Auckland Rail Programme Business Case

Economic assessment methodology

September 2023

Strictly confidential

Sean Myers
Head of Rail and Transit
WSP New Zealand
3/100 Beaumont Street
Auckland 1010

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Dear Sean,

We are pleased to provide our report that details the economic assessment methodology used to assess the investment programme as part of the Auckland Rail Programme Business Case.

This report is provided in accordance with the terms of our engagement (dated 11 February 2022) and is subject to the restrictions set out in Appendix A of this report.

If you have any queries please do not hesitate to contact Jarrod Darlington in the first instance.

James Harper
Partner
PwC Consulting
+64 22 012 9874
james.f.harper@pwc.com

Jarrod Darlington
Director
PwC Consulting
+64 27 306 9971
jarrod.s.darlington@pwc.com

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1. Assessment overview

This report provides a more detailed discussion of the economic assessment of the Auckland Rail Programme Business Case (ARPBC) investment programmes (short list and recommended programmes). It is intended to be read as an appendix to the ARPBC, specifically the Economic Case.

1.1 Overall approach

The economic evaluation of the investment programme is consistent with the processes and guidance outlined in Waka Kotahi's Monetised Benefits and Costs Manual (MBCM), updated in April 2023.

The overarching evaluation parameters are listed below:

- The discount rate for the evaluation is 4% as per the MBCM.
- A 60-year evaluation period is used in the base assessment, which is considered to be an appropriate period given the long-term nature of most of the investments which make up the programme.
- Benefits are calculated in 2022 dollars, using the appropriate update factors where necessary for values in the MBCM.
- Cost estimates, developed in 2023 dollars, have been converted back to 2022 dollars (for comparison with the benefits) by dividing by 1.056 to reflect one year of inflation[1].
- P50 capital cost estimates are used for the economic assessment.
- The evaluation period begins in FY25, which is the first year of expenditure for the recommended programme.
- Benefits and costs have been determined relative to the agreed Do Minimum for the ARPBC.

Benefits are derived from three main sources:

- Metro passenger benefits are predominantly derived from transport modelling undertaken by the Auckland Forecasting Centre (AFC), using the Auckland Macro Strategic Model (MSM). The investment programme has been modelled using combinations of forecast years (2031, 2041 and 2051) for the various configuration states, along with linear interpolation for estimating annual benefits between forecast years.
- Freight benefits are derived from KiwiRail's Decarbonisation Indicative Business Case (DecarbIBC) modelling for the relevant freight demand scenario.
- Interregional passenger benefits are derived from Te Manatū Waka – Ministry of Transport's Hamilton to Auckland Intercity Connectivity Project IBC (H2AIBC) (October 2022), but limited to the additional benefits that investment in the Auckland rail network would deliver to avoid double counting.

Cost estimates across the programme are based on three sources:

- The ARPBC cost model is used for the capital cost estimates and phasing of investment over time.
- KiwiRail has provided network renewal forecasts and an initial three year forecast of its operating costs along with operating cost elasticities to allow network and service changes associated with the investment programme to impact forecast operating costs.
- Auckland Transport has provided renewal forecasts for its rail assets and a base year (FY23) budget for operating costs that allows future operating costs to be forecasted based on changes to service provision and assets (e.g. rolling stock, stations etc).

[1] https://www.rbnz.govt.nz/monetary-policy/about-monetary-policy/inflation-calculator - Q3 2022 to Q2 2023

1.1.1 Recommended programme vs short list assessments

The range of benefits described in this report are consistent with those used to assess the recommended programme. The assessment of the shortlisted options was slightly more limited in its assessment of benefits, as discussed in the ARPBC, which was appropriate for the comparative nature of that assessment. We note that for the assessment of freight benefits, the assessment of the recommended programme draws on modelling undertaken by KiwiRail for its DecarbIBC, which was not available at the short list assessment stage. The overall approach to assessing the benefits is consistent between the two assessments, but the assessment of the recommended programme is informed by more detailed and accurate modelling inputs.

1.2 Inputs and assumptions

The major inputs and assumptions used in the economic analysis are provided in Table 1 below. Most are sourced from the MBCM. Additional inputs or assumptions for specific benefits are included in the detailed discussion in the following sections.

Table 1 Major inputs and assumptions

Input / assumption	Value	Source
Discount rate	4%	MBCM
Evaluation period	60 years	MBCM
Daily expansion factors (MSM period to daily (weekday))	AM = 1 IP = 5.3 PM = 1	MSM, AFC
Annualisation factors • Weekday to annual (patronage related benefits) • VoT related benefits ○ AM/PM daily ○ IP daily	 302 250 365	 MSM, AFC, observed rail patronage analysis Relates to weekdays only 250 for weekdays (as above). To extend to include weekends: • weekday IP (period scaled to daily) is ~50% of total weekday patronage • weekend day patronage is ~50% of weekday • total weekend day patronage ≈ weekday IP patronage (period scaled to daily)
Value of time (VoT) work purpose (2022$/hr)	AM/PM = $66.19 IP = $41.77	MBCM: Tables 14, 15, A17 and benefit update factors[2] 100% congestion increment in AM/PM 10% congestion increment in IP HCV I used for HCVs
VoT commute purpose (2022$/hr)	AM/PM = $42.86 IP = $25.11	
VoT other purpose (2022$/hr)	AM/PM = $39.97 IP = $24.16	
VoT Heavy Commercial Vehicles (HCV) (2022$/hr)	AM/PM = $148.97 IP = $88.91	
Walking benefit (2022$/km)	$10.20	MBCM Table 6, benefit update factors

[2] Waka Kotahi NZ Transport Agency Monetised Benefits and Costs Manual Update Factors

Input / assumption	Value	Source
Equivalent time to a minute late ratio (EL) (mins)	4.8	MBCM Table 30
Average minutes late (AML) reduction (bus to rail) (mins)	5.0	Assumption, based on previous analysis of Auckland bus services
Shadow price of carbon	Varies over time	MBCM Table 11
Air quality emission damage costs (2022$, per tonne) • $PM_{2.5}$ • NO_x • CO • Volatile organic compounds	 $905,053 $917,745 $5 $1,638	MBCM Table 9 and benefit update factors[2] Urban values are used
Annual deaths and serious injuries (DSIs), Auckland road network - year ending March 2023	649	AT monthly indicators report (May 2023)
Weighted cost per DSI (2022$)	$1.8 million	MBCM Tables A23, A28, A29 and benefit update factors[2] 50km/h speed limit areas assumed All movement values

1.2.1 Annualisation factor

MSM outputs are based on an average weekday. However, the investment programme provides benefits to all periods, including weekends and we therefore seek to assess benefits beyond the typical 250 working days per year.

The annualisation factors utilised in the economic assessment vary depending on the application. From a patronage perspective, and in cases where passenger volumes inform the benefits, a value of 302 is applied to the weekday volume from MSM. This factor comes assessing the annual weekday heavy rail boardings from 2018 (modelled) with observed AT HOP data. This value is applied to the station amenity, walking and emission benefits, as these are driven by passenger numbers.

For benefits that include a value of time in the calculation, we have refined the approach annualising weekday benefits. As the benefits from MSM are generated by period (i.e. AM, IP and PM), we adopt 250 as the annualization factor for the benefits generated from the weekday AM and PM periods. We believe this is appropriate as the values of time applied in the peak periods are increased beyond the base values of time to reflect the incremental value of time associated with congestion (referred to in the MBCM as the CRV). Applying the 302 value from above to the total daily benefits would likely overestimate the benefits given weekday peak congestion is not evident during most of the equivalent weekend periods. We note that in some areas of the Auckland network, weekend interpeak congestion can be worse than weekday interpeak congestion. To determine an appropriate annualisation factor to apply to the benefits generated from the weekday IP period, we use two calculations:

1. First, we consider what the expanded IP period patronage[3] is as a proportion of the daily weekday patronage. We find that this is around 50%. Put another way, this means that the AM and PM peak periods contribute about 50% of the daily patronage.

2. Secondly, we use the relationship between annual weekday boardings and total annual boardings to conclude that the sum of the two weekend days are equivalent to one weekday. This

[3] We utilise the daily expansion as MSM outputs are based on a 2-hour average period.

means that the expanded weekday IP outputs (i.e. 50% of the weekday) are equivalent to one weekend day.

Putting these conclusions together leads to an annualisation factor for the benefits derived from the weekday IP period of 365. This is made up of the 250 weekdays (as above for the AM and PM peaks) and residual days in the year, since each weekend day is equivalent to the expanded weekday IP.

1.2.2 Weighted values of time

For some of the benefit categories, where a breakdown by trip purpose is not available, a weighted value of time is used. To generate the weighted value of time we use the relative weighting of trips in the respective modelled period (which are broken down by trip purpose in MSM) to generate a weighted value of time for the AM and IP periods. To simplify the analysis, we treat the AM and PM periods as being equal, so the same weighted value of time applies to both of these periods. Based on the relationship described above between the AM and PM periods and the IP period, being equal part contributors to the weekday total patronage, we take the average of the two weighted values of time to generate an overall weighted value of time for use in the benefit calculations.

1.2.3 Capping of benefits

Metro passenger benefits

The final forecast year for MSM modelling that informs the metro passenger benefits is 2051. Beyond 2051 there is residual capacity in the Auckland Rail Network (ARN) – specifically the metro passenger services – as a result of the investment programme that can be utilised. This means that the metro patronage, and associated benefits, can continue to grow before any network or service constraints begin to restrict growth. However, growth cannot occur forever and our methodology caps the benefits at a point in the future.

Our capping methodology for metro passenger benefits assesses the residual capacity in the morning peak period based on the 2051 configuration state. We look across all three major passenger services (i.e. Western, Eastern and Southern) at three proxy locations[4] and use the residual capacity to determine how long growth in benefits, as a proxy for patronage, can occur beyond 2051. The adopted growth rate beyond 2051 is the annual growth rate of configuration state 2 (CS2). We use CS2 as we only have one data point for CS3 given it is implemented in the final year of the programme.

To simplify the methodology slightly, we use the relative weighting of patronage across the three services to determine a network wide capacity utilisation factor in 2051, being 61% of total (i.e. seated and standing) capacity. We adopt 90% of the theoretical cap (i.e. reaching 100% capacity) as our upper limit to reflect an erosion of benefits as services become more crowded.

For reference, metro patronage continues to grow until FY67, when the above cap is reached and after this benefit levels are held constant.

Freight benefits

Freight benefits are based on KiwiRail's freight demand scenario forecasts, which extend out to FY82. Benefits beyond FY82 are held constant at the FY82 values, noting this is near the end of the base case evaluation period of 60 years.

Interregional benefits

Interregional benefits are based on the H2AIBC forecasts, which extend out to FY76. Benefits beyond FY76 are held constant at the FY76 values, noting this is near the end of the base case evaluation period of 60 years.

[4] Morningside is used for the Western line, Panmure for the Eastern line and Takanini for the Southern line. These locations are chosen as they are one stop prior to the peak load points for the three lines.

1.2.4 Rule of half

The rule of half is a simplifying assumption used to calculate the benefits that accrue to transport system users who change their travel behaviour, such as by switching their mode of travel, as a result of changes to the cost or quality of travel. The MBCM provides the following discussion:

> *In the case of transport system users who change their mode of travel, some new users may have been almost indifferent between the two modes in the do-minimum. After changing their behaviour in response to an improvement in the activity scenario, they receive the full value of the incremental benefits. Other new users may only be marginally better off in the activity scenario compared with the do-minimum, and they receive almost zero benefit from the improvement. If it is assumed that new users are evenly distributed along the demand curve, then the average new user gains one half of the maximum incremental benefits. The sum of new user benefits can then be approximated by multiplying half of the maximum incremental benefit by the number of new users. This is also known as a consumer surplus calculation.*[5]

The rule of half is applied to the relevant benefits where benefits are accruing to new users. This is noted in each relevant benefit category.

[5] Waka Kotahi NZ Transport Agency, *Monetised Benefits and Costs Manual,* pg 20

2. Metro passenger benefits

2.1 PT user benefits

Improved rail services (i.e. more capacity, higher frequency) means that PT users who would otherwise be crowded off rail, and forced to use a mixture of bus and private vehicle travel, are now able to travel by rail and experience a reduction in their generalised cost of travel. The improved service offering also attracts new users to rail.

AFC runs an economics output macro within MSM that determines the PT user benefits (in minutes) for the different trip purposes within the model. We then multiply this by the respective values of time (including increments for congestion as appropriate) for the different trip purposes and annualise the results.

The PT user benefits are calculated using the following equation, which incorporates the rule of half for new user benefits:

$$0.5 * (do\ min\ PT\ demand + option\ PT\ demand) * (do\ min\ PT\ GC - option\ PT\ GC)$$

2.1.1 Fare revenue (resource cost correction)

Adjustments are made to account for differences between the change in costs perceived by individuals when making their transport decisions, and the change in societal or resource cost of their choices. These ‘resource cost corrections’ include the change in fare revenue. This is necessary as the utility, or generalised cost calculation in MSM that determines the transport mode that travellers choose includes fare costs. The premise behind their inclusion is consistent with the treatment in the MBCM (noted on page 271), which is more clearly described as follows:

- *‘All additional public transport users have to pay a fare, which is part of their perceived costs in making their mode choice decision (and subtracted from their total gain under the rule of half). However, as the resource cost of providing public transport (both capital and operating) is included elsewhere in an economic appraisal, fares are a transfer payment. Accordingly, it is necessary to add fares back in, as a component of the benefits, to derive the net resource benefit.’*[6]

The additional fare revenue is calculated within MSM for each period (i.e. AM, IP, PM) and then annualised for adding to the PT user benefits as the resource cost correction.

2.2 PT reliability benefits (mode shift)

The travel time reliability of the passenger rail services is greater than that of bus services, leading to travel time reliability benefits for ex-bus passengers that have switched to rail. The benefit of this reliability improvement is calculated using the annualised patronage data from the MSM ‘standout’ data provided by AFC and the following calculation from the MBCM:

$$EL * \left(\frac{VTT\left(\frac{\$}{h}\right)}{60} \right) * AML * NPT$$

- EL is the equivalent time to a minute late ratio.
- VTT is the vehicle travel time ($/h).

[6] Australian Transport Council, National Guidelines for Transport System Management in Australia, 2006, Volume 4, p 31

- AML is the reduction in average minutes late for bus services (minutes) - we have assumed a value of 5 minutes, informed by several studies for AT that have assessed HOP data detailing bus travel time compared to timetabled times.
- NPT is the number of passengers affected.

The rule of a half is applied to the benefits that accrue to passengers who were travelling by bus in the Do Minimum, and are now travelling by rail.

No travel time reliability benefits accrue to those people shifting from car as we make no assumption about the variability of their travel time before they shift to rail. Improvement in reliability for passengers previously/already travelling by rail are discussed separately below as the approach used is different.

2.3 Seated benefit

Additional capacity provided by the investment programme means that more passengers can be seated as a result of the investment programme (specifically due to the increased EMU fleet) compared to the Do Minimum. These extra seated passengers have an inherent comfort benefit, which is the difference in values of time for seated and standing journeys, multiplied by the length (time) of their journey.

To estimate the seated benefit generated by the investment programme, we adopt the seated benefits quantified as part of Auckland Transport's EMU Batch 3 business case, which assessed this in more detail. The annual benefits calculated in in the EMU Batch 3 business case were approximately $1.5 million, based on a Do Minimum fleet of 72 EMUs. As it is the Do Minimum service specification – which in turn is constrained by the fleet size – that ultimately determines this benefit, we consider this assumed level of benefit to be conservative. This is because the fleet size in the ARPBC Do Minimum will be 95 EMUs (i.e. inclusive of the Batch 3 EMUs that will be available by CRL Day 1), so there will be a higher number of people standing in the Do Minimum who can receive the benefit of getting a seat when the fleet increases as part of the investment programme.

The $1.5 million was based on an incremental value of time of $2.98. The revised values of time in the MBCM (Table 13) mean the incremental value of time (seated vs standing) is now $3.83 (2022 dollars). This leads to the $1.5 million being scaled up by a factor of 1.29, giving an estimated annual benefit of $1.93 million once additional seated capacity is delivered. This is still considered to be conservative for the reasons outlined above.

The detailed methodology from the EMU Batch 3 business case is provided below.

2.3.1 Detailed seated benefit methodology (EMU Batch 3)

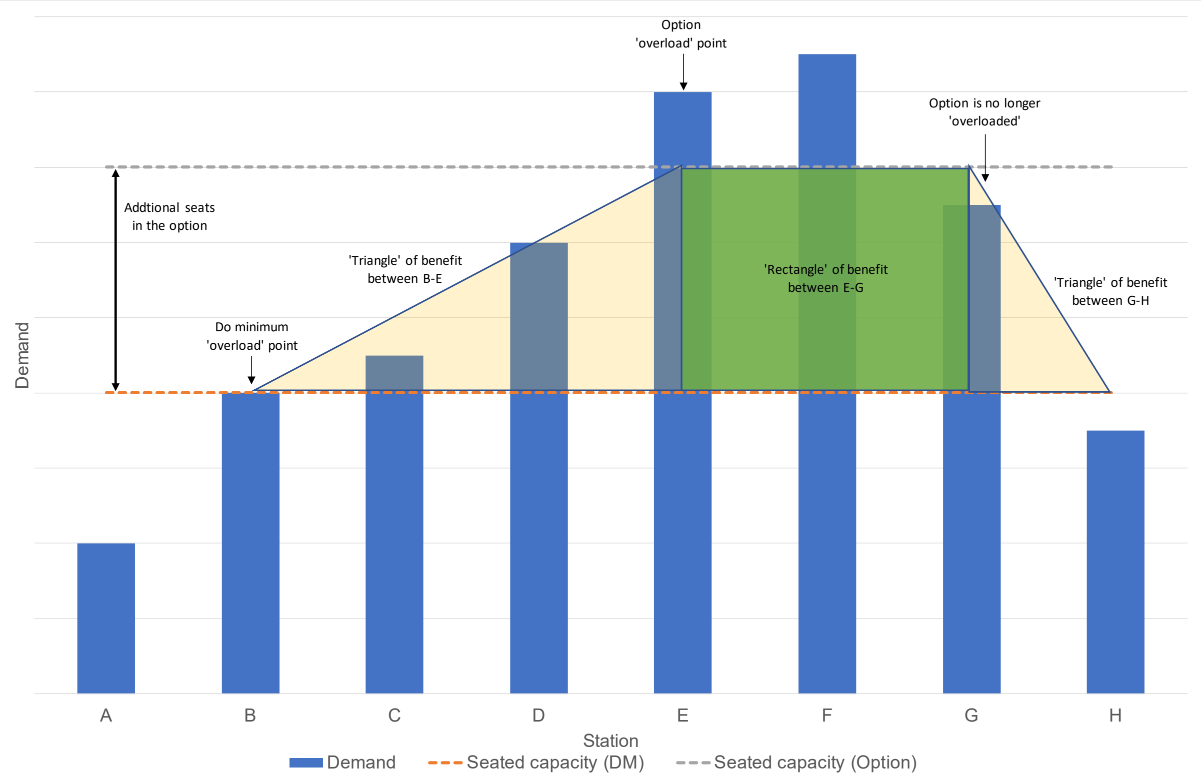
To calculate the journey time for those passengers who were standing in the do minimum, but who now get a seat once additional seated capacity is provided, we used the average speed of the rail services and the distance between the point at which seated capacity is exceeded ('overload point') and the point where passengers disembark. We determine these points (i.e. rail stations) by using the MSM demand plots and the service seated capacities for the do minimum and option, for the three forecast years, being 2028, 2038 and 2048.

Every person who gets on to the train between the do-minimum and option (i.e. with investment) overload points is now able to get a seat in the option, where they would have been standing in the do minimum. To calculate the benefit for this portion of travel, the journey time between the overload points is multiplied by the difference in seated capacities (i.e. the additional seated capacity provided by the investment) and then halved to reflect a 'triangle of benefit'. This is to account for demand increasing between those points and a simplifying assumption that it increases linearly.

Beyond the option overload point, the passengers to whom the benefit accrues is capped at the additional seats provided in the option, over the distance (and therefore journey time) between the option overload point and the point at which option seated capacity is no longer exceeded. This generates a 'rectangle' of benefit.

As demand continues to reduce, back to the point at which seated capacity in the do minimum is no longer exceeded, so too does the seated benefit. Over this distance, a second 'triangle' of benefit is generated. This approach is conceptualised in Figure 1 below.

Figure 1 Seated benefit calculation concept



Source: PwC analysis

2.4 Rail service punctuality improvements

Note that the punctuality key performance indicator (KPI) measures on-time performance.

We note that punctuality is typically referred to as travel time reliability, however we use Auckland One Rail's KPIs of punctuality (on time performance) and reliability (cancelled services – see below) to inform the estimation, and retain those descriptions to provide line of sight to the KPI information that informs the assessment assumptions. These KPIs relate to information discussed in more detail in the ARPBC Strategic Case, which informs the percentage of services used in the estimation for the rail punctuality and reliability benefits.

There is a time disbenefit for any rail user whose service is not punctual. The likelihood that passenger rail services are not punctual is higher in the Do Minimum than with the investment programme, due to network reliability improvements that will occur as part of the investment programme. Therefore, with the investment programme, this punctuality disbenefit (associated with travel time variability) is reduced. The disbenefit avoided is calculated using the following formula:

*Punctuality benefit = # of passengers affected * assumed the number of minutes saved * average value of time*

- # passengers affected = those that weren't punctual in the Do Minimum = % of services that aren't punctual * # total boardings for heavy rail (annual) Do Minimum.
- Assumed the number of minutes saved: 5 minutes improvement on average across all non-punctual services.

- Average value of time = average value of time across the three trip purposes (commuting to/from work, work travel purpose, other non-work travel purpose), given we have no information on the distribution of non-punctual services across the day.

Given a metro passenger service is considered punctual within 5 minutes of scheduled arrival, we believe we are conservative in assuming a 5-minute improvement for services that are not punctual, as the actual difference to schedule could be considerably higher. Further to this, services that are currently deemed punctual (i.e. arrival within 5 minutes of timetabled times) could also improve (i.e. reducing their time variance from scheduled times) which would deliver a small reliability benefit for a much larger number of passengers than we have considered.

We do not believe that this is double counting as MSM does not include any variation in travel times, and this benefit is only applied to Do Minimum rail users, where the reliability benefit we described earlier is only applied to ex-bus passengers.

2.5 Rail service reliability benefits

Note that the reliability KPI measures service delivery/cancellation.

There is a time disbenefit to any rail user whose service is cancelled. The likelihood that passenger rail services are cancelled is higher in the Do Minimum than with the investment programme, due to network reliability improvements that will occur as part of the investment programme. Therefore, with the investment programme, this cancellation disbenefit is reduced. The disbenefit avoided is calculated using the following formula:

*Disbenefit avoided = number of passengers affected * average minutes lost due to cancellation (assumption) * average value of time*

- Number of passengers affected = those that had a service cancelled in the Do Minimum = % of services that are cancelled * # total boardings for heavy rail (annual) Do Minimum.
- Assumed the number of minutes lost due to cancellation is 15 minutes on average. This is both actual time lost (based on the typical headway of 10 minutes in the Do Minimum) and perceived loss (e.g. the ‘frustration factor’, based on the 5-minute interchange penalty from the MBCM).
- Average value of time = average value of time across the three trip purposes (commuting to/from work, work travel purpose, other non-work travel purpose).

Even under the recommended programme, there is still the potential for some unplanned service cancellations, and the level of disbenefit avoided will depend on the improvement to network reliability. This is impacted by a number of factors, and we consider that this benefit as estimated represents the maximum level of benefit that could be achieved.

2.6 Station amenity

Infrastructure improvements to rail journeys and stations result in a more pleasant experience for all passengers that are boarding from the improved stations, which delivers an economic benefit.

The values of improvements associated with public transport service and infrastructure users are based on willingness-to-pay value derived from a stated preference (SP) survey or on values derived for similar improvements in other areas.

We assume that 25% of Do Minimum rail network users use one of the stations that will be upgraded as part of the station upgrade programme that forms part of the investment programme. These patrons get 100% of the benefit, with additional passengers as a result of the investment programme receiving 50% of the benefit (applying the rule of half).

*Station amenity benefit = (# of Do Min passengers + (# of additional passengers * 50%)) * IVT * average value of time*

- IVT: equivalent in-vehicle time (IVT) represents user's willingness to pay for certain infrastructure features for public transport stations e.g. security, amenity etc. The IVT used is three minutes, the upper limit of the benefits arising from multiple features being improved at a station from Table 34 in the MBCM.

The station amenity benefits are phased over time consistent with the proportion of the station upgrade programme that occurs within each configuration state. This ensures that only an appropriate level of benefit is accrued each year, as the station upgrade programme does not commence immediately, and occurs over a substantial period of time.

2.7 Walking benefit

The additional rail patronage as a result of the investment programme compared to the Do Minimum will generate additional health benefits due to the walk portion of the journey (all public transport trips have some degree of walking associated with them).

Using the change in the number of rail passengers, bus passengers and the number of people travelling by car in each modelled period, we estimate the number of new rail passengers and their 'source' - assumed to be bus or car.

Multiplying the average increase in walk distance (which differs by source) by the annual additional patronage (by source) and the value of the health benefit from walking, we calculate health benefit from induced walking due to the investment programme.

The walk distances used are:

- 500m for ex-car passengers, conservatively based on a walkable catchment of 1.2km (~15min) for rapid transit. This represents just under half the catchment distance, which provides a reasonable estimate of the average.
- 250m ex-bus passengers, acknowledging average bus stop spacing is around 500m. This means these passengers were already walking ~250m on average. The 250m used is therefore the difference between the average rail station catchment walk distance (as above) and the distance they are walking in the Do Minimum.

2.8 Road user travel time

Compared to the Do Minimum, the improved level of service enabled and delivered by the investment programme on the rail network encourages more people to switch from driving to travelling by train. This causes traffic congestion to decrease, so all remaining road users experience minor travel time benefits.

We calculate the travel time saving benefits for the different trip purposes as modelled in MSM. To do this, we multiply the user value of time (including increments for congestion as appropriate) and the annualised time saved by trip purpose, which comes from the MSM outputs.

The travel time saving benefits are calculated using the following equation, which incorporates the rule of half for new user benefits:

$$0.5 * (do\ min\ car\ demand + option\ car\ demand) * (do\ min\ car\ travel\ time - option\ car\ travel\ time)$$

2.9 Road reliability benefits

MSM is not a simulation model, and its outputs are based on averages. The road user benefits are therefore likely to be underestimated as MSM does not capture actual congestion-related variability into its calculations of delay. Literature on this topic finds that improved reliability can be in the order of 15% of travel time benefits, and so we apply this factor to the road user benefit value to provide an estimation of the benefit of improved reliability for the remaining road users for inclusion in the economic assessment of the investment programme.

2.10 Crash cost savings

Crash cost savings occur as a result of reduced exposure to crashes from reductions in private vehicle km travelled (VKT), as people shift mode to public transport (specifically rail, since capacities are increased). This benefit is estimated as follows:

*Crash cost savings = Daily VKT reduction * annualisation factor * annual Auckland DSI rate per km * average cost per DSI*

The death and serious injury (DSI) rate per VKT for Auckland is based on Auckland's actual DSI data for the year ending March 2023[7] and total network VKT. The average cost per DSI comes from the MBCM.

2.11 Emissions benefits (CO_2 and other emissions)

Reductions in emissions occur due to less private vehicle travel as more people switch to using public transport.

MSM calculates the reduction in four types of emissions (CO_2, CO, NO_X and $PM_{2.5}$) based on input emission rates and the change in road travel. The economic benefit of the reductions in these emissions is calculated by multiplying the reduction in emissions by the social cost per tonne emitted from the MBCM, which is a fixed price per tonne for CO, NO_X and $PM_{2.5}e$ emissions, but a price path (high and low paths) for CO_2 emissions that increases over time (in real terms).

The calculation of CO2 emission reduction benefits is based on model forecasts which include embedded assumptions around decarbonisation of the road-vehicle fleet – both private vehicle and HCVs (for freight). These are consistent with Waka Kotahi's Vehicle Emissions Prediction Model (VEPM). The long-term nature of this PBC means that the magnitude of possible emissions is limited, as the VEPM assumptions apply to the Do Minimum as well.

2.12 Second round benefits (land use change)

Second round benefits occur as a result of dynamic land use changes that the investment programme induces or unlocks. As accessibility improves as a result of the investment in the rail network, land values within station catchments will increase, which will in turn support higher land utilisation (e.g. increased density). These effects generate second round benefits, through the additional density, across all the benefit categories mentioned above.

Detailed analysis of dynamic land use changes was out of scope of the ARPBC and have not been incorporated into the modelling and assessment process. Instead we utilise a factor of conventional benefits as a proxy for these effects. We have adopted a percentage-based assumption (of conventional transport benefits) of 10%. We note that second round benefits can equate to up to around 30%[8] of conventional benefits in large transformative projects, so this could be considered conservative. However, we believe including any larger value should be based on quantitative analysis.

2.13 Wider Economic Benefits (WEBs)

The recommended programme delivers improvements in accessibility across the transport network (e.g. additional capacity, and reduced travel times and congestion) that will enable agglomeration, imperfect competition and labour supply benefits (i.e. WEBs). An allowance for these WEBs has been included in the economic assessment. An uplift of 25% of total conventional benefits has been assumed as a proxy for the WEBs, informed by other public transport investments.

Depending on the project, WEBs may represent a higher proportion of total benefits. For example, CRL which is also a transformative rail project, undertook detailed modelling of agglomeration, imperfect

[7] AT monthly indicators report (May 2023), retrieved from https://at.govt.nz/about-us/our-role-organisation/meetings-minutes/
[8] NZTA Transformative Transport Projects (Dynamic Webs and Land Use Benefits and Costs) Technical Paper for Investment Decision Making Framework Review, December 2019.

competition and increased labour supply benefits. In the case of CRL, WEBs accounted for nearly 30% of total benefits (or nearly 40% of the conventional benefits).

WEBs have only been included in the metro passenger benefits. Inter-regional agglomeration, and dynamic clustering, have not been estimated or included as part of this PBC but will be assessed in KiwiRail's computable general equilibrium (CGE) modelling being undertaken by Sense Partners.

2.14 Other benefit exploration

2.14.1 Level crossing removal

Due to the increased frequency of services enabled by the investment programme, road level crossings across Auckland are assumed to be needed to be removed. The costs of doing so, either grade separation or closure, are included in the programme costs. Beyond enabling higher service frequencies, which deliver a range of benefits described above, the benefits from removing level crossings are twofold; there will be safety benefits from removing the interface between the road and the rail line, and there is a decrease in barrier down time (limited to that down time in the Do Minimum) which results in a time savings for road users where the crossing is grade separated. For level crossings that are closed (i.e. not grade separated), there could be disbenefits associated with people and vehicles needing to re-route.

We have worked with AT and KiwiRail to assess potential safety benefits based on analysing level crossing data. There has been a number of near misses for both vehicles and pedestrians (five times more for pedestrians), but very few actual safety incidents. The pedestrian level crossing programme that is already progressing will be addressing a number of the issues, so the Auckland Rail PBC should avoid double counting any of these. Pedestrian fatalities on the rail network are virtually all through trespass, rather than at level crossings, and the security fencing investment by KiwiRail should help to reduce these incidents.

In summary, reviewing the observed safety-related data shows that it is difficult to determine and justify any quantifiable safety benefits, as either:

- There are current programmes that will be dealing with the observable safety problems, and those programmes are therefore generating those benefits.
- The benefits relate to a reduction in perceived risk, which is difficult to monetise in the context of an economic assessment.

We have also explored the non-rail transport network benefits, primarily from removing barrier down time at grade separated level crossings. Supporting Growth has undertaken analysis for the Takanini group of level crossings to estimate the non-rail benefits. The benefits are highly sensitive to the assumptions around train frequencies. The Auckland Rail PBC has adopted the assumption that train frequencies can only increase once the level crossings are removed, so we believe that any barrier down that is removed from level crossings that would be grade separated should be limited to what is in the Do Minimum (i.e. CRL Day One).

The actual quantum of down time removed varies from level crossing to level crossing as it is dependent on the traffic volumes passing through it (vehicles, pedestrians and cyclists).

We have also worked with AFC to now include level crossing removals (both closures and grade separations) to the extent possible in MSM (i.e. not all road crossings are in MSM). This means that the modelled delay at the level crossings will be removed from MSM and will be included in the road travel time savings, or time added in the case of level crossing closures. We note that this will not provide the level of detailed analysis consistent with Supporting Growth's approach (utilising additional project-level transport models), but is appropriate for programme level analysis. We believe that on balance, this approach of relying on incorporating the level crossing changes in MSM will be conservative. In reality, we expect the benefits associated with level crossing grade separations to be higher than estimated, and still greater than when any disbenefits associated with level crossing closures are incorporated.

2.14.2 Temporary speed restriction (TSR) removal/ reduction

TSRs are imposed on parts of the rail system where trains have to slow down for a range of reasons, e.g. due to poor maintenance of the track infrastructure. TSRs are expected to remain as a common occurrence in the Do Minimum, but are understandably not captured for metro passenger services in the MSM inputs that are used in the transport modelling. This means that Do Minimum journey times are actually longer than those in MSM, noting TSR application is highly variable. The improvement of the rail system with the investment programme will mean a reduction in TSRs, and an avoidance of the associated disbenefits.

Whether or not these benefits can be claimed by the investment programme is dependent on the level of funding for maintenance and renewals in the Do Minimum.

If sufficient funding is committed in the Do Minimum to maintain a higher degree of reliable operation once the RNGIM and AMTP (and now Rail Network Rebuild) programmes are complete, then that improvement is considered to be 'baked in' to the Do Minimum, and therefore no benefit is justified in the investment programme. However, if that level of funding is not committed, then it would be appropriate to realise the benefits in the investment programme of having fewer TSRs imposed on the network. The RNGIM business case quantified this in relation to the aspects that RNGIM could be expected to solve.

The project partners have agreed that sufficient funding is assumed to be committed in the Do Minimum, so any incremental benefit in the investment programme is difficult to quantify and justify. This assumption includes investment in maintenance plant and equipment in the first decade of the programme that will support a material uplift in network maintenance activities and outputs.

If this level of (assumed) committed funding changes, then the quantification of benefits will be considered to be conservative.

2.14.3 VKT reduction

The modelled reduction in VKT in MSM appears low, given the scale of patronage uplift. We have discussed with AFC, and there are numerous moving parts in the modelling, including the redistribution of trips amongst origin-destination pairs. This can result in marginal increases in length for a high number of trips, as trips rematch their origins and destinations as a result of a reduction in overall network congestion. This effect of a large number of journeys getting marginally longer can swamp any material reduction in VKT that occurs a result of mode shift. We conduct a sensitivity test where we use the number of ex-car passengers and average journey length to determine the reduction in VKT, all else equal (i.e. ignoring the effects of trip redistribution). This reduction is then used to calculate any benefits related to VKT reduction, e.g. crash cost savings and emission reductions.

2.14.4 Patronage uplift

Increased service frequency causes an increase in service ridership. This relationship between these two factors is called headway elasticity, which is a form of transit service elasticity.

Based on the literature, headway elasticity averages around 0.5%, meaning that each 1% increase in service frequency increases ridership by 0.5% on average, though there is a wide variation in these factors depending on conditions.

The investment programme sees an approximate doubling of service provision during the interpeak periods, which should see a corresponding increase in patronage of around 50%, based on the elasticities within the literature. MSM shows an increase in patronage in the interpeak of ~12%.

This potential underestimation of IP demand is picked up in patronage level sensitivity testing.

3. Residual value

Rail infrastructure tends to have a very long useful life, which means that at the end of the economic evaluation period many assets will still have remaining life that does not require re-investment. This provides a discounted future benefit added in the final year of the evaluation, reflecting the significant long-term investment nature of the recommended programme.

The traditional approach of straight-line depreciation of asset values has been adopted, as opposed to the net present value of future benefit streams.

The investment programme was broken into its major project components for estimating remaining useful life at the project level. Subject matter experts determined both the asset-based useful life and applicable percentage of implementation cost that should apply. The phasing of the investment programme is then used to determine the remaining useful life of each major project component at the end of the economic evaluation period. For example, Avondale-Southdown is not completed until year 30 of the programme, so has considerable useful life left at the end of the evaluation period (i.e. year 60) and our methodology accounts for these variables across the investment programme. This effect of future implementation, combined with the long lives of many of the assets being built and overall scale of the programme leads to a more material value for the residual value of the infrastructure than might be expected with more typical projects (i.e. delivered as soon as possible, and smaller scale).

4. Freight benefits

Freight-related benefits are derived from analysis undertaken within KiwiRail's DecarbIBC. The benefits have been derived in conjunction with KiwiRail to ensure the same base data and approaches are being adopted between the ARPBC and the DecarbIBC, limited to those freight services into or out of Auckland that will be enabled by, or benefit from the investment in the ARN. The monetisation of benefits is based upon the methodologies used to estimate the economic value of rail in 2019 (KiwiRail, 2021), with valuations updated to be consistent with the April 2023 update of the MBCM where appropriate.

The different benefit streams for freight-related benefits are discussed below.

4.1 Freight CO_2 avoided

There is a higher level of emissions from transporting the same amount of freight using trucks compared to using rail. The differential is based on the rail freight flows for freight demand scenario B1 (for the base case analysis) versus the Do Minimum. Other freight demand scenarios are included in the scenario analysis carried out as part of the phasing development, and various sensitivity tests.

*CO_2 avoided ($) = CO_2 price ($/tonne) * CO_2 avoided (tonnes)*

- CO_2 price ($/tonne) = the recommended shadow price of carbon
- CO_2 avoided (tonnes) = CO_2 per year from delivering freight on road - CO_2 per year from delivering freight on rail
- CO_2 per year (rail or road) = container-km (rail or road) * CO_2 emission rate (kg/km) per container (rail or road)

4.2 Fuel cost savings

There is a higher amount of fuel consumed from transporting freight using trucks compared to using rail. The fuel cost saving from delivering the freight growth (Scenario B1 over the Do Minimum) using rail instead of road is the net fuel avoided, i.e. truck fuel avoided plus the amount of fuel used to run the rail freight services.

Fuel cost saving = Truck fuel cost avoided - rail fuel cost incurred

- Truck fuel cost incurred = truck-km avoided * fuel consumption (L/km) per container-km for road * Diesel ($/L) - commercial, ex-RUC
- Rail fuel cost incurred = additional container-km per year * fuel consumption (L/km) per container-km for rail * Diesel ($/L) - commercial

4.3 Road maintenance cost avoided

Transporting freight using trucks causes damage to roads that does not occur when transporting freight using rail. There is however a corresponding increase in rail network maintenance that is required as a result of more freight services. As the ARPBC includes the increase in operating costs (including maintenance) within the ARN, only additional maintenance outside the ARN is included. The benefit is the net effect of this reduction in road maintenance and increase in rail network maintenance.

Net maintenance cost avoided ($) = truck-km avoided (km) * road maintenance cost ($/km) + additional rail network maintenance ($)

4.4 Rural decongestion

Transporting freight using trucks creates rural congestion for road users who are slowed down by freight trucks on rural roads. This congestion does not exist when transporting freight using rail. For three of four relevant freight services[9], the rural congestion avoided by using rail instead of trucks is estimated as:

*Rural congestion avoided for each freight journey = proportion of journey that is rural (%) * additional tonne-km avoided per year (tonne-km/year) * rural congestion value ($/tonne-km)*

4.5 Urban travel time avoided

In an urban setting, there is a similar effect. There is no corresponding estimate for an urban congestion value ($/tonne-km), so urban travel time avoided is used as a proxy. All four relevant rail freight journeys (NIMT, Metroport, Northland, Ports of Auckland Ltd (POAL)) have some (or all) of their truck-equivalent journeys on the urban road network. The urban travel time avoided by using rail instead of trucks is estimated as:

*Urban travel time avoided = proportion of journey that is urban (%) * additional truck-km avoided per year (truck-km/year) / average urban freight speed (km/hr) * freight VoT for urban travel ($/hr)*

4.6 Crash cost reductions

Crash cost savings occur as a result of reduced exposure to crashes from reductions in truck-km travelled, as freight is transported on rail instead of by trucks on the road. This reduction in VKT is used in conjunction with DSI costs and exposure rates to estimate the reduction in crash costs that come from the freight mode shift from road to rail.

4.7 Non-greenhouse gas emissions (air quality)

The levels of other emissions from transporting freight using trucks on roads is higher for the same reasons described above for CO_2 and crash costs, i.e. a reduction in road-based VKT.

*Emission reduction benefit = annual tonnes of emissions * value of emission (tonnes)*

- Annual emissions avoided (tonnes) = emission rate (kg/km) * annual truck-km avoided /1000
- Annual truck-km avoided = the distance travelled if trucks were delivering the growth in freight instead of rail

[9] Ports of Auckland Ltd (POAL) freight services are confined to the urban road network.

5. Interregional passenger benefits

We have calculated the benefits for interregional passengers generated by the ARPBC investment programme based on the H2AIBC analysis.

There are two interregional passenger benefits that are assessed:

1) Benefits due to **existing** interregional passengers (i.e. those included in the H2A forecasts) as a result of the investment within the Auckland Rail Network (ARN) that would deliver improvements (e.g. reduced journey times).

2) Benefits associated with **additional** patronage uplift that could be induced as a result of the predicted travel time improvements.

We have assumed that the interregional benefits realised by the ARPBC investment programme begin at configuration state CS1, once 4-tracking between Westfield-Pukekohe is completed.

Benefits from the H2AIBC were provided from FY31 to FY76, and we have assumed that benefits remain constant after FY76.

ARPBC investment programme

5.1 Interregional benefits due to additional ARN improvements

Public transport user benefits from the H2AIBC are based on 9 minutes of travel time savings for users. The completion of 4-tracking between Westfield-Pukekohe that occurs as a result of the ARPBC investment programme will result in an additional 20 minutes of travel time savings for PT users (a total of 29 minutes saved compared to the H2AIBC Do Minimum).

To calculate the additional benefits due to the ARN improvements, we scale up the H2AIBC public transport user benefits proportional to the increase in travel time saved, i.e. by a factor of 222% ((29 minutes / 9 minutes) -1).

5.2 Interregional benefits due to patronage uplift

If the estimated travel time savings on the ARN are realised, then it is likely that there will be additional mode shift to rail for interregional journeys, leading to additional uplift in patronage.

To estimate this effect, we adopt an assumption of 10% uplift in patronage, and use this to factor up the benefits calculated in the H2AIBC analysis. We have broken down the interregional benefits into the following categories for our analysis:

- **Total benefits (including CO_2-e):** provided in the H2AIBC analysis.
- **CO_2-e benefits:** provided in the H2AIBC analysis.
- **PT generalised cost saving benefits:** We have assumed that the PT generalised cost saving benefits are 34% of the total benefits. This is because in the H2AIBC, PT generalised cost saving benefits are 34% of the total project benefits (excluding station amenity benefits, as these are unrelated to the potential travel time savings).
- **Other benefits** are the remainder, i.e.. total benefits - (CO_2-e benefits + PT generalised cost saving benefits)

The rule of half is applied to the user benefits (PT generalised cost savings and other benefits) associated with the assumed uplift in patronage.

6. Results

The total and present value (PV) of the individual benefit streams for the recommended programme are presented in Table 2 below. The PV is calculated over a 60-year evaluation period, using a 4% discount rate.

Table 2 Economic benefit summary – recommended programme (2022$, millions)

Benefit type	Total	PV
Metro benefits		
PT user benefits	22,322	5,400
PT reliability benefits (mode shift)	3,210	797
Seated travel benefits	129	37
Rail service punctuality benefits	445	123
Rail service reliability benefits	601	165
Station amenity improvement benefits	1,317	298
Health benefits from walking	343	84
Road user travel time benefits	5,968	1,433
Road user reliability benefits	895	215
VOC reduction benefits	-	-
Crash cost reduction benefits	350	85
CO2 emissions reduction benefits	133	35
Air quality improvement benefits	634	190
Second round impact benefits	3,635	886
Residual value	5,878	581
Total excl. WEBs	**45,862**	**10,329**
WEBs	9,996	2,437
Total incl. WEBs	**55,857**	**12,766**
Freight benefits		
CO2 emissions reduction benefits	895	257
Fuel cost saving	6,691	1,722
Net maintenance cost avoided	1,996	536
Rural congestion reduction benefits	3,301	890
Urban congestion reduction benefits	2,067	551
Crash cost reduction benefits	3,419	919
Air quality improvement benefits	3,063	960
Total freight benefits	**21,432**	**5,834**
Interregional benefits		
PT user benefits	7,665	1,586
CO2 emissions reduction benefits	1	0
Other benefits	313	65
Total IR benefits	**7,980**	**1,652**
Totals		
Total benefits excl WEBs	**75,274**	**17,815**
Total benefits incl WEBs	**85,270**	**20,252**

Source: PwC analysis

Table 3 summarises the economic assessment and benefit-cost ratio (BCR) for the recommended programme over a 60-year evaluation period.

Table 3 Economic assessment summary – recommended programme (2022$, millions)

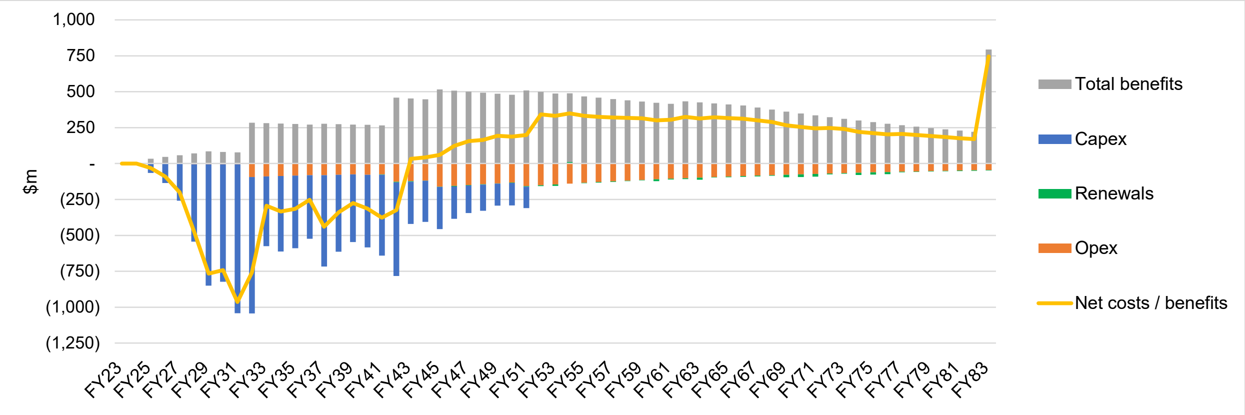
Summary	Total	PV
Benefits		
Metro benefits	39,983	9,748
Freight benefits	21,432	5,834
Inter-regional benefits	7,980	1,652
Residual value benefit	5,878	581
Total (excl. WEBs)	**75,274**	**17,815**
WEBs	9,996	2,437
Total (incl. WEBs)	**85,270**	**20,252**
Costs		
Capex	(19,677)	(11,901)
Renewals	(1,408)	(245)
Opex	(19,314)	(5,060)
Total	**(40,399)**	**(17,206)**
NPV (excl. WEBs)	n/a	**609**
NPV (incl. WEBs)	n/a	**3,046**
BCR (excl. WEBs)	n/a	**1.0**
BCR (incl. WEBs)	n/a	**1.2**

Source: PwC analysis

The recommended programme has a BCR of 1.0 when the estimate for WEBs is excluded, or 1.2 when they are included. When WEBs are excluded, the BCR of 1.04 (to 2 decimal places) and positive NPV shows that the estimated benefits of the programme are higher than the estimated costs, albeit slightly. When WEBs are included, or an allowance is made for some of the likely areas of conservatism discussed above, the positive NPV increases further.

The recommended programme's BCR reflects, in part, the major investment and long delivery time of the step change that is required. This means that the early part of the programme is sustained investment, with benefits not starting to be realised until after the step change is complete. Further to this, while the step change is large, the benefits can only start to build after that point – they do not immediately jump to a high value. This means there will be a long period over which the return on investment is realised. Figure 1 illustrates this point as the costs and benefits over time are presented graphically. Note that the large benefit in the final year of the period reflects the inclusion of the residual value of the infrastructure in the analysis.

Figure 2 Programme costs and benefits over time (PV, 2022$, millions)



Source: PwC analysis

7. Sensitivity analysis

This section presents the discussion of the economic sensitivity tests undertaken for the preferred programme.

7.1 Discount Rate

The base economic assessment uses a discount rate of 4%, recommended by the MBCM. Sensitivity tests using a lower discount rate of 3%, and a higher discount rate of 6% have been undertaken, consistent with MBCM guidance.

7.2 Evaluation period

The base case uses a 60-year evaluation period, reflecting the long life infrastructure that forms a large part of the overall programme. A 40-year period is also tested, consistent with more 'typical' projects and a longer evaluation period of 80 years is also tested, which is an appropriate sensitivity test given many of the assets being constructed have 100 year lives and may not be built until later in the programme period.

7.3 Metro patronage

Given some degree of uncertainty in relation to metro passenger forecasts, a sensitivity test has been undertaken where the benefits (as a proxy for patronage) are increased and decreased by 20%. This upper and lower bound cover a range of possible reasons that could lead to lower or delayed benefits, or higher or accelerated benefits, including:

- the rate of recovery of rail patronage post COVID-19 and the major disruptions associated with the Rail Network Rebuild could be slower than expected. The 20% reduction represents a slower recovery from current patronage levels (which are currently at 75% of pre-COVID volumes), effectively removing any 'rebound' and growth reverting to 'typical' increases. When the uplift associated with CRL occurs, it is therefore occurring from a considerably lower base.
- the rate of growth, especially from the southern growth area around Drury and Paerata could be slower than forecast in the base case demands if the current rate of development continues to lag behind earlier expectations (as a result of lower demand or demand shifting elsewhere in Auckland). This is consistent with Auckland Council's Future Development Strategy 2023-2053 (Draft)[10], which shows considerable delays to development timing in large parts of Ōpaheke, Drury, Paerata and Pukekohe (generally 10-15 years or more). A reduction in 20% of metro passenger benefits is considered to be in excess of the upper limit for the impact that slower southern growth could contribute to.
  - Southern Line patronage represents around 40% of total network patronage, with demands from south of Papakura increasing from less than 30% of Southern Line patronage to about 55% by 2051. While patronage is not an exact representation of benefits, it is a reasonable proxy for a sensitivity test (noting that longer distance travel will generate more benefits than shorter distance travel). This suggests that the growth from the southern growth area could be contributing some 10% - 15% of total metro patronage (based on 40% x (55% - 30%) = 10%, scaled up to reflect the distance contribution). This gives us reasonable confidence that a 20% reduction in metro patronage would be over the upper limit of this sensitivity test, acknowledging that growth is forecast by the FDS to be delayed, as opposed to completely removed.
- delays to the implementation of light rail in Auckland (across the three corridors) could impact metro patronage. There could be slight reductions given the overall network effect that is present when light rail is in place as part of the RTN. However, earlier modelling undertaken during the options development phase suggested these impacts would be very limited. This means the sensitivity test of a 20% reduction in metro passenger benefits will significantly overstate the impacts of light rail being delayed (in isolation of other changes).

[10] Retrieved from https://akhaveyoursay.aucklandcouncil.govt.nz/future-development-strategy , 28 August 2023

- higher growth than expected could result from exogenous factors beyond the recommended programme (such as policy changes). A test with 20% increased metro benefits (as the proxy for patronage) is also included to reflect this. Given ERP targets are more than double forecast patronage (by 2035), an increase in patronage of 20% would still fall well short of hitting the ERP targets. If policies are implemented that could achieve the required level of growth, the benefits could be higher.

7.4 Inter-regional (H2A) patronage

For Inter-regional patronage, the base case includes a 10% increase in patronage reflecting the additional 20 minute travel time saving that is expected for Inter-regional passengers as a result of the recommended programme. Against a base improvement of 9 minutes in the H2AIBC, the resulting 29 minute saving could have a more material impact on demand and so a range of +20% (upper bound) and 0% (lower bound) is tested for additional Inter-regional patronage.

7.5 Freight sensitivity

To test the sensitivity of freight-related benefits, two tests are undertaken as discussed below.

7.5.1 Freight demand scenarios

For the first, the different freight demand scenarios produced by KiwiRail are used to provide a lower and upper bound estimate. For the lower bound estimate, freight scenario A is used, which is a lower mode shift to rail, but still more than the Do Min. For the upper bound estimate, freight scenario D is used, which eases almost all rail operating constraints (in a freight context) and reflects a larger mode shift to rail from road freight.

7.5.2 Freight benefit area

For the second freight sensitivity test, the benefits remain limited to those related to the four Auckland freight services, but now confined to the geographical area within the ‘Golden Triangle’ (between Auckland, Hamilton and Tauranga). This test reflects more uncertainty around the rail network’s ability to accommodate additional demand outside that area without additional investment. This test is only included to generate a lower-bound estimate.

7.6 Carbon price

The base assessment of the recommended programme uses the middle shadow price of carbon. As sensitivity tests, the low and high shadow prices from the MBCM are used.

7.7 VKT estimation approach

Given the embedded assumptions around fleet decarbonisation and the redistribution of trips in MSM that could potentially be muting VKT reductions, a sensitivity test was developed for VKT-related benefits (being CO2, crash cost reduction and air quality benefits). This test is an alternative approach that utilises the forecast additional public transport patronage to estimate the potential VKT reduction and in turn the corresponding benefits that are driven by changes in VKT. It is only included to generate an upper-bound estimate.

7.8 Second round impacts (land use change)

The base assessment of the recommended programme adopted an uplift of 10% of conventional benefits as a proxy for the second round impacts of land use change as a result of the investment programme. This assumption is informed by other public transport investments in the absence of dynamic land use modelling. However, the literature notes that these effects can be higher – ranging from 5% to 30%. A sensitivity test is included where the second round impacts are removed (i.e. 0%) and increased to 15% (which is still a potentially conservative upper bound estimate given the range in the literature).

7.9 WEBs

The base assessment of the recommended programme adopted an uplift of 25% of total conventional benefits as a proxy for the WEBs, informed by other public transport investments. However, WEBs may represent a higher proportion of total benefits and a sensitivity test is included where the uplift is assumed at 35% of total conventional benefits (for metro passenger benefits). As the MBCM notes that the inclusion of WEBs is itself a sensitivity test on the base case, the lower bound estimate is simply the base case excluding WEBs.

7.10 Cost

To test the sensitivity of the recommended programme to changes in cost, we use the P95 cost estimates for the capital costs to inform the lower bound estimate (i.e. lower bound BCR) along with a 10% increase in renewals and operating cost estimates. For an upper bound estimate, we reduce the P50 capital costs, renewals and operating cost estimates by 10%.

7.11 Prioritisation bookends

The two ‘bookends’ of prioritising freight services (at the expense of metro passenger services), and vice versa, were developed by removing the constraints that exist for the relevant market during the first half (approximately) of the programme. The constraint is track capacity on the NIMT, which is alleviated once the 4-tracking south of Westfield is implemented (~2042 in the base case phasing). The base case phasing includes some degree of service compromise for both markets; that is, neither market is prioritised.

Table 4 summarises the approach to each bookend, along with the impacts on benefits and operating costs (opex). In both bookend tests there are no impacts on inter-regional passenger services and there is no change to the phasing of the capital spend, as the prioritisation relates to track access (i.e. slot allocation) as opposed to changing any physical infrastructure.

Table 4 Prioritisation bookend sensitivity tests

		Freight priority	Metro priority
Discussion		The number of network slots for freight increase, alleviating the constraint on benefits that exists under the base phasing. Metro services are limited by removing two Papakura peak overlay services (Southern Line), until the 4-tracking south of Westfield is competed in 2042.	Metro services are enabled to run the CS1 service timetable from FY32 onwards due to the increase in available network slots for metro services on the NIMT. Freight slots on the NIMT are capped at 22 trains per day (down from 30 in the base case), starting in FY32, and ending in FY42, when the southern 4-tracking allows both sufficient slots for both markets.
Metro service	**Benefits**	Metro benefits decrease due to the reduction in level of service and capacity on the Southern Line. The reduction in benefits is estimated by decreasing benefits by the proportion of total passengers who aren't able to travel due to the removal of services.	The additional metro services generate benefits from running the CS1 service timetable from FY32 onwards, as opposed to 2042 under the base phasing.
	Opex	The removal of metro passenger services reduces the associated opex due to the decrease in the underlying opex drivers (RSUK and services).	Higher levels of service cause metro service opex to increase due to the increase in the underlying opex drivers (RSUK and services).
Freight service	**Benefits**	Freight benefits are no longer capped, so increase in line with the demand scenario under the freight priority sensitivity between FY32-42.	Freight benefits are capped at the lower number of freight slots between FY32-42 compared to the base case. Benefits are generated in proportion to the number of trains above the do minimum that can still operate with the lower cap imposed.
	Opex	There will be an increase in freight tonnage on the network due to the removal of the cap on freight slots that exists in the base phasing between FY32-42. This will result in a small, but negligible, increase in network opex.	There will be a reduction in freight tonnage on the network due to the capping of freight slots between FY32-42, which will have a small impact on network opex. We estimate that this would result in an approximate 0.4% reduction in network opex comapred to the base case.

The two bookend sensitivity tests suggest that:

- Prioritising freight (over metro passenger services) generates slightly more net benefits and a higher (more positive) NPV. This occurs because the additional benefits from the freight services are greater than the metro passenger benefits foregone, at the same time as reducing metro service operating costs slightly (due to the removal of the services).

- Prioritising metro passenger services (over freight services) generates a slightly poorer economic outcome overall. The additional metro passenger benefits are higher than the freight benefits foregone, but the additional operating costs associated with those services increases the overall PV of the costs (reducing the BCR slightly).

7.12 Avondale-Southdown early works

A sensitivity test was run with the Avondale-Southdown early works deferred from the early part of the programme in the base phasing (to tie in with delivery of CC2M through the corridor) to late in the programme when the main Avondale-Southdown works are scheduled in the 2040s. This deferral of cost reduces the PV of the investment, and thus the overall PV of the programme.

7.13 Assumption sensitivities

Finally, a lower and upper bound sensitivity test is undertaken for a number of more minor assumptions used in the economic analysis. The changes to each of these input assumptions are discussed below and summarised in Table 4 10:

- Peak congestion – refers to the percentage of congestion related value (CRV) that is applied to the value of time from the MBCM in the peak period.
- Interpeak congestion – refers to the percentage of congestion related value (CRV) that is applied to the value of time from the MBCM in the interpeak period.
- Station amenity in-vehicle time (IVT) – refers to the number of IVT minutes that is adopted to reflect the benefits associated with the station upgrade programme.
- Ex-bus reliability – refers to the assumed level of average minutes late that is adopted to generate a journey time reliability benefit for passengers that shift mode from bus (in the Do Min) to rail (in the option). The sensitivity test moves 2 minutes either side of the base assumption 5 minutes.
- Rail service punctuality – refers to the equivalent minutes saved from increased punctuality. The Auckland One Rail KPI is simply within 5 minutes (or not), meaning the actual variance could be much higher. The base case adopts a 5 minute improvement, and the sensitivity tests use 3 minutes lower/higher than this.
- Seated benefits – this is based on the analysis undertaken in the EMU Batch 3 business case, which used a fleet of 72 EMUs as the basis for the assessment (assuming all units (excluding spares) in service in the peak periods). Given Batch 3 forms part of the Do Min, i.e. a fleet of 95, we scale up this benefit in the upper bound test by 32% (95/72 -1) to reflect a larger fleet and therefore the potential to have more people standing in the Do Min.

7.14 Sensitivity test results

The results of the sensitivity tests are included below in Table 5.

For reference, the BCR (excl. WEBs) for the recommended programme is 1.1.

For comparison with the WEBs sensitivity test, the BCR (incl. WEBs) for the recommended programme is 1.2. Consistent with MBCM guidance, BCRs are presented to 2 decimal places (2dp) for BCR <1.0, or 1dp for BCR>1.0.

Table 5 Sensitivity test results

Test	Lower bound		Upper bound	
	Value	BCR (excl WEBs)	Value	BCR (excl WEBs)
Discount rate	6%	0.79	3%	1.2
Evaluation period	40 years	0.86	80 years	1.1
Metro patronage	-20%	0.97	+20%	1.1
Inter-regional patronage	0%	1.0	+20%	1.0
Freight demand	Scen A	0.84	Scen D	1.2
Freight benefit area	Golden Triangle	1.0	n/a	
Carbon price	Low	1.0	High	1.0
VKT estimation approach	n/a		VKT adjusted	1.1
Second round impacts	0%	0.98	15%	1.1
WEBs	0%	1.0	+35%	1.2
Cost	P95, R&O +10%	0.84	P50 minus 10%	1.2
Prioritisation bookends	Metro priority	1.0	Freight priority	1.1
Avondale-Southdown early works	n/a		Deferred	1.1
Assumption sensitivities • Peak congestion • Interpeak congestion • Station amenity IVT • Ex-bus reliability • Punctuality improvement • Seated benefits	75% 0% 2 min 3 min 2 min -	0.96	100% 25% 3 min 7 min 8 min +32%	1.1

8. Appendix A: Restrictions

This report has been prepared for WSP as part of the Auckland Rail Programme Business Case (ARPBC) to detail the economic assessment methodology used to assess the potential investment programme(s) and should be read in conjunction with the ARPBC. This report has been prepared solely for this purpose and should not be relied upon for any other purpose. We accept no liability to any party should it be used for any purpose other than that for which it is being prepared.

This report has been prepared solely for use by WSP and may not be copied or distributed to third parties without our prior written consent. We acknowledge that a copy will be included in the ARPBC and shared with Auckland Transport, KiwiRail and Waka Kotahi.

To the fullest extent permitted by law, PwC accepts no duty of care to any third party in connection with the provision of this report and/or any related information or explanation (together, the “Information”). Accordingly, regardless of the form of action, whether in contract, tort (including without limitation, negligence) or otherwise, and to the extent permitted by applicable law, PwC accepts no liability of any kind to any third party and disclaims all responsibility for the consequences of any third party acting or refraining to act in reliance on the Information.

We have not independently verified the accuracy of information provided to us by WSP, Auckland Transport and KiwiRail, and have not conducted any form of audit in respect of any of these three organisations. Therefore, we therefore express no opinion on the reliability, accuracy, or completeness of the information provided to us and upon which we have relied.

The statements and opinions expressed herein have been made in good faith, and on the basis that all information relied upon is true and accurate in all material respects, and not misleading by reason of omission or otherwise.

The statements and opinions expressed in this report are based on information available as at the date of the report.

We reserve the right, but will be under no obligation, to review or amend our report, if any additional information, which was in existence on the date of this report, was not brought to our attention, or subsequently comes to light.

This report is issued pursuant to the terms and conditions of our engagement dated 11 February 2022.