traffic Addressable by Rail

The share of traffic which could feasibly go on rail (i.e. the share of traffic where it is technically possible and economically feasible to use rail) is given below. We refer to this as the share of traffic addressable by rail. The share of traffic addressable by rail should be considered a key input into the rail share, but not the ultimate determinant of the rail share.

Table 32 Share of Traffic Addressable by Rail and Adjusted Share of Traffic Addressable by Rail

	Northport	Tauranga	Firth of Thames	Manukau	POAL
Share of traffic addressable by rail	90%	85%	50%	10%	25%
Just in time traffic adjustment	-10%	-10%			
Adjusted traffic addressable by rail	80%	75%	50%	10%	25%

Source: Murray King, Richard Paling

Just in time deliveries are likely to favour road because it is quicker and more direct. For this reason, the Northport and Tauranga 'addressable by rail' traffic share was reduced by 10 percentage points to account for 'just in time' deliveries favouring road.

Northport's initial share of traffic addressable by rail is 90%, this is because in Section 8.2.3 below it was noted that 8% of POAL traffic is destined for Northland. Therefore, if Northport was chosen as the preferred port, we can expect 8 – 10% of traffic to not go by rail as its final destination is very close. Similarly, Tauranga's initial share of traffic addressable by rail is 85%, because in the same analysis it was noted that 15% of POAL traffic is destined to go the Waikato region which is too close for rail to be viable.

7.5.2 Rail Shares Derivation

The share of traffic addressable by rail, which we have derived above, only tells us what share of traffic could technically go by rail. Other considerations, such as cost (related to distance) and speed, are used to determine the actual percentage of traffic which will travel by rail (i.e. the rail share). There was a disagreement among our experts regarding this matter.

Northport is further from Auckland by rail than by road and the journey is slower per km. Therefore, it is likely that many goods will choose to use road at Northport even though rail is a possibility. Tauranga is further from Auckland by rail than by road as well, but the journey is not as slow as the Northport option. The extent of these effects is where our experts disagreed.

The first estimate generally thought most goods would opt to use rail, and as a result, reduced the share of traffic addressable by rail at Northport by 25% to get a final rail share of 60%. However, the second estimate took a more conservative view on rail use, and as a result, reduced the share by 50% to get a rail share of 40% at Northport. For the Tauranga option, the first estimate did not reduce the share of traffic addressable by rail at all, leaving the rail share at 75%. The second estimate reduced the rail share by 10% to get a final rail share 67.5% at Tauranga.

The two estimates are given in more detail below. A midpoint between the two estimates was chosen as the rail shares which would be used throughout the analysis and in the CBA.

Table 33 Rail Share Estimates and Ultimate Midpoint Estimate

	Northport	Tauranga	Firth of Thames	Manukau	POAL
Estimate 1 & 2 – Share of traffic where rail is a possibility	80%	75%	50%	10%	25%
Estimate 1 – Share of traffic which takes up the opportunity to use rail	75%	100%	100%	100%	100%
Estimate 1 – Rail share	60%	75%	50%	10%	25%
Estimate 2 - Share of traffic which takes up the opportunity to use rail	50%	90%	100%	100%	100%
Estimate 2 – Rail share	40%	67.5%	100%	100%	100%
Midpoint estimate	50%	70%	50%	10%	25%

Source: Murray King, Richard Paling

8. The split Tauranga/Northport option

8.1 Why a Separate Appendix for the Split Option is Needed

The road and rail costs models, which we have described in their respective appendices, is fundamentally altered to allow for the assumptions that the split option requires. Additionally, the explanation how we reached our assumptions of the freight divide between Northport and Tauranga is complex and requires several sections. For these reasons, we have broken off this specific option into its own appendix.

8.2 How freight is allocated in the split option

8.2.1 100% of the car trade will move to Tauranga

The following analysis by Murray King found that in the event of a split option between Northport and Tauranga, Tauranga would take 100% of the car market and the cars would travel by road.

8.2.1.1 Northport cars need to travel further than Tauranga cars

The crux of this result rests in a mapping exercise to map data from the Statistics NZ on car imports by port and MoT data on cars' region of first registration. This helps us identify what regions car imports from POAL are destined for. The following table shows the results of this analysis and allows us to derive a percentage of the POAL car trade going to each respective region.

Table 34 Estimate cars to each region from POAL

Destination	Number of cars	Percentage (rounded)
Northland	4340	2%
Auckland	157646	73%
Waikato	20811	10%
Bay of Plenty	5936	3%
Gisborne	1088	1%
Hawkes Bay	6495	3%
Taranaki	3787	2%
Manawatu/Whanganui	10244	5%
Wellington	6746	3%
Total	217093	100%

Source: Murray King, Statistics NZ, MoT

Note that the MoT car registration data was adjusted for Tauranga (Bay of Plenty) and Wellington to remove local imported car supply from their respective ports (as we are only interested in the supply which must be serviced through Auckland).

Using the regions and percentages above, we can derive the average weighted distance (using the percentages as the weights) from Northport and Tauranga to these car markets. This analysis is listed in the table below.

Table 35 Distance to Each Region and Weighted Average Distance

Region	Distance to Northport (km)	Distance to Tauranga (km)
Northland	36	367
Auckland (Penrose)	148	203
Waikato	349	112
Bay of Plenty	262	8
Gisborne	617	270
Hawkes Bay	549	291
Taranaki	498	317
Manawatu/Whanganui	651	396
Wellington	779	525
Weighted Average Distance	234.0	220.3

Source: Murray King

The table above shows that if all cars were handled through Northport, each car would travel 6% further on average than if all cars were handled through Tauranga. Therefore, even though Northport is closer to Auckland than Tauranga (148km vs. 203km in the table directly above), this is more than offset by Tauranga being closer to the rest of the car market south of Auckland.

Penrose was used as the 'centroid' of Auckland as it is close to a concentration of car dealerships. If Wiri is chosen instead, cars from Northport will need to travel 27% further than cars from Tauranga, as opposed to only 6% if Penrose is used as the 'centroid'. Hence, either way, cars from Northport travel further than cars from Tauranga.

8.2.1.2 All cars will go by truck which allows the benefits of Tauranga to be realised

One potential issue is that if cars go by rail from these ports, then all the cars will arrive at the same rail location, regardless of if they came from Northport or Tauranga. Therefore, if all cars travel by rail, the shorter distance from Tauranga will not be realised in practice. However, we are confident that cars will travel by road as opposed to rail. This is because rail has significant disadvantages. Rail requires double handling, stockpiling of cars at the port, and a handling and storage area in Auckland among other concerns.

For this reason, we believe all cars will travel by road and be handled at a distribution point close to the port. Trucks leaving these distribution points would go directly to the final destination (no double handling). Therefore, since the distribution points would be roughly at the port location, the shorter distance from Tauranga to the car markets would be realised in practice.

8.2.2 27% of bulk traffic will go to Northport and 73% to Tauranga

The vast majority of bulk traffic arriving at POAL are imports for use within Auckland. Bulk traffic is carried by road in all cases. If the port is moved from Auckland, bulk traffic will face significant extra costs. Murray King spoke to the industry using bulk from POAL about the likely effects on their business if the port moved to Northport or Tauranga.

Many businesses responded by saying that such a move would be "disastrous". The overall picture appears to be that firms would have to deal with roughly a tenfold increase in costs. These costs largely arise from increases in the number of trucks used, tonne-kilometres generated, and supply chain complexity. Most of the firms do not appear to have the large margins necessary to absorb these costs, hence, costs would be passed on to consumers through higher prices. In some cases, the extra costs could mean that plants are put at risk closure or relocation, and it may be that some traffic is no longer economic at all without a local port.

Murray King allocated bulk traffic to Northport or Tauranga on a per commodity basis. Most commodities were allocated to a specific port because either the end user (usually a factory) was closer to that port or one port was clearly in favour because it had existing supply chains there. Some commodities currently in operation were also removed after receiving advice from POAL and industry that they would not be at POAL much longer.

Overall, this analysis yielded that 27% of bulk would likely go to Northport and 73% would likely go to Tauranga. There are a few opportunities for bulk to go by rail, but they are uncertain. Hence, for the CBA we have continued the assumption that 100% of bulk will go by road.

8.2.3 Most TEU traffic will go to Tauranga but exact percentage is uncertain

To identify how TEU traffic is likely to be reallocated, it is necessary to identify what the origins and destinations of current TEU traffic are. Data from the NFDS (National Freight Demand Study) was used to identify freight flows through POAL by region of destination or origin.

However, it is well known that imports are generally routed into an Auckland distribution centre before being packaged and sent to the final destination (which may be outside of Auckland). Therefore, some of the traffic going to the Auckland's distribution centres is actually destined for areas outside of Auckland. Unfortunately, data on the distribution of imports from Auckland's distribution centres was not available in the NFDS. To get around this, we have assumed that imports routed to Auckland's distribution centres have the same distribution profile as manufactured and retail goods (import and exports) for which the NFDS does give data. Manufactured and retail goods is often considered a good proxy for TEU movements.

Using this methodology, Murray King estimated that Auckland's TEU traffic (import and exports) is split as follows.

Table 36 POAL Import and Export Destinations by Tonnes

Millions of tonnes (%)	To/from Northland	To/from Waikato and further S/E	To/from Auckland	Total

Imports	0.215	1.406	3.269	4.89
Exports	0.31	0.33	0.98	1.62
Total	0.525 (8.06%)	1.736 (26.67%)	4.249 (65.27%)	6.51 (100%)

Source: Murray King, MoT

Combining the above with other analysis carried out by Murray King, we can estimate with confidence that 8% of traffic would relocate to Northport and 30% would relocate to Tauranga. This leaves 62% of traffic currently at POAL with an uncertain destination. Murray King suggested two possible scenarios to which could arise regarding the allocation of this remaining 62%.

1. The 30% of traffic which will go to Tauranga could create economies of scale which could attract more disproportionately more Auckland traffic to Tauranga. Under this scenario we estimate that the final allocation of POAL traffic would be 20% to Northland and 80% to Tauranga.
2. Another possible scenario is that prices to get freight to Auckland remain roughly equal between Tauranga and Northport. In this scenario we would predict that the remaining 62% is split approximately evenly between the two ports. Hence, our final allocation of POAL traffic would be 40% to Northport and 60% to Tauranga.

In the CBA we have modelled the split option using the second assumption. The second option was chosen as it more closely aligns our assumptions with the assumptions made by the infrastructure workstream when developing the infrastructure costs for the split option.

8.3 How the split option is integrated into the road and rail cost models

From the section above, we know that cargo is split as follows between Northport and Tauranga.

Table 37 Cargo Shares Between Northport and Tauranga for the Split Option

	Northport	Tauranga
TEU	40%	60%
Bulk	27%	73%
Cars	0%	100%

Source: Murray King

The key inputs into the rail and road models were:

- Vehicle km travelled by truck (road costs)
- Tonnes of cargo travelling by rail which is used to derive net tonne km travelled by rail which is used to calculate all the costs (rail costs)

Once we get these two inputs, the split option's rail and road costs model is virtually the same as the standard rail and road costs model we have described in sections 4 and 7.

8.3.1 Derivation of vehicle km travelled and integration into road costs model

Table 37 above indicates that a certain percentage of traffic (for a given cargo type) should be routed to Northport and the remaining percentage of traffic should be routed to Tauranga. This is actually mathematically equivalent to splitting the number of truck trips at Northport or Tauranga (for a given cargo type) by these cargo percentages. This result arises as a result of multiplication's commutative property[12]. Hence, in the CBA we work out the number of trucks needed for a certain cargo type using the following formula.

$$TrucksFromPortUnderSplitForCargoType = TrucksFromPortForCargoType \times CargoShare$$

Where $TrucksFromPortUnderSplitForCargoType$ is the amount of trucks used in the either the Northport or Tauranga option to transport only cars or only TEUs or only bulk.

The CBA keeps track of which trucks belong to which port, since trucks belonging to one port will travel a different distance to those of other ports. Therefore, to calculate the vehicle km travelled (VKT) from each port, we use the following formula.

$$VKTToPortUnderSplit = TrucksFromPortUnderSplit \times DistanceToPort$$

Where $TrucksFromPortUnderSplit$ is the addition of $TrucksFromPortUnderSplitForCargoType$ for each cargo type. The distances to the port by road are the same as those given in section 4.2.1. $VKTToPortUnderSplit$ is what we would use as our input to the road costs model. The only variation made to the road costs model is that it now must consider that traffic is moving from Northport and Tauranga at the same time. For example, assuming the port has already transitioned (POAL traffic is 0) then the total pollutant cost per km would be the following.

$$\begin{aligned} TotalPollutantCosts &= VKTToNorthportUnderSplit \times PollutantFactorAtNorthport \\ &+ VKTToTaurangaUnderSplit \times PollutantFactorAtTauranga \end{aligned}$$

Hence, instead of only considering traffic and pollutants from a single port, the CBA considers that two ports are operating at once and considers traffic and pollutants from both ports.

8.3.2 Derivation of tonnes km travelled by rail and integration into the rail costs model

The derivation of tonnes km travelled by rail in the split option follows a similar method to the derivation of tonne km travelled above. We assume in the CBA that only TEUs travel by rail. Section 4.1.2 describes this in more detail.

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[12] To give a simple example, consider a situation with 1000 TEUs of traffic and a 75% cargo share by some port. The number of TEUs to be routed through this port would be 1000 * 0.75 = 750 TEU. Then if there are 2 TEUs per truck, then we would have 375 trucks. But also, we could calculate the total number of trucks needed first, 1000 / 2 = 500 trucks and then take 0.75 of the trucks to get 375 trucks. Either way the result is the same, but we use the second method in the CBA.

Because multiplication is commutative, we don't need to recalculate the tonnes of freight travelling by rail for each port to incorporate the assumptions of the cargo shares in Table 37. Instead, we can simply multiply the tonnes of TEU freight travelling by rail under the Northport or Tauranga options by the TEU cargo share as shown below.

$$TonnesOfFreightByRailToPortUnderSplit = TonnesOfFreightByRailToPortForTEU \times CargoShareTEU$$

As before, the CBA keeps track of which tonnes correspond to which port, as tonnes from different ports must travel different distances. To get the tonnes km travelled for a port (either Northport or Tauranga here) we use the formula below.

$$TKMByRailToPortUnderSplit = TonnesOfFreightByRailToPortUnderSplit \times DistanceFromPortToSouthdown$$

The distances to Southdown are the distances given in Table 29.

Now to calculate rail costs, the only change which must be made is that the CBA must consider that freight is occurring at both Northport and Tauranga after the transition. For example, rail costs would be calculated as follows.

$$TotalRailCost = TKMByRailToNorthportUnderSplit \times CostPerTonneKmTravelledForNorthport + TKMByRailToTaurangaUnderSplit \times CostPerTonneKmTravelledForTauranga$$

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